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UNEDITED ROUGH DRAFT TRANSLATION

(PART ONE OF FIVE PARTS)

ENCYCLOPEDIA OF CONTEMPORARY ENGINEERING.
STRUCTURAL MATERIALS.

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Moscow 1963

Encyclopedia of Contemporary Engineering

STRUCTURAL MATERIALS

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ABSTRACT: Solution of the principal economic problem of the Party and the Soviet nation - that of creating the material and technical basis for Communism - is intimately related to the development, production and application of efficient modern structural materials. The attainment of high parameters in machines working with gaseous and liquid media at very high and very low temperatures, the creation of equipment to work with broad pressure ranges, would be impossible without progress in materials science, without the creation of materials meeting the new requirements set forth by the development of contemporary engineering. The key problem in modern engineering - high reliability - will be solved sooner on the basis of materials with high and stable physico-mechanical, chemical and other properties. At the same time, the scale of modern industry requires that the new materials be relatively inexpensive, readily available, and based on the use of domestic raw materials. Synthetic polymers, which possess a number of the necessary properties - high strength coupled with low specific gravity, good thermal and acoustic insulation, friction and antifriction properties, stability to many chemical agents, etc., come closest to satisfying the above requirements. During recent years, and particularly since the resolutions of the May Plenary Session of the Central Committee of the Communist Party of the Soviet Union (1958), an enormous number of synthetic materials have been developed in the USSR - high-strength and heat-resistant plastics, including glass-reinforced and lightweight foam plastics, which have come into extensive use in the manufacture of parts for power and communications equipment, and various types of fibers possessing many valuable properties. These materials will be used in all branches of the national economy, not only as metal

substitutes, but also as highly efficient structural materials. The new superstrength steels and heat-resistant alloys should be used extensively in modern engineering; beryllium, tungsten, molybdenum, niobium, titanium and other metals, as well as alloys made with them, will come into use in industry on an increasing scale. Certain metals and alloys that were assimilated long ago - such as aluminum and magnesium alloys, which have been used preferentially in aviation engineering, will come to be numbered among the basic structural materials in construction, mechanical engineering and other branches of industry. It has become urgently necessary to generalize information on metallic and nonmetallic structural materials so that, in designing various machines and other equipment, designers, engineers and production engineers may make use of materials that conform most fully to the prerequisites for long-term dependable operation. This confers an element of timeliness on the appearance of the encyclopedia "Structural Materials," in which the reader will find the handbook data on the materials of modern engineering assembled for the first time. The encyclopedia includes survey articles on the most important properties of heat-resistant, antiscaling, magnetic, semiconductor, corrosion-resistant, thermoacoustically insulating and other materials that are of greatest interest to workers in industry. An extensive section is devoted to modern testing and nondestructive quality-control methods for materials. Treatment of theoretical problems in physical metallurgy and material behavior in general is held to the necessary minimum; those interested in these problems are referred to the bibliographies given at the end of each article. Production processes are discussed only to the extent that they affect the properties of the materials. The editors invite readers to submit comments on the individual volumes as they appear; these will be received gratefully and taken into consideration in preparation of later volumes.

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EDITOR'S NOTE

Solution of the principal economic problem of the Party and the Soviet nation – that of creating the material and technical basis for Communism – is intimately related to the development, production and application of efficient modern structural materials. The attainment of high parameters in machines working with gaseous and liquid media at very high and very low temperatures, the creation of equipment to work with broad pressure ranges, would be impossible without progress in materials science, without the creation of materials meeting the new requirements set forth by the development of contemporary engineering. The key problem in modern engineering – high reliability – will be solved sooner on the basis of materials with high and stable physicomechanical, chemical and other properties. At the same time, the scale of modern industry requires that the new materials be relatively inexpensive, readily available, and based on the use of domestic raw materials. Synthetic polymers, which possess a number of the necessary properties – high strength coupled with low specific gravity, good thermal and acoustic insulation, friction and antifriction properties, stability to many chemical agents, etc., come closest to satisfying the above requirements.

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CONVENTIONAL SYMBOLS AND ABBREVIATIONS

amp – ampere
A – Angstrom unit
abs – absolute
at – technical atmosphere
at-% – atom-percent
atm – physical atmosphere
v – volt
va – volt-ampere
w – watt
w-hr – watt-hour
g – gram
g-atom – gram-atom
hy – henry
°C – degree Centigrade
°K – degree of Kelvin absolute scale
cps – cycle per second
g-eq – gram-equivalent
d, ø – diameter
db – decibel
RR – railroad
cal – small calorie
kg-m – kilogram-meter
hp – horsepower
m – meter
max – maximum
min – minute
μ – micron
mm – millimeter
mm water – millimeter of water column
mm Hg – millimeter of mercury column
mol. – molecular

e.g. – for example

NK – natural rubber

rpm – revolutions per minute

r – roentgen

sec – second

SK – synthetic rubber

st – stoke

TU – Technical Specifications

sp.gr. – specific gravity

UZ – ultrasound, ultrasonic

hr – hour

ev – electron-volt

emf – electromotive force

PREFIXES ENCOUNTERED BEFORE NAMES OF BASIC UNITS OF MEASUREMENT

deka – (10)

hecto – (10^{2})

k – kilo (10^{3})

M – mega (10^{6})

d – deci (10^{-1})

c – centi (10^{-2})

m – milli (10^{-3})

μ – micro (10^{-6})

mμ – millimicro (10^{-9})

PERIODICALS

"AZh" – Akusticheskiy zhurnal [Journal of Acoustics]

"BP" – Bumazhnaya promyshlennsst' [Paper Industry]

"VM" – Vestnik metallopromyshlennosti [Herald of the Metals Industry]

"VS" – Vysokomolekulyarnyye soyedineniya [Macromolecular Compounds]

"ZhPKh" – Zhurnal prikladnoy khimii [Journal of Applied Chemistry]

"ZhETF" – Zhurnal eksperimental'noy i teoreticheskoy fiziki [Journal of Experimental and Theoretical Physics]

"ZL" – Zavodskaya laboratoriya [Industrial Laboratory]

"IAN SSSR. OTN" – Izvestiya Akademii nauk SSSR. Otdeleniye tekhnicheskikh nauk [Bulletin of the USSR Academy of Sciences, Technical Sciences Section]

"KZh" – Kolloidnyy zhurnal [Colloid Journal]

"K i R" – Kauchuk i rezina [Caoutchouc and Rubber]

"LM i IP" – Lakokrasochnyye materialy i ikh primeneniye [Paints and Varnishes and Their Application]

"M i AP" – Mekhanizatsiya i avtomatizatsiya proizvodstva [Mechanization and Automation of Production]

"P" – Priborostroyeniye [Instrument Making]

"PM" – Plasticheskiye massy [Plastics]

"SVM" – Sinteticheskiye vysokopolimernyye materialy [Synthetic High-Polymer Materials]

"S i I" – Stanki i instrument [Machines and Tools]

"S i K" – Steklo i keramika [Glass and Ceramics]

"TP" – Tekstil'naya promyshlennost' [Textile Industry]

"Tr. NIIRP" – Trudy nauchno-issledovatel'skogo in-ta rezinovoy promyshlennosti [Transactions of the Scientific Research Institute of the Rubber Industry]

"UKh i TP" – Uspekhi khimii i tekhnologiya polimerov [Advances in the Chemistry and Technology of Polymers]

"FM i M" – Fizika metallov i metallovedeniye [Physics of Metals and Metallography]

"KhV" – Khimicheskiye volokna [Chemical Fibers]

"Kh i TP" – Khimiya i tekhnologiya polimerov [Chemistry and Technology of Polymers]

"KhN i P" – Khimicheskaya nauka i promyshlennost' [Chemical Science and Industry]

"KhP" – Khimicheskaya promyshlennost' [Chemical Industry]

"TsM" – Tsvetnyye metally [Nonferrous Metals]

FOREIGN PERIODICALS

"Aircraft Engng" – Aircraft Engineering (UK)

"Aircraft Prod." – Aircraft Production (UK)

"Amer. Ceram. Soc. Bull." – The American Ceramic Society Bulletin (USA)

"Arch. Eisenhüttenwesen" – Archiv für das Eisenhüttenwesen [Archives for the Metallurgy of Iron], (Federal Republic of Germany)

"Aviat. Week" – Aviation Week (USA)

"Brit. Plast." – British Plastics (UK)

"Chem.-Ingr-Techn." – Chemie-Ingenieur-Technik [Chemical Technician and Engineer] (Federal Republic of Germany)

"Faserforsch. and Textiltechn." – Faserforschung and Textiltechnik [Fiber Research and Textile Engineering], (Federal Republic of Germany)

"Foundry Trade J." – Foundry Trade Journal (UK)

"Industr. and Engng Chem." – Industrial and Engineering Chemistry (USA)

"Iron Age" – The Iron Age (USA)

"J. Amer. Ceram. Soc." – Journal of the American Ceramic Society (USA)

"J. Appl. Mech." – Journal of Applied Mechanics (USA)

"J. Electrochem. Soc." – Journal of the Electrochemical Society (USA)

"J. Inst. Metals" – Journal of the Institute of Metals (with the Bulletin and Metallurgical Abstracts) (UK)

"J. Metals" – Journal of Metals (USA)

"J. Res. Nat. Bur. Standards" – Journal of Research of the National Bureau of Standards (USA)

"Man-Made Text." – Man-Made Textiles (UK)

"Mater. and Methods" – Materials and Methods (USA)

"Materie plast." – Materie plastiche [Plastics] (Italy)

"Metal Finish." – Metal Finishing (USA)

"Metal Ind." – Metal Industry (UK)

"Metal Progr." – Metal Progress (USA)

"Mining Engng" – Mining Engineering (USA)

"Mod. Plast." – Modern Plastics (USA)

"Nat. Bur. Standards Circ." – National Bureau of Standards Circular (USA)

"Nondestruct. Testing" – Nondestructive Testing (USA)

"Planseeber. Pulvermetallurgie" – Planseeberichte für Pulvermetallurgie [Plansee Reports on Powder Metallurgy] (Austria)

"Precis. Metal Mold." – Precision Metal Molding (USA)

"Proc. Indian Acad. Sci." – Proceedings of the Indian Academy of Sciences (India)

"Proc. Roy. Soc." – Proceedings of the Royal Society (UK)

"Prod. Engng" – Product Engineering (USA)

"Rayonne et fibres synthet." – Rayonne et fibres synthetiques [Rayon and Synthetic Fibers] (Belgium)

"Rech. aeronaut." – La recherche aeronautique [Aeronautical Research] (France)

"Rev. aluminum" – Revue de l'aluminium [Aluminum Review] (France)

"Rubber and Plast. Age" – The Rubber and Plastics Age (UK)

"Rubber Chem. and Technol." – Rubber Chemistry and Technology (USA)

"SAE Trans." – Society of Automotive Engineers Transactions (USA)

"Skinner's Silk and Rayon Rec." – Skinner's Silk and Rayon Record (UK)

"Text. Res. J." – Textile Research Journal (USA)

"Text. World" – Textile World (USA)

"Trans. Amer. Soc. Metals" – Transactions of American Society for Metals (USA)

"Z. ges. Textilind." – Zeitschrift für die gesamte Textilindustrie [Journal for the Entire Textile Industry] (Federal Republic of Germany)

"Z. Metallkunde" - Zeitschrift für Metallkunde [Journal of Metals]
(Federal Republic of Germany)

Mechanical and Physical Properties

Property	Symbol	Unit
Modulus of normal elasticity in tension (static)	E	kg/mm^2
Modulus of normal elasticity in tension (dynamic)	E_d	kg/mm^2
Modulus of tangential elasticity (shear modulus)	G	kg/mm^2
Isostatic compression modulus	K	kg/mm^2
Poisson's ratio	μ	-
Proportional limit in tension	σ_{pts}	kg/mm^2
Conventional yield point in tension (permanent deformation 0.2%)	$\sigma_{0.2}$	kg/mm^2
Ultimate tensile strength	σ_b	kg/mm^2
Ultimate bending strength	σ_{izg}	kg/mm^2
Ultimate tensile strength of notched specimen	σ_{bn}	kg/mm^2
Ultimate compressive strength	σ_{-b}	kg/mm^2
Proportional limit in torsion	τ_{pts}	kg/mm^2
Conventional yield point in torsion (permanent shear deformation 0.3%)	$\tau_{0.3}$	kg/mm^2
Ultimate torsional strength	τ_b	kg/mm^2
Shear strength	τ_{sr}	kg/mm^2
Breaking strength in tension	S_k	kg/mm^2
Relative elongation after failure for lengths of		
$\ell = 5d$; $\ell = 10d$	δ_5; δ_{10}	%
$\ell = 5.65\sqrt{F}$	$\delta_{5.65\sqrt{F}}$	%
$\ell = 11.3\sqrt{F}$	$\delta_{11.3\sqrt{F}}$	%
Upsetting ratio in compression	Δ	%
Necking ratio after failure	ψ	%
Rockwell hardness (A, B and C scales)	RA, RB, RC	-
Brinell hardness	HB	kg/mm^2
Vickers hardness	HV	kg/mm^2
Microhardness	H	kg/mm^2
Specific impact strength in bending	a_n	kg-m/cm^2

Endurance limit in bending with symmetrical cycle	σ_{-1}	kg/mm^2
Creep limit at high temperatures (stress causing 0.2% strain at 100, 300, etc., hours)	$\sigma_{0.2/100}$	kg/mm^2
Fatigue limit at high temperatures (stress breaking specimen at 100, 300, etc., hours)	$\sigma_{100}; \sigma_{300}$	kg/mm^2
Sagitta	f	mm
Power factor	$\cos\varphi$	—
Specific gravity	γ	g/cm^3
Temperature coefficient of linear expansion	α	1/°C
Thermal conductivity coefficient	λ	cal/cm•sec•°C
Specific heat	c	cal/g °C
Resistivity	ρ	ohms•mm^2/m
Surface resistivity	ρ_s	ohms
Volume resistivity	ρ_v	ohms•cm
Refractive index	n	—
Magnetic permeability	μ	hy/m
Temperature	t°	°C
Boiling point	t°_{kip}	°C
Melting point	t°_{pl}	°C
Vitrification temperature	T_g	°C

Manuscript Page No.	[Transliterated Symbols]
xxxvi	НК = NK = natural'nyy kauchuk = natural rubber
xxxvi	СК = SK = sinteticheskiy kauchuk = synthetic rubber
xxxvi	ТУ = TU = tekhnicheskiye usloviya = technical specifications
xxxvi	УЗ = UZ = ul'trazvuk = ultrasound
xxxix	д = d = dinamicheskiy = dynamic
xxxix	пц = pts = proportsional'nost' = proportionality
xxxix	изг = izg = izgib = bending

xxxix	н = n = nadrezannyy = notched
xxxix	ср = sr = srez = shear
xl	кип = kip = kipeniye = boiling
xl	пл = pl = plavleniye = melting

ABLATION – destruction of material on interaction with a high-enthalpy, high-temperature and high-speed gas flow, characterized by intense heating of the surface zone of the material and removal of mass from it due to fusion, vaporization, sublimation and other phenomena. Diffusing through the boundary layer, the gasified part of the material absorbs heat, with the result that the heat flow arriving at the surface of the material is reduced (so-called "thickening" of the boundary layer or thermal blocking). The use of ablation-susceptible "consumable" materials that absorb large quantities of energy per unit of mass lost and possess low thermal conductivities and a specific complex of other physicomechanical properties is an effective way of protecting the skins of high-speed aircraft from intense short-term aerodynamic heating, and the walls of rocket-engine chambers from hot gases. Ablation may be regarded as a particular case or part of heat and mass exchange between the material and the heated gases, which incorporates the following fundamental, arbitrarily classified effects (the Roman numerals denote the groups of the effect factors, while the Arabic numerals denote the individual elements within each group): I. Absorption of heat on heating of the material in the solid and liquid phase to temperatures corresponding to the phase transitions. II. Removal of heat from the surface zone of the material due to conduction (1) and radiation (2). III. Effects related to removal of mass: a) mechanical effects – "friction" erosion, loss of material in the solid state due to tangential forces set up by the gas stream (1), "abrasive" erosion, due to impacts of solid particles or droplets (2); b) thermomechanical – scaling and cracking as a result of thermal expansion and dropping away of solid particles (3), exfoliation – separation of softened or weakened particles of material by forces produced by the onrushing stream or by accelerations (4), heat absorption on fusion and sweeping of the fused layer by the gas stream or runoff of this layer under the action of inertial forces (5); c) thermal effects – absorption of heat on heating of a liquid film and loss of mass in vaporization (6), sublimation – absorption of heat and mass loss on transition to the gaseous state directly from the solid state (7), superheating of vapors of vaporizing or sublimating material (8); d) thermochemical effects – absorption of heat in pyrolysis and loss of thermal decomposition products (9), evolution of heat in combustion (10), dissociation (11) and ionization (12) of vapors of the material in the boundary layer, and thermochemical interaction of vapors of the material with the main gas stream (13).

The following factors influence the process of heat and mass transfer between the material of the object and the external medium: the magnitudes of the heat flows to the surface of the material, the composition of the medium, the velocity of motion, the nature of the flow (laminar or turbulent) in the boundary layer, the dimensions (e.g., wall thickness) and shape of the object, the chemical nature and structure of the material and the properties that depend on them – the heats of the phase transitions, the heat-transfer coefficient, the radiative and catalytic properties of the surface, and the strength and deformation indices. To maintain the necessary strength in the load-bearing elements of the structure, to maintain it in functioning condition, and to provide heat protection at minimum weight, an attempt is made to select materials that realize useful effects (I, II-2, III-6, 7, 8, 9, 11, 12), and minimize the unfavorable effects (III-1, 2, 3, 4, 10) under the conditions in question.

The ablative properties of a material are characterized by several parameters: the effective heat of ablation or effective enthalpy, the velocities of linear removal V_{ℓ} or loss V_m of mass and the indices to the thermal-insulation properties, e.g., the temperature gradient through the thickness of the material. There are a variety of definitions for the "effective enthalpy" of a material. From one standpoint, it includes the heat (H^a_{eff}) required to heat 1 kg of the removed material to the temperature of the phase transformation and then take it through the phase transformation itself. According to another standpoint, the effective enthalpy (H_{eff}) also incorporates the heat expended in heating the vapors of the material (and on the other processes) in the boundary layer.

Following the onset of steady-state ablation

$$H_{эфф}=\frac{q_0}{V_м}=\left\{\int_{T_0}^{T_a} C_p dT+\alpha[H_п+\beta(\Delta H)_0]\right\}: \\ :\left(1-\frac{q_r}{q_0}\right),$$

where q_0 is the heat flow to the unconsumed surface at the ablation temperatue, C_p is the specific heat capacity, T_a is the surface temperature of the material subject to ablation, H_p is the heat of the phase transformation (vaporization, sublimation), $(\Delta H)_0$ is the enthalpy difference of the boundary layer in the absence of "sweating," $q_r = \sigma\varepsilon T^4$ is the heat flow radiated by the body (σ is the Stefan-Boltzmann constant and ε is the emittance), α is the gasification coefficient, the fraction of the total mass lost in the form of vapor and gaseous pyrolysis products, $\beta\approx N\left(\frac{29}{M_п}\right)^{0,21}$ is the mass transfer coefficient; here: $N \approx$ $\approx 2/3$ or $2/9$ for laminar and turbulent boundary layers, respectively, and M_p is the molecular weight of the vapor (values of β calculated by the above formula correspond to the case of an air flow and certain particular streamlining conditions).

TABLE 1

Материал A	B Тепловой поток (ккал/м²·сек)		
	500	1500	3000
C Стеклотекстолит	400	1200	2200
D Асботекстолит	800	1700	2000
E Слоистый пластик на основе ткани из рефразиловых волокон	1300	2500	3700

A) Material; B) heat flow (kcal/m^2•sec); C) glass-reinforced textolite; D) asbestos textolite; E) laminated plastic with woven Refrazil base.

TABLE 2

A Материал	Линейный унос $V_л$ B (мм/сек)	Убыль массы C $V_м$ (кг/м²·сек)
D Графит	0,06	0,14
E Стеклопластик фенольный	0,29	0,51
F Асбопластик фенольный	0,32	0,56
G Найлон	0,86	0,99
H Силикат циркония . . .	0,89	4,10
I Нержавеющая сталь . .	1,69	13,10

A) Material; B) linear rate of removal V_ℓ (mm/sec); C) rate of mass loss V_m (kg/m^2•sec); D) graphite; E) transparent phenolic plastic; F) phenolic asboplastic; G) nylon; H) zirconium silicate; I) stainless steel.

Among the various classes of materials – metals, ceramics, plastics – filled polymers are most suitable for use as heat-insulating coatings working by the ablation mechanism. Illustrative values of H_{eff} in kcal/kg (without consideration of radiation and various streamlining conditions) for certain phenolic plastics are given in Table 1.

It is expedient to employ materials with small thermal conductivity coefficients. The larger q_0, the greater the portion of the material that will be subject to ablation. For moderate thermal loads, the structures may be protected with thermal insulation and radiating coatings; at high rates of supply of energy to the surface, ablative thermal insulation becomes an important factor. The indices V_ℓ and V_m, which characterize erosion resistance, are particularly important for materials used in the nozzles of rocket engines and other devices of which stability of the aerodynamic contours and weight parameters is required. Increasing H_{eff} lowers the rate of ablation:

$$V_м \sim \varrho V_л \sim q_0 H_{эфф}.$$

where ρ is the density of the material. Typical values of the ablation rate for a number of materials at the critical point, with an initial heat flow of 5300 kcal/m^2•sec in an air medium (velocity 750 m/sec, enthalpy 4500 kcal/kg, temperature 8300°) are given in Table 2.

I-1a5

References: Issledovaniya pri vysokikh temperaturakh [High-Temperature Research] Collection of articles edited by V.A. Kirillin and A.S. Sheyndlina, Translation from English, Moscow, 1962; Adams, Posledniye dostizheniya v teorii ablyatsii [Recent Advances in Ablation Theory], "Voprosy raketnoy tekhniki," [Problems of Rocket Engineering], 1960, No. 4 (64); Skala, ibid., 1960, No. 8 (68); Lucas W.R. and Kingbury, I.E., "Mod. Plast.", 1960, Vol. 38, No. 2, pages 135-40, 211; Schmidt, D.L. ibid., pages 135-40, 211; Schmidt, D.L., ibid., No. 3, pages 131-41.

B.I. Panshin

Manuscript Page No.	[Transliterated Symbols]
3	л = l = lineynyy = linear
3	м = m = massa = mass
3	эфф = eff = effektivnyy = effective
3	а = a = ablyatsiya = ablation
3	п = p = prevrashcheniye = transformation
3	п = p = par = vapor

ABRASIVES – rocks and minerals (natural and artificial), usually of higher-than-normal hardness, used in agglomerated or ground form for surface dispersion and machining (grinding, cutting, lapping, boring, polishing, and the like); also used as high-strength materials to resist prolonged abrasive action in the rubbing parts of mechanisms (antabrasives, abrasiostats).

The natural abrasives include diamond, corundum, emery, garnet, quartz and its varieties – silica, agate, quartz sand, quartzite and sandstone (dense rocks), tripoli, diatomite, gaize, Mohs (loose powders), feldspar and talc; granite, basalt lavas, pumice, crocus (Fe_2O_3) and chalk. The most commonly encountered artificial abrasives are electrocorundum, carborundum, and boron carbide. The basic characteristics of abrasives are: 1) hardness, strength and toughness; 2) the shape of the abrasive grain, 3) abrasive capability and 4) grain size.

We classify abrasives as those with high hardness (diamond and alumina abrasives), medium hardness (quartz, silica, agate, garnet, feldspar, granite, basalt lavas and pumice) and low hardness (tripoli, diatomite, gaize, crocus, chalk, talc, and porous shales). Abrasives of high and medium hardness are used chiefly as cutting and grinding materials, while abrasives of low hardness are used principally for polishing.

The hardness of an abrasive is characterized by its position on hardness scales. The various abrasives array themselves in the following series on the ten-point Mohs scale: diamond 10, corundum 9, quartz 7, garnet 6.5-7.5, feldspar 6–6.5, hematite (crocus) 5.5–6, talc 1, chalk less than 1. The microhardnesses of artificial abrasive materials (kg/mm^2) are as follows: diamond 10,060, boron carbide 3300-4300, silicon carbide 2800-3300, electrocorundum 1800-2600.

Abrasive grains are most often crystalline fragments, and less often monocrystals with regular crystalline shape or a crystalline aggregate. The cutting edge of the grain is the side formed by any pair of intersecting crystallographic planes. Since different crystallographic planes intersect at different angles, the grain cutting edge also acquires various tip angles.

The physical characteristic of an abrasive that is of greatest practical importance is its abrasive ability, which represents a complex of properties: hardness, toughness, brittleness, duration of effectiveness, etc. The abrasive ability of ground abrasives (particles 160-120 μ in diameter) is established by a standard procedure, by determining the amount of glass dispersed when it is used to grind the material to be tested. If the abrasive ability of quartz is taken as 1, the relative abrasive abilities of other abrasives are as follows: garnet 3.3, corundum 4.8, diamond (bort) 35.4. As compared with the abrasive ability of diamond, which is taken as unity, the abrasive abilities of artificial abrasives are: electrocorundum (93.6% Al_2O_3) 0.149; monocorundum (a variety of electrocorundum) 0.15-0.25; silicon carbide 0.25-0.45; boron carbide 0.56-0.64. The mesh characterizes the size and uniformity of the abrasive-grain dimensions; it is determined by clasdifying the grains on the basis of linear dimensions by screen analysis, settling in a liquid, or some other method. The mesh number is determined by the linear dimensions of the grains in the main fraction. The more uniform the shapes and sizes of the abrasive grains, the better will be their working properties.

Machining finish obtained with an abrasive process is inversely proportional to the size of the abrasive grains; here, admixtures of coarser grains produce defects on the machined surface, while finer grains reduce the abrasive effect, since such grains do not fully participate in the process. In their commercial form, abrasives are crushed materials with standard grain sizes (GOST 3647-59). Crushed abrasives are classified as follows on the basis of grain size in the USSR: grinding granular (Nos. 200-16, 2500-160 μ fractions), grinding powders (Nos. 12-3, 160-40 μ fractions) and micropowders (Nos. M40-M5, 40-3 μ fractions). Diamond powders (GOST 9206-59) are classified into 50 grades - from A50 (630-500 μ) to AM1 (smaller than 1 μ). Abrasives are characterized by imperfect cleavage, so that they regenerate themselves during the abrasive process, producing new irregular sharp fractures. Abrasive products should be quite porous.

Abrasive stones, from pieces of which abrasives products of the necessary shape and dimensions are obtained directly, should be set apart on the basis of method of use from other abrasives, which are used chiefly in dispersed form. Abrasive stones generally consist of silicaceous rocks - sandstones, novaculite (chalcedonous) shales and quartzites, as well as granites, basalt lavas, and pumice.

Abrasive stones (in the form of millstones, whetstones, and the like) are used only to a limited degree because of the difficulty of making tools of the necessary size and dimensions from them and the possibility of using them only at low working speeds (not over 5-6 m/sec). The importance of diamond among the dispersed abrasives is increasing steadily. The abrasive next in importance after diamond is corundum, which is used in the form of powders, pastes and, less often, in abrasive products in ceramic and organic binders, for the grinding and polishing of metallic products (ball bearings) and glass (optical lenses), where natural corundum is more effective than synthetic corundum.

Abrasives are used as follows: quartz sand preferentially for rough grinding of glass; garnet and crocus for glass (miller) polishing; emery chiefly in felt-based wheels for rough machining of noncritical components; pumice for grinding and dressing wood, leather and stone. The soft adhesives – chalk and talc – are included in various polishing preparations for finishing leather, polishing rice, etc. Silica is used to make sandpapers for finishing leather, plastics and wood, and the material is made available in the form of grinding grains and powders (most often in 14 grades from 24 to 240). Corundum is produced for the most part in micropowder form (No. 28, No. 7, etc.) and emery in the form of grinding grains (No. 90 and coarser).

The most widely used artificial abrasives are as follows: with high hardness – boron, tungsten and silicon carbides, electrocorundum (specific brands are alundum, aloxite and novodiamantine); those of medium and low hardness – ground glass, synthetic red (iron) and green (chromium oxide) crocus, polirite (cerium oxide), oxides of copper, zinc, nickel, manganese and thorium, steel filings, Italian powder (stannic acid), as well as polishing compounds containing brushed natural abrasives and various salts.

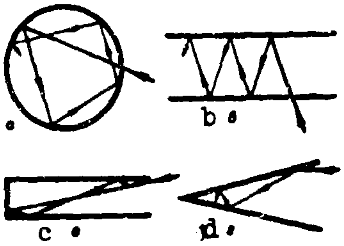
The following forms of artificial abrasives are produced in the USSR: boron carbide (crystalline, with additives of pure boron and graphite), which is used as a substitute for diamond powders in truing hard alloys (carbide cutting tools), in grinding ruby, quartz and corundum; green silicon carbide (high abrasive ability) and the black variety (less brittle), used in machining tough materials with low breaking strength (gray iron, brass, bronze, aluminum, copper, glass, porcelain, bone, plastics, and the like); normal electrocorundum E in grades E92, E93 and E95 for grinding metals, white EB for machining special steels, glass, and precision thread-grinding; monocorundum M for machining alloys having high breaking strength (for example, nitrided steels).

References: Nemetallicheskiye iskopayemyye [Nonmetallic Natural Deposits], Vol. 1, Moscow-Leningrad, 1936; Temkin, B.S., Shlifuyushchiye i poliruyushchiye materialy [Grinding and Polishing Materials], Moscow, 1947; Trebovaniya promyshlennosti k kachestvu mineral'nogo syr'ya [Industrial Requirements as to Quality of Mineral Raw Materials], No. 37; Koyfman, M.I., Korund i nazhdak, [Corundum and Emery], Moscow-Leningrad, 1947; Abrazivnyye instrument' [Abrasive Tools], catalogue, Moscow, 1958 ; Abrazivnyye instrumenty. catalogue, Handbook, Moscow, 1961.

P.P. Smolin

Manuscript Page No.	[Transliterated Symbols]
8	ГОСТ = GOST = Gosudarstvennyy obshches yuznyy standard = State All-Union Standard

ABSOLUTELY BLACK BODY - a body characterized by the ability to absorb completely all radiation incident upon it irrespective of the wavelength of the radiation and the temperature; it also possesses the highest radiative power for a given temperature. The absorption coefficient of the absolutely black body is unity at any temperature. The absolute black body does not exist in nature; it is an imaginary body, but the concept of the absolute black body is of great importance in the theory of radiation, the basic laws of which have been derived as they apply to black-body radiation (see thermal radiation). A physical model of the absolute black body can be realized in the form of a closed cavity having opaque and uniformly heated walls, the radiation and absorption of which through a small hole in the wall (Fig., a) are for all practical purposes subject to all laws of radiation for the absolute black body. The physical model of the absolute black body is based on the principle of absorption of the rays by the cavity walls as a result of multiple reflection. By the same token (each element of the internal surface of the cavity simultaneously radiates and reflects the



Models of the absolutely black body: a) Spherical cavity with hole; b) tube element; c) cylindrical depression in a body; d) wedge-shaped depression in a body.

radiation of the other elements), the absolute black body model possesses a radiating power close to the possible maximum at the given temperature. In engineering, absolute black body models are used in the form of uniformly heated tubular element b and cylindrical (c), wedge-shaped (Mendenhall wedge) or conical (d) depressions in a heated body.

References: Ribo, G., Opticheskaya pirometriya [Optical Pyrometry] Translated from the French, Moscow-Leningrad, 1934; Mikheyev, M.A., Osnovy teploperedachi [Fundamentals of Heat Transfer], 3rd edition, Moscow-Leningrad, 1956; Plank, M., Vvedeniye v teoreticheskuyu fiziku [Introduction to Theoretical Physics], Part 5, Translated from the German, Moscow-Leningrad, 1935; Kul'bush, G.P., Elektricheskiye pirometry [Electrical Pyrometers], Moscow-Leningrad], 1932.

A.I. Kovalev

ABSORPTION COEFFICIENT – the ratio of the radiant energy absorbed by a body to the radiant energy incident on it: $\alpha = E_{pogl}/E_{pad}$. For an absolutely black body this factor equals 1, while for an absolutely white body it equals 0. The absorption coefficient of real bodies lies within the limits $0 < \alpha < 1$ and depends on the chemical composition, physical state, and thickness of the absorbing layer and the wavelength distribution of the incident radiant energy.

G.A. Zhorov

ACETATE FIBER – artificial fiber from acetylcellulose which has valuable service qualities. The starting raw material for the production of acetate fiber is regenerated cellulose acetate (the content of combined acetic acid is 54.5-56.5%) Acetate fiber is formed by the dry method from acetylcellulose solutions with a degree of polymerization of 350-400 mixed with acetone and alcohol (85:15) or acetone and water (90:10) on a bobbin-type spinning mill. The physio-mechanical properties of acetate fibers are: specific weight 1.32, moisture content (under standard conditions) 6-8%, dry rupture length 11-14 km, loss of strength in the wet state 40-45%, dry elongation 22-30%, wet elongation 28-35%. Suspension dyes are used for water-bath dyeing, while acetone-soluble dyes or high-dispersion pigments which ensure bright and fast colors are used for dyeing in the mass.

Acetate fiber is twice as elastic as viscose and cuprammonium fibers, for which reason fabrics from acetate fibers have a low susceptibility to crushing. Acetate fibers possess a substantial thermoplasticity (deformation of the fiber starts at 140-150°). The processes by which acetate fibers are produced are distinguished by their relative simplicity and harmlessness, stability of spinning solutions, higher (by a factor of 2.5-3) concentration of the spinning solution in comparison with that used for the forming of viscose fiber, higher rate of fiber formation when using the dry method, absence of finishing operations in the wet state, moderate specific consumption of solvents due to their regeneration, feasibility of complete reprocessing of wastes and refuse. Shortcomings of the production process are: inflammability and danger of explosion when acetone comes into contact with air, which require the use of special electrical fittings and motors, substantial heat generation in the spinning compartment zone which necessitates air conditioning. Acetate fibers are used in the pure form and together with other fibers for the production of fabrics and knitted products. Knitted underwear and outerwear are made from acetate rayone, while staple acetate fiber together with other fibers is used for wrinke-resistant fabrics and articles. Acetate fibers are not colorable by dyes which are used for dyeing cellulose and protein fibers are used together with the latter for obtaining various color effects in fabrics.

References: Rogovin, Z.A. Osnovy khimii i tekhnologii proizvodstva khimicheskikh volokon [Fundamentals of the Chemistry and Technology of Chemical Fibers Production]. 2nd edition, Moscow, 1957; Birger, G.Ye., Proizvodstvo khimicheskikh volokon i ikh primeneniye [The Production and Utilization of Chemical Fibers]. Moscow, 1959; Kanter, D.Ts., Nekrasova, T.A. and Golosenko, O.M. "TP," No. 9, page 16, 1958.

L.S. Gal'braykh

ACICULAR TROOSTITE – is the structure of products of the intermediate transformation of austenite (see Steel).

ACID- AND ALKALI-RESISTANT RUBBER – rubber which protects apparatus, machinery, and equipment from the detrimental action of acids and alkalies. Depending on their purpose and the field in which they are to be used, such rubbers should, in addition to resistance to various media, exhibit good adhesion to metals (when employed for anticorrosion coatings), durability (when used for packaging components in pumps), and heat or frost resistance (when used at high or low temperatures). Their chemical stability depends to a large extent on the temperature and concentration of the medium. The service life of acid- and alkali-resistant rubbers ranges from several months to 4-6 years and depends on the purpose for which the material is intended, the operating conditions, the concentration and temperature of the medium, whether or not it contains suspended particles, the type of apparatus, the surface area in contact with the medium, the number of strokes (for packaging components), and other factors. Their chemical stability is determined chiefly by the properties of the initial gum rubber and the composition of the rubber mixture. Addition of silica gel to the mixture in place of chimney soot or lamp black substantially increases its resistance to a number of chemical reagents. The same filler may promote an increase in resistance to one medium and a decrease in resistance to another. For example, silica gel, which improves resistance to hydrochloric acid, lowers resistance to alkalies. A combination of fillers is used to obtain rubbers stable in both types of media. Addition of softeners such as paraffin, ceresin, etc., which migrate to the surface of the rubber, also increases the chemical stability of the mixture. Rubbers with strong sulfur bonds are produced by using thiram as an accelerator and reducing the sulfur content.

TABLE 1

Среда 1	2 Кислоты				Едкий натр 7	Механические свойства резин 8
	азотная 3	серная 4	фосфорная 5	соляная 6		
9 Концентрация (вес. %)	до 5	до 50	любая	любая	любая	Предел прочности при разрыве 45—100 кг/см² Относит. удлинение 200—350%. Твердость по ТМ-2—45—60
10 Температура (°C)	до 25	до 65	до 70	до 20	до 70	

1) Medium; 2) acids; 3) nitric; 4) sulfuric; 5) phosphoric; 6) hydrochloric; 7) sodium hydroxide; 8) mechanical properties of rubber; 9) concentration (% by weight); 10) temperature (°C); 11) up to; 12) any; 13) ultimate tensile strength – 45-100 kg/cm²; 14) relative elongation – 200-350%, hardness in TM-2 apparatus – 45-60.

TABLE 2

Среда 1	2 Кислоты					Едкий натр 8	Механические свойства резины 9
	азотная 3	серная 4	фосфорная 5	соляная 6	фтористоводородн. 7		
10 Концентрация (вес. %)	12 до 10	до 50	до 80	13 любая	до 44	любая	14 Предел прочности при разрыве. 200—250 кг/см² Относительное удлинение 300—500(%). Твердость по ТМ-2—60—75 15
11 Температура (°C)	до 70	до 65	до 60	до 20	до 20	до 70	

1) Medium; 2) acids; 3) nitric; 4) sulfuric; 5) phosphoric; 6) hydrochloric; 7) hydrofluoric; 8) sodium hydroxide; 9) mechanical properties of rubber; 10) concentration (% by weight); 11) temperature (°C); 12) up to; 13) any; 14) ultimate tensile strength – 200-250 kg/cm²; 15) relative elongation – 300-500%, hardness in TM-2 apparatus – 60-75.

Acid- and alkali-resistant rubbers are produced from the following types of raw rubber: sodium divinyl (SKB), divinyl styrene (SKS), divinylnitrile (SKN), butyl (BK), polyisobutylene (PI), chorsulphated polyethylene (KhP), ethylene-Propylene (EP), and chloroprene.

SKB-based rubbers are widely used in the manufacture of soft rubbers, semiebonites, and ebonite. Ebonites are, however, brittle and thermoplastic (softening at 60-70°).

Table 1 presents data on the resistance of SKB rubbers to various acids and alkalies.

SKB-based rubbers are elastic, adhere well to metals, and are heat-resistant to 80° and frost-resistant to −40°.

Acid- and alkali-resistant rubbers based on SKS-30 (and, to some extent, those based on SKMS-50) are strong, elastic, highly durable, heat-resistant to 100-120°, and frost-resistant to −40 or −50°.

Table 2 presents data on the acid and alkali resistance of rubbers based on SKS-30.

TABLE 3

Среда 1	2 Кислоты				Едкая щелочь 7	Механические свойства резины 8
	азотная 3	серная 4	соляная 5	уксусная 6		
9 Концентрация (вес. %)	до 25	до 75	до 36	до 98	до 50	Предел прочности при 12 разрыве 100—150 кг/см² Относительное удлинение 300—400%. Твердость по ТМ-2—70—80 13
10 Температура (°С)	до 100 11	до 100	до 100	до 70	до 70	

1) Medium; 2) acids; 3) nitric; 4) sulfuric; 5) hydrochloric, 6) acetic; 7) sodium hydroxide; 8) mechanical properties of rubber; 9) concentration (% by weight); 10) temperature (°C); 11) up to; 12) ultimate tensile strength − 100-150 kg/cm²; 13) relative elongation − 300-400%, hardness in TM-2 apparatus − 70-80.

TABLE 4

Среда 1	2 Кислоты					Едкая щелочь 8
	азотная 3	серная 4	соляная 5	фосфорная 6	уксусная 7	
Концентрация 9 (вес. %)	11 до 50	до 40	нестойки к горячей кислоте 12	до 80	нестойки к горячей кислоте	до 40
Темп-ра (°С) 10	до 50	до 60		до 100	..	до 100

1) Medium; 2) acids; 3) nitric; 4) sulfuric; 5) hydrochloric; 6) phosphoric; 7) acetic; 8) sodium hydroxide; 9) concentration (% by weight); 10) temperature (°C); 11) up to; 12) unstable in hot acid.

Acid- and alkali-resistant rubbers based on SKN have a chemical stability similar to that of SKS rubbers; they are resistant to petroleum products containing up to 30% aromatic hydrocarbons and to propane and butane. They are heat-resistant to 150°, durable, and frost-resistant to −30 to −35° (for SKN-26) or −45 to −50° (for SKN-18).

Rubbers based on chloroprene are characterized by high resistance

TABLE 5

Среда 1	Концентрация (вес. %) 2	Температура (°C) 3	Стойкость 4	Механические свойства ХП 5
Аммиак 6	Жидкий, 17 безводный	20	Не действует или слабо действует 21	Предел прочности при разрыве 180—240 кг/см² 24
Хромовая кислота 7	50	65	То же	—
То же 8	Концентриров. 18	20	22 »	Относит. удл. 200—500% 25
Соляная кислота 9	36	50	»	Твердость по ТМ-2—60—80 26
То же	36	70	Умеренно действует	—
Плавиковая кислота 10	43	70	Не действуют или слабо действует 23	Температура хрупкости —25, —40°
Азотная кислота 11	19 До 20	70	То же	27 —
То же	До 70	0	Умеренно действует	—
Фосфорная кислота 12	85	93	Не действует или слабо действует	—
Серная кислота 13	До 50	93	То же	—
То же	95,5	50	Умеренно действует	—
Уксусная кислота 14	Ледяная	20	То же	—
Едкий кали 15	концентр. 24	То же	Не действует или слабо действует	—
Едкий натр 16	50	70	То же	—

1) Medium; 2) concentration (% by weight); 3) temperature (°C); 4) resistance; 5) mechanical properties of KhP; 6) ammonia; 7) chromic acid; 8) the same; 9) hydrochloric acid; 10) hydrofluoric acid; 11) nitric acid; 12) phosphoric acid; 13) sulfuric acid; 14) acetic acid; 15) potassium hydroxide; 16) sodium hydroxide; 17) liquid, anhydrous; 18) concentrated; 19) up to; 20) glacial; 21) weak action or none at all; 22) the same; 23) moderate action; 24) ultimate tensile strength – 180-240 kg/cm²; 25) relative elongation – 200-500%; 26) hardness in TM-2 apparatus – 60-80; 27) embrittlement temperature – –25 to –40°.

to the action of acids and alkalies, as well as by good adhesion to metals (Table 3). They are heat-resistant to 80-90°, frost-resistant to –30 to –35°, and resistant to petroleum products containing up to 25% aromatic hydrocarbons. These rubbers are widely used for lining railroad tank cars intended for transporting hydrochloric acid.

Acid- and alkali-resistant rubbers based on PI are inert to chemical reagents and resistant to thermal and oxygen aging. PI-based mixtures begin to flow at loads of 3 kg/cm². A composition of type P-155 or P-200 PI, soot, and graphite is usually employed; it is produced in sheets under the trademark PSG and these are cemented or hot-air welded at 200°.

Table 4 presents data on the acid and alkali resistance of PI-based PSG mixtures.

BK-based rubbers have a higher resistance to aggressive media than those based on unsaturated polymers and are comparable to PI compositions. In contrast to PSG coatings, protective linings of BK are mechanically strong, elastic, and durable, do not flow, and resist fats and vegetable oils, which destroy PI. The principal drawback of BK rubbers is their lack of adhesion to metals.

Acid- and alkali-resistant rubbers based on KhP have a high resistance to chemical reagents, aliphatic hydrocarbons, ozone, and oxygen and are heat-resistant and durable. Table 5 presents data on the acid and alkali resistance of KhP rubbers.

Acid-resistant hoses of KhP are distinguished by good operational characteristics in working with sulfuric acid, hydrofluoric acid, and other oxidizing agents. KhP rubbers are widely used in chemical enterprises for lining tanks and chlorination and pickling baths and in the manufacture of packing components which must be both chemically stable and durable.

Acid- and alkali-resistant rubbers based on an ethylene-propylene copolymer (EP) are characterized by high elasticity, durability, and ozone, acid, and alkali resistance. EP has a higher acid and alkali resistance than BK.

EP-based rubbers adhere poorly to metals. They are used principally in the manufacture of packing components intended to operate in highly active aggressive media.

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F.Ye.Fradkina

ACIDPROOF CERAMICS - are ceramic materials characterized by a high chemical stability to the effect of acids (hydrofluoric acid being excluded), alkalis and gases. Acidproof ceramics are made from high-melting or refractory clays (talcum, feldspar, etc.) and also from porcelain or semiporcelain, and are characterized by a high mechanical strength and a low permeability for gases. Special acidproof ceramics may be made from special bodies or pure oxides and must prove an elevated chemical stability to the action of extremely strong chemical substances (phosphoric acid, for example), and also have a low thermal expansion coefficient, an increased heat endurance, a high mechanical strength and other specific properties. Depending on the composition, the acidproof ceramics are characterized by the data given in Table 1.

TABLE 1

Physicochemical Properties of Acidproof Ceramics

Показатели 1	Величины показателей 2
3 Кислотостойкость (%)	92,0—99,8
4 Щелочестойкость (%)	80—95
5 Объемный вес ($г/см^3$)	2,10—2,30
6 Водопоглощение (%)	10,0—0,1
7 Предел прочности ($кг/см^2$):	
8 при сжатии	250—20 000
9 при растяжении	50—1100
при скручивании . . . . . . 10 .	50—800
Модуль упругости ($кг/см^2 \cdot 10^6$) 11 .	3-5—30-40
Коэфф. термич. расширения в интервале 20—100° $x \cdot 10^{-6}$ . . 12 .	0,05 -8
13 Теплопроводность (ккал/м·час·град)	0,9—12
Термостойкость (количество теплосмен; 600°—20°, вода). . . . . 14 .	2—10

1) Characteristics; 2) values of the characteristics; 3) acidproofness (%); 4) alkaliproofness (%); 5) weight by volume (g/cm^3); 6) water absorption (%); 7) strength (kg/cm^2); 8) compression strength; 9) tensile strength; 10) torsion strength; 11) modulus of elasticity ($kg/cm^2 \cdot 10^6$); 12) coefficient of thermal expansion within 20-100°, $x \cdot 10^{-6}$; 13) heat conductivity (kcal/m·hr·degree); 14) heat endurance (number of thermal shocks; 600°-20°, water).

In Table 2, data on the chemical stability of the basic types of ceramic materials are given.

TABLE 2

Chemical Stability of Diverse Ceramic Materials

1 Показатели	2 Каменные керамич. изделия	Кислотоупорный кирпич 3	Фарфор 4	Кордиеритовые изделия 5	Карборундовые изделия 6	Форстеритовые изделия 7
8 Кислотостойкость (%) . . .	94—98	92—94	97—98	92,2—99,5	97—98	94—95
9 Щелочестойкость (%).	80—92	80—85	86—88	94—95	85—86	88—89

1) Characteristics; 2) stony ceramics; 3) acidproof brick; 4) porcelain; 5) cordierite products; 6) carborundum products; 7) forsterite products; 8) acidproofness (%); 9) alkaliproofness (%).

The acid- and alkaliproofness are determined according to GOST 473-53. Acidproof ceramics are subdivided into 2 groups with regard to their properties, the methods of production, and the purposes: 1) with a coarse-grained body, as acidproof bricks or tiles, used for lining of chemical reaction apparatus, etc.; 2) with a fine-grained body, as materials for centrifugal and piston pumps, ventilators and pipes for the transport of aggressive fluids, cocks for high pressures, diverse apparatus for reactions (towers, condensers, vessels for diverse purposes, tanks for stationary lead accumulators, and also packings of reaction columns. The greater part of these products is delivered in diverse standardized types and shapes. The products from acidproof ceramics may be glazed in order to increase the tightness to gas and moisture. Acidproof ceramics are used in the chemical, textile, cellulose- and paper, hydrolytic, metallurgic, and pharmaceutic industries and in important types of acidproof ceramics delivered by the industry are listed in Table 3.

The low heat endurance of the acid proof ceramics, especially of that with a compact body, is a disadvantage of them; therefore, a rapid heating and cooling of the products must be avoided.

TABLE 3

Properties of the Main Types of Acid-proof Products

1 Вид изделий	2 Кислотостойкость (%)	3 Водопоглощение (%, не более)	4 Предел прочности (кг/см², не менее)		7 Гидравлич. давление (атм, не менее)	8 Термич. стойкость для изделия (количество теплосмен, не менее)
			5 при сжатии	6 при изгибе		
9 Кислотоупорный кирпич	92—94	8—12	150—250	—	—	2
10 Кислотоупорные плитки марки К	95—98	5—7	200—250	120—150	—	2
11 Термокислотоупорная плитка марки ТК	95—97	6—10	200—250	120—150	—	3—8
12 Плитка для гидролизной промышленности	97	6	250	150	—	10
13 Трубки кислотоупорные	97—98	3—5	300—400	—	3—4	1—2
14 Хим. аппаратура	97—98	3—6	300—400	—	—	1
15 Краны	97—98	3—6	300—400	—	3	1
16 Кольца насадочные:			19 разрушающий груз (кг)*			
17 керамические	98	5	350—11000	—	—	2
18 полуфарфоровые	98	2	2000—2500	—	—	5—6

* Depending on the ring diameter.

1) Type of the product; 2) acidproofness (%); 3) water absorption (%, not more than); 4) ultimate strength (kg/cm^2, not less than); 5) in compression; 6) in bending; 7) hydraulic pressure (atm, not less than); 8) heat endurance (number of thermal shocks, not less than); 9) acidproof brick; 10) acidproof tiles, grade K; 11) thermoacidproof tiles, grade TK; 12) tiles for the hydrolysis industry; 13) acidproof pipes; 14) chemical apparatus; 15) cocks; 16) packing rings; 17) ceramic; 18) semiporcelain; 19) destructive load (kg).

V.L. Balkevich

I-64K

ACID RESISTANCE — is the property of materials to withstand the action of acids, preponderantly of mineral acids: H_2SO_4, HNO_3, and Hcl. The acid resistance of pure substances, including polymers, depends mainly on their chemical type and the properties of the reaction products. The latter may be a nondegradated polymer forming a film on the surface, the film, for example, which developes on cellulose fibers under the action of H_2SO_4 (parchment paper), etc. Concentrated H_2SO_4 and HNO_3 act, as a rule, as sulfonating or nitrating agents, the former as a dehydrant also. Fluorine-substituted polymer hydrocarbons and some resins possess the highest, saturated hydrocarbons a medium and many of the polyesters a low acid resistance. The fillers may play an essential part in technical polymers. Thus, carbon blacks and silica gel improve the acid-resistance; fillers, however, which are soluble in acids — chalk, for example — reduce the acid-resistance. The acid-resistance of polymers may be improved by preparation of their surface, applying of special coatings, for example, which have a high acid-resistance. The latter decreases when the temperature rises. A rapid evaluation of the acid resistance is carried out by treatment of the material with acids at higher temperatures, or at room temperature with more highly concentrated acids. The former method gives more reliable results.

N.N. Lezhnev

ACID-RESISTANT NICKEL ALLOYS are nickel-base alloys which are characterized by high corrosion resistance in many aggressive media, in connection with which they find wide application in chemical machinery construction (see Corrosion of Nickel Alloys). Many of the alloys also have excellent high-temperature strength. As a rule, the nickel alloys containing chromium and tungsten are resistant in aggressive oxidizing media. The alloys of the Ni-Cu and Ni-Mo-Fe systems which do not contain chromium are resistant in aggressive nonoxidizing media. The Ni-Cu alloys which are additionally allowed with aluminum and silicon are characterized by high strength after aging, which expands considerably their field of application in chemical machinery design. Moreover, additional alloying with silicon markedly improves the casting properties of the nickel alloys. Simultaneous alloying with silicon and copper considerably improves the corrosion resistance of the nickel alloys in hot solutions of sulfuric acid. The Ni-Mo alloys have high corrosion resistance in hydrochloric acid and alloying of these alloys with iron improves their pressure workability. The chemical composition and physicomechanical properties of the most widely used acid-resistant nickel alloys are shown in Tables 1 and 2.

Monel metal (NMZhMts 28-2.5-1.5) is used for detail parts of medium strength and high corrosion resistance in the fabrication of equipment for the petroleum refining and pharmaceutical industries, pumps for mine waters, for elements of unique architectural trim. This alloy is stable in hydrofluoric acid, sea water, concentrated alkalis (with the exception of NH_4OH), dilute solutions of sulfuric acid. It is not

TABLE 1

Chemical Composition of Acid-Resistant Nickel Alloys

Сплав 1	2 Содержание элементов (%)											3 Другие элементы
	C	Mn	Si	Cr	Co	Al	Mo	Fe	W	Cu	Ni	
Монель-металл (НМЖМц 28-2,5-1,5) 4	<0,2	1,2—1,8	0,2	—	—	<0,05	—	2—3	—	27—29	65—70	—
Монель К 5	<0,25	<1	<1	—	—	2—4	—	<2	—	6 Остальное	63—70	—
Монель S 5	<0,25	0,5—1,5	3—5	—	—	<0,5	—	<3	—	7 То же	62—68	—
Инконель 8	<0,12	<1	<0,5	14—17	—	—	—	6—10	—	<0,5	6 Остальное	—
Хастелой A 9	<0,12	<3	<1	—	—	—	20—22	18—20	—	—	7 То же	—
Хастелой B 9	<0,12	<3	<1	<1	—	—	26—30	4—7	—	—	•	V 0,3
Хастелой C 9	<0,12	<1	<1	15,5—17,5	—	—	16—17	4,5—7	3,75—5,25	—	•	—
Хастелой D 9	<0,12	0,8—1,25	8,5—10	<1	—	—	—	<1	—	3,6—6,5	•	—
Хастелой F 9	<0,05	—	—	21—23	—	—	5,5—7,5	Остальное	—	—	44—47	Ta+Nb 1,75—2,5
Хастелой W 9	<0,12	<1	<1	5,5	<2,5	—	25	5,5	—	—	Остальное	V 0,6
Хастелой X 9	<0,15	—	—	22	—	—	9	20	—	—	45	—
Нионель 10	<0,05	<0,5	<0,5	19,5—23,5	—	—	25—35	Остальное	—	1,5—3	38—46	Ti 0,6—1,2
Иллиум G 11	<0,1	1	—	18—22	—	2	6	6	3	6	58	Ti 0,02

1) Alloy; 2) element content (%); 3) other elements; 4) Monelmetal (NM-ZhMts 28-2.5-1.5); 5) Monel; 6) balance; 7) same; 8) Inconel; 9) Hastelloy; 10) Nionel, 11) Illium G.

recommended for operation at temperatures above 375° nor in oxidizing media or aerated acid solutions. It is produced in the form of rod, forgings, sheet, strip, wire, tubing and castings.

Monel K is used for parts of high strength and high corrosion resistance (pump valves, springs). This alloy is strengthened by aging. With respect to corrosion properties it is close to ordinary monel metal. It is not recommended for operation at temperatures above 315° in media containing sulfur compounds. It is produced in the form of rod, forgings, strip, tubing.

TABLE 2

Physical and Mechanical Properties of Acid-Resistant Nickel Alloys

Свойства 1	Монель-металл 2	Монель K* 3	Монель S* 3	Инконель 4	Хастеллой A 5	Хастеллой B	Хастеллой C	Хастеллой D	Хастеллой F 5	Хастеллой W	Хастеллой X	Нионель	Иллиум G 7
Вид материала 8	Прокат 9	Прокат 9	Отливки	Прокат	Прокат	Прокат	Прокат	Отливки 10	Прокат	Прокат	Прокат 9	Прокат 9	Отливки 10
E (кг/мм²) 11	17 500	—	14 800	—	19 000	21 500	21 000	20 300	20 400	—	—	19 900	17 100
σ_b (кг/мм²)	49—59	91—105	77—102	56—70	77—84	85—98	85—90	80	72	87	80	64	48
$\sigma_{0,2}$ (кг/мм²)	18—31	63—77	56—81	21—31	33—36	40—46	40—48	—	31	37	36	25	20
δ (%)	30—50	10—25	1—4	35—50	40—48	40—45	38—46	1	46	55	43	50	7.5
ψ (%)	—	—	—	—	40—56	40—45	25—50	1	—	—	—	43	11.3
HB (кг/мм²)	110—140	20—30 (RC)	275—350	120—170	200—215	210—235	160—210	30—39 (RC)	88 (RB)	—	—	72—80 (RB)	168
γ (г/см³) 12	8,84	8.47	8.36	8.51	8.8	9.24	8.94	7.8	8.17	9.03	8.23	7.86	8.56
$\alpha \cdot 10^6$ в интервале 20—100 (1/°C) 13	14	14	12,2	11,5	11	10	11.3	11	14.2	11.3	13.8	12.9 (26—93°)	13.9 (0—100°)
λ (кал/см·сек·°C) 14	0,062	0.048	—	0.036	0.04	0.027	0.03	0.05	—	—	—	—	0.029
c (кал/г·°C) 15	0,127	0.127	—	0.109	0.096	0.091	0.092	0.109	0.1025	—	0.105	—	0.105
16 $t°_{пл}$ (°C)	1300—1350	1310—1349	1260—1290	1395—1425	1595—1650	1600—1650	1270—1305	1110—1120	—	—	—	—	1254—1327
Темп-ра горячей обработки (°C) 17	9[illegible]—1150	730—1175	—	870—1260	1035—1230	1035—1250	1010—1230	—	850—1160	—	980—1200	—	—

*Mechanical properties after aging.

1) Property; 2) Monel metal; 3) Monel; 4) Inconel; 5) Hastelloy; 6) Nionel; 7) Illium G; 8) material form; 9) rolled stock; 10) castings; 11) (kg/mm²); 12) (g/cm³); 13) in range; 14) (cal/cm-sec-°C); 15) (cal/g-°C); 16) $t°_{pl}$ (°C); 17) hot working temperature (°C).

Monel S is used for cast parts operating in aggressive media with friction and sliding (valve seats, for example) and also for parts requiring high pressure tightness.

Inconel is used for parts of high strength and high corrosion resistance operating in oxidizing media, and also for parts operating at high temperatures. It is not recommended for operation at temperatures above 815° in media containing sulfur compounds.

Hastelloy A (EI460) is used for detail parts of equipment operating in hydrochloric acid at temperatures to 70°, in sulfuric acid diluted to 50% at temperatures up to the boiling point. It is not recommended for use in oxidizing media. This alloy machines satisfactorily, may be deformed in the hot and cold conditions. The optimal combination of corrosion resistance and strength is obtained after water or air quench from 1150-1175°. This alloy welds satisfactorily using gas, electric, and argon-arc welding.

Hastelloy B (EI461) serves for fabricating detail parts of equipment operating in hydrochloric acid of all concentrations at temperatures up to the boiling point and also in other nonoxidizing acids (phosphoric, sulfuric with concentration to 60%). It is not recommended for use in oxidizing media. It is used for operations in air up to 760°. This alloy deforms and welds satisfactorily. The best combination of corrosion resistance and strength of the alloy is achieved after air or water quench from 1175°. Quench from 1050-1060° with a soak time of 2-4 hours is also used. Tempering at 750° for 100-200 hours increases the alloy hardness to RC 45-50. It is satisfactorily welded using gas, electric, and atomic-hydrogen welding.

Hastelloy C (EI375) is used for detail parts of equipment operating at moderate temperatures in oxidizing media (moist chlorine, hypochlorite, ferric chloride, cupric chloride, nitric acid, phosphoric acid, mixture of hydrochloric acid with sulfuric acid under oxidizing conditions, sea water, many organic media, including acetic and formic acids and their salts). It is used for operations in air to 1090°. It is not recommended for operation in nitric acid at temperatures above 50°. This alloy is satisfactorily welded using gas, arc and hydrogen welding. It is produced in the form of sheet, plate and castings. Optimal corrosion resistance and strength are obtained after water quench from 1220°.

Hastelloy D is used for cast parts operating with hot solutions of sulfuric acid of all concentrations up to 70°. The corrosion resistance of the alloy diminishes in highly concentrated solutions of sulfuric acid (70-90%) at temperatures above 70°. It is not recommended for use in strongly oxidizing media. This alloy has high hardness and is very difficult to work. Annealing at 1050-1080° for 2-4 hours with subsequent slow cooling is used to improve the machinability. The alloy is cast into earth or chill molds.

Hastelloy F is used for detail parts of equipment operating in contact with acids and alkalis in oxidizing and reducing conditions. It has good resistance to stress corrosion in chloride solutions. It is produced in the form of sheet, rod, and castings. The best corrosion resistance, strength, and workability are achieved after water or air quench from 1175°.

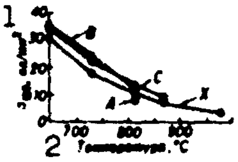

Fig. 1. Stress-rupture strength after 100 hours of the Hastelloy alloys A, B, C, X. 1) σ_{100}, kg/mm^2; 2) temperature, °C.

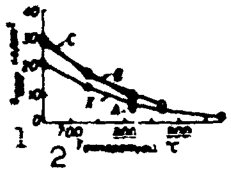

Fig. 2. Stress-rupture strength after 1000 hours of the Hastelloy alloys A, B, C, X. 1) σ_{1000}, kg/mm^2; 2) temperature, °C.

Nionel serves for the fabrication of containers for storing phosphoric and sulfuric acids, hot solutions of caustic soda. It may also be used in oxidizing media.

Illium G is used for high-strength cast parts in chemical machinery construction, for pump parts, and for parts of equipment in the viscose industry. It has good resistance to the action of sulfuric, phosphoric, nitric, and organic acids, mixtures of mineral acids and salts, and as also to the action of sea water, fluorine and sulfur compounds (H_2S, SO_2). It is not recommended for operation in contact with the halogens and their acids.

In addition to the forementioned Hastelloy-type corrosion-resistant alloys, the following special high-temperature alloys of this same type are widely used. Hastelloy W, which has high mechanical properties and is used for fabricating labyrinth rings for gas turbine engines. This alloy welds satisfactorily using various forms of welding with the use of filler metal of the same composition. Hastelloy X, which is used for detail parts of gas turbine engines (structural rings, gas collector housing, detail parts of the nozzle ring and combustion chamber). It welds well. In comparison with the other weldable alloys it has higher strength at high temperature.

The stress-rupture strength of some of the Hastelloy-type alloys is shown in Figs. 1 and 2.

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V.P. Batrakov, F.F. Khimushin

ACOUSTIC DEFECTOSCOPY – techniques for detecting flaws in multilayered metallic and nonmetallic structures and various combinations of them, separation in laminated plastics and certain other defects in other products; they are based on the use of elastic (usually bending) vibrations, usually in the audible (below 20 kc) frequency range.

The impedance method (sometimes known as the reaction method) is based on evaluation of the mechanical resistance (mechanical impedance) of the product being examined at the point of its contact with a pickup that sets the structure into elastic vibration. Used in detecting flaws in bonded, soldered and other types of joints between a thin skin and stiffening elements (spars, ribs, etc.) or fillers (foam plastics, honeycomb panels, and the like) in multilayered structures. Usually, the mechanical impedance is evaluated from the amplitude of the product's reaction force to the vibrating pickup in contact with it. A block diagram of an impedance defectoscope appears in Fig. 1. The sound generator supplies the upper piezoelectric element, which excites elastic vibrations in the pickup rod. The variable component of the reaction

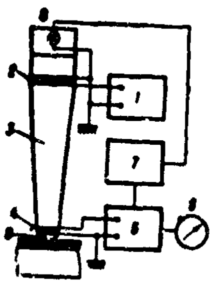

Fig. 1. Block diagram of acoustic impedance defectoscope: 1) Sound generator; 2) piezoelectric element; 3) rod; 4) piezoelectric element; 5) amplifier; 6) needle indicator; 7) relay device; 8) signal lamp; 9) contact terminal piece.

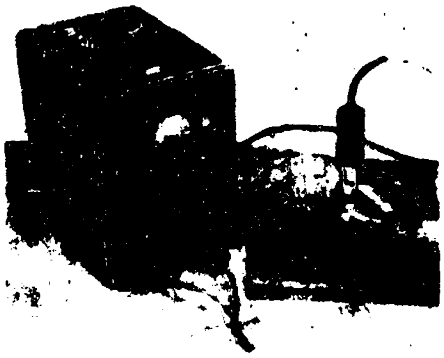

Fig. 2. General appearance of IAD-2 impedance defectoscope.

Fig. 3. Specimen flaw recording from bonded joint in large honeycomb panel.

force and the voltage across the lower piezoelectric element, which is proportional to the former, will be larger the higher the mechanical impedance of the product at the point of contact with the sensor. If there is no flaw in the joint, and the structure is vibrating as a single unit, the impedance is determined by the rigidity of the entire section and is rather large. If there is a flaw in the joint, the segment of skin that has separated from the internal element will vibrate independently, so that there will be a sharp decrease in the mechanical impedance and the signal level at the lower piezoelectric element and, consequently, at the output of the amplifier. Defects are announced by a signal lamp in the pickup and can also be read off the output indicator. This technique makes it possible to detect flaws in joints between internal elements of a structure and the skin with which the pickup is encountered; in sandwich structures with two skins, each skin is checked separately. The IAD-1 and IAD-2 defectoscopes are used in control work. The IAD-2 instrument (Fig. 2) has a working frequency range extending from 1 to 8 kilocycles. The power supply is 220-volt, 50-cycle alternating current; the device draws 100 va and weighs 11 kg. During operation, the operator moves the pickup over the surface of the object, watching the signal lamp. The dimensions and shapes of flaws are evaluated by using the pickup to outline the zone at which the joint is broken. This procedure is used to detect flaws in products made from various metallic and nonmetallic (glass-reinforced textolite, plastics, delta wood, etc.) materials provided that the skin material has a sufficiently high elastic modulus. Control is impossible from the side of the material having small elastic modulus (rubber, foam plastic, etc.). The material of the internal element of the structure makes no difference. Separation in laminated nonmetallic materials (for example, glass-reinforced plastics) situated at depths ranging up to 3-4 mm but not exceeding half the section can also be detected by the impedance method. The sensitivity of the method is determined by the parameters of the structures being controlled. With increasing skin rigidity and increasing rigidity of the internal element of the object, sensitivity rises. The minimum area of defect that can be detected is 15-20 mm^2. The limiting skin thickness for aluminum alloys, given a sufficiently rigid internal structural element, is 2 mm for control by the impedance method. The dependability and efficiency of the joint checkout may be increased by mechanizing the control process and recording the results. Figure 3 shows a trace of flaws in thebonded joint between the skin and filler in a large honeycomb panel, as obtained on a semiautomatic PI-1 apparatus. The defects appear in the form of light spots. The diagram gives a complete picture of the number, dimensions, shape and positions of the flaws detected.

The method of free oscillations (sometimes called the vibration method) is based on impact excitation of the product to be controlled and analysis of the nature of its damping natural vibrations. It is used to detect zones of joint separation (usually in bonded joints) between elements of multilayered metallic, nonmetallic and combined structures, detection of separation in nonmetallic products, etc. In the simplest variant of the method (tapping), the operator detects flaws by

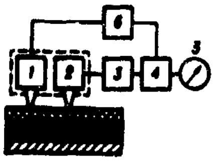

Fig. 4. Block diagram of defectoscope working by the free-oscillation method: 1) Vibrator; 2) piezoelectric receiver; 3) filter; 4) amplifier; 5) indicator; 6) power unit.

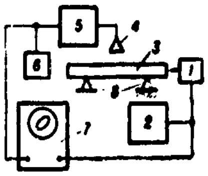

Fig. 5. Block diagram of apparatus for defectoscopy by the natural-frequency method (USA). 1) Vibrator; 2) sound generator; 3) product being tested; 4) microphone; 5) amplifier; 6) vacuum-tube voltmeter; 7) electronic oscilloscope; 8) workpiece supports.

ear, i.e., by the change in the tone of the sound. The use of apparatus eliminates subjective errors in evaluating product quality and expands the potential of the method. A block diagram of a defectoscope working on the free-oscillation method appears in Fig. 4. The defectoscope pick-up contains a vibrator that periodically strikes the surface of the product to be controlled and a piezoelectric receiver, which converts the damped pulses of elastic oscillations into electrical signals. After filtering and amplification, these signals are fed to the needle indicator. If there is a flaw in the joint, the nature of the pulses, and particularly their frequency spectrum, changes; the defectoscope filter blocks out those frequency components of the pulses that correspond to sound regions of the product. The presence of a defect causes higher-frequency components to appear in the pulse spectrum; these pass through the filter and deflect the needle of the output indicator. The type ChIKP-1, ChIKP-2 and other defectoscopes are used for controlling by the free-oscillation method. The ChIKP-2 instrument consists of two modules – a measuring module weighing 1 kg and a power pack weighing

4.5 kg. Power is by 220-volt 50-cycle alternating current; the power drawn is 200 va. In the control procedure, the operator presses the pickup against the surface of the product to be inspected, watching the defectoscope output indicator readings. Sensitivity diminishes with increasing depth of the flaw. The extent of the flaw is evaluated by outlining with the pickup. The ChIKP-2 defectoscope can detect separations and broken-joint zones between nonmetallic coatings and the base (which is usually metallic). With a coating thickness 5 to 80 mm thick, the smallest defect that can still be detected ranges from 2 to 8 cm^2, respectively.

Unlike the impedance method, the free-oscillation method is used to detect separations and joint defects situated at depths to several tens of millimeters. It is particularly effective in checking for bonding defects between sheets of nonmetallic materials, which have poor conductivity for elastic vibrations (textolite, asbotextolite, plywood, and the like), as well as between nonmetallic materials and a metal. In the latter case, the control is usually performed on the nonmetallic side.

The natural-frequency method is based on measurement of resonance frequencies in bending vibrations. It is used in the USA to evaluate bond quality and detect cracks in abrasive grinding wheels. It can be used to control other products. Figure 5 shows a block diagram of an apparatus (USA) for defectoscopy by this method. The vibrator, which is fed by a sound generator, excites bending vibrations in the product being controlled. The product is mounted on supports that coincide with the nodes of its vibrations. A microphone converts the sound waves radiated by the object into an electrical voltage. After amplification, this voltage is fed to a vacuum-tube voltmeter and the plates of an electronic oscilloscope. The signal from the generator goes to the other pair of oscilloscope plates; by varying its frequency, we may determine the fundamental resonance frequency of the object from the maximum voltmeter reading. The oscilloscope makes it easier to find this frequency by helping separate it from the harmonics (using Lissajous figures). In quality-control work on abrasive grinding wheels, a decline in bonding quality or the presence of tracking lowers the natural frequency, and this serves as a basis for identifying rejects.

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Yu.V. Lange

ACOUSTIC PROPERTIES – properties characterizing the behavior of materials toward sound waves (ZV). One of these properties is the velocity of propagation of the ZV, which is determined by the formula $c=\sqrt{\frac{K}{\rho}}$, where ρ is the density and K is a coefficient taking account of the elastic properties of the medium. The speed of sound depends on the nature of the ZV (longitudinal or transverse) the state of the medium and the temperature.

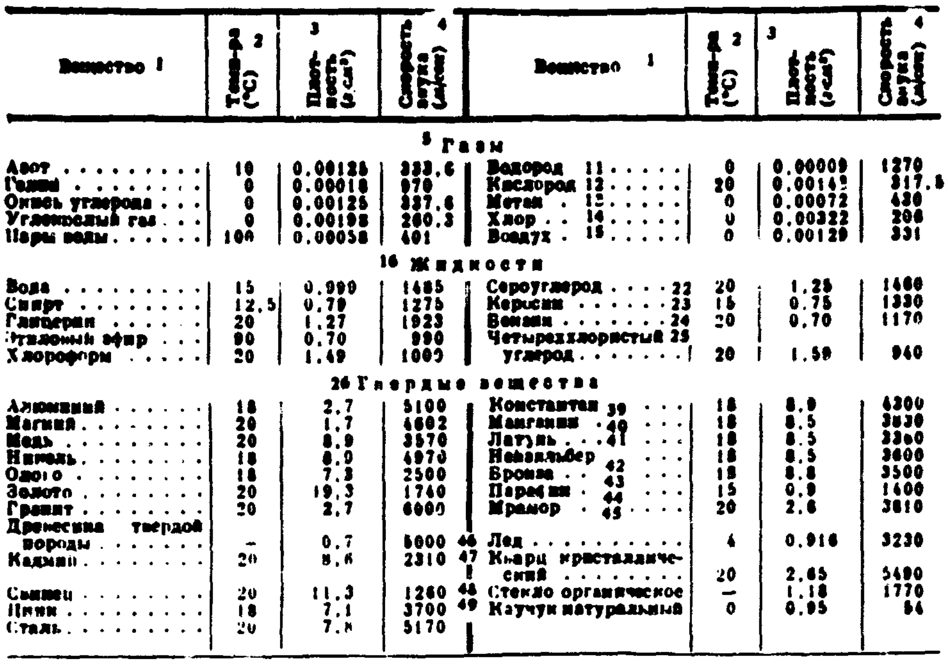
When a ZV strikes an obstacle, part of the energy is reflected, while the rest enters the obstacle, where it is partle absorbed by the work of friction in the material and partly radiated. The property of materials by which they absorb ZV energy is characterized by the sound absorption coefficient α, i.e., the ratio of the sound-wave energy absorbed by the material to the energy of the incident wave. The sound absorption coefficient depends on the frequency of the ZV, the state of the material and its dimensions. It is particularly large for gaseous and solid substances with small open pores.

The ratio of the intensity of the sound that has passed through the material to the intensity of the incident ZV is known as the acoustic permeability coefficient τ. Engineering also uses the sound insulation coefficient σ, which is the reciprocal to τ.

The reflected part of the ZV is characterized by the sound reflection coefficient β, which is the ratio of the reflected ZV intensity to the incident intensity. The coefficient β influences reverberation, i.e., the continuation of the sound after the source has ceased sound-

TABLE 1

Velocity of Sound Propagation in Various Substances



Вещество 1	Темп-ра (°C) 2	Плотность (г/см³) 3	Скорость звука (м/сек) 4	Вещество 1	Темп-ра (°C) 2	Плотность (г/см³) 3	Скорость звука (м/сек) 4
5 Газы							
6 Азот	10	0.00125	333.6	Водород 11	0	0.00009	1270
7 Гелий	0	0.00018	970	Кислород 12	20	0.00142	317.5
8 Окись углерода	0	0.00125	337.6	Метан 13	0	0.00072	430
9 Углекислый газ	0	0.00198	260.3	Хлор 14	0	0.00322	206
10 Пары воды	100	0.00058	401	Воздух 15	0	0.00129	331
16 Жидкости							
17 Вода	15	0.999	1485	Сероуглерод 22	20	1.26	1160
18 Спирт	12.5	0.79	1275	Керосин 23	15	0.75	1330
19 Глицерин	20	1.27	1923	Бензин 24	20	0.70	1170
20 Этиловый эфир	20	0.70	990	Четыреххлористый 25 углерод	20	1.59	940
21 Хлороформ	20	1.49	1005				
26 Твердые вещества							
27 Алюминий	18	2.7	5100	Константан 39	18	8.9	4300
28 Магний	20	1.7	4602	Манганин 40	18	8.5	3830
29 Медь	20	8.9	3570	Латунь 41	18	8.5	3360
30 Никель	18	8.9	4970	Нейзильбер 42	18	8.5	3600
31 Олово	18	7.3	2500	Бронза 43	18	8.8	3500
32 Золото	20	19.3	1740	Парафин 44	15	0.9	1600
33 Гранит	20	2.7	6000	Мрамор 45	20	2.6	3810
34 Древесина твердой породы	—	0.7	5000	46 Лед	4	0.916	3230
35 Кадмий	20	8.6	2310	47 Кварц кристаллический	20	2.65	5490
36 Свинец	20	11.3	1260	48 Стекло органическое	—	1.18	1770
37 Цинк	18	7.1	3700	49 Каучук натуральный	0	0.95	54
38 Сталь	20	7.8	5170				

1) Substance
2) Temperature (°C)
3) Density (g/cm^3)
4) Speed of sound (m/sec)

5) Gases

6) Nitrogen
7) Helium
8) Carbon monoxide
9) Carbon dioxide
10) Water vapor
11) Hydrogen
12) Oxygen
13) Methane
14) Chlorine
15) Air

16) Liquids

17) Water
18) Alcohol
19) Glycerine
20) Ethyl ether
21) Chloroform
22) Carbon disulfide
23) Kerosene
24) Gasoline
25) Carbon tetrachloride

26) Solids

27) Aluminum
28) Magnesium
29) Copper
30) Nickel
31) Tin
32) Gold
33) Granite
34) Hardwood
35) Cadmium
36) Lead
37) Zinc
38) Steel
39) Constantan
40) Manganin
41) Brass
42) German silver
43) Bronze
44) Paraffin
45) Marble
46) Ice
47) Crystal quartz
48) Organic glass
49) Natural rubber

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TABLE 2

Coefficient of Sound Absorption in Various Materials

1 Материал	2 Толщина (мм)	3 Коэффициент звукопоглощения при частоте звуковой волны (гц) 512	1024
4 Асборит	20	0.44	0.48
5 Асбосиликит АСА	45	0.80	0.83
6 Асбестит АЦА	25	0.36	0.30
7 Акустолит АСП	30	0.26	0.23
8 Авиационный изоляционный материал АТИМХ-10	—	0.07	0.22
9 Авиационный изоляционный материал АТИМХ-15	—	0.15	0.43
10 Бетон	—	0.015	0.019
11 Войлок	25	0.55	0.66
12 Фиброакустит	25	0.67	0.64
13 Линолеум на бетонной основе	5	0.05	0.06
14 Вермикулит	20	0.60	0.65
15 Вата минеральная	28	0.68	0.75
16 Пеностекло	20—120	0.40	0.40
17 Стекло оконное	5	0.027	—
18 Мрамор	—	0.010	—
19 Резина	5	0.08	0.12

1) Material; 2) thickness (mm); 3) sound absorption coefficient at sound wave frequency of (cps); 4) asborite; 5) asbosilicate ASA; 6) asbestite ATsA; 7) acoustolite ASP; 8) ATIMKh-10 aviation insulating material; 9) ATIMKh-15 aviation insulating material; 10) concrete; 11) felt; 12) fibroacoustite; 13) linoleum on concrete base; 14) vermiculite; 15) mineral wool; 16) foam glass; 17) window glass; 18) marble; 19) rubber.

TABLE 3

Sound Insulation Coefficients of Various Materials

Материал 1	Коэффициент звукоизоляции (дб) 2
3 Алюминий	26.0
4 Сталь	10.6
5 Свинец	20.0
6 Стекло оконное	6.0
7 Бетонная стена	1.02
8 Фанера 3-слойная	6.0

1) Material; 2) sound insulation coefficient (db); 3) aluminum; 4) steel; 5) lead; 6) window glass; 7) concrete wall; 8) 3-ply plywood.

ing.

The three coefficients are linked by the relationship $\alpha + \beta + \tau = 1$. The acoustic permeability coefficient is generally much smaller than the others.

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References: Dreyzen, I.G., Kurs elektroakustiki [Course in Electroacoustics], Vol. 1, Moscow, 1938; Key, D. and Lebi, T., Siravochnik fizika-eksperimentatora [Handbook of the Experimental Physicist], translated from the English, Moscow, 1949; Iofe, V.K. and Yanpol'skiy, A.A., Raschetnyye grafiki i tablitsy po elektroakustike [Working Diagrams and Tables in Electroacoustics], Moscow-Leningrad, 1954; Bedilo, A.T., Zvukoizoliruyushchiye i zvukopogloshchayushchiye materialy i izdeliya [Sound-Insulating and Sound-Absorbing Materials and Products], L'vov, 1957; Bubley, R.Ye., Akustika [Acoustics], Kiev, 1959.

V.V. Korolev

Manuscript Page No.	[Transliterated Symbols]
33	3B = ZV = zvukovaya volna = sound wave

ACOUSTIC RESISTANCE (specific acoustic impedance) – the ratio of the applied acoustic pressure (in bars) to the acoustic velocity (the velocity of particle vibration due to the sound):

$$\frac{p}{v} = \rho \cdot c \cdot r_a,$$

where r_a is the acoustic resistance, ρ is the density of the medium, c is the velocity of propagation of sound in the medium, p is the acoustic pressure and v is the acoustic velocity. The acoustic resistance characterizes the ability of the medium to absorb energy from a sound source oscillating with a given amplitude.

Acoustic Resistances of Gases, Liquids and Solids

Среда [1]	Акустическое сопротивление·10^{-4} ($г/см^2$ сек) [2]	Среда [1]	Акустическое сопротивление·10^{-4} ($г/см^2$ сек) [2]
	3 Газы		
4 Водород	0.0011	Воздух (сухой) 7	0.00415
5 Водяной пар	0.0023	Кислород 8	0.0046
6 Метан	0.0030	Окись углерода 9	0.0050
	Жидкости 10		
11 Бензин	9.4	Вода морская (соленость 0.036‰) 15	15.3
12 Спирт	10.0	Ртуть 16	191
13 Керосин	10.7	Трансформаторное масло 17	12.8
14 Вода (пресная)	14.3		
	Твердые тела 18		
19 Свинец	246	Медь 26	418
20 Алюминий	169	Сталь 27	456
21 Латунь	360	Стекло 28	120—150
22 Чугун	206	Кварц (по оси X) 29	152
23 Магний	92.6	Древесина (дуб) 30	32
24 Полистирол	29.4	Парафин 31	13
25 Никель	495	Резина 32	13.3
		Бакелит 33	30.2

1) Medium

2) Acoustic resistance·10^{-4} (g/cm^2·sec)

3) Gases

4) Hydrogen
5) Water vapor
6) Methane

7) Air (dry)
8) Oxygen
9) Carbon monoxide

10) Liquids

11) Gasoline
12) Alcohol
13) Kerosene
14) Water (fresh)
15) Sea water (salinity 0.036 o/oo)
16) Mercury
17) Transformer oil

18) Solids

19) Lead
20) Aluminum
21) Brass
22) Cast iron
23) Magnesium
24) Polystyrene
25) Nickel
26) Copper
27) Steel
28) Glass
29) Quartz (along X-axis)
30) Wood (oak)
31) Paraffin
32) Rubber
33) Bakelite

References: Furduyev, V.V., Elektroakustika [Electroacoustics], Moscow-Leningrad, 1948; Landau, L.D., Lifshits, Ye.M., Mekhanika sploshnykh sred [Mechanics of Continuous Media], Moscow, 1954; Krasil'nikov, V.A., Zvukovyye i ul'trazvukovyye volny v vozdukhe, vode i tverdykh telakh [Sonic and Ultrasonic Waves in Air, Water and Solids], 3rd Ed., Moscow, 1960; Skuchik, Ye., Osnovy akustiki [Fundamentals of Acoustics], translation from the German, Vol. 1-2, Moscow, 1958-59.

V.V. Korolev

ACRYLAN – synthetic carbon-chain modified polyacrylonitrile fiber based on the mixture of copolymers of acylic acid nitrile with vinyl acetate (95:5%) and acrylic acid nitrile with 2-methylvinylpyridine (50:50%). Acrylan is stable to sunlight and biological attack, and does not dissolve or swell in ordinary organic solvents. Sp. gr. 1.17; moisture content 1.27% under standard conditions; residual moisture on drying 1.6%. Loses 5% of strength on heating for 20 hours at 150°. The dielectric constant (frequency 60 cps) is 4.5. Acrylan is readily dyed with acid, basic, and vat dyes, as well as by acetate-fiber dyes. The breaking length of acrylan is 22.5 km dry and 18 km wet; the respective elongations are 35 and 44%. The elasticity (reversible deformation) for an elongation of 2% is 99%, but only 67% for 10% elongation. As regards resistance to rubbing, acrylan is inferior to polyamide and polyester fibers, but better than wool. Acrylan is mixed with cotton for use in the fabrication of special clothing for workers in the chemical industry. 35-45% of high-shrinkage fiber is added to ordinary stable fiber to produce a high-volume yarn. Acrylan products are distinguished by shape and dimensional stability.

L.M. Musichenko

ACRYLATE LATICES are latices of rubber-like copolymers of the acrylic or metacrylic esters with other monomers. The properties of the products and films made from the acrylate latices are determined by the composition of the copolymer. The products made from the latices based on the saturated polymers (for example, nitrile-acrylate) are outstanding in their high resistance to atmospheric influences, to the action of ultra-violet rays, ozone, heat, etc. Products made from the divinyl acrylate latices have outstandingly high elasticity and frost resistance. The presence in the polymer of the divinyl bonds makes possible the conduct of the sulfur vulcanization process, but decreases the resistance of the films to atmospheric influences. The acrylate latices contain polar polymers which integrate well with the polar resins and do not dissolve in the aliphatic hydrocarbons. A general property of the acrylate latices is the excellent luster of the films obtained from them.

Among the acrylate latices based on the saturated polymers, use is made of the copolymer ethylacrylates (Lactoprene E, Hycar PA-21, Hycar 4021) and the butylacrylates (Lactoprene BN). The vulcanizates based on the ethylacrylate latices have a brittle temperature of −8° and have high oil resistance. Aging for 3 days at 175° does not cause noticeable reduction of strength of the products. Products made from Lactoprene BN are characterized by resistance to the action of hot oils, heating to high temperatures in the air, atmospheric attack, and a comparatively low brittle temperature (−27°). Vulcanization can be accomplished by introduction into the latex of sulfur and triethylene tetramine. At the present time the widest application has been made of the acrylate latices with unsaturated acrylate elastomers obtained by copolymerization of methacrylate with divinyl (for example, the Butakons ML 501, ML 507, ML 508 and ML 590).

The divinyl acrylate latices are widely used in the paper industry as binders for pigments in the production of rubberized paper and cardboard. The application of coatings made from caolin or a mixture of caolin with pigments with the use of casein, animal glue or starch with ML 501 latex as a binder improves the luster, the surface appearance, the water resistance, texture, and suitability of the paper for printing. The ML 507 latex is used for protection of the paper surface in the production of washable wallpapers. In the textile industry use is made of the ML 508 Butakon as the basis for the preparation of adhesives for the laying of rugs and the fabrication of nonwoven textile materials. The divinyl acrylate latices (in particular the ML 590 Butakon) are widely used for dressing leather, since they provide satisfactory frost resistance, good luster and adhesion and excellent oil resistance of the coating.

The acrylate latices whose production methods have been developed in the USSR contain ternary copolymers of divinyl, acrylate ester and metacrylic acid. The presence of carboxyl groups in these copolymers still further improves the adhesive properties of the latices and the physical and mechanical properties of the films. The DMA-80-1 and DMMA-65-1 latices are used for dressing leathers, as leather substitutes in industry, in the paper industry and in other fields.

A.I. Yezriyelev, A.V. Lebedev

ADHESION (sticking) – the formation of a bond between two unlike bodies (phases), solid or liquid, that are brought into contact. The appearance of the bond is due to forces of interaction (ionic, van der Waals, metallic). In the limiting case of chemical interaction between the adhesion pair (chemosorption bond), a surface chemical compound is formed.

In a number of cases a double electric layer forms when two unlike bodies are brought into contact: electric charges of opposite signs appear on the adhesion pair, and their attraction, together with the intermolecular interaction, gives rise to adhesion. In the case of adhesion between high polymers, the principal role in the formation of the adhesion bond is taken by diffusion of molecules and individual chains of one polymer into the volume of the other. The interweaving of the chains produces tenacious adhesion, and instead of an interface a three-dimensional transitional layer forms in such cases. Adhesion of identical polymers is known as autohesion. In autohesion, prolonged contact results in transformation of the two parts of the phase into a single one. In practice, adhesion of solid bodies and polymers is most frequently encountered, for example, in bonding materials and application of polymer coatings.

The extent of adhesion is evaluated on the basis of the force (adhesion strength) or work (work of adhesion) necessary to break the adhesion bond. Instruments for measurement of adhesion are known as adhesiometers. The most common adhesion testing procedures are for tension, shear and peeling. Adhesion is characterized by a force in the

Fig. 1. Influence of linear dimensions d of nominal adhesion-bond area on its strength σ (schematic).

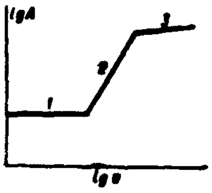

Fig. 2. Influence of rate v of process of breaking adhesion bond by peeling on work of adhesion A (schematic).

first two cases, and by a work in peeling. The force and work of adhesion depend on the area of actual contact, the speed at which the adhesion bond is broken, temperature and other factors. The larger the contact area, the greater will be the adhesion. The actual contact area between two bodies is usually considerably smaller than the nominal area due to surface roughness. Exceptions are as follows: 1) adhesion between two liquid phases (for example, in welding), 2) formation of an adhesion bond by application of a melt or solution to the surface of a solid body with subsequent cooling or evaporation of the solvent (soldering, hot tinning, formation of paint coatings, polymer films, adhesive sandwich layers), 3) formation of a second solid body as a new phase on the surface of the first solid body in growth of two-dimensional crystallization nuclei (for example, electrocrystallization). Increasing the duration of contact, the pressure and the temperature increases the actual contact area. In any method of establishing contact, however, the adhesion bond contains defects and nonuniformities, which, when the bond is broken, act as stress concentrators. Failure begins at these points and this is responsible for the scale effect,

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which consists in a decrease in adhesion strength with increasing linear dimensions of the nominal contact area (Fig. 1). The adhesion strength and work of adhesion increase with increasing speed of the process in which the joint is broken (Fig. 2). This is accounted for by an increase in mechanical losses and electrical phenomena related to the double electric layer. The free energy $f_A = \sigma_{12} - \sigma_{10} - \sigma_{20} < 0$, which characterizes the loss of free energy per 1 cm^2 of adhesion-seam surface in the isothermally reversible adhesion process, is the thermodynamic characteristic of adhesion. Here, σ_{12} is the surface tension of adhesion bond, σ_{10} is the surface tension of one body (phase), and σ_{20} is the surface tension of the other body (phase). The work of adhesion (in isothermally reversible rupture) $W_A = - f_A$. Measurements of adhesion encounter a number of difficulties. Among other things, rupture of a strong adhesion bond is frequently of mixed adhesive-cohesive nature (rupture takes place partly inside the body with the lower strength).

References: Adam, N.K. Fizika i khimiya poverkhnosti [Physics and Chemistry of Surfaces], translated from the English, Moscow-Leningrad, 1947; Krotova, N.A. O skleivanii i prilipanii [Bonding and Adhesion], Moscow, 1956; Deryagin, B.V. and Krotova, N.A., Adgeziya [Adhesion], Moscow-Leningrad, 1949; Voyutskiy, S.S., Autogeziya ' adgeziya vysokopolimerov [Autohesion and Adhesion of High Polymers], cow, 1960.

G.M. Bartenev

ADHESIVE-BONDED AND RIVETED JOINT – is a permanent combined joint of materials by means of an adhesive and of rivets. It differs from the adhesive joint by a higher (by 1.5-3 times) strength especially in the case of nonuniform peeling off, and, in joints of heatproof materials, under the effect of heat, and also by a higher reliability during a long-time service (the aging of the adhesive has a lower effect on the strength of the combined joint). The impact strength of the adhesive-bonded and riveted joint is higher, and the process of destruction is delayed. The compression strengths of diverse joints between the skin and the carrying elements of a Duralumin panel are quoted in the Table (the height is 1130 mm, the thickness of the skin is 1.1-1.4 mm, the size of the edge profiles is 30 × 30 mm, and the open space between them is 165 mm, A VK-32-EM adhesive was used).

TABLE

Темп-ра испытания (°C) 1	2 Критич. напряжение в обшивке клеезаклепочной панели (кг/мм²)	Относит. прочность панелей (%; прочность клеезаклепочной панели принята за 100%) 3	
		4 клеевая	5 клепаная
20	21.3	86	81
100	19.7	97	88
150	17.5	86	91
300	7.0	0	105

1) Test temperature (°C); 2) critical stress in the skin of the adhesive-bonded and riveted panel (kg/mm²); 3) relative strength of the panels (in %; the strength of the adhesive-bonded and riveted panel is assumed to be 100%); 4) adhesive joint; 5) adhesive-bonded and riveted joint.

The adhesive-bonded and riveted joint differs from one which is only riveted by a higher tightness and strength, especially in the case of cyclic loads (the durability of the adhesive-bonded and riveted joint may be by 5-10 times higher). 3 types of adhesive-bonded and riveted joints are to be distinguished, based on their design and their calculated stability. 1) a mainly adhesive joint, the rivets being applied only in a small quantity on places where stresses are active, on the edges of honeycomb panels, for example; 2) a mainly riveted joint, the adhesive being applied only in order to somewhat tighten and reinforce the joint (a thick adhesive layer, incomplete adhesion, impossibility of curing the adhesive by heating, an adhesive which is not resistant to heat, etc.); 3) a combined joint, the calculation of which must take into account both the part of the adhesive and of the rivets. The adhesive used for adhesive-bonded and riveted joints must manifest an elasticity in the layer which is sufficient to ensure a combined working of the adhesive (MPF-1, BF-2, BF-4, PU-2, VK-32-200, etc.) and of the rivets, and further, a fluidity which enables it to fill the gaps. It is expedient to use cold-curing adhesives.

The adhesive-bonded and riveted joint may be carried out in 2 ways: the riveting is done after the adhesive is cured; in this case, the holes for the rivets are drilled previously, (riveting by pressing is recommended); or the riveting is carried out before the adhesive is cured, and the curing of the latter occurs only in the finished combined joint (in this case, an equipment for pressing the adhesive is not necessary because the rivets themselves press the adhesive joint). A greater strength and tightness of the joint results by the first method; the second method is the more simple. It is recommended that the rivets be covered with liquid adhesive, that washers from an adhesive film be placed under the heads, and that a surfacial tightening of the joint be carried out in order to ensure tightness.

Adhesive-bonded and riveted joints are used for the bonding of pieces of metal, plastic, and wood materials, rarely of elastic or soft materials (rubbers, foamed plastics, and loose fibrous heat insulation). The adhesive bonded and riveted joint, as well as the riveted joint, are unsuitable for brittle materials (glass, ceramics). The adhesive-bonded and riveted joint may also be used to repair riveted joints under field conditions.

References: Goryunov Yu.B. Primeneniye kleyevykh i kleyezaklepochnykh soyedineniy pri remonte samoletov [The Application of Adhesive and Adhesive-bonded and Riveted Joints in the Repair of Aircraft], in the Collection: Klei i tekhnologiya skleivaniya [Adhesives and the Technology of Adhesive Bonding].

A.T. Tumanov

ADHESIVE-BONDED AND WELDED JOINT – is a permanent combined joint of metals by means of an adhesive together with resistance welding. The combination of the process of electric point-welding (rarely of step-by-step contact-roller welding) with the adhesive-bonding makes it possible to obtain joints in which many of the disadvantages are absent which characterize both the welded joints (nontightness, for example), and the adhesive joints (poor resistance to high temperatures or to non-uniform peeling off).

The design of adhesive-bonded and welded joints is similar to that of the joints made by resistance point-welding. The adhesive relieves the welding points and this fact makes it possible to increase the steps between them and to reduce their size; the effect of the welding on the structure and the properties of the basic metals is diminished in this way, and the strength of the joint is increased. Double-row checkered welding points must be used for the bonding of thick sheets. It is expedient to arrange the points in such a manner that the distance between the center and the edge of the overlap is not greater than the diameter of the cast core.

The adhesive-bonded and welded joint may be carried out by several methods. The 1st method (the basic one) is the electric point-welding on the liquid adhesive layer which is applied to the entire surfaces to be joined; the welding is carried out by machines of the MTIP type with a relatively weak impulse of the welding current. The 2nd method is the resistance welding of openings in the adhesive film or in the layer of a rapidly drying adheisve which was applied discontinuously by means of templates. This method is more laborious than the former. Its advantage, however, is the fact that the adhesive does not affect the forming process and the quality of the welded seam, that the time for beginning welding is not limited by the working life of the adhesive, and, if an adheisve film is used, the adhesive does not run out; these facts make it possible to bond parts of any shape and to heat them (if the adhesive is cured by heating) in any position. Welding on an adhesive film is carried out by machines with a strong impules of current (mainly, to avoid gaps between the surfaces to be jointed. The <u>3rd method</u> is the welding of the surfaces to be joined and the subsequent extrusion of the adhesive into the gaps between them. This method is simple, it is used for joining a skin with profiles welded-on by a single-raw seam; the strength of this joint, however, is lower than welding carried out on the adhesive.

The curing of the adhesive is carried out without external pressure; no complex presses for the adhesive-bonding of the pieces are necessary. Not every adhesive is adoptable for adhesive-bonded and welded joints. Only such adhesive are applicable as those which possess a sufficiently low viscosity (if a liquid adhesive is used), which evolve a minimum quantity of gases when heated in the welding zone, whose contamination of the cast core of the welding points by nonmetallic inclusions is insignificant, which form a stable joint at low pressures (in the range of 1 kg/cm^2 and below), and which have a sufficiently long working life (if a liquid adhesive is used). In most cases, the epoxy adhesives VK32-EM, VK-1, FL-4S, etc., are used for resistance welding on liquid adhesive. The strength of an adhesive-bonded and welded joint depends upon a number of factors in the design and technology; the type and size of the joint, the mechanical properties of the metals to be joined, the quantity, arrangement and diameter of the welding points, the type of the adhesive, the thickness of the bond line, the welding conditions, the curing process of the adhesive, etc. The strength factor, i.e., the ratio of the strength of the joint to the strength of the basic metal is approximately equal to the unit in the case of shift; in the case of peeling off, however, it amounts only to tenths of the former.

Under the conditions of static shear, the adhesive-bonded and welded joint is usually more stable than adhesive, welded or riveted joints. The typical strength of the above-mentioned joint types is shown in Fig. 1 in relation to the temperature.

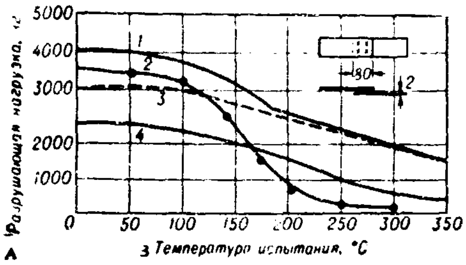

Fig. 1. Static shearing strength of overlapped Duralumin joints: 1) Adhesive-bonded and welded joint (VK-1 adhesive); 2) adhesive joint (VK-1 adhesive); 3) electric point-welding; 4) riveted joint (rivets with d = = 5 mm).

The adhesive-bonded and welded joints surpass the adhesive and the welded ones in regard to the stability against nonuniform peeling off (longitudinal compression, twisting of the panels formed by a skin which is reinforced by struts, and peeling off the skin from the frame), but they may be inferior to riveted and, especially, to adhesive-bonded and riveted joints.

The strength of the adhesive-bonded and welded joint in the case of shearing impacts is higher than that of similar adhesive, welded or riveted joints. Investigations of the effect of the design of the joint, of the grades of the metal and the adhesive, of the loading conditions and of other factors on the strength of the diverse types of joints under cyclic loads give different results for adhesive-bonded and welded, adhesive, welded, and riveted joints, but carrying capacity of the adhesive-bonded and welded joint is in every case higher than that of welded or riveted ones.

The typical diagram of the fatigue strength of the different types of overlapping joints of Duralumin is shown in Fig. 2. The rupture of adhesive-bonded and welded joints occurs in the metal at the edge of the overlap, i.e., in the zone which is not weakened by the welding heat, whereas rupture on the boundary of the welding point is characteristic for welded joints.

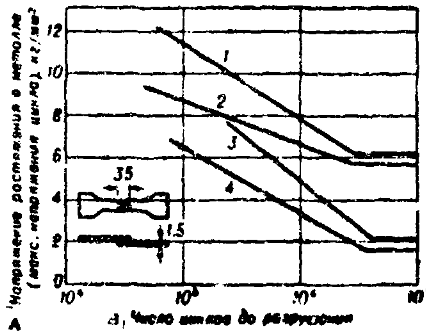

Fig. 2. Fatigue shearing strength for the overlapping joint of Duralumin: 1) Adhesive-bonded and welded joint (VK-1 adhesive); 2) adhesive joint (VK-1 adhesive); 3) riveted joint (rivets with d = 4 mm); 4) electric point-welding (the asymmetry coefficient of the cycle is 0.1, at normal temperature). A) Stress in the metal (maximum stress of the cycle), kg/mm^2; B) number of cycles until rupture occurs.

It is recommended that adhesive-bonded and welded joints be used for the reinforcing of stressed structures in designs of aluminum, magnesium, or titanium alloys as well as of low-alloy stainless carbon steels in the form of sheets and profiles with a thickness of 1-4 mm and more.

References: Pugachev A.I., Tekhnologiya izgotovleniya i svoystva kleyesvarnykh soyedineniy iz alyuminiyevykh splavov [Technology of the Production, and the Properties of Adhesive-bonded and Welded Joints of Aluminum Alloys], Moscow, 1959; Shavyrin V.N., Kleyesvarnyye kostruktsii

i ikh primeneniye [Adhesive-Bonded and Welded Designs and Their Application], "Svarochnoye proizvodstvo" [Welding Industry], 1959, No. 11; Pugachev A.I. [et al.], Kleyesvarnyye soyedineniya v aviakonstruktsiyakh [Adhesive-Bonded and Welded Joints in Aricraft Design], in the Collection Klei i tekhnologiya skleivaniya [Adhesives and the Technology of Adhesive-Bonding], Moscow, 1960.

A.T. Tumanov

ADHESIVE JOINT – is a permanent joint of parts by means of an adhesive (without melting it), which forms a thin layer (the bond line) between the parts. The advantages of the adhesive joint are: a method to bond heterogeneous materials together; tightness; resistance to corrosion, electric, thermal and acoustic insulation; absence of stress concentrators such as holes, and – as a result – an increased stability against vibrations; continuity of the joint, which contributes to the stability of thin-walled structural elements; the smooth outline of the bonded parts, etc. The disadvantages of the adhesive joints are: a relatively low heat resistance caused by the organic nature of the adhesives; a low peel strength, and resistance to "aging." Diverse constructive junctions are used for adhesive joints (Fig 1). The adhesive joints are subdivided in classes according to the adhesive and the material used, the shape of the object, the method and quality of the joint, and the intensity and type of the stressed state in the joint under the action of external forces. The mentioned factors are significant for the design, the calculation and the production of objects bonded by adhesives.

Adhesive joints are most efficient in cases of the junction of thin-walled structural elements operating under shear stress. The efficiency of adhesive joints of the overlap type, i.e., the relation of the stress σ_p in the material which causes a destruction of the joint to the tensile strength δ_b the material, is quoted in Table 1 in percents ($\frac{\sigma_p}{\sigma_b} 100\%$) as a function of the thickness δ of the material and the length of the overlap. The data in Table 1 are obtained for the material D16AT, and the adhesive BF-6 at a short-time static loading at 20°. The ultimate shearing strength of an overlapped or fished joint,

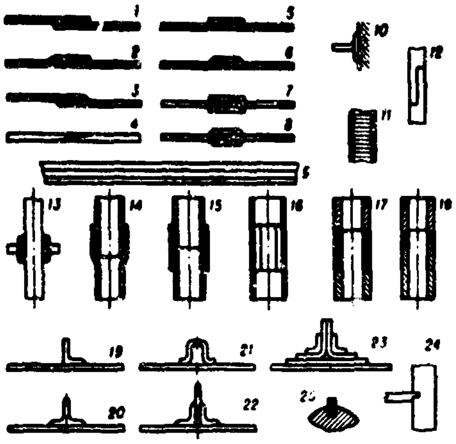

Fig. 1. Forms of the constructive junctions of parts in adhesive joints; 1) Simple lap; 2) overlapping; 3) lap with bevelled edges; 4) miter joint; 5) fishing; 6) fishing with bevelled edges; 7) fishing on both sides; 8) fishing on both sides, with bevelled edges; 9) flat ("Laminar") mating surfaces; 10) butt joint; 11) joint of a honeycomb core with panels; 12) concealed joint; 13) joint of a shaft with a nave; 14) joint of pipes by expansion; 15) joint of pipes by an external ring (sleeve) or by sectional laps; 16) joint of pipes with an insert; 17) telescopical joint; 18) miter joint of pipes; 19) angle with panel; 20) T-beam with panel; 21) U profile with panel; 22) joint of walls by means of two angles; 23) joint of a panel and a glued profile with a border of varying thickness; 24) joint by a groove; 25) fastening of a pin on a shaft.

i.e., the destructive load related to the bond area, decreases with the increasing length of the latter, but the maximum force sustained by the joint increases in this case until the stress in the joint parts approaches the tensile strength of the material (Fig. 2). In practice, the shearing strength of adhesive joints is higher the thicker the material, the higher its modulus of elasticity, and the higher its yielding. The carrying capacity of adhesive joints depends on the type of the joint (Fig. 3). The weakening effect of the bending is removed in joints fished on both sides, and they are by 5-20% more stable than joints with a (simple) overlap (fishing) on one side only, in which the bending effect, and, in turn, the stress in the bond line, is caused by the eccentricity of the force P (transmitted by the panels) to the plane of the bond area, $M_{\text{нз}} \approx 0{,}5\,(\delta_1+\delta_2)$ where δ_1 and δ_2 are the thicknesses of the material. Miter joints are the most stable, especially in the case of cyclic loads, but they are considerably more difficult to produce.

TABLE 1

1 Длина нахлестки l (мм)	2 σ_p/σ_b при толщине материала δ (мм)				
	0.25	0.5	1.0	1.5	2.0
5	78	45	28	20	18
10	95	85	45	30	25
20	98	92	70	50	40
35	100	98	83	72	57

1) Length of the overlap, l, mm; 2) σ_p/σ_b at a thickness of the material equal to σ (mm).

The following 3 types of breaking may be distinguished when the adhesive joint is affected by a load which involves stresses perpendicular to the surface of the connection: 1) uniform; 2) not uniform, and 3) peeling off (exfoliation), i.e., the extreme case of nonuniform breaking, if the tensile stress is concentrated on the border of the joint. The efficiency of an adhesive joint in the case of breaking (even a uniform one) is for the most part lower than in the case of

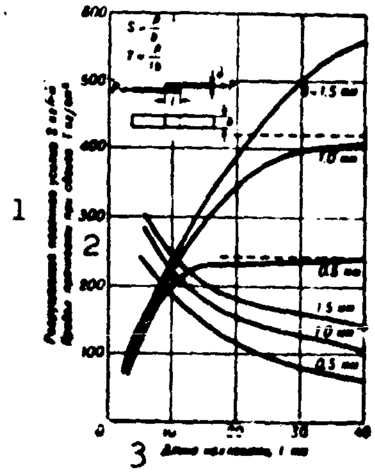

Fig. 2. Shearing strength of an adhesive joint (D16AT material, and BF-8 adhesive, at 20°) as a function of the length of the overlap and the thickness of the material. 1) Breaking force per linear unit, S, kg/cm; 2) shearing strength, T, kg/cm^2; 3) length of the overlap, l, mm.

shearing. It is determined by the ratio of the indices for the adhesive and cohesive properties of the adhesive and the limit tensile strengths of the joint parts.

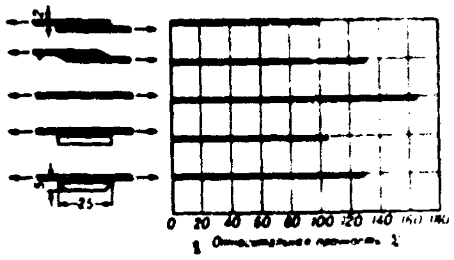

Fig. 3. Effect of the type of adhesive joint on the static shearing strength (Duralumin, BF-2 adhesive). 1) Relative strength, %.

The strength of an adhesive joint of a nonuniform breaking (of the joint between the skin and the framework of an aircraft wing, or of the vane of a helicopter, for example) is only a fraction of that of a uniform breaking; the strength increases with an increasing thickness of the skin and a reduced distance between the supports (Fig. 4). The functioning of an adhesive joint becomes especially difficult when there is a combined action of shearing and peeling off stresses. In this case the destruction occurs subsequently, part for part, and the maximum load per unit length does not depend on the bonded area. The strength of a thin flexible material decreases when the tearing-off angle increases from 0 (shear) to 45, 90, and 180° (the standard method for testing glued-on fabrics); its value is 100% (66 kg/cm), 33, 9.4, and 8.8%, respectively, for the AK-20 adhesive and the ANMZ material. The working of an adhesive joint under the conditions of a nonuniform breaking and peeling off can be avoided by reinforcing the joint by determining the optimum shape of the cross section of the frame part, by a local increase of the stiffness of the skin, by the selection of an elastic adhesive, by reinforcing the adhesive joint with rivets or by welding, etc.

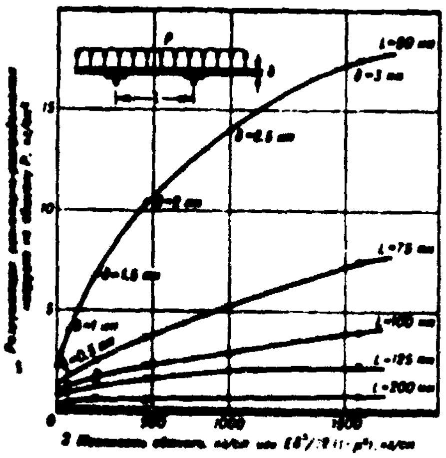

Fig. 4. Breaking load in the peel test of an adhesive joint between a skin and the longitudinal elements of the framework as a function of the cylindrical stiffness $E\delta^3/12(1-\mu^2)$ (where δ is the thickness of the Duralumin skin; E is the modulus of elasticity, and μ is the Poisson's ratio), and of the length L of the span between the frame elements (static short-time test at 20°; BF-2 adhesive; the border of the T-beam has a width of 35 mm). 1) Uniformly distributed breaking load of the skin, P, kg/cm^2; 2) stiffness of the skin, or $E\delta^3/12(1-\mu^2)$, kg/cm.

The compression strength of an adhesive is by 10-100 times higher than its tensile strength. An external compressing force increases the shearing strength of the adhesive joint. The breaking load P, $P = k\tau F$ where τ is the limit shearing strength of the adhesive joint, F is the bond area, and k is an empirical coefficient, is valid in the case of the joint of block-shaped materials (i.e., in the case of a uniform distribution of the stress in the bond line) (see Table 2).

The strength of adhesive joints of any material depends essentially on the temperature which affects the adhesion and cohesion properties of the adhesive, on the thermal stresses, and on other factors. The nature and the degree of the effect of the temperature on the strength of an adhesive joint depend on the type of the adhesive and on the stressed state (Fig. 5). A decomposition of the adhesive occurs as a result of a long heating or of a short action of high temperatures. The strength of the adhesive joint is in both cases gradually or rapidly deteriorated.

New types of adhesives with an increased heat resistance (for some hundred hours) at elevated temperatures (to 1000°) are in development. The application of general laws pertaining to the time dependence of the strength of materials is extended to the adhesive joints, Generally, at moderate temperatures, the phenomena of cyclic fatigue are more dangerous than the phenomena of a decrease in the strength under the long-time action of a constant load. At elevated temperatures, the danger of destruction by static fatigue may become equal (or even greater) than the danger caused by dynamic fatigue (Table 3).

TABLE 2

Схема нагружения 1	2 Сдвиг + сжатие			3 Сдвиг	4 Сдвиг [illegible]	
α k	−60 5,6	−45 2.2	−30 1.5	0 1.0	30 0,85	55 0.8

1) Scheme of the load; 2) shearing + compression; 3) shearing; 4) shearing + peeling off.

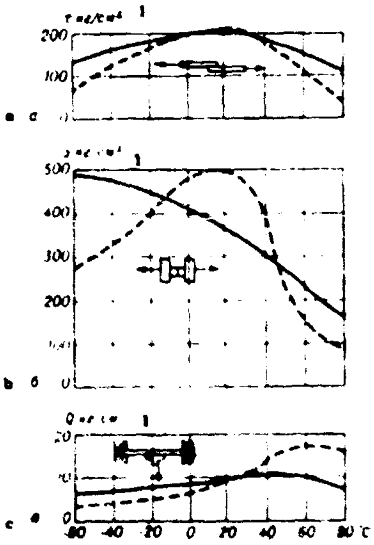

Fig. 5. Effect of temperature on the strength of adhesive joints bearing various types of load: a) Shear; b) uniform peeling off; c) nonuniform peeling off. Signs: ——— = PU-2 adhesive; ---- = BF-2 adhesive; 1) kg/cm².

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The shearing and peel strengths of an adhesive joint are the higher the thinner the layer of the adhesive. Reinforced adhesive layers are necessary for joints which function under conditions of a nonuniform peeling off, in joints of panels with honeycombs, in the adhesive joints of foamed plastics, fabrics, and other porous materials. The design of adhesive-bonded objects must taken into account the specific working properties of the adhesive joints and of the selected adhesive.

TABLE 3

1 Нагрузка	2 Предел прочности при сдвиге (кг/см²) соединения внахлестку из стали Я1Т длиной 15 мм, толщиной 2 мм на клее ПУ-2 при темп-ре:					
	20°	40°	60°	80°	100°	120°
3 Кратковременная (1 мин.) статическая	200	185	170	160	100	60
4 Длительная (200 час.) статическая	180	135	100	75	40	27
5 Циклическая (200 час.) с частотой 17 гц . .	70	65	50	40	35	27

1) Load; 2) ultimate shearing strength (kg/cm^2) of an overlapped joint of YalT steel with a length of 15 mm and a thickness of 2 mm, glued with PU-2 adhesive at the temperature; 3) static short-time (1 min); 4) static long-time (200 hrs); 5) cyclic (200 hrs) with a frequency of 17 cps.

References: Panshin B.I., in the Collection Klei i tekhnologiya skleivaniya [Adhesives and the Technology of Adhesive Bonding], Moscow, 1960; Adgeziya, klei, tsementy i pripoi [Adhesion, Adhesives, Cements, and Solders], edited by N. Debroyn and R. Huwinck, translated from English, Moscow, 1954; Spies G.I., "Aircraft Engng.," 1953, Vol. 25, No. 289, pages 64-71; Epstein G., Skleivaniye metallov [Adhesive Bonding of Metals], translated from English, Moscow, 1956.

A.T. Tumanov

AG-4s - a fiberglass molding plastic. See glass-reinforced plastics.

AGATE (technical) – collective term for chalcedony proper (fibrous modification of force) and its laminar varieties. Sp. gr. 2.57-2.64, bulk 2.570 g/cm^3, i.e., somewhat lower than that of quartz due to the presence of opal impurities and submicroscopic porosity (0.66-0.81%). Color may be gray, white, red, etc. Agate consists of a large number of thin layers, the number of which may range up to 3-10 thousand in 1 cm. Within a given layer, the fibers may be extended along the c-axis of the quartz (quartzine), perpendicular to it or at an angle of 30°. The Mohs hardness of agate is 6.5-7, the Shore hardness 115-120, and the pendulum hardness 540; the elastic modulus is $1 \cdot 10^6$ kg/cm^2. The hardness of agate diminishes rapidly as the temperature rises. At room temperature, the hardness of agate parallel to the fiber is almost 2 times that perpendicular to the fiber. As the temperature rises from 200°C, the difference between the hardnesses in these directions becomes smaller and nearly vanishes at 400°.

Applications of agate are based on its high elasticity, toughness, hardness, acid and abrasion resistance and its ability to take a mirror polish. Agate is used to make 1) mortars and pestles for analytical chemical work, 2) rollers for burnishing leather and paper, 3) dies for extruding graphite and similar materials in the production of pencils and other objects, 4) spinnerets in the production of synthetic fibers, 5) precision industrial stones (knife edges, pallets, thrust bearings, bushings, watch jewels, etc.) for analytic and dial balances, timepieces, centrifuges, electrical measuring instruments (voltmeters, ammeters) and 6) special jewels for precision instrument building. Homogeneous uncolored agates without foreign inclusions, fissuring, traces of opalization or distinct lamination are used; the dimensions of the individual pieces of agate should permit fabrication of wafers with areas of 15-20 cm^2.

V.I. Fin'ko

AGING OF ALUMINUM ALLOYS – the ability of metallic alloys to undergo hardening induced by heating at elevated temperatures (artificial aging) or occurring spontaneously at room temperature after quenching from high temperatures (natural aging).

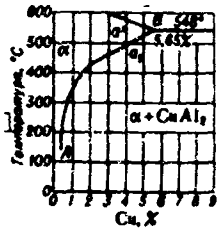

Fig. 1. Solubility diagram of copper in aluminum. 1) temperature, °C.

Post quenching heating at disproportionately high temperatures reduces the strength of the alloy, causing it to be over-aged. Structural changes occur in the alloy during aging, leading to formation of Guinier-Preston zones (during natural aging) or of structures approximating those produced by decomposition (during artificial aging). The effect of natural aging can be reduced by a moderate increase in temperature. This recovery process returns the alloy to its initial post-quenching condition. Transferring the alloy to room temperature again causes natural aging.

Natural aging. The term natural aging refers to the ability of metallic alloys to undergo spontaneous hardening at room temperature after quenching from high temperatures. Hardening by quenching and aging is observed exclusively in solid solutions and then only when the solubility of the metal added to the base metal is greater at high temperatures than at low temperatures. Many metallic alloys, particularly those of aluminum and copper, satisfy this condition.

Figure 1 is the solubility diagram of copper in solid aluminum. The solubility line AB on the graph divides it into two parts. The portion to the left of the solubility line corresponds to a homogeneous solid solution, while that to the right of the solubility line corresponds to nonhomogeneous alloys containing crystals of a chemical compound of copper and aluminum ($CuAl_2$) with a copper content of ~54% by weight, as well as α crystals. It can be seen from the diagram that an alloy containing 4% Cu is a homogeneous solid solution in the high-temperature (above 500°) region. When such an alloy is slowly cooled the excess copper precipitates from the solid solution in the form of $CuAl_2$ particles, which are distributed along the grain boundaries and within the grains. The majority of the alloy thus now consists of aluminum crystals containing a total of 0.1-0.2% copper.

In this slowly cooled state the alloy is quite soft and its strength approximates that of pure aluminum. The hardness (HB) of an alloy in this state is approximately 40 kg/mm^2. However, if an alloy containing 4% copper is heated to high temperature and cooled rapidly to room temperature (by quenching in water) precipitation of the copper from the solid solution is retarded. The solid solution is supersaturated with copper, i.e., is in a state which does not normally obtain at room temperature. In this unstable condition the alloy exhibits the interesting phenomenon called aging (from the German Alterung, which has this meaning).

The hardness of an alloy containing 4% copper amounts to 60 kg/mm^2 when measured immediately after quenching. If the metal is permitted to stand at room temperature its hardness reaches 66 kg/mm^2 after 2 hr, up to 76 kg/mm^2 after 12 hr, and up to 80 kg/mm^2 after 24 hr. Aging is virtually complete after 5-6 days at room temperature.

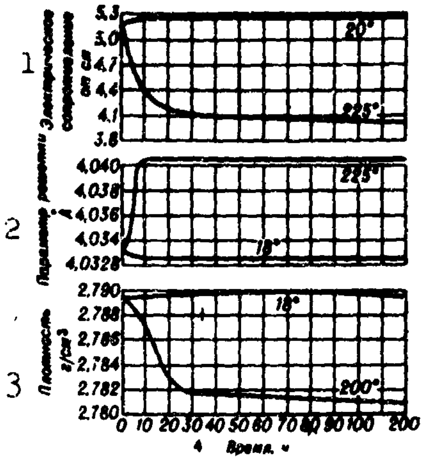

Fig. 2. Change in the characteristics of an aluminum alloy containing 4.5% copper during natural and artificial aging. 1) Electrical resistance, ohm-cm; 2) lattice parameter, A; 3) density, g/cm^3; 4) time, hr.

The increase in the strength and hardness of aluminum-copper alloys during aging increases with the copper content, but there is a limiting concentration corresponding to the maximum solubility of copper in aluminum at the eutectic temperature, 5.5-5.6%. It has been established that all the characteristics of aluminum-copper alloys are altered during natural aging: electrical resistance and density increase and plasticity decreases. However, plasticity does not undergo as pronounced a change during natural aging as during artificial aging.

It is natural to assume that the processes occurring in the solid solution and leading to aging consist in precipitation of copper from the solution to form $CuAl_2$ particles, as is the case during slow cooling of the alloy. The fact that such particles cannot be detected with an optical microscope can be explained by the extreme fineness of the precipitate (small particle size). However, the interatomic distances in the solid solution should increase during natural aging, rather than decreasing as is the case in actuality, since the copper atoms precipitated from the solid solution are smaller than the aluminum atoms. Accordingly, as the interatomic distances decrease during natural aging the density of the alloy rises and its volume is reduced. Electrical resistance increases during natural aging, while when precipitation from the solid solution occurs it should decrease in conformity with the drop in solid-solution concentration. Magnetic permeability is also "anomalously" altered during natural aging. These data indicate that the supersaturated solid solution is retained during natural aging rather than that it decomposes. Actually, the changes in the solid solution during natural aging are confined to displacement of the copper atoms within the crystal lattice over short distances, of the order of tens or hundreds of A, and accumulation of these atoms in the planes of the cubic lattice to form two-dimensional (laminar) structures, the so-called Guinier-Preston zones (see below). The copper concentration in these zones is approximately the same as in $CuAl_2$ (54% by weight), so that the interatomic distances within the zones are somewhat less than in the regions between the zones. These nonuniformities lead to development of strong internal stresses at the zone boundaries; the substantial hardening of the alloy during natural aging is attributable to these stresses. The temperature range over which the processes designated by the general term natural aging take place does not necessarily correspond to the "room-temperature" region, as is the case for aluminum alloyed with 4% copper and other aluminum-based alloys. Thus, the processes which occur in aluminum alloyed with magnesium, zinc, and copper (type V95) at room temperature are designated by the general term artificial aging. In this case the natural-aging temperature range lies below the room-temperature region. Conversely, in copper-beryllium alloys (containing ~2.5% beryllium) natural aging occurs at temperatures substantially above the room-temperature range.

Artificial aging. In contrast to natural aging, which occurs at room temperature in certain metallic alloys, artificial aging is induced by heating to high temperatures after quenching. Artificial aging involves precipitation of atoms of the dissolved metal from the solid solution in isolated groups. This process is occasionally called dispersion hardening, a term which attempts to show that the changes in the solid solution originate in precipitation of dispersed particles of the hardening phase. In contrast to dispersion hardening, natural aging is referred to as solution hardening (hardening in which the solution is retained).

The change in the characteristics of an alloy during artificial aging has a totally different character from that observed during natural aging. Thus, the electrical resistance, mean interatomic distance in the solid solution, paramagnetic permeability, and certain other characteristics are altered in the normal fashion, i.e., as should be observed when dissolved atoms are precipitated from the solvent lattice (Fig. 2). Hardening during artificial aging occurs in roughly the same manner as at room temperature. However, the plasticity of the alloy is markedly reduced (Fig. 3) and its corrosion resistance decreases. Artificial aging is consequently avoided for alloys of the duralumin type. The corrosion resistance of duralumin alloys with a high magnesium content (~1.5%; D16 alloys) remains at virtually the same level after artificial aging as after natural aging.

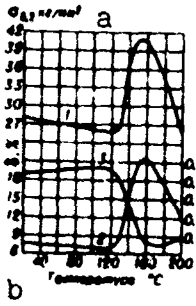

Fig. 3. Change in $\sigma_{0.2}$ (1), $\sigma_{0.2}/\sigma_b$ (2), and δ (3) of duralumin with a high silicon content (0.8%) at different aging temperatures (aging time 40 hr). a) kg/mm^2; b) temperature, °C.

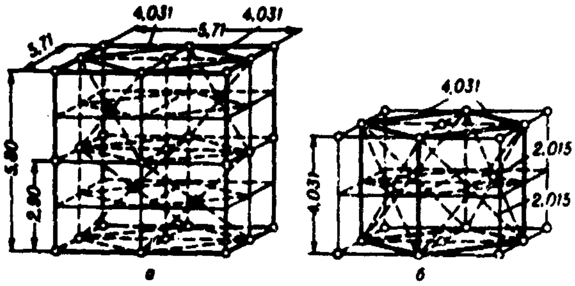

Fig. 4. Structure of elementary cell of θ'-$CuAl_2$ (a) and of elementary cell of solid solution (b).

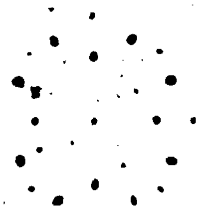

Fig. 5. X-ray diffraction pattern obtained with monocrystal of pure aluminum, using Loewy's method.

The change in the structure of an alloy during natural aging is restricted to formation of Guinier-Preston zones, which retain coherent bonds to the aluminum lattice. However, when the alloy is heated to 100-150° after quenching the diffraction pattern resulting from aging is altered in such fashion as to indicate expansion of the copper-enriched regions of the solid solution (initial Guinier-Preston zones). These areas become thicker. If heating at 150° is continued the initial diffraction pattern, corresponding to formation of Guinier-Preston zones, gradually becomes fainter and eventually disappears. It is replaced by a different pattern, which indicates the occurrence of other processes in the solid solution leading to formation of an initial intermediate structure, the so-called θ"-phase, which gradually is converted to the more stable θ'-phase (Fig. 4a). These reordering processes lead to gradual loss of the bonds between the structures produced and the solid-solution crystal lattice. However, the new structure retains substantial similarities to the lattice. This is easily seen when the two structures are compared. Figure 4a represents the elementary cell of the new structure. The light circles represent sites occupied by aluminum atoms and the dark circles sites occupied by copper atoms. Figure 4b shows a part of the solid-solution crystal lattice. The heavy lines enclose its elementary cell. Losing its bonds to the basic lattice on heating to higher temperatures (250-350°), the new structure undergoes a profound transformation to form a stable lattice of the compound $CuAl_2$, in which the copper is precipitated from the solid solution during slow cooling from high temperatures. A stable $CuAl_2$ lattice is formed during postquenching heating as the final result of the transformations occurring in the supersaturated solid solution. Extremely fine laminar copper structures, Guinier-Preston zones, are formed during the initial stage. Continued heating causes changes which give rise to new structures. When the final stable $CuAl_2$ structure is formed hardening ceases and the alloy gradually softens: the metal becomes overaged. Such metal is equal in strength to the annealed alloy.

Aluminum-copper alloys, which were used as an example for consideration of aging processes, are not widely employed because of their low strength. Higher strength can be achieved by adding both copper and magnesium to the aluminum. Manganese is also added to increase strength and corrosion resistance. When the magnesium content is high (~1.5%) both $CuAl_2$ and the ternary compound Al_2CuMg serve as the hardening phase in alloys of this type (duralumin).

Guinier-Preston zones are two-dimensional (laminar) structures in quenched (supersaturated) metallic solid solutions and are produced by natural aging; they are uniformly distributed throughout the crystal over an area extending for several tens or hundreds of Angstroms and 1-2 atomic layers thick. In Al-Cu or Cu-Be alloys these two-dimensional structures are oriented in three mutually perpendicular directions, corresponding to the three mutually perpendicular planes of the elementary-cell cube. The existence of these two-dimensional structures was established by Guinier in France and Preston in England (1938), who investigated the natural aging of Al-Cu monocrystals by precision x-ray methods.

Figure 5 shows the x-ray diffraction pattern of pure aluminum. The x-rays were directed perpendicular to the plane of the crystal cube. This direction corresponds to the fourth axis of symmetry of the cube. The symmetry of the crystal is reflected in the x-ray pattern. When quenched in water after heating at high temperatures (in the monophasic region) an aluminum alloy containing 4% copper is an unstable or supersaturated solid solution of copper in aluminum. The x-ray diffraction pattern of such an alloy is quite similar to that of pure aluminum. During natural aging new diffraction spots superimposed on the initial diffraction pattern, at first weak and then more intense, appear several hours after quenching. These changes in the diffraction pattern become quite obvious after a few days (Fig. 6). They are caused by displacement of the copper atoms within the solid solution. As a result of these dislocations the copper atoms accumulate predominantly in those lattice planes parallel to the planes of the cubic aluminum crystal lattice, forming copper-enriched areas extending for several tens or hundreds of Angstroms and 1-2 atomic layers thick.

Fig. 6. X-ray diffraction pattern obtained with monocrystal of aluminum alloyed with 4% copper after natural aging.

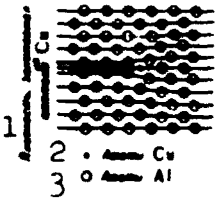

Fig. 7. Diagram of Guinier-Preston zone in solid-solution crystal lattice. 1) Plane occupied by Cu atoms; 2) Cu atoms; 3) Al atoms.

The copper-enriched areas are somewhat compressed and the adjacent areas somewhat expanded (Fig. 7). The distance between the plane occupied by copper atoms and the first plane occupied by aluminum atoms is approximately 10% less than the normal distance between planes of this type in the just-quenched solid solution. The subsequent planes are displaced by less and less, so that approximately the fifteenth plane is again in the normal position.

The irregularities caused by formation of these zones lead to development of strong internal stresses at the zone boundaries, which results in considerable hardening of the metal.

Recovery. If an aluminum-copper alloy aged at room temperature is heated for a few minutes or even several seconds at 200–250° and then cooled rapidly to room temperature, the hardening undergone by the metal at room temperature is completely eliminated. All the characteristics of the alloy return to their initial (preaging) levels. If the alloy is then permitted to stand at room temperature it again undergoes hardening, just as after quenching. When a "recovered" alloy is permitted to stand at room temperature its hardness is altered in the same manner as after quenching and reaches the same value after 5–6 days.

Since the diffraction pattern produced by natural aging disappears during recovery, it may be concluded that the "Guinier-Preston zones formed during this process, which harden the alloy, decompose and the copper atoms are again distributed in a statistically uniform manner in the aluminum crystal lattice. Attempts have been made to utilize recovery under practical conditions, for softening materials during cold working (stamping, drawing, beating, etc.), since the material then undergoes spontaneous hardening once more.

However, a marked decrease in corrosion resistance occurs after recovery, restricting the practical utilization of this process.

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Overaging refers to the late stages of artificial aging, when the hardening resulting from this process halts and the alloy gradually becomes softer. Overaging occurs only when the holding time at the maximum artificial-aging temperature is too long or when this temperature is exceeded during normal or even brief holding.

Structurally, overaging is characterized by the final stages of decomposition of the supersaturated solid solution to form stable hardening-phase structures characteristic of the annealed alloy ($CuAl_2$ for Al-Cu alloys and Al_2CuMg for Al-Cu-Mg alloys, etc.).

In final analysis, an overaged alloy consists of a basic mass of low-concentration solid solution and precipitated hardening-phase particles (crystals), which are distributed principally along the grain boundaries. The mechanical characteristics and corrosion resistance of an overaged alloy approximate those of the annealed alloy.

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D.A. Petrov

III-114s

AGING OF POLYMER MATERIALS – a chemical process involving a change in molecular structure leading to a change in the physical characteristics of the material and consequent loss of its valuable technical properties. In essence, this process consists in a complex chain reaction involving formation of free radicals or, less frequently, ions; it is accompanied by Destruction and structuring of the material. Aging is an irreversible process, in contrast to changes in the physical characteristics of polymers caused by destruction of intermolecular bonds, as when the temperature is raised. Aging results from exposure to various agents, the most common of which is heat, although light and mechanical stress are more specific. The most usual chemical agents are oxygen, ozone (see Ozone resistance of polymer materials), moisture, etc. Ordinary, or thermal aging of polymers is usually a consequence of an oxidative process taking place under the action of atmospheric oxygen dissolved in the polymer and activated by heat. We must distinguish: 1) aging of a homogeneous polymer containing no low-molecular additives (pure rubbers, plastics, fibers, etc.) and aging of polymers containing such additives or dispersed solid particles of filler; 2) aging at moderate (up to 80-100°) and high temperatures, since the mechanism of the process differs materially in these two cases.

Aging of homogeneous and pure polymers is a chain autocatalytic oxidation process occurring at moderate temperatures through intermediate formation of polymer peroxides, whose decomposition is often associated with breaking of the molecular chain and development of two free valences. This process can be described as ramified degeneration.

It may tend toward preferential destruction (as in the case of natural rubber) or toward preferential structuring (as in the case of butadiene rubber, polystyrene, etc.), depending on the molecular structure of the polymer and the reaction conditions (oxygen pressure, temperature, thickness of sample undergoing oxidation, etc.). Macroscopically, preferential destruction is manifested principally in softening of the polymer to the point of "resinification" and sometimes in liberation of volatile products. Preferential structuring is manifested in an increase in hardness and brittleness and loss of plasticity and elasticity. Oxidation itself begins with initiation, i.e., formation of free radicals; at moderate temperatures this basically involves decomposition of the hydroperoxide R = OOH to form the radicals $RO^{\cdot}$, $RO_2^{\cdot}$, and $HO^{\cdot}$. A chain is then formed in accordance with the equation $RO^{\cdot} + RH$ (polymer molecule) $\rightarrow ROH + R'$; where R is a carbonyl radical $R + ROOH \rightarrow ROH + RO^{\cdot}$. The reaction terminates in recombination of the radicals ($R^{\cdot} + R^{\cdot}$, $RO^{\cdot} + RO^{\cdot}$, $RO_2^{\cdot} + RO_2^{\cdot}$), which leads to nonreactive products. Decomposition of polymer hydroperoxides almost always proceeds in accordance with the first equation. The presence of double bonds in the polymer (gum rubber, etc.) somewhat complicates the reaction mechanism. At moderate temperatures the dominant reaction is obviously that between oxygen and the methylene group located in the α-position with respect to the double bond; at elevated temperatures (100-120°), the dominant reaction is with the double-bonded C atom. In addition, unsaturated polymers are capable of undergoing reactions leading to polymerization and formation of nonchain cyclic structures. At 150-200° the decomposition-rate constant of the peroxide is higher than its formation-rate constant, so that no peroxide is formed and the reaction loses its degenerative character. Under these conditions the reaction reaches an explosive rate in the absence of serious delays in diffusion.

Aging of polymer materials containing low-molecular additives and solid fillers. Low-molecular additives participating in the chain-forming process may substantially alter the rate, direction, and character of the reaction. Thus, antioxidants, which bond free radicals, prevent chain reactions and yield a virtually unramified process. This also leads to a decrease in the rate of structural change. The presence of compounds containing iron, manganese, copper, and sometimes sulfur, phosphorous, etc., accelerates the aging of polymer materials. The polymers most sensitive to "catalytic poisons" are those whose chains contain large numbers of double bonds (primarily natural rubber). Active fillers, such as carbon soot, silicon dioxide (powdered silica gel), etc., have a complex effect on the aging of polymer materials. Since they carry large numbers of weak free radicals, such fillers serve to trap the free radicals produced during oxidation of the polymer, thus having an antioxidizing action. However, active fillers sorb air, thus increasing the effective solubility of oxygen in the polymer and accelerating oxidation and aging. Moreover, the oxides which coat the surface of certain types of soot (e.g., chimney soot) catalyze oxidation. One consequently often encounters the twofold action of soot under practical conditions.

Aging of polymer materials under the action of mechanical stresses constitutes a special group of phenomena. Such stresses weaken or rupture the chemical bonds in the polymer molecule, especially in the case of rather rapid alternating deformation (e.g., extension and compression), where the stresses cannot be relaxed. This phenomenon is a variety of aging. It usually leads to acceleration of oxidation (mechanical activation) and therefore to intensification of aging. Mechanical activation is also observed during the wearing of polymer materials, such as automobile tires, conveyor belts, etc., the abrasion of which is a combination of mechanical, chemical, and mechanical-chemical phenomena. The relative roles of these factors depend on the temperature and operating conditions (the tires of light automobiles are less deformed and more severely heated than those of heavy machinery, so that oxidation predominates in the former case and a mechanical process in the latter case).

Oxidation of gums and rubbers at moderate temperatures occurs at a constant rate over almost the entire "technical life" of the material. Oxygen-absorption rate as a function of temperature can usually be expressed by the Arrhenius equation, while the activation energy varies from 17-18 to 28-30 kcal/mole, depending on the composition of the polymer. The dependence of the change in the structure of the polymer on temperature, i.e., the aging of the polymer, is considerably more complex. This function can be determined only for certain mechanical indices. Once the temperature function is known it is possible to extrapolate data on temperature-accelerated aging to normal operational or storage conditions for the polymer in question. Other methods for producing accelerated aging give only comparative results, which must be regarded as qualitative and treated with care. There are cases in which the varying sensitivity of polymers to changes in the accelerating agent (in oxygen pressure, radiation strength, etc.), as well as to rises in temperature in some cases, results in a polymer more resistant to aging under operational conditions than another polymer becoming less resistant during accelerated aging. Aging of polymers is often accompanied by evolution of volatile products, especially at high temperatures, so that in order to avoid migration of volatile ingredients different materials should not be aged in the same chamber. For the same reason, the chamber must be slowly ventilated with a laminar flow of heated air, whose humidity should also be strictly controlled.

Aging induced by heat alone is usually associated either with ease of thermal destruction and subsequent chain depolymerization and structuring or with a nonchain cyclization reaction. In the former case the most stable polymers are those distinguished by low heats of polymerization, a phenomenon associated with steric effects; such materials include polymethylmethacrylate, poly-alpha-methylstyrene, polyisobutylene, etc. Conversely, a high heat of polymerization guarantees resistance to thermal destruction (as in polyethylene, polyphenols, etc.). Polymers with a substantial content of vinyl side chains (sodium-butadiene rubber, etc.) tend toward thermal cyclization. Oxidative processes proceed most readily in polymers with a considerable number of double bonds in the 1,4 position (polyisoprene). Polymers with polar substitutions, such as fluoropolymers, are very stable. Polymers containing phenol rings in the main chain are highly resistant to thermal aging. Resistance to thermal aging under different conditions varies with the composition and structure of the polymer molecule; this necessitates careful selection of the polymer most resistant under the conditions in question. The choice of low-molecular additives becomes important in this case. Antiaging agents of the phenol type have the best protective action for certain polymers, while amines are best for others, etc. Compounds with two functional groups (antifatigue agents) are used to increase the resistance of polymer materials to oxidation under fatigue conditions. All these low-molecular additives should be highly soluble in the polymer in question, light-resistant, etc. Protective coatings and impregnating substances are also employed. In some cases it is possible to eliminate the stresses which accelerate aging.

Certain polymers (polyesters, polysaccharides, certain rubbers) are unstable under the combined action of heat, light, oxygen, and water vapor (see Atmosphere resistance).

Aging of polymer materials under the action of radiant energy, ozone, and heat. A photochemical process can take place only when radiant energy of a given wavelength is absorbed. The greatest aging is consequently observed under the action of ultraviolet and ionizing radiation. All polymers undergo structural alteration, i.e., aging, when exposed to sufficiently intense radiation. Secondary processes (oxidation, chain structuring, and destruction) vary widely in polymers with different compositions and structures. On the whole, however, it can be said that light activates aging to a greater extent than heat. Thus, the rate at which rubber prepared from natural gum is oxidized on irradiation with ultraviolet light is approximately 3 times greater at 40° than the rate of "thermal" oxidation at 70°. In this case the light activates pre-radical formation (initiates the chain reaction), the oxidation rate being proportional to the square root of the radiation intensity. In order to prevent photooxidation and aging one can use substances which: 1) reduce the intensity of the light absorbed by the polymer (dyes, soot, etc.); 2) inhibit the chain reaction (substances of the nickel dibutyldithiocarbamate type, etc.). Surface coatings (powdered aluminum in a binder, wax, paraffin, etc.) are sometimes employed. The latter two substances also increase ozone resistance.

Aging of polymers reduces their useful life under operational and storage conditions. Prevention of this phenomenon is consequently a serious national-economic problem.

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istry and Technology of Polymers], translated from English, Moscow, 1958; Buist, J.M., and Weathering of Rubber, Cambridge, 1956.

N.N. Lezhnev

AIR PERMEABILITY – see Gas Permeability.

AIR-QUENCHABLE STEEL – steel that permits quenching in air, which greatly reduces the warping of components during heat treatment but requires considerably greater alloying.

The decisive factor in the formation of martensite is the critical quenching rate, i.e., that cooling rate at which the structural transformation to perlite and intermediate phases is suppressed. The critical quenching rate depends on the carbon and alloying-element content of the steel, as well as on the austenitization temperature; in the general case, the critical quenching rate decreases as the carbon and alloying-element content and the austenitization temperature increase.

TABLE 1

Chemical Composition of Air-Quenchable Steel

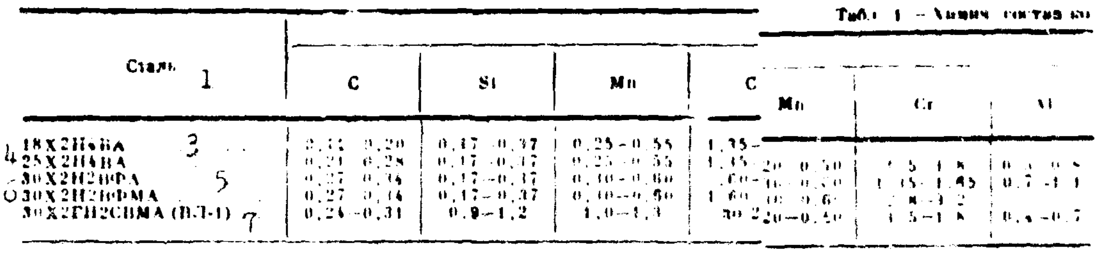

Табл. 1 – Химич. состав ...

Сталь 1	C	Si	Mn	C	Mn	Cr	Ni
18Х2Н4ВА 3	0,14–0,20	0,17–0,37	0,25–0,55	1,35–			
25Х2Н4ВА 4	0,21–0,28	0,17–0,37	0,25–0,55	1,35–	20–0,50	1,5–1,8	[illegible]
30Х2Н2ВФА 5	0,27–0,34	0,17–0,37	0,30–0,60	,00–	[illegible]–0,50	1,35–1,65	0,7–1,1
30Х2Н2ВФМА 6	0,27–0,34	0,17–0,37	0,30–0,50	1,60	[illegible]–0,60	2,8–3,2	
30Х2ГН2СВМА (ВЛ-1) 7	0,24–0,31	0,9–1,2	1,0–1,3	30 2	20–0,50	1,5–1,8	0,4–0,7

1) Steel; 2) content of elements (%); 3) 18Kh2N4VA; 4) 25Kh2N4Va; 5) 30Kh2N2VFA; 6) 30Kh2N2VFMA; 7) 30Kh2GN2SVMA (VL-1); 8) up to.

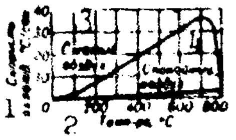

Fig. 1. Influence of still and compressed air on component cooling. 1) Cooling rate, °C/sec; 2) temperature °C; 3) compressed air; 4) still air.

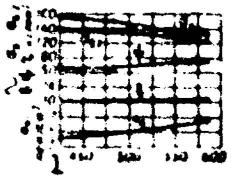

Fig. 2. Influence of tempering on mechanical characteristics of 30Kh2N2VFA steel. 1) kg-m/cm²; 2) kg/mm².

Quenching in liquid media always causes substantial deformation (warping) of components with complex shapes fabricated from structural steels, especially high-strength steels. Subsequent straightening of such components is difficult, even impossible in some cases involving very complex components. This considerable warping, especially on quenching in oil, makes it necessary to fabricate components with large tolerances for subsequent correction to the requisite size.

Such deformation of components can be materially reduced or even completely eliminated if the steel is capable of being quenched by cooling in air. Quenching in moving air is sometimes employed to increase the cooling rate (Fig. 1). Air quenching of components permits the use of clamping devices, the cost of whose fabrication is offset by the decrease in expenditures for machining and heat treatment and by the elimination of straightening operations.

The principal advantage of air cooling during quenching over cooling in liquid media lies in the fact that it is possible to conduct final machining of the component before quenching, i.e., in the annealed state.

Straightening and machining of components quenched to a high ultimate strength often cause local stresses and surface defects, which reduce resistance to brittle when high-strength steels are employed under the action of surface-active and corrosive media. Elimination of deformation during quenching consequently increases the operational reliability of components. However, air-quenchable steel has one considerable drawback; it requires considerably greater alloying than steel quenched in liquid media and its use is thus not always economical. Alloying of structural steels is most widely conducted when quenching is to be carried out in liquid media.

The most commonly employed types of air-quenchable steel are ing in air; 16) quenching from [illegible] (cooling in air [illegible]), tempering at 560° (cooling in oil); 17) quenching from 9[illegible] ([illegible]ling in air or oil), tempering at 610-650° (cooling in air); 18) quenching from 890-910° (cooling in air), tempering at 580-620° (cooling in air); 19) quenching from 930 ± 10° (cooling in air), tempering at 200-300°.

TABLE 3

Mechanical Characteristics of 30Kh2N2VFA and 30Kh2GSN2VM Steels at Elevated Temperatures

Сталь 1	2 Термич. обработка	Темп-ра 3 (°C)	E	σ_b	$\sigma_{0,2}$	δ	ψ
				4 (кг/мм²)		(%)	
30Х2Н2ВФА (прутки) 5	7 Закалка с 940° на воздухе, отпуск при 640°	300	18100	108	96	13	49
		400	16500	105	91	12	50
		450	15150	102	91	12	54
		500	15200	92	86	12	50
30Х2ГСН2ВМ (прутки) 6	8 Закалка с 930° на воздухе, отпуск при						
	310°	300	—	170	—	—	—
	410°	400	17000	155	—	—	—
	480°	450	16300	135	—	—	—
	510°	500	15700	120	—	—	—

1) Steel; 2) heat treatment; 3) tempe ature (°C); 4) kg/mm²); 5) 30Kh2N2VFA (bars); 6) 30Kh2GSN2VM (bars); 7) quenching from 940° in air. tempering at 640°; 8) quenching from 930° in air, tempering at.

TABLE 4

Long-term Strength, Creep Strength, and Durability of 30Kh2N2VFA Steel on Bending

1 Термич. обработка	Темп-ра (°C) 2	$\sigma_{дп}$	3 $\sigma_{0,2/100}$ по остаточной деформации	4 $\sigma_{0,2/100}$ по общей деформации	σ_{-1}	$\sigma^{н}_{-1}$ *
					5 на базе 10^7 циклов	
		6 (кг/мм²)				
Закалка с 940° — охлаждение на воздухе, отпуск при 640° — охлаждение на воздухе 7	20	—	—	—	56	36
	300	98			—	
	400	80	64	36	52	31
	450	75	44	24	—	
	500	54	37	20	50	29
	550	22	24	14	42	24

*Tests conducted by cantilever bending at 20° and pure bending at 300-550° with notched specimens.

1) Heat treatment; 2) temperature (°C); 3) $\sigma_{0.2/100}$ from residual deformation; 4) $\sigma_{0.2/100}$ from total deformation; 5) based on 10^7 cycles; 6) kg/mm²); 7) quenching at 940° (cooling in air), tempering at 640° (cooling in air).

The physical characteristics of 30Kh2N2VFA and 30Kh2N2VFMA steel include: $\gamma = 7.85$, $\alpha = 11.73 \cdot 10^{-6}$ (20-100°) and $14.95 \cdot 10^{-6}$ (400-500°) 1/°C, and $\lambda = 0.094$ (20°) and 0.083 (500°) cal/cm·sec·°C.

Technological characteristics. Hot deformation of 18Kh2N4VA ar

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25Kh2N4VA steels is conducted over the temperature range 1100-850°, while that of 30Kh2N2VFA, 30Kh2N2VFMA, and 30Kh2GN2SVMA steels is carried out at 1180-850°. Air-quenchable steel has satisfactory weldability and is cut in the same manner as steel quenched in liquid media. The Brinell hardness of air-quenchable steel (d_{otp}) amounts to 4.0 mm after annealing or high-temper normalization. Maximum softening of 30Kh2N2VFA, 30Kh2N2VFMA, and 30Kh2GN2SVMA steels is achieved by isothermal annealing involving heating to 800°, furnace cooling to 650° (or transfer to another furnace at 650°), holding at 650° for from 8 to 16 hr, and cooling in air. The impact strength of air-quenchable steels, particularly 30Kh2N2VFA and 30Kh2N2VFMA, varies comparatively little as the temperature is lowered to 70°. Air-quenched 30Kh2N2VFA, 30Kh2N2VFMA, and 30Kh2GN2SVMA steels display through hardenability for cylinders 80 mm in diameter and plates 40 mm thick; after quenching in air steels of these types are subject to the least deformation and have the highest heat resistance at 400-550°. Steels of types 18KhNVA and 25Kh2N4VA have unlimited hardenability.

Air-quenchable steels are employed in the manufacture of shafts, disks, tie bolts, and other severely loaded components with complex configurations.

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M.F. Alekseyenko

ALBEDO — see Reflection, light, coefficient of.

ALCLAD – semifinished product (usually sheet or tubing) of aluminum alloy coated (clad) with a thin layer of high-purity aluminum, e.g., AD1, D16 and similar alloys. The cladding layer protects the alloy from corrosion electrochemically and must have a more negative electrochemical potential than the basic alloy. Hence pure aluminum cannot be used to clad aluminum alloys. Alloys of the Al-Mg-Zn-Cu system (high-strength plastic aluminum alloys), e.g., alloy V95, are for this reason clad with zinc-aluminum alloys (1% Zn, remainder Al). The thickness of the cladding layer is determined by anticorrosion requirements and its absolute magnitude must not drop below 35 μ. In practice, the cladding thickness is specified in percent relative to the thickness of the sheet or tube. For thin sheets (less than 2.0 mm), the cladding thickness makes up at least 4% of the sheet thickness on each side, and at least 2% for thicker sheets. For special requirements, when there is a danger that significant amounts of alloying elements will diffuse from the alloy to be protected into the cladding layer, the sheets are given heavy-duty cladding 10% thick on a side. The cladding layer lowers the material's ultimate strength to some extent (by 1.5-2 kg/mm^2) and may be quite detrimental to fatigue strength (see Mechanical properties under cyclic loading).

O.S. Bochvar, K.S. Pokhodayev

ALEXANDRITE – see Chrysoberyl.

ALFENOL – see Magnetically soft high-permeance alloy.

ALFER — see Magnetostrictive materials.

ALGINATE FIBER – artificial fiber with alginic acid (high-molecular, linear polymer), contained in sea weeds (in the amount of 25-40%) of shore waters of the Pacific Ocean and in the seas at the shores of the USSR, England, France and Norway, as a base. The fibers are spinned from water solutions of alginates (sodium, potassium and calcium alginates) in the form of filament threads. The fibers are distinguished by their inflammability and solubility in dilute alkaline solutions. To reduce this solubility, alginate fibers are treated by chromium, beryllium, iron and aluminum salts; here the so-called metal-alginate fibers are spinned (beryllium compounds are toxic

Calcium alginate fibers are characterized by higher indicators than potassium and sodium alginate fibers. The specific weight (average) of calcium alginate fibers is 1.75 and it depends on the Ca content (for 9-10% Ca it increases to 1.78). This fiber is produced with the number N_m el. 4500 (15 microns). The moisture content of fibers with 0.14% Ca under standard conditions comprises 19%, and 9.5% it increases to 30%; when the relative humidity is 100%, the moisute content increases to 51.9%. The rupture length in the dry state varies from 10.0 to 14.0 km and in the wet st-te it drops by 60-70%; the elongation here varies correspondingly from 10-14 to 25-26%. The rupture length decreases sharply, and the elongation increases in an atmosphere with 65% and particularly 100% relative humidity in comparison with dry air (in dry air it is 19.8 km and 10%, in an atmosphere with 65% relative humidity it is 10.05 km and 14%, in an atmosphere with 100% relative humidity it is 2.6 km and 26%). The rupture length of sodium and potassium alginate fibers comprises 11 km. Metal alginate fibers with aluminum have the highest wet strength, in addition, they are characterized by low solubility.

Alginate fibers are used for: the production of bulky fabrics with a soft touch, obtaining skeleton and fashion fabrics and lace products (for this purpose alginate fibers are processed together with wool and other fibers and then the alginate fibers are removed from the finished fabric by a solution of common salt. Alginate and metal alginate fibers are for producing fireproof uniforms, theater curtains, and other fireproof articles, and also for camouflage nets (chrome alginate fibers). In medicine alginate fibers are used in the form of threads, surgical cotton and gauze for rapid retardation of bleeding and for healing of burns without seams and scars; alginate fiber threads which are used during surgical operations do not have to be subsequently removed, since the live tissues dissolve them without harm to the organism.

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V.M. Bukhman

ALKALI RESISTANT MATERIALS – are metals, alloys and nonmetallic compositions resistant to corrosion in caustic alkalis. The alkaliproofness of metal materials depends, generally, on its resistance to dissolution in alkalis of the oxides or hydroxides forming a film on the metal surface. The type of alkaliproofness of nonmetallic materials is based on their chemical stability and their inability to react with alkalis. Gold, indium, cadmium, nickel, platinum, rhodium, silver, titanium, and chromium are corrosion-resistant to solutions of caustic alkalis; iron, copper, lead, and tantalum possess a lower resistance; tin dissolves slowly in caustic alkalis; aluminum and zinc dissolve quickly. The following alloys resist concentrated solutions of caustic alkalis: a) iron-chrome-nickel and copper-nickel alloys, Monel metal, steel of the Kh18N9 grade, cast iron with addition of nickel (the grades SChShch-1 and SChShch-2) at high temperatures; b) the same metals and, moreover, bronze (at alkali concentrations higher than 33%), iron-silicon alloys (containing 14-16% Si), brass, and Elektron metal at normal temperatures. Iron-chrome-nickel alloys, gold (in the case of NaOH), nickel (up to 500°), steel of the Kh18N9 grade, chrome-nickel alloys, and zirconium (up to 600°) are corrosion-resistant to melted alkalis. The alkali resistant materials used for the lining of apparatuses and also for the facing of fundaments and of floors of working places may be of inorganic or organic nature. Cast black-colored basalt and diabas tiles are tight and are corrosion-resistant to all alkali solutions. Ceramic tiles (acid-proof according to GOST 961-57) are resistant to diluted alkali solutions. Diabas cement resists diluted alkali solutions but not hot water. Bituminol is a hard putty based on bitumen and coal-tar pitch; it resists diluted alkali solutions at temperatures from −20° to +60°. Bitumen asphalt with an alkaliproof filler (limestone or dolomite) is used to face floors affected by alkali solutions of a concentration up to 40%. Pitch asphalt or pitch concrete (based on coal-tar pitch and resins) with an alkaliproof filler may be used for the same purposes. Ptich putty, resistant to alkali media, is used to join blocks and to form inpenetrable layers. The Arzamit P cement, stable in 50% alkali solutions, is composed of a resol resin and a filler (silica, graphite, barium sulfate, etc.). Arzamite P is used as a binder in the lining of constructions. Viniplast (see <u>Polyvinyl chloride plastics</u>) is a plastic resistant to 50% alkali solutions; sheet viniplast is used for the protective lining of containers. Polyisobutylene sheet PSG, a plastic with filler (carbon black or graphite), resists 60% caustic alkali solutions at 100°. Asbovinyl resists diluted alkali solutions and acids at normal temperatures. High-pressure polyethylene, polystyrene and, especially, Ftoroplast-4 and Ftoroplast-3 are highly chemically resistant to alkalis. Ftoroplast-4 is absolutely resistant to alkalis at temperatures from −50° to +70°. Some paint-and-varnish materials used in the coating of metal constructions belong also to the alkaliproof materials; such materials are, for example, epoxy varnish, having an excellent resistance to alkali solutions; modified phenolformaldehyde varnish with a good resistance, and nitrocellulose and organosilicon varnishes with a sufficient resistance to alkali solutions. To the epoxy materials belong as follows. the ground-coat E-4021; the alkaliproof varnish E-4100, resistant to a 40% KOH for 30 days; the alkaliproof (green) enamel OEP-4171, resistant to a 40% KOH at 100° for not less than 8 hours and the epoxy-nitrocellulose enamel EP-51, resistant to the action of alkalis.

III-15sh2

Vinyl paint-and-varnish materials resistant to the effect of alkali solutions are as follows: the VKhL-4000 varnish, the VKhE-4023 enamel, and the divinylacetylene varnish.

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M.V. Cherkez

ALLOYED CAST IRON – is a cast iron which, in addition to the elements usually present in common nonalloyed cast iron, contains specially added, so called alloying ingredients, such as nickel, chromium, molybdenum, vanadium, titanium, aluminum, copper, zirconium, magnesium, cerium, boron, calcium, tellurium, which impart various properties to the cast iron. Manganese and silicon belong also to the alloying ingredients, if their content does not surpass 2 and 4%, respectively.

Alloying of cast iron improves the mechanical properties (strength, plasticity, wear resistance) (Table 1) by affecting the structure of the metal base and the distribution of graphite, and also by deoxidation (see Magnesium iron, Wear resistant iron); it equalizes the hardness of castings with different cross sections; it increases or decreases the stability of the carbides; it increases resistance to corrosion, heat, and scale formation, the nonmagnetizability, etc.

The metal base of the iron structure is improved by addition of nickel, chromium, molybdenum, copper, titanium, aluminum, etc.; the carbides are stabilized by chromium, vanadium, molybdenum, zirconium, tellurium, boron, etc.; wear-resistance is increased by nickel, chromium, manganese, and copper; corrosion-resistance in aggressive fluids and in oxidizing gases is increased by chromium, nickel, molybdenum, aluminum, and silicon; the stability of the carbides is decreased, i.e., the graphitization is promoted by nickel, aluminum, silicon, and titanium, Vanadium, titanium, aluminum, calcium, cerium, and magnesium act as deoxidizing agents. Hence, many of the alloying elements affect in a combined manner the properties of cast iron.

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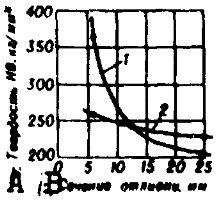
With regard to the degree of alloying, i.e., the total content of alloying ingredients, the cast iron grades are subdivided into low-alloy (up to 3% of alloying ingredients), medium-alloy (from 3 to 10%), and high-alloy (more than 10%); with regard to the microstructure, the cast iron grades are subdivided into gray iron with lamellar or spheroidal graphite having a metal base from a pure ferritic up to a pure austenitic structure, including the pearlitic, sorbitic, and bainitic structures, and in white and chilled irons (see Gray iron, Chilled iron).

An addition of up to 3% of alloying ingredients improves the mechanical properties of the cast iron due to an increased dispersity of the structure of the metal base. Thus, nickel in an amount of up to 3% prevents the formation of chilled areas in the castings because it decreases the stability of the primary carbides and improves the metal base by increasing the pearlite content and stabilizing the ferrite in the pearlite. At the same time, nickel increases the strength of the cast iron and equalizes the hardness across the section of the casting (see Fig.). A high-strength cast iron may be obtained by reducing the total carbon content and substituting two parts of nickel (by weight) for one part of silicon (by weight), on the premises that the content of combined carbon does not surpass the eutectic carbon content.



Equalization of the hardness and structure of cast iron by addition of nickel: 1) 0.2% Ni; 2) 1.5% Ni. A) Hardness, HB, kg/mm^2; B) diameter of the casting, mm.

TABLE 1

Effect of Nickel and Chromium on the Mechanical Properties of Low-Alloy Gray Iron

Чугун 1	2 Содержание элементов (%)					3 Механические свойства	
	$C_{общ}$ 4	$C_{связ}$ 5	Si	Ni	Cr	σ_b	HB
						6 (кг/мм²)	
7 Среднекремнистый нелегированный	3.10	0.79	1.69	—	—	24.2	228
Среднекремнистый хромоникелевый 8	3.15	0.90	1.76	1.13	0.45	31.2	262
9 Высококремнистый нелегированный	3.33	0.67	2.34	—	—	20.8	183
Высококремнистый хромоникелевый 10	3.35	0.82	2.32	0.86	0.42	49.3	217

1) Cast iron; 2) percentage of elements; 3) mechanical properties; 4) obshch; 5) svyaz; 6) kg/mm^2; 7) medium-silicon, nonalloyed; 8) medium-silicon, chrome-nickel; 9) high-silicon, nonalloyed; 10) high-silicon, chrome-nickel.

Chromium, due to its carbide-forming effect, is added to gray iron as a hardening agent in quantities which dpend on the wall thickness of the casting. The chromium content may reach up to 1% in thick-walled castings without chilling taking place; the chromium content must not surpass 0.5% in castings of a medium size. The chilling effect of chromium is prevented by its addition combined with nickel. The Ni:Cr ration lays between 2:1 and 3:1 (Table 1) in cast iron with a high carbon content; this ratio rises up to 5:1 in cast iron with a relatively low carbon and silicon content. Chromium is added to cast iron with spheroidal graphite only in the casting of large sized parts.

Molybdenum affects the structure of the metal base by improving the mechanical properties of gray iron; high-strength irons with an acicular (bainitic) structure may be obtained by addition of molybdenum to chrome-nickel iron or chrome-iron (Table 2).

Low-alloy chrome-nickel and chrome-nickel-molybdenum irons hardly differ from nonalloyed iron with regard to their physical properties. Low-alloy chrome-nickel and chrome-nickel-molybdenum iron is used for high-strength castings which play an important role in the parts of diesel engines, compressor crankshafts, camshafts, and also parts which are exposed to vibration, wear, and heating at high temperatures. Clutches, brake drums, and dies for casting aluminum alloys and copper alloys are made from gray iron of an acicular structure. Low-alloy chilled iron is used in the manufacture of rollers for rolling mills, etc.

Small quantities of titanium are added only to gray iron with lamellar graphite, because the graphitizing capacity of titanium exceeds that of the silicon, and prevents the formation of chilled areas in gray iron with lamellar graphite. An addition of titanium to gray iron 1 with spheroidal graphite is not feasible due to its inhibiting effect on the formation of spheroidal graphite. Titanium forms titanium carbonitrides which not only improve the mechanical properties of the iron but cause it to have a fine-grained structure (Table 3).

TABLE 2

Chemical Composition and Mechanical Properties of Gray Iron with Acicular Structure

Чугун 1	2 Содержание элементов (%)						3 Механические свойства			
	C	Si	Mn	Ni	Cr	Mo	σ_b 4 (кг/мм²)	$\sigma_{0,2}$	δ(%)	HB (кг/мм²) 4
5 С пластинчатым графитом	2,9—3,4	1,6—2,3	0,7—1,0	1,1—2,0	0,13—0,35	0,5—1,0	41,4—54,6	—	—	241—302
6 С шаровидным графитом	2,9—3,2	1,6—2,6	0,6—1,2	1,0—4,0	0,25—0,5	0,8—1,2	75—100	55—75	1—5	280—350

1) Cast iron; 2) percentage of elements; 3) mechanical properties; 4) kg/mm^2; 5) with lamellar graphite; 6) with spheroidal graphite.

TABLE 3

Effect of Titanium on the Mechanical Properties of Gray Iron with Lamellar Graphite

Плавильный агрегат 1	Добавка ферротитана (%) 2	3 Содержание элементов (%)			4 Механич. свойства	
		C	Si	Ti	σ_b 5 (кг/мм²)	HB
Вагранка 6	0	3.58	2.12	0.048	12.3	163
	2	3.68	2.36	0.228	19.0	187
Дуговая электропечь 7	0	3.09	2.17	0.050	23.8	190
	5	3.18	2.21	0.156	28.1	196
Тигельная печь 8	0	3.44	1.82	0.060	21.8	163
	1	3.40	1.86	0.093	23.6	225
	2	3.44	2.08	0.232	28.2	189

1) Melting unit; 2) addition of ferrotitanium; 3) percentage of elements; 4) mechanical properties; 5) kg/mm^2; 6) cupola furnace; 7) arc furnace; 8) cruicible furnace.

Alloying with titanium is carried out by adding ferrotitanium or pig iron containing titanium (see Pig iron). Titanium-containing cast iron is used for parts exposed to wear (see Cast iron for piston rings) and for parts which must have an increased strength.

Addition of up to 3% copper increases the strength and hardness of gray iron with lamellar graphite. Low-alloy gray iron with lamellar graphite, containing 1.5-2% copper, is used mainly for castings which are exposed to wear; malleable iron (see Malleable iron) is alloyed with copper in order to increase its wear-resistance. Copper significantly inhibits the formation of spheroidal graphite in high-strength magnesium-alloy iron.

Gray iron with lamellar graphite is alloyed with elements which stabilize the carbides, in order to increase the strength and wear-resistance of castings, on the condition that the content of combined carbon does not surpass that of eutectic carbon. The latter condition does not apply to tellurium and born which are added to white iron for castings which are exposed to wear in an abrasive medium (see Wear-resistant cast iron).

Small quantities of aluminum are added to modify white iron which is to be tempered into malleable iron (see Modifying of cast iron). Magnesium, calcium and cerium serve as deoxidizing agents and modifiers promoting the formation of cast iron with spheroidal graphite (see Magnesium-alloy cast iron).

These metals belong to the group of micro-alloying constituents.

Medium-alloy and high-alloy cast iron is used for castings with special properties. Different structures of the metal base are formed depending on the composition of the alloying constituents, their quantity and ratio, and, as a result of these factors, the cast iron assumes special mechanical, physical, or chemical properties.

III-15ch5

References: Comstock, J., Titan v chugune i stali [Titanium in Cast Iron and Steel], [translated from English], Moscow, 1956; Hall, A.M., Nikel' v chugune i stali [Nickel in Cast Iron and Steel], translated from English, Moscow, 1959; Grilliat, J and Poirot, R., "Fonderie," 1960, No. 178.

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ALLOYS FOR HEATING ELEMENTS – metal alloys with a high specific electrical resistance and hot strength, which are widely used in many areas of technology as resistance elements for electric furnaces and various loading devices. The working temperature of articles fabricated from these alloys reaches 1200°. The principal requirements imposed on high-hot-strength electric heating materials are: 1) high hot strength, which is necessitated by operational conditions and must include chemical stability in air and special furnace gases. 2) A high ρ and a low temperature coefficient. 3) Satisfactory technological and mechanical characteristics, i.e., the ability to undergo machining when hot or cold in order to produce wire and strips of the necessary size. 4) Satisfactory mechanical strength at high temperatures, which must be sufficient to support the weight of the material itself and certain incidental loads during high-temperature operation. 5) low cost.

These requirements are most fully satisfied by nickel-chromium alloys (nichromes) and iron-based steels containing chromium and aluminum. These alloys have a phase structure consisting of solid solutions, which explains their high ρ. Formation of nickel-chromium solid solutions also considerably increases the hot strength of nickel. The chromium content of nichrome rarely exceeds 30%, since a higher content leads to structural heterogenization and a decrease in alloy plasticity. When producing thin wire 0.3 mm or less in diameter the chromium content should not exceed 20%. In order to reduce the cost of nichromes and improve their workability part of the nickel is replaced by iron (up to 20-25%). Iron-containing nichromes are called ferronichromes.

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Alloys with this composition can also be based on ternary nickel-chromium-iron solid solutions.

TABLE 1

Chemical Composition of Nichromes (GOST 9232-59)

Сплав 1	C	Mn	Si	Cr	Ni	Al	Fe	S	P
	2 не более							не более	
Х15Н60 3	0,15	1,5	0,4–1,3	15–18	55–61	≤ 0,2	Остальное	0,025	0,035
4 Х20Н80	0,15	0,7	0,4–1,3	20–23	75–78	≤ 0,2	≤ 0,1	0,025	0,03
Х20Н80Т3 5	0,08	0,5	< 1	19–23	Остальное	0,4–1,1	≤ 2,5	0,015	0,02

1) Alloy; 2) no more than; 3) Kh15N60; 4) Kh20N80; 5) Kh20N80T3; 6) remainder.

TABLE 2

Principal Physical and Mechanical Characteristics of Kh15N60 and Kh20N80 Alloys

Свойства 1	Х15Н60 2	Х20Н80 3
$t°_{пл}$ (°C)	1390	1400
4 γ (г/см³)	8,4	8,4
5 α·10⁶ при 20–100° (1/°C)	16	12,9
6 c (кал/г·°C)	—	0,107
7 λ (кал/см·сек·°C)	0,033	0,034
8 ρ при 20° (ом·мм²/м)	1,1	1,08
9 Температурный коэфф. электросопротивления при 20–100°	13,7·10⁻⁵	8·10⁻⁵
10 σ_b отожженный (кг/мм²)	60–65	40–50
11 δ отожженный (%)	25–30	45–50

1) Characteristic; 2) Kh15N60; 3) Kh20N80; 4) $\gamma (g/cm^3)$; 5) $\alpha \cdot 10^6$ at 20-100° (1/°C); 6) c (cal/g·°C); 7) λ (cal/cm·sec·°C); 8) ρ at 20° (ohm·mm²/m); 9) temperature coefficient of electrical resistance at 20-100°; 10) σ_b of annealed alloy (kg/mm²); 11) δ of annealed alloy (%).

TABLE 3

Mechanical Characteristics of Nichromes at High Temperatures*

1 Состав сплава (%)				2 Обработка	σ_b				$\sigma_{0,2}$ за 100 час 3		
					4 (кг/мм²)						
Ni	Cr	Fe	Mn		20°	500°	800°	1000°	500°	600°	800°
80	20	5 до 1,5	до 2	6 Отожженная	78	72	28,8	3,5	38,5	25,6	3,4
60	15	до 25	до 2	»	71	57	26	6,5	18,6	15,2	—
50	30	20	до 2	»	103	73	32	—	—	—	—

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*The alloys shown are experimental.

1) Composition of alloy (%); 2) treatment; 3) $\sigma_{0.2}$ over 100 hr; 4) kg/mm²; 5) up to; 6) annealed.

TABLE 4

Chemical Composition of Iron-Based High-Hot-Strength Alloys with High Electrical Resistance (GOST 9232-59)

Сплав 1	C	Mn	Si	Cr	Ni	Al	Fe	S	P
	2 не более							не более	
Х13Ю4 3	0,15	0,7	≤1,0	12,0—15,0	<0,6	3,5—5,5	Остальное	0,025	0,035
4 0Х23Ю5	0,06	0,5	≤0,7	21,5—24,5	<0,6	4,5—5,5	»	0,020	0,025
0Х23Ю5А 5	0,05	0,3	≤0,6	21,5—23,5	<0,6	4,5—5,2	7 »	0,015	0,015
6 0Х27Ю5А	0,05	0,3	≤0,6	26,0—28,0	<0,6	5,0—5,8	»	0,015	0,015

1) Alloy; 2) no more than; 3) Kh13Yu4; 4) OKh23Yu5; 5) OKh23Yu5A; 6) OKh27Yu5A; 7) remainder.

Kh20N80T3 alloy contains 2.0-2.9% titanium. The titanium content of Kh15N60 and Kh20N80 alloys should be 0.4%, provided that a lower content is not indicated in the specifications for the components to be fabricated. Alloys intended for wire of microscopic size cannot contain aluminum, while a zirconium content of up to 0.3% is permissible if no titanium is present. Especially rigid requirements are imposed on the sulfur and phosphorous contents. Sulfur forms a sulfide eutectic along the grain boundaries, while phosphorous increases the brittleness of the alloy. The carbon content is also limited, since any substantial carbide-phase precipitation leads to a decrease in the plasticity and service life of nichromes. Manganese, aluminum, and silicon are metallurgical impurities and their content should not exceed 1%. Only Kh20N80T3 is supplementally alloyed with titanium and aluminum in order to increase its strength, hot strength, and heat resistance (a contribution of the aluminum).

GOST 2238-58 gives the values of ρ for nichromes as a function of wire diameter. Nichromes have high plasticity and strength at both room and working temperatures.

Despite the fact that high-hot-strength alloys of the nichrome type have a good combination of physicochemical and mechanical characteristics, they are being displaced by cheaper iron-based heat-resistant steels.

The titanium content of these alloys should not be more than 0.3%. The "Electrostal'" Plant produces certain steels of this type with a high chromium content (EI-290, EI-340) and with rare elements as modifying additives (EI-595, EI-626); structurally these steels are solid solutions based on α-iron. A higher chromium content causes appearance of a σ-phase, which embrittles the metal. The carbon content of heat-resistant steels is strictly limited (to 0.06-0.12%), since formation of carbides reduces plasticity and service life. Although silicon increases the electrical resistance of iron to a greater extent than other elements, it is unwise to add more than 1%, since larger quantities of this element cause the allow to lose its capacity for machining. In certain handbooks Kh13Yu4 and OKh23Yu5 are referred to as fekhral' and khromal'.

TABLE 5

Specific Electrical Resistance of Iron-Chromium-Aluminum Alloys and Diameter of Wire Produced (GOST 2238-58)

Сплав 1	d проволоки (мм) 2	ρ номинальное при 20° 3	Допустимые отклонения ρ 4
		5 (ом мм²/м)	
Х13Ю4 6	0.2–10.0	1.26	±0.08
7 0Х23Ю5	0.2–10.0	1.37	±0.08
0Х23Ю5А 8	0.2–10.0	1.35	±0.05

1) Alloy; 2) d of wire (mm); 3) nominal ρ at 20°; 4) permissible deviation in ρ; 5) ohm·mm²/m; 6) Kh13Yu4; 7) OKh23Yu5; 8) OKh23Yu5A.

Fekhral' has a mean temperature coefficient of electrical resistance at 15-100° of 0.00018 1/°C, i.e., 2-3 times that of khromal' or ferronichrome. Fekhral' is widely used in the manufacture of loading rheostats, household appliances, low-temperature resistance furnaces,

TABLE 6

Principal Physical and Mechanical Characteristics of Alloys Nos. 1, 2, 3 and 4

Свойства 1	Сплав № 1 2	Сплав № 2 (0Х23Ю5) 3	Сплав № 3 4	Сплав № 4 5
$t_{пл}$ (°C)	1500—1510	1490—1510	1560—1580	1650—1680
ρ при 20° (ом·мм²/м) 6	1,3—1,35	1,4—1,45	1,8—2	2—2,2
α·10⁶ при 20—100° (1/°C) 7	14,5—15	14,5—16	16—17	16—17
γ (г/см³) 8	7—7,2	6,9—7,2	6,8—7	6,75—6,85
$σ_b$ (кг/мм²) 9	60—70	70—80	80—100	—
δ (%)	15—25	15—20	2—7	Хрупкое разрушение при разрыве 15
HB (кг/мм²) 10	150—170	160—180	240—260	270—300
Обрабатываемость 11	В горячем и холодном состояниях		Только в литом состоянии — шлифование	
Рабочая темп-ра в нагреват. приборах (°C) 12	13 1000	1200	14 1300	1450

1) Characteristic; 2) alloy No. 1; 3) alloy No. 2 (OKh23Yu5); 4) alloy No. 3; 5) alloy No. 4; 6) ρ at 20° (ohm·mm²/m); 7) α·10⁶ at 20-100° (1/°C); 8) γ (g/cm³); 9) σ_b (kg/mm²); 10) HB (kg/mm²); 11) machinability; 12) working temperature in heating devices (°C); 13) when hot or cold; 14) by polishing only when cast; 15) brittle fracture under tension.

TABLE 7

Loss in Weight of Alloy No. 2 on Oxidation in Comparison with Type Kh20N80 Nichrome

Сплав 1	Темп-ра испытания (°C) 2	Продолжительность испытания (часы) 3	Потеря в весе (г/м² час) 4
Сплав № 2 5	1200	240	0,06
Нихром Х20Н80 6	1200	120	2,89
Сплав № 2	1400	120	0,5
Нихром Х20Н80	1400	120	7 Оплавляется

1) Alloy; 2) test temperature (°C); 3) test time (hr); 4) loss in weight (g/m·hr); 5) alloy No. 2; 6) Kh20N80 nichrome; 7) fuses.

etc. Work conducted to investigate the physicochemical properties of and to develop a fabrication technology for OKh23Yu5 alloy (alloy No. 2) also led to recommendation of the Fe-Cr-Al alloys numbered 1, 3, and 4. Alloy No. 1 contains 16-19% Cr and 4.0-6.0% Al and is intended for operation at temperatures of up to 1000°. Alloys Nos. 3 and 4 are recommended for operation at temperatures of up to 1300-1450°. Alloy No. 3 contains 40-45% Cr and 7.5-12% Al, while alloy No. 4 contains 65-70%

Cr and 7.5-12% Al.

High-chromium alloys Nos. 3 and 4 containing 7-10% aluminum also have a uniform coarsely crystalline structure consisting of ternary solid solutions. They are intended for practical utilization only in the cast state. Despite there very valuable combination of electrical and technical characteristics they have not come into wide use, since they are very complex to produce and very b ittle. Alloy No. 2, which is highly scale-resistant, is the more widely employed. It is the only iron (or even nickel) alloy which can operate at 1200° without considerable oxidation. For data on the scale resistance and ρ of the aforementioned alloys in various media see GOST 9232-59.

Components of alloy No. 2 can successfully function at various temperatures in air, oxygen, hydrogen, nitrogen, hydrogen sulfide, and hydrocarbons. Like all other iron-chromium-aluminum alloys, alloy No. 2 becomes brittle at high temperatures as a result of extreme grain growth and fractures on bending by 45-90°. A coarse-grained alloy can be made plastic by heating it to 300° or more. Straightening and bending of components must be carried out at these temperatures.

Investigation of the hot strength of alloy No. 2 by centrifugal bending over the temperature range 600-1200° made it possible to establish the maximum stresses which this alloy can withstand for 500 hr on deformation by bending (Table 8).

It can be seen from the data cited that alloy No. 2 has a very low creep strength on bending at 1000-1200°. It can consequently be used for long periods without additional loading. Wire, sheets, and tubes are now produced from alloy No. 2; it is employed experimentally in industrial pyrolysis apparatus.

TABLE 8

t° испытания (°C) 1	Предельное напряжение для достижения стрелы изгиба 5 мм (кг/см²) 2
600	400
700	100
800	30
900	15
1000	10
1200	2—2.5

1) Test temperature (°C); 2) maximum stress required to produce a bend rise of 5 mm (kg/cm²).

Alloys of the Kanthal type are produced in Sweden. These alloys are very similar in composition to OKh23Yu5, but also contain 3.2-3.8% cobalt and have strictly limited carbon, silicon, and manganese contents (no more than 0.04-0.05% of each element). This highly precise chemical composition permits certain types of Kanthal to reach working temperatures of 1250-1300°.

Alloys are tested for service life by the accelerated method described in GOST 2419-58. In essence, this method consists in testing wire specimens by high-frequency alternate heating to the maximum working temperature and cooling until the surface darkens. Three specimens from each batch of wire are tested and the results are regarded as satisfactory if they do not deviate from the arithmetic mean by more than ±12%.

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V.S. Zharoprochnyye splavy No. 1 i No. 2 [High-Hot-Strength Alloys Nos. 1 and 2], Sverdlovsk-Moscow, 1943; Kornilov, I.I., Zharoprochnyy splav No. 3 [High-Hot-Strength Alloy No. 3], Moscow-Leningrad, 1947; Kornilov, I.I., Mikheyev, V.S., Tr. In-ta metallurgii AN SSSR [Transactions of the Institute of Metallurgy, Academy of Sciences USSR], 1957, No.1, pages 124-131.

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III-83s

ALLOYS FOR SOLDERING TO GLASS – alloys used in the manufacture of radio, electron-beam, and x-ray tubes. They should be readily wetted by molten glass and yield vacuum-type joints with glass and ceramics. The coefficient of thermal expansion (α) of these alloys should be similar to the α of glass over the range between the lowest working temperatures and the annealing temperature of glass. N29K18 (kovar) and N30K13D alloys are used for soldering to heat-resistant glasses ($\alpha \sim 3-5\cdot10^{-6}$), while Kh18TFM, N47Kh, N47Kh3, N47KhB, N47D5, and N33K1 alloys are used for soldering to less heat-resnstant glasses ($\alpha \sim 8-10\cdot10^{-6}$). The most widely used alloys are N29K18 and Kh18TFM.

References: Solov'yeva, N.A., Yudkevich, M.I., in book: Pretsizionnyye splavy [Precision Alloys], Moscow, 1956 (Sb. tr. TsNIIChM [Collection of Works of the Central Scientific Research Institute of Ferrous Metallurgy imeni I.P. Bardin], No. 15); Smolyarenko, D.A., Kaplan, A.S., Standartizatsiya [Standardization], 1959, No. 3, page 13.

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ALLOYS FOR THERMOCOUPLES – alloys which make it possible to obtain NK-SA and NZh-SK thermocouples without correction for the temperature of the free ends. For all their simplicity, ordinary thermoelectric thermocouples have one substantial drawback, the fact that their thermal emf depends on the heating of their free ends. In this connection it is necessary to use resistance-calibrated leads and to include a special device (corrector) in the temperature-indicating circuit to correct automatically for the temperature of the free ends. A better solution to the problem is use of thermoelectrode alloys which, when coupled, begin to display a pronounced thermal emf at 50–100° (or somewhat higher), depending on operational conditions. Alloys of this type for uncorrected thermocouples were first developed in the USSR. The metallurgical industry produces thermoelectrode wire from NK and SA alloys (GOST 6072-51) for NK-SA thermocouples, which measure temperatures of 300–1000° (GOST 6071-51), and from NZh and SK alloys for NZh-SK thermocouples, which measure temperatures of 100–900° (TUTsM 1381-60). The table shows the basic characteristics of NK, SA, NZh, and SK alloys. The figure shows the thermoelectric characteristics of NK-SA and NZh-SK thermocouples.

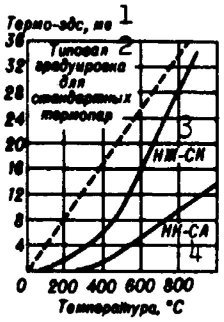
Use of uncorrected thermocouples simplifies the pyrometric setup by eliminating the need for compensating leads and a corrector in the temperature-indicating (galvanometer) circuit and increases the accuracy with which the temperature can be read from the indicator scale, which has more widely spaced divisions, since reading begins not at 0 degrees but at a higher temperature. Moreover, there is no need to

Physical and Mechanical Characteristics of NK, SA, NZh, and SK Alloys

1 Сплав	2 σ_b (кг/мм²)	δ* (%)	ρ при 20° (ом·мм²/м)	Термоэлектрич. неоднородность (мв, не более)
	не менее 3		4	5
6 НК	45	25	0,345±0,02	0,05 (900–1000°)
7 СА	43	25	0,345±0,02	0,03 (900–1000°)
8 НЖ	50	20	0,16±0,02	0,1 (700–800°)
9 СК	45	20	0,48±0,02	0,1 (700–800°)

*Length – 100 mm.

1) Alloy; 2) σ_b (kg/mm^2); 3) no less than; 4) ρ at 20° (ohm·mm^2/m); 5) thermoelectric nonuniformity (mv, no more than); 6) NK; 7) SA; 8) NZh; 9) SK.



Thermoelectric characteristics of NK-SA and NZh-SK thermocouples. 1) Thermal emf, mv; 2) typical calibration for standard thermocouples; 3) NZh-SK; 4) NK-SA; 5) temperature, °C.

determine the temperature of the free ends.

References: Popov, M.M., Termometriya i kalorimetriya [Thermometry and Calorimetry], Moscow-Leningrad, 1934; L'vov, M.A., Pribory dlya izmereniya temperatur v metallurgii [Temperature-Measuring Instruments in Metallurgy], Moscow, 1944; Toperverkh, N.I., Izmeritel'nyye i reguliruyushchiye pribory na metallurgicheskikh zavodakh [Measuring and Regulating Instruments in Metallurgical Plants], Khar'kov-Moscow, 1941; Kul'bush, G., Kalinin, A., Tochnaya industriya [Precision Industry], 1933, Nos. 3-4; Keinath, Jr., Arch. techn. Messen [Archives of Technical Measurement], 1934, Vol. 4, No. 37, page 97; Thomas, H., Z.

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A.L. Shpitsberg

ALLOY STEEL FOR PERMANENT MAGNETS – tungsten, chromium, and cobalt steels containing approximately 1% C. Magnets with high coercive strength are obtained by quenching the steel to martensite. The full

Chemical Composition, Magnetic Characteristics, and Hardness of Alloy Steels for Permanent Magnets (GOST 6862-54)*

Сталь 1	2 Содержание элементов (%)							3 Магнитные свойства			HB (кг/мм²) 10
	C	Si	Cr	Ni	Mn	Co	Mo	4 остаточная индукция B_r (гс) 6	коэрцитивная сила H_c (э) 7 5	$B_r H_c \cdot 10^{-6}$ (гс·э) 9	
								8 не менее			
ЕХ 11	0.95–1.10	0.17–0.40	1.3–1.6	≤ 0.3	0.2–0.4	–	–	9000	58	0,35	241–217
ЕХ3 12	0.90–1.10	0.17–0.40	2.8–3.6	≤ 0.3	0.2–0.4	–	–	9500	60	0,60	255–229
13 Е7В6	0.68–0.78	0.17–0.40	0.3–0.5	≤ 0.3	0.2–0.4	5.2–6.2W	–	10000	62	0,65	321–255
ЕХ5К5 14	0.90–1.05	0.17–0.40	5.5–6.5	≤ 0.6	0.2–0.4	5.5–6.5	–	8500	100	0,90	341–269
15 ЕХ9К15М	0.90–1.05	0.17–0.40	8.0–10.0	≤ 0.6	0.2–0.4	13.5–16.5	1.2–1.7	8000	170	1,40	341–285

*P ≤ 0.03, S ≤ 0.02.

1) Steel; 2) content of elements (%); 3) magnetic characteristics; 4) residual induction B_r; 5) coercive force H_c; 7) gausses; 8) oersteds; 8) no less than; 9) gauss·oersted; 10) kg/mm^2; 11) YeKh; 12) YeKh3; 13) Ye7V6; 14) YeKh5K5; 15) YeKh9K15M.

heat-treatment cycle is complicated by the fact that steels of this type have a tendency toward precipitation of carbides. Steel to be machined is first subjected to softening tempering at 650-825°. The carbide transformations which take place during this process greatly reduce the coercive force of the steel ("breakdown"). The "broken down" steel then undergoes "corrective" treatment – normalization at 1000-1250°. The final operation is quenching from 800-1050° in water or oil after holding for no more than 10-15 min (in order to avoid carbide-induced "breakdown"), which produces finely acicular martensite. The table shows the chemical composition and characteristics of alloy steels for permanent magnets. The magnetic characteristics of chromium and tungsten steels do not greatly exceed those of simple carbon steels with the same carbon content. The part played by the chromium and tungsten essentially reduces to increasing the hardenability of the alloy and stabilizing its magnetic properties. Cobalt steel has far higher magnetic characteristics. Steels of this type are limited in use. They are being displaced by alni and alnico alloys, which have much higher magnetic characteristics (see Alni alloys).

References: Zaymovskiy, A.S., Chudnovskaya, L.A., Magnitnyye materialy [Magnetic Materials], 3rd Edition, Moscow-Leningrad, 1957 (Metally i splavy v elektrotekhnike [Metals and Alloys in Electronics], Vol. 1).

B.G. Livshits and A.A. Yudin

ALLOY STRUCTURAL CASTING STEEL – low- and medium-alloy steel for cast machine components; it is distinguished from carbon steel by its higher strength and plasticity. The total alloying-element content of these steels generally does not exceed 5%; the carbon content of refinable steels is 0.20–0.50% and that of cementable steels is 0.07–0.20%. In complex alloying with several elements at the same time the advantages given the steel by each element may be combined; this imparts good casting properties to the steel and gives the castings a fine-grained structure, good hardenability and temper resistance, and high plasticity, viscosity, and strength. Complex alloying with silicon, manganese, chromium, nickel, etc., makes it possible to increase the σ_b of the steel to 150–170 kg/mm^2 while retaining satisfactory plasticity. The following are the principal types of heat treatment employed for shaped castings: annealing, normalization and tempering, quenching in a liquid medium and tempering, and isothermal quenching in a hot medium. It is wise to use less stringent heat treatment, such as normalization and tempering, isothermal quenching, or annealing, for complex elongated components with a tendency to warp.

Alloy structural casting steels differ little in physical, chemical, and certain technological characteristics from shaping steels of similar composition; as far as mechanical characteristics are concerned, these two types of steel differ in plasticity and impact strength. In cast steel these characteristics are somewhat lower along the grain and higher across the grain than those of shaping steel.

Table 1 shows the chemical composition of the alloy structural casting steels widely used in industry.

Molybdenum can be employed as a substitute for tungsten in 35KhML and 30KhNML steels. When the steel is smelted in furnaces with acid linings the permissible sulfur and phosphorus contents can be raised by 0.01% each. Table 2 shows the mechanical characteristics of these steels after final heat treatment. The mechanical properties of castings are checked on specimens cast in lost-metal molds or cut from separately cast test bars heat-treated at the same time as the castings.

TABLE 1

Chemical Composition of Alloy Structural Casting Steels

Сталь 1	2 Содержание элементов (%)									5 ТУ или ГОСТ
	C	Si	Mn	S	P	Cr	Ni	Cu	4 Др. элементы	
				не более						
6 27ГЛ	0,22–0,32	0,17–0,37	1,1–1,50	0,05	0,05	—	—	—	—	19 ГОСТ 7832–55
7 40Г2Л	0,37–0,45	0,20–0,37	1,4–1,8	0,04	0,04	0,3	0,4	—	—	20 АМТУ 432-56
8 40ХЛ	0,35–0,45	0,17–0,37	0,5–0,8	0,04	0,04	0,8–1,1	0,4	0,3	—	ГОСТ 7832–55
9 35ХНЛ	[illegible]	0,17–0,37	0,5–0,8	0,04	0,04	0,5–0,8	[illegible]	0,3	—	″
10 20ГСЛ	0,16–0,22	0,6–0,8	1,0–1,3	[illegible]	[illegible]	0,4	0,4	0,3	—	″
11 35ХМЛ	0,30–0,40	0,17–0,37	0,5–0,8	0,04	0,04	0,8–1,1	0,4	0,3	0,2–0,3 Mo	″
12 16ХГТЛ	[illegible]	0,17–0,37	1,0–1,4	0,035	0,035	1,5–1,8	[illegible]	—	0,06–0,12 Ti	АМТУ 432-56
13 30ГСТЛ	0,25–0,35	1,0–1,3	1,0–1,3	0,04	0,04	0,3	[illegible]	[illegible]	[illegible] Ti	ГОСТ 7832–55
14 35ХГСМЛ	[illegible]	0,6–0,9	0,9–1,2	[illegible]	[illegible]	0,7–1,0	0,4	—	[illegible] Mo	АМТУ 432-56
15 30ХНМЛ	0,25–0,35	0,17–0,37	0,5–0,8	0,04	0,04	1,3–1,6	1,2–1,6	[illegible]	[illegible]	ГОСТ 7832–55
16 30ХНВЛ	0,25–0,35	0,17–0,37	0,5–0,8	0,04	0,04	1,3–1,6	1,3–1,6	0,3	[illegible] W	″
17 27ХГСНЛ	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0,7–1,0	[illegible]	—	—	АМТУ 432-56
18 30ДХСНЛ	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0,7–1,0	[illegible]	1,1–1,6		ГОСТ 7832–55

1) Steel; 2) content of elements (%); 3) no more than; 4) other elements; 5) TU or GOST; 6) 27GL; 7) 40G2L; 8) 40KhL; 9) 35KhNL; 10) 20GSL; 11) 35KhML; 12) 16KhGTL; 13) 30GSTL; 14) 35KhGSML; 15) 30KhNML; 16) 30KhNVL; 17) 27KhGSNL; 18) 30DKhSNL; 19) GOST; 20) AMTU.

Figure 1 shows the variation in the mechanical characteristics of certain types of steel as a function of heat-treatment regime and casting-wall thickness. The mechanical characteristics of the steels at various temperatures were determined on specimens cut from bars 30 mm thick, while the properties of bars with different thicknesses were determined after tempering at 650-670°.

Castings with complex shapes are subjected to normalization and tempering rather than quenching and tempering, in order to reduce internal stresses.

Increasing casting-wall thickness from 12-25 mm to 100 mm causes a decrease in mechanical characteristics. In this case there is a drop of 7-10% in yield strength and ultimate strength, 15-18% in relative elongation, and 25-30% in relative reduction in area.

Figure 2 shows the change in the mechanical characteristics of types 30KhNVL and 30DKhSNL steels at elevated temperatures.

Thin-walled castings (with walls 10-15 mm thick) of 40G2L, 35KhGSML, and 27KhGSNL steels can be quenched and tempered at a rather low temperature to increase their strength. Figure 3 shows the influence of tempering temperature on the increase in the strength of 27KhGSNL steel.

Isothermal quenching in potassium nitrate or alkali at 280-320° with a holding time of 2-3 hr makes it possible to obtain higher strength in combination with high plasticity in 27KhGSNL and other steels; in comparison with quenching in oil use of this type of heat treatment promotes a decrease in the warping of complex elongated castings, but also causes a reduction in the hardenability of the steel.

Type 16KhGTL can be used as a cementable steel; in this case the castings are subjected to double quenching and tempering at 150-170°.

Annealing or normalization and tempering are employed as preliminary heat treatment for high-strength steel castings.

A decrease in plasticity and impact strength resulting from embrittlement of the grains during crystallization is observed in high-strength steels (35KhGSML, 27KhGSNL, etc.) when test bars are cast in hot molds (ceramic or lost-metal). The curves given in Fig. 4 characterize the strength of 27KhGSNL steel under repeated static loading (static durability).

Figures 5 and 6 show the mechanical characteristics of high-strength steels at elevated and low temperatures.

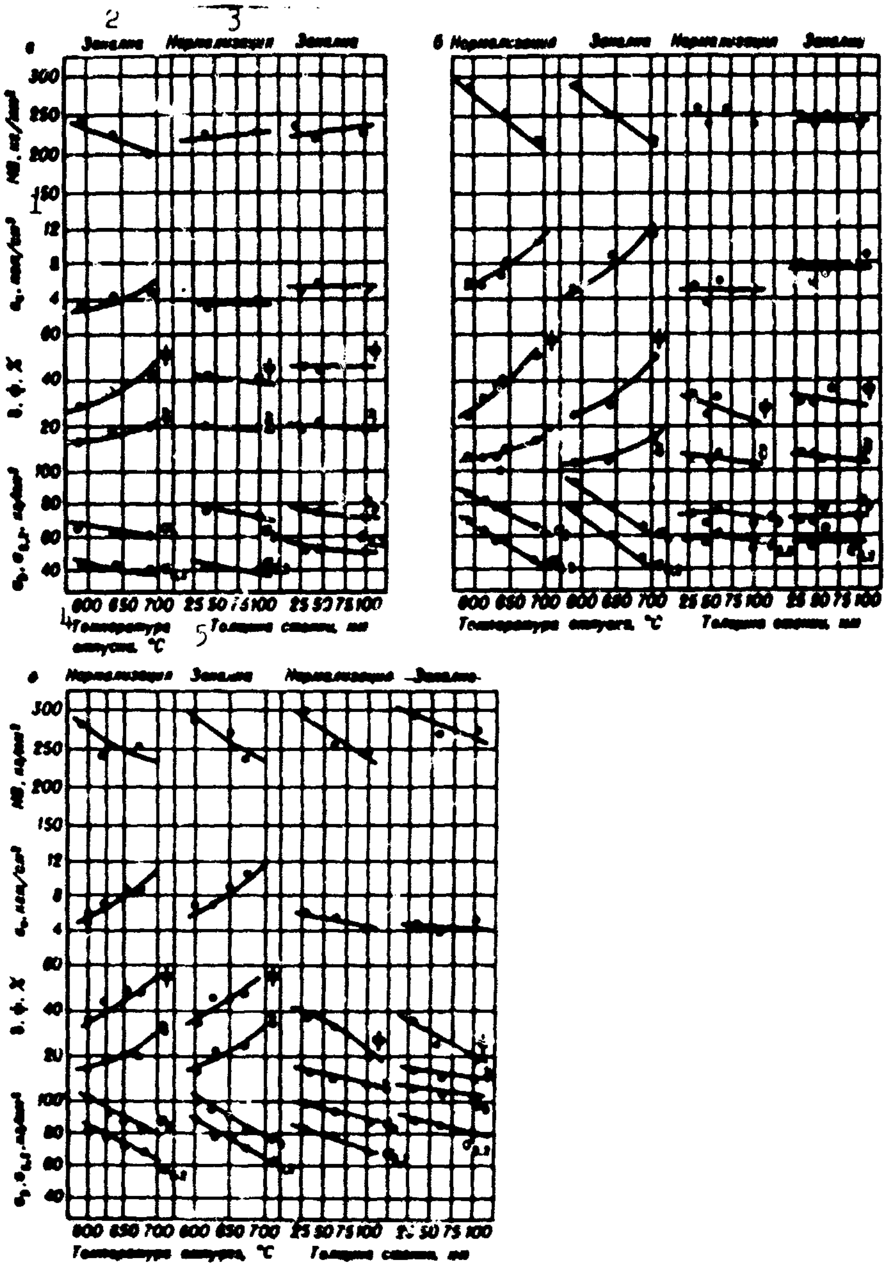

Fig. 1. Influence of tempering temperature and casting-wall thickness on the mechanical characteristics of steel: a) 40KhL; b) 30KhNML; c) 30DKhSNL. Normalization and and quenching temperature – 850–880°. 1) kg/mm^2; 2) quenching; 3) normalization; 4) tempering temperature, °C; 5) wall thickness, mm.

The physical characteristics of the majority of alloy structural casting steels include: $\gamma = 7.8$ (7.78 for 27KhGSNL steel) and $\alpha \cdot 10^6$ (1/°C) = 11.0 (25–100°), 13.0 (25–300°), and 14.5 (25–600°).

The majority of alloy structural casting steels have a $\lambda = 0.08$–0.095 (20°) cal/cm·sec·°C.

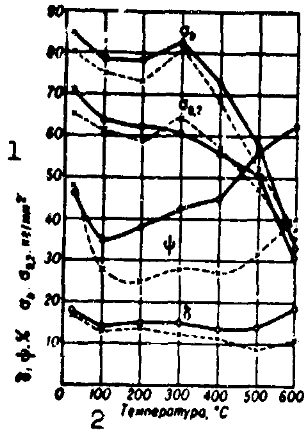

Fig. 2. Mechanical characteristics of cast 30KhNVL (solid line) and 30DKhSNL (dash line) steels at elevated temperatures. Quenching and annealing at 670°. 1) kg/mm^2; 2) temperature, °C.

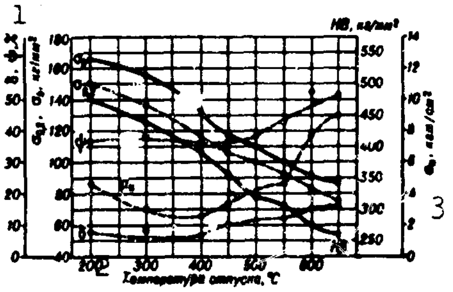

Fig. 3. Influence of tempering temperature on the mechanical characteristics of 27KhGSNL steel. Quenching in oil from 890° (wall thickness – up to 15 mm). 1) kg/mm^2; 2) tempering temperature, °C; 3) kg-m/cm^2.

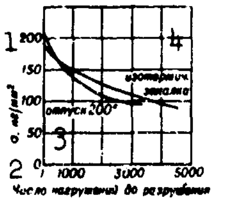

Fig. 4. Curves showing static durability of 27KhGSNL steel. Quenching from 890°. 1) kg/mm^2; 2) number of loading cycles to fracture; 3) tempering at 200°; 4) isothermal quenching.

The corrosion resistance of these steels is rather low.

With respect to technical characteristics, alloy structural casting steels have a free linear shrinkage of 2.0-2.2%. Figure 7 shows the flowability of certain types of steel. These steels are smelted in electric arc and induction furnaces, while open-hearth furnaces are used for large castings. Casting is carried out in loam, shell, chill,

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TABLE 2

Mechanical Characteristics of Alloy Structural Casting Steels After Final Heat Treatment (no less than)

Сталь 1	ТУ или ГОСТ 2	Темп-ра окончат. термич. обработки (°C) 3		σ0,2	σb	δ5	ψ	aн (кгм/см²) 7
		4 нормализация или закалка	5 отпуск	6 (кг/мм²)		(%)		
8 Нормализация и отпуск								
10 20ГСЛ	30 ГОСТ 7832—55	870—890	570—600	30	55	18	30	3,0
11 35ХМЛ	То же	860—880	600—650	40	60	12	20	3,0
12 35НГВЛ	»	860—880	600—650	45	60	12	20	3,0
30ХНМЛ 13	»	860—880	600—650	35	70	12	20	3,0
14 30ХНВЛ	»	850—870	600—650	55	70	12	20	3,0
15 30ДХСНЛ	»	860—870	600—650	60	80	10	20	3,0
9 Закалка и отпуск								
16 27ГЛ	ГОСТ 7832—55	860—870	560—600	45	65	10	20	5,0
17 40Г2Л	АМТУ 432-58 31	850—870	600—650	40	75	12	30	4,0
То же 18	То же	850—870	550—600	60	90	8	15	2,0
19 30ГСЛ	ГОСТ 7832—55	870—880	570—600	40	65	14	30	5,0
40ХЛ 20	»	850—860	600—650	50	65	12	25	3,5
21 35ХНЛ	»	860—870	570—600	50	70	12	25	4,0
22 16ХГТЛ	АМТУ 432-58	890—910	150—170	60	90	7	20	3,0
35ХМЛ 23	ГОСТ 7832—55	860—870	600—650	55	70	12	25	4,0
24 30ГСТЛ	»	910—920	640—660	55	70	12	25	4,0
25 35ХГСМЛ	АМТУ 432-58	880—900	630—670	60	80	12	30	4,0
»	»	880—900	570—630	85	100	8	20	2,5
30ХНМЛ 26	ГОСТ 7832—55	860—870	600—650	65	80	10	20	4,5
27 30ХНВЛ	То же	860—870	600—650	65	80	10	20	4,5
30ДХСНЛ 28	»	860—870	600—650	70	90	10	20	4,0
27ХГСНЛ	АМТУ 432-58	880—900	540—560	75	90	10	30	4,0
29 »	То же	880—900	32 В селитру с темп-рой 300°	100	130	6	20	2,5
»	»	880—900	200—240	120	150	5	20	2,0

1) Steel; 2) TU or GOST; 3) final heat-treatment temperature (°C); 4) normalization or quenching; 5) tempering; 6) kg/mm²; 7) kg-m/cm²; 8) normalization and tempering; 9) quenching and tempering; 10) 20GSL; 11) 35KhML; 12) 35NGVL; 13) 30KhNML; 14) 30KhNVL; 15) 30DKhSNL; 16) 27GL; 17) 40G2L; 18) the same; 19) 30GSL; 20) 40KhL; 21) 35KhNL; 22) 16KhGTL; 23) 35KhML; 24) 30GSTL; 25) 35KhGSML; 26) 30KhNML; 27) 30KhNVL; 28) 30DKhSNL; 29) 27KhGSNL; 30) GOST; 31) AMTU; 32) in potassium nitrate from 300°.

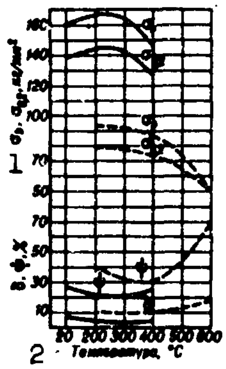

Fig. 5. Mechanical characteristics of 35KhGSML steel at elevated temperatures (dashed curves — quenching in oil from 890° and tempering at 600°, solid curves — isothermal quenching in potassium nitrate at 380°). 1) kg/mm²; 2) temperature, °C.

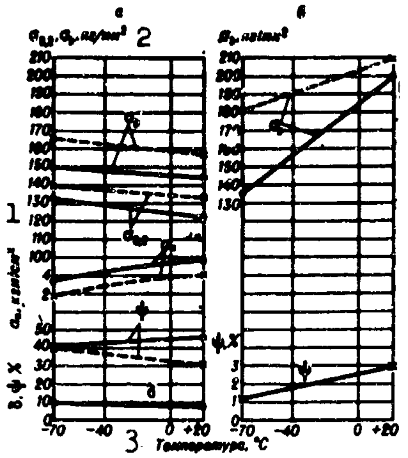

Fig. 6. Mechanical characteristics of 27KhGSNL steel at low temperatures (solid curves – isothermal quenching, dashed curves – quenching and tempering at 200°. 1) kg-m/cm²; 2) kg/mm²; 3) temperature, °C.

lost-metal, and ceramic molds. The most flexible molds (e.g., shell molds) are employed for thin-walled castings of high-strength steel, which have an especially strong tendency toward hot cracking. Castings of alloy structural casting steel with a low carbon content weld well. Castings of such steels with carbon contents of 0.3% or more, which tend to air-harden, should be heated to 150-350° before welding or sealing up defects; the castings are annealed immediately after welding in order to relieve stresses and prevent formation of welding cracks.

Alloy structural casting steels are readily cut in the annealed state.

These steels are used in instrument building (components of instruments, apparatus, etc.), shipbuilding (stern-posts, anchors, propellers, etc.), machine building (steam- and water-turbine housings, valve and nozzle housings, wheels, spiral conveyors, cylinders and slide-valve housings for steam engines, pistons, etc.), the manufacture of metallurgical equipment (components of presses, hammers, rolling spans, rolling rollers, punches, die blocks, etc.), and in railroad machine building (locomotive frames, firebox frames, wheels, crankshafts, journal boxes, etc.).

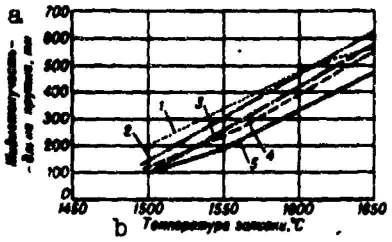

Fig. 7. Flowability of steels: 1) 40KhL, 30KhNML; 2) 35DKhSL, 30DKhSNL; 3) 35KhML, 30KhNVL; 4) 35KhGSL; 5) 27KhGSNL. a) Flowability – bar length, mm; b) casting temperature, °C.

Steels alloyed with manganese and silicon are used for casting components with increased yield strength, ultimate strength, and durability; manganese steels containing nickel, silicon, and tungsten are employed for components which must have substantial hardness and strength and high impact strength. Steels alloyed with nickel and chromium are used for components which must combine high plasticity with high impact strength and fatigue strength at room and low temperatures (components of pumps, refrigeration equipment, and mining and metallurgical equipment). Steels alloyed with manganese and chromium and having an elevated carbon content are intended for components subject to wear (sprocket wheels and gears for reduction gears and drill winches, pipe-cutter components); components for cementation are cast from low-carbon steels (16KhGTL). Chromium-nickel steels containing molybdenum, tungsten, titanium, and copper are used for high-stress components which must combine high strength with high plasticity, fatigue resistance, and durability (sprocket wheels, gears, shafts, excavator-bucket components, etc.), as well as for components which must function at elevated temperatures (components of oil-drilling and petroleum-cracking equipment, in boiler and pipe fabrication and shipbuilding). The multicomponent alloy steels 35KhGSML, 27KhGSNL, etc., are employed for casting high-strength thin-walled aircraft components (chassis components: tie beams, connecting pieces, brackets, and struts, as well as various load-bearing assemblies, motor support frames, etc.).

References: Metallovedeniye i termicheskaya obrabotka stali i chuguna [Metalworking and Heat Treatment of Steel and Pig Iron], Handbook, Moscow, 1956; Akimov, G.V. and Akimova, K.I., Yedinaya spetsifikatsiya metallicheskikh materialov mashinostroyeniya Soyuza SSR [Composite Specifications for Metallic Machine-Building Materials in the USSR], Pt. 3, Moscow, 1948; Nekhendzi, Yu.A., Stal'noye lit'ye [Steel Casting], Moscow, 1948; Kershenbaum, Ya.M., Markhasin, E.L., Yaroshevskiy, F.M., Tekhnologiya proizvodstva neftepromyslovogo oborudovaniya [Production Technology of Petroleum-Refining Equipment], Moscow-Leningrad, 1948; Steel Castings Handbook, 1950, Cleveland, 1950; Trubitsyn, N.A., Saveyko, V.N., Bidulya, P.N., Goryachaya treshchinoustoychivost' litoy uglerodistoy stali [Hot-Cracking Resistance of Cast Carbon Steel], Moscow, 1958 (Peredovoy nauchno-tekhn. i proizv. opyt [Advanced Scientific, Technical, and Production Experience], No. M-58-207/4).

ALLOYS WITH HIGH ELECTRICAL RESISTANCE – rheostatic alloys with working temperatures of up to 400° and heat-resistant alloys for heating elements with working temperatures of up to 1200°.

TABLE 1

Chemical Composition of, Products Manufactured from, and Purpose of Rheostatic Alloys (GOST 492-52)

Сплав 1	2 Химич. состав (%)				3 Вид полуфабриката	4 Примерное назначение
	Mn	Zn	Ni	Cu		
Манганин МНМц3-12 . . 5	11,5—13,5	—	2,5—3,5	Остальное 8	9 Ленты, листы, полосы и проволока	Для электротехнич. целей и измерит. приборов 11
Константан МНМц40-1,5 6	1—2	—	39—41	»	Ленты и проволока	Для электротехнич. целей и компенсац. проводов 12
Нейзильбер МНЦ15-20 . . 7	—	18—22	13,5—16,5	»	Ленты и проволока	Для приборов точной механики, электротехнич. целей и технич. посуды 13

1) Alloy; 2) chemical composition (%); 3) type of semifinished product; 4) typical application; 5) MNMts3-12 manganin; 6) MNMts40-1.5 constantan; 7) MNTs15-20 argentan; 8) remainder; 9) strips, sheets, bands, and wire; 10) strips and wire; 11) for electronic components and measuring instruments; 12) for electronic components and compensating leads; 13) for precision mechanical instruments, electronic components, and technical vessels.

Rheostatic alloys can be divided into two groups, those for precision resistors and those for starters and regulating rheostats. Alloys for precision resistors should have a ρ highly constant with time, a low temperature coefficient of electrical resistance, and a low thermal emf when coupled with copper; alloys for starters and regulating rheostats can have less stable characteristics than the alloys of the 1st group. Rheostatic alloys should also have good corrosion resistance and high plasticity for cold drawing into fine wire.

All the aforementioned requirements are most fully satisfied by

TABLE 2

Basic Physical and Mechanical Characteristics of Manganin, Constantan, and Argentan

Свойства 1	2 Манганин	3 Константан	Нейзильбер 4
$t^{\circ}_{пл}$ (°C)	960	1260	1080
γ (г/см³) 5	8,4	8,9	8,7
α·10⁶ при 20–100° (1/°C) 6	16	14,4	16,6
7 c при 18° (кал/г·°C)	0,0975	0,0977	0,095
λ (кал/см·сек·°C) 8	0,052	0,05	0,06–0,08
9 ρ при 20° (ом·мм²/м)	0,435	0,48	0,26
10 Температурный коэфф. электросопротивления при 20–100° (1/°C)	$3\cdot10^{-5}$	$2\cdot10^{-5}$*	$2\cdot10^{-4}$
11 Термоэдс в паре с медью (мкв/°C)	1	40	14,4
σ$_b$ — отожженный (кг/мм²) 12	50–55	40–50	38–45
13 δ—отожженный (%)	30	30	35–45
14 Допустимая рабочая температура (°C)	100	500	250

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*A value of $2\cdot10^{-6}$ can be obtained by careful screening (see Constantan).

1) Characteristic; 2) manganin; 3) constantan; 4) argentan; 5) γ (g/ /cm³); 6) α·10⁶ at 20–100°(1/°C); 7) c at 18° (cal/g·°C); 8) λ(cal/cm· ·sec·°C); 9) ρ at 20° (ohm·mm²/m); 10) temperature coefficient of electrical resistance at 20–100° (1/°C); 11) thermal emf when coupled with copper (μv/°C); 12) σ_b of annealed alloy (kg/mm²); 13) δ of annealed alloy (%); 14) permissible working temperature (°C)

alloys consisting of solid solutions formed over a wide concentration range during the interaction of metals in group I of the periodic system (Cu, Ag, Au) with metals in groups VI, VII, and VIII (Cr, Mn, Ni). Copper-based alloys are of the greatest commercial importance. The precision alloy known as manganin is widely employed. Addition of nickel to this alloy greatly reduces its thermal emf when it is coupled with copper (to 1 μv/°C), which permits almost complete avoidance of thermal currents.

Manganin strips, bands, and wire have a ρ of 0.42–0.48 ohm·mm²/m at 20°, while their temperature coefficient of electrical resistance is $3\cdot10^{-5}$ 1/°C over the range 20–100°.

There are alloys of the manganin type which contain 3-4% aluminum (izabellin) plus 1.5% iron (novokonstantan) instead of nickel. These alloys have considerably more precise characteristics than manganin and are used principally for technical purposes, as in starters.

Investigation of ternary Mn-Cu-Ni alloys has established that those containing 65-70% Mn, 15-20% Ni, and 5-20% Cu have a ρ = 1.9-1.96 ohm·mm^2/m and a temperature coefficient of electrical resistance of $5 \cdot 10^{-5}$ 1/°C at 20-100°. The ρ of these alloys is thus 4 times higher than that of manganin. Alloys with this composition have very good technical characteristics and can be used to produce strips, wire, and other products for the electronics industry.

A copper-nickel alloy of the constantan type has less precise characteristics than manganin. According to the GOST, its total impurities should not exceed 0.9%. Mn is also a metallurgical impurity.

As can be seen from Table 2 constantan has a far higher thermal emf than manganin, which makes manufacture of precision resistors from constantan quite advantageous. A less expensive high-resistance alloy than manganin or constantan is argentan, in which part of the nickel is replaced by zinc (Table 1). This alloy has a lower electrical resistance than manganin or constantan. Argentan wire becomes brittle above 200-250°.

Nickeline (a copper alloy containing 30-35% Ni and 2-3% Mn) has roughly the same characteristics. There are also precision rheostatic alloys based on precious metals, particularly silver containing 10-17% manganese and 3-9% tin, but these are of no great practical significance.

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N.N. Kornilov and P.B. Budberg

ALLOYS WITH SPECIAL PHYSICAL CHARACTERISTICS - alloys whose principal function is to ensure a definite value for some physical characteristic; mechanical and technical characteristics play a subordinate role in this case. Many of these materials are precision alloys in the sense of having rigid requirements imposed on their composition and production technology.

Alloys with special physical characteristics can be divided into the following groups: 1) soft magnetic materials, which are characterized by high initial and maximum permeability, a low coercive force, and small hysteresis and eddy losses. The requirements imposed on these alloys depend on the purpose for which they are intended. For example, materials for relay cores should have a low coercive force and residual induction, while those for the cores of high-power electromagnets should have a high saturation induction. Soft magnetic materials include iron (armco, carbonyl, and electrolytic), electric sheet steel, and high-permeability alloys (permalloy, alsifer, alfenol, and termenol). 2) hard magnetic materials (alloys for permanent magnets) should have a high coercive force, a high residual induction, and a softening curve with a high curvature factor. They include quenched martensitic steels (chromium, tungsten, and cobalt), cast and cermet alloys of the alni type, and shaping alloys. Oxide and crust magnets constitute a special group. Additional requirements are imposed on hard magnetic materials in certain cases (e.g., maximum specific hysteresis losses for materials to be used in the rotors of hysteresis motors). 3) Magnetic materials with special characteristics: an elevated permeability constant (perminvar, izoperm, magnetodielectric) or high saturation induction (permendyur, etc.). This group includes alloys exhibiting high magnetostriction and thermomagnetic alloys. 4) Alloys with a high specific electrical resistance; these include alloys for precision resistors, which must have a low temperature coefficient of electrical resistance and a low thermal emf when coupled with copper (manganin, constantan), alloys for starters and regulating rheostats (nickelene, argentan), heat-resistant alloys for heating elements (nichrome, ferronichrome, fekhral', khromal', megapir, etc.), and alloys for tensometers, whose resistance must be highly sensitive to deformation. 5) Alloys whose coefficient of thermal expansion is 0 (invar, superinvar) or fixed (alloys for soldering the glass and ceramics). 6) Alloys whose temperature coefficient of modulus of elasticity is close to zero (elinvar, etc.). 7) Alloys for thermocouples, thermobimetallic materials, etc.

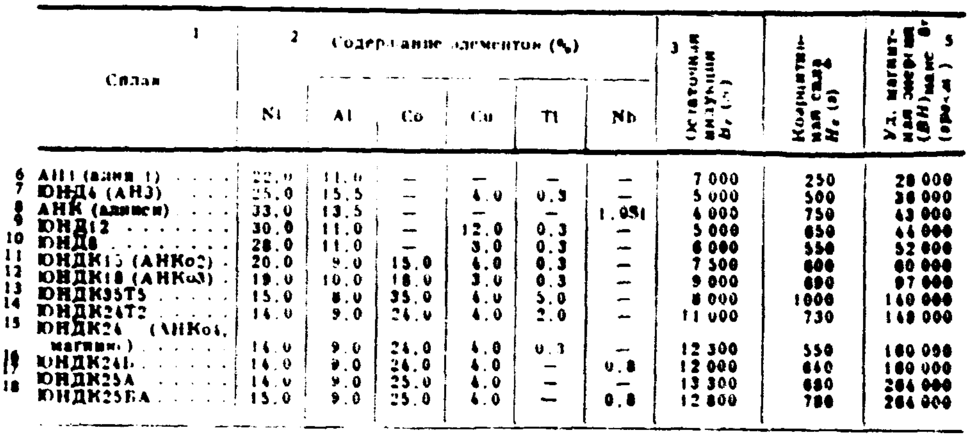
References: Pretsizionnyye splavy [Precision Alloys], Sb. trudov TsNIIChM [Collection of Works of the Central Scientific Research Institute of Ferrous Metallurgy imeni I.P. Bardin [No. 15, Moscow, 1956; No. 22, Moscow 1959; No. 23, Moscow, 1960; Livshits, B.G., Fizicheskiye svoystva metallov i splavov [Physical Characteristics of Metals and Alloys], Moscow, 1959; Zaymovskiy, A.S. and Chudnovskiy, L.A., Magnitnyye materialy [Magnetic Materials], 3rd Edition, Moscow-Leningrad, 1957 (Metally i splavy v elektrotekhnike [Metals and Alloys in Electronics], Vol. 1); Usov, V.V. and Zaymovskiy, A.S., Provodnikovyye reostatnyye i kontaktnyye materialy [Lead, Rheostat, and Contact Materials], 3rd edition, Moscow-Leningrad, 1957 (metally i splavy v electrotekhnike [Metals and Alloys in Electronics], Vol. 2); Bozort, R., Ferromagnetizm [Ferromagnetism], translated from English, Moscow, 1956.

I-20a

ALNI ALLOYS – nonplastic alloys for permanent magnets based on the Fe-Ni-Al system, the ones most widely used by virtue of their high magnetic properties and ease of fabrication. A special point to be observed in heat-treating these alloys is that they are cooled from high temperature at a critical rate that ensures a state of high coercivity (Table 2). The composition of the alloy is selected in such a way as to obtain the optimum properties at a suitable critical cooling rate. The

TABLE 1

Chemical Compositions and Magnetic Properties (after GOST 9575-60 and GOST 4402-48)



	Сплав 1	Содержание элементов (%) 2						Остаточная индукция B_r (гс) 3	Коэрцитивная сила H_c (э) 4	Уд. магнитная энергия $(BH)_{макс}$/8π (эрг/см³) 5
		Ni	Al	Co	Cu	Ti	Nb			
6	АН1 (ални 1)	22.0	11.0	—	—	—	—	7 000	250	28 000
7	ЮНД4 (АН3)	25.0	15.5	—	4.0	0.3	—	5 000	500	38 000
8	АНК (алниси)	33.0	13.5	—	—	—	1.0Si	4 000	750	43 000
9	ЮНД12	30.0	11.0	—	12.0	0.3	—	5 000	650	44 000
10	ЮНД8	28.0	11.0	—	3.0	0.3	—	6 000	550	52 000
11	ЮНДК15 (АНКо2)	20.0	9.0	15.0	4.0	0.3	—	7 500	600	60 000
12	ЮНДК18 (АНКо3)	19.0	10.0	18.0	3.0	0.3	—	9 000	690	97 000
13	ЮНДК35Т5	15.0	8.0	35.0	4.0	5.0	—	8 000	1000	160 000
14	ЮНДК24Т2	14.0	9.0	24.0	4.0	2.0	—	11 000	730	148 000
15	ЮНДК24 (АНКо4, магнико)	14.0	9.0	24.0	4.0	0.3	—	12 300	550	180 000
16	ЮНДК24Б	14.0	9.0	24.0	4.0	—	0.8	12 000	640	180 000
18	ЮНДК25А	14.0	9.0	25.0	4.0	—	—	13 300	680	284 000
	ЮНДК25БА	13.0	9.0	25.0	4.0	—	0.8	12 800	780	284 000

1) Alloy
2) Content of elements (%)
3) Residual induction B_r (gausses)
4) Coercive force H_c (oersteds)
5) Specific magnetic energy $(BH)_{maks}$ 8π (ergs/cm^3)
6) AN1 (alni 1)
7) YuND4 (AN3)
8) ANK (alnisi)
9) YuND12
10) YuNDK15 (ANKo2)
11) YuNDK35T5
12) YuNDK24(ANKo4, magniko)
13) YuNDK24B
14) YuNDK25BA

TABLE 2

Recommended Heat-Treatment Conditions (after GOST 9575-60 and GOST 4402-48)

AN1	Quenching from 1200° in boiling water or normalization from 1200° (for thin magnets)
YuND4	Normalization from 1100°
ANK	Normalization from 1200°
YuND12 YuND8	Quenching from 1280° (cooling in hot water); tempering at 590°
YuNDK15	Quenching from 1300° in a magnetic field with $H \geq 100$ kiloamperes/m (cooling from 900 to 700° at an average rate of 1-5° per sec); tempering at 590°
YuNDK35T5	Quenching from 1220° in a magnetic field $H \geq 100$ kiloamperes/m (cooling as rapid as possible to 850-800°, subsequent cooling to 700° at a rate of 0.5-2° per sec); tempering at 590°
YuNDK24T2	Same, but quenching from 1250°
YuNDK24 YuNDK24B	Same, but at a rate of 1-1.5° per sec
YuNDK25A YuNDK25BA	Same, but at a rate of 1.5-2° per sec.

magnetic properties of Fe-Ni-Al alloys are highest at contents of 27-32% Ni and 12-14% Al, but the Ni content should be lowered and the Al content raised for magnets weighing more than 1-2 kg in order to lower the critical cooling rate. Copper additives raise the properties, compensating for the decrease in properties that results from deviation from the optimum Ni-Al composition. Copper also stabilizes the properties with regard to variations in chemical composition. The introduction of 1% Si (alnisi) lowers the critical cooling rate sharply – which is of importance in producing high properties in heavy magnets. A further increase in magnetic energy can be achieved by the introduction of Co (more than 12%) and Cu (up to 6%). A high content of copper (8-12%) improves the flow properties of mold-cast alloys. A sharp increase in magnetic energy is obtained by thermomagnetic treatment (cooling in a magnetic field from the critical temperature) in alloys with increased Co content (> 18%). The particularly high properties of the last two alloys listed in Table 1 are attained by creating crystallographic and magnetic texture simultaneously (by orienting the directions of crystallization during solidification and heat treatment in a magnetic field).

Alni alloys are stable to structural and magnetic aging; partial demagnetization to stabilize the magnetic flux is justified only for precision-instrument magnets. The basic shortcoming of these alloys is brittleness. Magnets made from them are fancy-shaped castings and admit of machining only by grinding. For small magnets, this process gives a very small useful yield. Magnets weighing up to a few tens of grams and complex-shaped magnets are made by the powder-metallurgical method. The coercive force of the cermet magnets is the same as that of the cast magnets, but the residual induction and, accordingly, the energy are 10% lower than those of the case types.

The field of application of alni-alloy magnets is extremely wide: electrical measuring instruments, telephone apparatus, recorders, magnetos, electrical machines, magnetic clutches, etc.

References: Livshits, B.G. and L'vov, V.S., Vysokokoertsitivnyye splavy na zhelezonikel'alyuminiyevoy osnove [High-Coercivity Alloys on the Iron-Nickel-Aluminum Base], Moscow, 1960; Zaymovskiy, A.S. and Chudnovskaya, L.A., Magnitnyye materialy [Magnetic Materials], 3rd edition, Moscow-Leningrad, 1957 (Metally i splavy v elektrotechnike [Metals and Alloys in Electrical Engineering], Vol. 1); Dovgalevskiy, Ya. M., Splavy dlya postoyannykh magnitov [Alloys for Permanent Magnets], Moscow, 1954; Bozort, R., Ferromagnetizm [Ferromagnetism], translated

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from the English, Moscow, 1956.

B.G. Livshits, A.A. Yudin

ALODIZING OF ALUMINUM ALLOYS - see Chemical oxidation of aluminum alloys.

I-27a

ALPHA + BETA-BRASS - brass containing from 36 to 45% Zn and having a mixed structure consisting of crystals of the α- and β-phases of the copper-zinc system after heat treatment and mechanical working. The alpha + beta-brasses include L62, L60, LS59-1, LS60-1, LO60-1, LMtsA57-3-1, LMts58-2, LZhS58-1-1, LZhMts59-1-1 and LAN59-32. The brasses of this group are somewhat stronger than alpha-brass.

Ye.S. Shpichinetskiy

I-28a

ALPHA-BRASS - brass containing up to 33% Zn and having the structure of the α-solid solution of the copper-zinc system after heat treatment and mechanical working. The alpha-brasses include brasses L96, L90, L85, L80, L68 and L70. Alpha-brasses are easily cold- and hot-worked.

Ye.S. Shpichinetskiy

ALPHA-TITANIUM - an allotropic modification of titanium. Titanium has two allotropic modifications, which are designated α and β. The temperature of the allotropic transformation for pure titanium is 882°. Alpha-titanium is the low-temperature modification, stable below 882°, and has a dense-packed hexagonal lattice; the high-temperature modification (β-titanium) is stable at temperatures above 882°, and has a body-centered cubic lattice. The crystal lattice constants of α-titanium are $a = 2.9503 \pm 0.0003$A; $c = 4,6830 \pm 0.0005$A; $c/a = 1.5873 \pm 0.0007$. The constants of the β-titanium crystal lattice at 20° (extrapolation) are 3.283 ± 0.003A. The lattice constants of α- and β-titanium are strongly influenced by oxygen, nitrogen and carbon impurities. Oxygen and nitrogen, which form interstitial solid solutions, influence the parameter c more strongly than a, i.e., they expand the crystal lattice in the direction perpendicular to the base plane (0001), increasing its hexagonality. At room temperature, there are 12 slip systems and 18 twinning planes in α-titanium. The presence of a large number of slip and twinning planes accounts for the high plasticity of titanium at room temperature as compared with other hexagonal-lattice metals (magnesium, zinc, cadmium). The ratio $c/a = 1.5873$, which is 2.9% smaller than the ideal value for dense packing (1.633). The compression of the lattice in the direction of the c-axis reduces the difference between the number of atoms in the base plane and the other lattice planes, thereby depriving the base plane of its exclusive position as the only slip plane. The density of α-titanium at $25 \pm 2°$ is 4.507 ± 0.005 g/cm^3. The density of β-titanium (at 900°), as calculated from the lattice constants, is 4.32-4.35 g/cm^3, as a function of the purity of the original titanium.

References: Parratt, L.G., "Phys. Rev.," 1936, Vol. 50, No. 1; Duwes, P., "Trans. Amer. Inst. Mining and Metallurgical Engrs," 1951, Vol. 191, page 765; McQuillain, A.D., "Proc. Roy. Soc. A," 1950, Vol. 204, page 309; Rostoker, W., "Trans. Amer. Inst. Mining and Metallurgical Engrs," 1952, Vol. 194, page 981.

Ye.A. Borisova

ALPHIZED TITANIUM LAYER - see Titanium alloys.

ALSIFER — see Magnetically soft high-permeance alloy.

ALTERNATING STRESS CYCLE – a cycle in which maximum and minimum stresses differ in sign. See Fatigue.

G.T. Ivanov

I-32a

ALUMEL – an alloy used in pyrometry as the negative thermoelectrode of the chromel-alumel (KhA) thermocouple, and in the form of compensation wires; type designation NMts AK2-2-1.

TABLE 1

Chemical Composition of Alumel (%)

Осн. элементы 1				2 Примеси										
Al	Si	Mn	Ni+Co*	Fe	Mg	Cu	C	S	P	Bi	Pb	As	Sb	Сумма 3
				4 не более										
1.8—2.5	0.85—2.0	1.8—2.2	Остальное 5	0.3	0.05	0.25	0.2	0.02	0.005	0.002	0.002	0.002	0.002	0.6

*Cobalt is present as an impurity in nickel. To ensure the required thermal electromotive force value, the newly revised GOST provides for a cobalt content between 0.6 and 1.0%.

1) Basic elements; 2) impurities; 3) total impurities; 4) not over; 5) remainder.

TABLE 2

Physicomechanical Properties of Alumel

Свойства 1	2 Показатель	3 Состояние материала
4 $t^\circ_{пл}$ (°C)	1430—1450	—
5 γ (г/см³)	8.5	—
6 ρ (ом·мм²/м)	0.25—0.35	—
7 Температурный коэфф. электросопротивления	0.00137	—
8 σ_b (кг/мм²)	56 110	Отожженный 9 Нагартованный до 80% 10
δ (%)	30 2	Отожженный Нагартованный до 80%
11 HB (кг/мм²)	130 230—300	Отожженный Нагартованный
12 Магнитные свойства	Магнитен 13	14

1) Property; 2) index; 3) state of material; 4) t°_{pl} (°C); 5) γ (g/cm^3); 6) ρ ($ohms \cdot mm^2/m$); 7) temperature coefficient of resistivity; 8) σ_b (kg/mm^2); 9) annealed; 10) work-hardened to 80%; 11) HB (kg/mm^2); 12) magnetic properties; 13) magnetic; 14) work-hardened.

KhA thermocouples are used to measure temperatures up to 1000°. Use of the thermocouples above 1000° is not recommended, since on prolonged holding at high temperatures, the change in thermal electromotive force becomes quite pronounced. Alumel is produced in 4 thermal electromotive force classes. There is a chromel of the corresponding calibration class for calibration of each alumel class. By grouping alumels and chromels of identical classes, we obtain the standard calibration for the chromel-alumel thermocouple.

References: Popov, M.M., Termometriya i kalorimetriya [Thermometry and Calorimetry], 2nd edition, Moscow, 1954; Toperverkh, N.I., Izmeritel'nyye i reguliruyushchiye pribory na metallurgicheskikh zavodakh [Measuring and Control Instruments for Metallurgical Plants], Khar'kov-Moscow, 1941; Berkovskiy, I.Ya. and Kolokolova, A.G., Nikelevyye Splavy [Nickel Alloys], Moscow-Leningrad, 1941; L'vov, M.A., Pribory dlya izmereniya temperatur v metallurgii [Instruments for Temperature Measurement in Metallurgy], Moscow, 1944; Smiryagin, A.P., Promyshlennyye tsvetnyye metally i splavy [Industrial Nonferrous Metals and Alloys], 2nd edition, Moscow, 1956.

A.L. Shpitsberg

Manuscript Page No.	[Transliterated Symbols]
149	ХА = KhA = khromel'-alyumel' = chromel-alumel
149	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = State All-Union Standard
149	пл = pl = plavleniye = melting

I-18a

ALUMINIZING OF STEEL – saturation of the surfaces of steel components with aluminum with the object of increasing resistance to scaling at 700-900° and above as well as resistance to atmospheric corrosion. Low-carbon steel is most frequently aluminized. Steel is aluminized in powdered mixtures consisting of 50% Al (or ferroaluminum), 49% Al_2O_3 and 1% NH_4CL or 99% ferroaluminum and 1% NH_4CL. Holding for 8 hours at 1000° produces a layer 0.40-0.45 mm deep consisting of the solid solution of aluminum in α-iron with inclusions of the compound Fe_2Al_5. To reduce the brittleness of the aluminized layer, the parts are sometimes given diffusion annealing at 900-1100°. Aluminizing of steel is particularly important in metallizing large workpieces. In this process, a layer of aluminum powder 0.4-0.6 mm thick is applied to the surface of the piece, followed by a coat of insulation and diffusion annealing. For steel aluminizing in liquid metal, a melt of aluminum with 6-8% iron, a bath temperature of 700-800° and holding time from 3 to 45 minutes are used. Steel is aluminized in the fabrication of internal-combustion engine exhaust manifolds, air and steam radiators, parts of apparatus for cracking petroleum and natural gas, steam-boiler nozzle heads, gas-generator tractor combustion chambers, and the like. Galvanizing is gradually being supplanted by aluminizing of steel in fused aluminum (sheets, wire, pipes, structural components, household utensils).

<u>References</u>: Prosvirin, V.I. and Zudin, I.F., Povysheniye zharouporнosti zhelezouglerodistykh splavov alitirovaniyem [Increasing the Heat

Resistance of Iron-Carbon Alloys by Aluminizing], Moscow-Leningrad, 1944; Florin, K.P., "Tr. Mosk. in-ta khim. mashinostr." [Transactions of the Moscow Institute for Chemical Machinery], 1957, Vol. 12; Gorodnov, P.T., "Metallovedeniye i termicheskaya obrabotka metallov" [Physical Metallurgy and the Heat Treatment of Metals], 1961, No. 2, pages 55-57; Gorodnov, P.T., Povysheniye zharostoykosti stal'nykh izdeliy metodom alitirovaniya [Increasing the Heat Resistance of Steel Parts by Aluminizing], Moscow, 1962.

A.N. Minkevich

ALUMINUM, Al – a chemical element of the 3rd group of Mendeleyev's periodic system, atomic number 13, atomic weight 26.98; it consists of a single stable isotope, Al^{27}. As a result of its high chemical activity, aluminum is found in the earth's crust only in compounds with other elements. Its content in the earth's crust amounts to 8.80% (by weight). together with oxygen and silicon, aluminum accounts for 82.58% of the mass of the earth's crust, occurring primarily near its surface. Aluminum is obtained by electrolysis of alumina, Al_2O_3, dissolved in molten cryolite, Na_3AlF_6. The alumina is extracted from bauxite, which is a complex ore consisting of aluminum-oxide hydrates, which are its principal constituent, as well as oxides, hydrated oxides, carbonates, and other compounds of silicon, iron, calcium, magnesium, and sodium. Aluminum is usually trivalent (Al^{3+}), although under certain conditions the aluminum atom may be converted to a monovalent ion (Al^{+}), which forms compounds of lower valence. There are several artificial radioactive isotopes of Al, the majority of which are short-lived. The only radioactive isotope of Al suitable for tracer investigations is Al^{26} ($T_{1/2} \sim 10^6$ years). The elementary cell of the aluminum crystal lattice is a face-centered cube (lattice parameter – 4.0413A). The specific gravity of solid aluminum is 2.7 (at 20°), while that of molten aluminum is 2.3 (at 800°); $t°_{pl}$ for high-purity aluminum (99.996% Al) is 660.24°, while that for technical-grade aluminum (99.5% Al) is 658°. The boiling point, $t°_{kip}$, is 2200°; the latent heat of fusion of Al is 976 cal/g. Its specific heat is 0.226 in the solid state (at 100°) and 0.308 cal/g•°C in the liquid state (700°). The neutron cross-section of aluminum is 0.215 barn.

The thermal conductivity of this metal is 0.57 cal/cm•sec•°C over the temperature range 0-100°, while its electrical conductivity is 67-65% that of copper, depending on its prity. In air aluminum is covered with a film of aluminum oxide, which protects it against further oxidation and results in a comparatively high corrosion resistance. Concentrated nitric acid and organic acid have no effect on aluminum, but it is broken down by caustic alkalies, hydrochloric acid, and sulfuric acid. This metal readily undergoes pressure working – rolling, extrusion, drawing, forging, and stamping. It is good for gas, contact, and other types of welding. Depending on its purity, the ultimate strength of cast aluminum is 5-9 kg/mm^2, its relative elongation is 45-1210, and its Brinell hardness is 13-28 kg/mm^2. Rolled aluminum has an ultimate strength of 8-15 kg/mm^2, a relatively elongation of 5-3%, and a hardness of 25-32 kg/mm^2 (depending on the degree of cold-working).

Its combination of low specific gravity, high electrical conductivity, and high corrosion resistance in many aggressive media makes it possible to use aluminum in electronics (for the manufacture of cables, busbars, capacitors, and rectifiers), in chemical machine building (apparatus for the production of nitric acid, organic chemicals, etc.), in the foodstuffs industry (for cans, pots, milk cans, etc.), in residential construction, and for protecting metal surfaces subject to destructive corrosion. It is utilized in nuclear power engineering for the casings of reactor heat-evolving elements. There are indications that it is possible to use liquid aluminum as a heat-transfer medium in power reactors. Aluminum has found especially wide technological use in the form of alloys with other metals (see Aluminum alloys) and as a plating material. The program adopted by the CPSU at its 22nd Congress provides for a large increase in aluminum production and for use of this metal in electrification, machine building, construction, and everyday life.

References: Belyayev, A.I., Metallurgiya legkikh metalloy [Metallurgy of Light Metals], 4th Edition, Moscow, 1954; Spravochnik po mashinostroitel'nym materialam [Handbook of Machine-Building Materials], Vol. 2, Moscow, 1959.

M.B. Al'tman

ALUMINUM-ALLOY CAST-IRON – is a heat- and corrosion-resistant cast iron with a high aluminum content; it is used moreover in electrical industry as a nonmagnetic material (see Heat-resistant cast iron, Corrosion-resistant cast iron, Non-magnetic cast iron). The aluminum-alloy cast-iron is known under the name Chugal' (cast iron + aluminum) and Pyroferal (Table 1).

TABLE 1

Chemical Composition and Mechanical Properties of the Aluminum-Alloy Cast-Iron

Чугун 1	2 Содержание элементов (%)						3 Механич. свойства		
	C	Si	Mn	P	S	Al	$\sigma_в$	$\sigma_{изг}$	HB
				не более			6 (кг/мм²)		
7 Чугаль	1,2—2,0	1,3—2,0	0,6—0,8	0,1	0,05	20—24	11—17	20—25	170—300
8 Пирофераль	1,2—1,4	до 0,5	до 0,5	0,4	0,1	28—30	—	31	370HV

1) Cast iron; 2) percentage of the elements; 3) mechanical properties; 4) izg; 5) not more than; 6) kg/mm²; 7) Chugal'; 8) Pyroferal.

TABLE 2

Physical Properties of Aluminum-Alloy Cast-Iron

Чугун 1	γ (г/см³) 2	α·10⁶ (1/°C)	Линейная усадка (%) 3	Обрабатываемость 4	Предельная жаростойкость (°C) 5
6 Чугаль	5,5—6,7	13—14	1,4—1,8	Хорошая	7 1100
8 Пирофераль	5,4	15,8	—	9 Только абразивами	1200

1) Cast iron; 2) g/cm³; 3) linear shrinkage (%); 4) workability; 5) maximum heat resistance (°C); 6) Chugal'; 7) good; 8) Pyroferal; 9) only by abrasives.

Chugal' is modified by cerium, magnesium, and other elements in order to form speroidal graphite.

Pyroferal castings tend towards a spontaneous destruction caused probably by the reaction of the graphite and the melted Al_4C_3 carbide with hydrogen and formation of acetylene (C_2H_2). In order to prevent this phenomenon, the castings are submitted to a heat treatment and the shelf time is reduced to a minimum; the castings are covered by oil and kept on a dry place. An addition of 0.4% Ti reduces the grain-size of the pyroferal.

Chugal' resists nitric acid and sea water. It is used as a heat resistant material in the manufacture of many parts working at high temperatures. Pyroferal does not react with molten borax and various salts, it resists carburizing and cyaniding agents during heat treatment, and it resists the cracking products of hydrocarbons. Pyroferal is used as a heat resistant material in the scrapers of pyrite ovens, in carburizing boxes, crucibles for molten salts, etc.

References: Eminger, Z. and Weber, K., Proizvodstvo otlivok iz spetsial'nykh staley [Manufacture of Castings of Special Steels], translated from Czech, Moscow, 1960; Meyerovich, I.B., Modifitsirovaniye dlya polucheniya chuguna s sharovidnym grafitom [Modifying to Obtain a Cast Iron with Spheroidal Graphite], in the book: Spravochnik po chugunnomu lit'yu [Handbook on Iron Casting], Moscow-Leningrad, 1960; "Aluminium," 1961, Vol. 37, No. 1, pages 29-31.

A.A. Simkin

Manuscript Page No.	[Transliterated Symbols]
155	изг = izg = izgib = bending

ALUMINUM ALLOYS - alloys of low specific gravity based on aluminum. The worldwide production of aluminum has recently been rising rapidly, at a growth rate considerably higher than that of steel, copper, lead or zinc production. Al is displacing copper, zinc, lead and tin in a number of technical fields, and even steel in some branches. The seven-year plan for the development of the USSR's national economy provides for an increase in Al production by a factor of 2.8-3.0. The basic merits of aluminum alloys are as follows: low specific gravity, high electrical and thermal conductivity, good corrosion resistance, the ability to form tough protective and decorative films, and high reflectivity; good technological properties, which make it possible to fabricate complex-shaped, high-precision and very large workpieces from aluminum alloys; good machinability, easy chemical milling (precision etching) and polishing, good contact welding and, for a number of aluminum alloys, good fusion welding as well.

High rigidity in structures made from aluminum alloys is of considerable value, and the high unit strength of aluminum alloys is an important factor in all forms of transportation. Presses designed in the USSR with capacities up to 70,000 tons are producing large aluminum-alloy semifinished products that require only a minimum of machining. The excellent foundry properties of aluminum alloys open broad prospects for production of complex castings with a variety of properties, high surface finish and precision dimensions. On a worldwide scale, aluminum alloys are used extensively in construction to fabricate window frames, doors, wall facings, roofs, trusses, and the like; it is used on power transmission lines for wires and supports; in transportation, aluminum alloys are a basic structural material for airplanes, helicopters, trolleys, buses, automobiles and trucks, railroad cars, seagoing and river vessels, and pipelines; aluminum alloys are used extensively in fabrication of many types of rockets; aluminum alloys are used in hoisting cranes, excavating machinery, oilfield derricks, i.e., in all cases where low specific gravity, high strength, good corrosion resistance and production adaptability make it possible to design efficient and economical structures that quickly cover their initially higher cost (as compared with steel structures). At the same time, aluminum alloys are used to fabricate dishes, decorative trim, "gold" costume jewelry, wrappers, etc. Alloys with small temperature coefficients of resistivity and linear expansion have also been produced and are used in various instruments.

Al may contain as impurities Fe, Si, Ti, Na and certain other elements. The methods of producing pure Al are constantly being improved, so that it is now possible to produce Al of 99.999% purity on a respectable scale. This superpure Al is distinguished by high corrosion resistance and electrical conductivity, high thermal conductivity and high reflectivity.

Aluminum alloys are endowed with various properties by adding Mg, Cu, Zn, Si, C, Mn, Zr, Cr, Li, Cd, and Ce to the aluminum. Before the Second World War, the alloys most extensively used were Al-Si alloys (silumins) and their more complex derivatives, Al-Mg alloys (magnals), alloys of Al with Cu and Mg (duralumin), alloys of Al with Mg and Si and with Cu, e.g., AV alloy (avial), alloy AK8 (sometimes known as superduralumin). During and after the war, the highest-strength alloys of Al with Mg and Zn and with Cu (σ_b = 60-70 kg/mm^2), the self-hardening welding alloys of Al with Mg and Zn (σ_b = 40-45 kg/mm^2), which do not require heat-treatment after welding; heat-resistant alloys of Al with Cu and Mn, and those with Cd and Li (σ_b = 36-40 kg/mm^2 at 180° after 1000 hours of soaking at this temperature) were developed rapidly; alloys of Al and Ce also came into use.

Fundamentally new opportunities for strengthening Al were opened by the powder-metallurgical method of producing aluminum alloys. The extremely thin oxide film that forms in an atmosphere with regulated oxygen content on the particles of extremely fine-dispersed Al powder imparts exceedingly high hot strength (at 500°) to the sintered Al after briquetting, sintering and subsequent deformation (see Sintered aluminum powder — SAP). Together with SAP, where the Al strengthening agent is oxygen, or, more precisely, Al oxide, the powder-metallurgical technique has made it possible to create a number of sintered aluminum alloys (SAS) strengthened by Si, Fe and Ni in quantities that considerably exceed their maximum solubility in the solid state or their concentrations in the eutectic. These alloys have low α ($14 \cdot 10^{-6}$) and unusually high corrosion resistance in boiling water.

Foam aluminum (which is lighter than water) is produced on an industrial scale by decomposing Ti or Zr hydride in fused Al and by other methods.

Aluminum alloys may be classified into 4 basic groups on the basis of production methods: shaping alloys for the fabrication of various semifinished products (sheets, plates, rods, profiles, tubing, wire, etc.) by mechanical working (see Aluminum alloys, shaping); foundry alloys for the production of fancy-shaped castings (see Aluminum alloys, foundry); sintered aluminum alloys for fabrication of semifinished products and workpieces from powders (sintered aluminum powder occupies an important position among these) and foam aluminum.

In shaping aluminum alloys, the content of alloying elements may vary over a broad range, but, as a rule, it does not exceed the maximum solubility in Al. The foundry alloys usually contain a considerable quantity of the eutectic, so that they are more heavily alloyed and have superior foundry properties (molten-state flow, formation of dense castings on crystallization, etc.). In sintered aluminum alloys, the content of alloying elements may run as high as 20–25%. Titanium, zirconium or other elements that enter the aluminum from hydrides used in the foaming process are present in foam aluminum; their contents vary from 1.0 to 10%.

Depending on intended use and the mechanical, corrosion, technological, physical and other specifications, aluminum alloys are classified as alloys of high, medium and low strength; heat-resistant, weldable and forging alloys; riveting and decorative alloys and alloys with special physical properties. As a rule, aluminum alloys are prepared with addition of a considerable amount of primary aluminum, as well as high-grade scrap. There are special secondary aluminum alloys that permit wider use of low-grade scrap, with some broadening of the impurity spectrum (see Aluminum alloys, secondary). Some aluminum alloys (the lowest grades) are used in ferrous metallurgy to deoxidize steel. Attempts to use aluminum alloys in coal mines as supporting columns did not yield satisfactory results, since sparking occurs when these columns are struck against steel, and this is dangerous in the mine atmosphere, which contains detonating gas. The chemical compositions of aluminum alloys are given in the table below.

References: Bochvar, A.A., Metallovedeniye [Physical Metallurgy], 5th edition, Moscow, 1956; Voronov, S.M., Deformiruyemyye alyuminiyevyye splavy [Aluminum Shaping Alloys], Moscow, 1951; Petrov, D.A. Voprosy teorii splavov alyuminiya [Problems of Aluminum Alloy Theory], Moscow,

Chemical Compositions of Aluminum Alloys (%)

Alloy	Elements					Impurities (not over)									
	Cu	Mg	Mn	Si	Other elements	Si	Fe*	Cu	Mn	Ni	Zn	Mg	Others	Total Fe+Si or Fe+Ni	Total of all impurities
AD1	—	—	—	—	—	0,35	0,3	0,05	—	—	—	—	0,1	0,6 Fe+Si	0.7
AD	—	—	—	—	—	0,55	0,5	0,1	0,1	—	0,1	0,1	0,1	1,0 Fe+Si	1,2
AMTs	—	—	1,0—1,6	—	—	0,6	0,7	0,2	—	—	0,1	0,05	0,1	—	1.75
AMTs2	—	0,8—1,3	0,9—1,4	—	—	0,7	0,7	0,1	—	—	—	—	0,1	—	1.6
AMg1	—	0,5—1,8	—	—	—	0,05	0,05	0,01	—	—	—	—	0,07	—	0.18
AMg2	—	1,8—2,8	0,2—0,6	—	—	0,4	0,4	0,1	—	—	—	—	0,1	—	1.0
AMg5	—	4,8—5,5	0,3—0,6	0,02—0,15 V or 0,02—0,1 Ti	—	0,5	0,5	0,05	—	—	0,2	—	0,1	—	1.35
AMg5P	—	4,7—5,7	0,2—0,6	—	—	0,4	0,4	0,2	—	—	—	—	0,1	0,6 Fe+Si	0,9
AMg6	—	5,8—6,8	0,5—0,8	—	0,02—0,1 Ti 0,0001—0,005 Be	0,4	0,4	0,1	—	—	0,2	—	0,1	—	1,2
AL8	—	9,5—11,5	—	—	—	0,3	0,3	0,3	0,1	—	0,1	—	0,07 Ti 0,07Be		1,1
AL13	—	4,5—5,5	0,1—0,4	0,8—1,3	—	—	0,5	0,1	—	—	0,2	—	—	—	0,6
AL22	—	10,5—13	—	0,8—1,2	0,01—0,05 Ti 0,03—0,07 Be	—	0,5	—	—	—	0,1	—	—	—	0,6
AMg3	—	3,2—3,8	0,3—0,6	0,5—0,8	—	—	0,5	0,05	—	—	0,2	—	0,1	—	0,85
AD31	—	0,4—0,9	—	0,3—0,7	—	—	0,5	0,1	0,1	0,15 Ti	0,2	—	0,1	—	1,15
AD33	0,15—0,4	0,8—1,2	—	0,4—0,8	0,15—0,35 Cr	—	0,7	—	0,15	0,15 Ti	0,25	—	0,15	—	1,4
AD35	—	0,8—1,4	0,5—0,9	0,8—1,2	—	—	0,5	0,1		0,15 Ti	0,2	—	0,10	—	—
AK	—	—	—	4,5—6,0	—	—	0,6	0,2	—	0,1 Zn+ +Sn	—	—	0,1	—	0,9
AV	0,2—0,6	0,45—0,9	0,15—0,35	0,5—1,2	—		0,5	—	—	—	0,2	—	0,1	—	0,8
AK6	1,8—2,6	0,4—0,8	0,4—0,8	0,7—1,2	—	—	0,7	—	—	0,1	0,3	—	0,1	0,7 Fe+Ni	1,1
AK8	3,9—4,8	0,4—1,0	0,4—1,0	0,6—1,2	—	—	0,7	—	—	0,1	0,3	—	0,1		1,2
AK6-1	1,8—2,6	0,4—0,8	0,4—0,8	0,7—1,2	0,01—0,2 Cr 0,02—0,1 Ti	—	0,7	—	—	0,1	0,3	—	0,1	0,7 Fe+Ni	1,1
AL2	—	—	—	10—13	—	—	0,8	0,8	0,5	—	0,3	—	—	—	2,2
AL9	—	0,2—0,4	—	6—8	—	—	0,6	0,2	0,5	Sn 0,01	0,3	—	—	—	1,0
AL4	—	0,17—0,3	0,25—0,5	8—10,5	—	—	0,6	0,3	Sn 0,01	—	0,3	—	Ti 0,15	—	1,1
AL4V	—	0,2—0,4	0,2—0,5	8—11	—	—	0,9	1,0	—	0,3	0,5	—	—	—	2,6
AL5	1,0—1,5	0,35—0,6	—	4,5—5,5	—	—	0,6	—	0,5	—	0,3	Sn 0,01	0,2 Ti+ +Cr	—	1,0
AL3	1,5—3,5	0,2—0,8	0,2—0,8	4,0—6,0	—	—	1,0	—	—	—	0,3	—	0,01 Sn	—	1,3
AL3V	1,5—3,5	0,2—0,8	0,2—0,8	4—6	—	—	1,1	—	—	0,5	0,5	—	—	—	2,0
AL14V	1,5—3,0	0,2—0,6	0,2—0,6	6—8	—	—	1,1	—	—	0,3	0,5	—	—	—	1.8
AL10V	5—8	0,2—0.5	—	4—6	—	—	1,2	—	0,5	0,5	0,6	—	—	—	2,5
AL15V	3,5—5,0	—	0,2—0,6	3—5	—	—	1,2	—	—	0,5	2,0	0,5	—	—	4,0
D1	3,8—4,8	0,4—0,8	0,4—0,8	—	—	0,7	0,7	—	—	0,1	0,3	—	0,1	0,7 Fe+Ni	1,8
D1P	3,8—4,5	0,4—0,8	0,4—0,8	—	—	0,5	0,5	—	—	—	0,1	—	0,1	—	1,2
AL25	1,5—3,0	0,8—1,3	0,3—0,6	11,0—13,0	0,8—1,3 Ni 0,05—0,2 Ti		0,8**	—		0,2 Cr	0,5 —	—	0,1Sn 0,07Pb	—	1,2
AL30	0,8—1,5	0,8—1,3	—	11,0—13,0	0,8—1,3 Ni		0,7**	—	0,2	0,001 Sn 0,02 Pb 0,2 Ti	0,2	—	—	-	1,2
D6	4,6—5,2	0,65—1,0	0,5—1,0	—	—	0,5	0,5	—	—	0,1	0,3	—	0,1	—	1,5
D16	3,8—4,9	1,2—1,8	0,3—0,9	—	—	0,5	0,5	—	—	0,1	0,3	—	0,1	0,5Fe+Ni	1,5

D16P	3,8—4,5	1,2—1,6	0,3—0,7	—	—	0,6	0,5	—	—	—	0,1	—	0,1	—	1,2
D19	3,8—4,3	1,7—2,3	0,5—1,0	—	0,02—0,1 Ti 0,0001—0,005 Be	0,5	0,5	—	—	—	0,1	—	0,1	—	1,2
D19P	3,2—3,7	2,1—2,6	0,5—0,8	—	0,02—0,1 Ti 0,0001—0,005 Be	0,3	0,3	—	—	—	0,1	—	0,1	—	0,8
VD17	2,6—3,2	2,0—2,4	0,45—0,7	—	—	0,3	0,3	—	—	—	0,1	—	0,1	0,8 Fe+Si	0,8
D18P	2,2—3,0	0,2—0,5	—	—	—	0,5	0,5	—	0,2	—	0,1	—	0,1	—	1,4
V65	3,9—4,5	0,15—0,3	0,3—0,5	—	—	0,25	0,20	—	—	—	0,1	—	0,1	0,45 Fe+Si	0,65
AK2	3,5—4,5	0,4—0,8	—	0,5—1,0	1,8—2,3 Ni 0,5—1,0 Fe	—	—	—	0,2	—	0,3	—	0,1	—	0,6
AK4-1	1,9—2,5	1,4—1,8	—	—	1,0—1,5 Ni 0,02—0,1 Ti 1,0—1,5 Fe	0,35	—	—	0,2	—	0,3	—	0,1	—	0,85
AK4	1,9—2,5	1,4—1,8	—	0,5—1,2	1,0—1,5 Ni 1,1—1,6 Fe	—	—	—	0,2	—	0,3	—	0,1	—	0,6
AL7	4—5	—	—	—	—	1,2	1,0	—	—	—	0,3	0,03	—	—	2,5
AL7V	3—5	—	—	—	—	1,5	1,1	—	0,5	0,3	0,5	0,3	—	—	4,0
AL1	3,75—4,5	1,25—1,75	—	—	1,75—2,25 Ni	0,7	0,8	—	—	—	0,3	—	—	—	1,6
D20	6—7	—	0,4—0,8	—	0,1—0,2 Ti	0,3	0,3	—	—	0,2Zr	0,1	0,05	0,1	—	1,05
D21	6,0—7,0	0,25—0,45	0,4—0,8	—	0,1—0,2 Ti	0,3	0,3	—	—	0,1	0,1	—	0,1	—	—
VAD23	4,9—5,8	—	0,4—0,8	—	0,1—0,25 Cd 1,0—1,4 Li	0,3	0,3	—	—	0,15Ti	0,1	0,1	0,1	—	—
AL19	4,5—5,3	—	0,6—1,0	—	0,25—0,45 Ti	0,3	0,8	—	—	—	—	0,05	0,5	—	1,1
AL21	4,6—6,0	0,8—1,3	0,15—0,25	—	2,6—3,6 Ni 0,1—0,2 Cr	0,5	0,6	—	—	—	0,3	—	—	—	1,4
AL18V	7,5—9,5	—	0,3—0,8	1,5—2,5	1,0—1,8 Fe	—	—	—	—	0,5	0,5	0,8	—	—	1,7
V92	—	3,9—4,6	0,6—1,0	—	0,0001—0,005 Be 2,9—3,6 Zn	0,2	0,3	0,05	—	—	—	—	0,1	—	—
V93	0,8—1,2	1,6—2,2	—	—	6,5—7,5 Zn 0,15—0,4 Fe	0,2	—	—	0,1	0,1Ti	—	—	0,1	—	0,5
V94	1,8—2,4	1,2—1,6	—	—	6,0—6,7 Zn 0,02—0,08 Ti	0,2	0,2	—	0,1	0,05Cr	—	—	0,1	—	0,65
V95	1,4—2,0	1,8—2,8	0,2—0,6	—	5,0—7,0 Zn 0,1—0,25 Cr	0,5	0,5	—	—	—	—	—	0,1	1,0 Fe+Si	1,1
V53-1	1,2—1,6 Cu + Mg not over 3,4	1,5—2,0	0,2—0,4	—	4,6—5,5 Zn 0,1—0,2 Cr	0,05	0,05	—	—	—	—	—	0,1	—	0,11
V53-2	1,2—1,6 Cu + Mg not over 3,4	1,5—2,0	0,2—0,4	—	4,6—5,5 Zn 0,1—0,2 Cr	0,2	0,4	—	—	—	—	—	0,1	—	0,7
V96	2,2—2,8	2,5—3,2	0,2—0,5	—	7,6—8,6 Zn 0,1—0,25 Cr	0,3	0,5	—	—	—	—	—	0,1	—	0,9
AL16V	2—4	—	0,1—0,5	3,0—5,0	2,0—4,0 Zn	—	1,1	—	—	0,3	—	0,3	—	—	1,7
AL17V	1,5—3,5	—	0,2—0,6	3,0—5,0	4,0—7,0 Zn	—	1,1	—	—	0,3	—	0,3	—	—	1,7
AL11	—	0,1—0,3	—	6—8	10—14 Zn	—	0,8	0,6	0,5	—	—	—	—	—	1,8
AL24	—	1,5—2,0	0,2—0,5	—	3,5—4,5 Zn 0,1—0,2 Ti	0,3	0,5	0,2	—	0,1 Zr 0,1 Be					1,0
SAP-1	—	6—9 Al_2O_3	—	—	—	—	0,2	—	—				Grease 0,25 H_2O 0,1	—	—
SAP-2	—	9,0—13 Al_2O_3	—	—	—	—	0,2	—	—	—	—	—	Grease 0,25 H_2O 0,1	—	—
SAB-1	—	—	—	25—30	5—7 Ni	—	—	—	—	—	—	—			
SAB-2	—	—	—	25—30	3—5 Fe	—	—	—	—	—	—	—	—	—	

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*The Fe content is given for sand casting in the case of the foundry alloys.
**Chill-mold casting.

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I.N. Fridlyander

Manuscript Page No.	[Transliterated Symbols]
159	САП = SAP = spechennaya alyuminiyevaya pudra = sintered aluminum powder
159	САС = SAS = spechennyy alyuminiyevyy splav = sintered aluminum alloy

ALUMINUM ALLOYS, SECONDARY – aluminum-based alloys obtained by recovery of breakage and scrap formed in the production and use of semifinished products and workpieces of primary aluminum alloys. Secondary aluminum alloys may be cast in pigs (GOST 1583-53) or for shaping GOST 1131-41). Foundry-type secondary aluminum alloys are delivered in the form of pigs weighing from 3 to 19.5 kg. They are used for the production of fancy castings and for addition to the charge in the manufacture of primary aluminum alloys (D1, AK6, AK8, etc.) and the fabrication of components for general machine building.

As compared with the corresponding primary aluminum alloys, the secondary alloys contain larger quantities of foreign metallic impurities, as well as gaseous and solid nonmetallic inclusions, to the detriment of their foundry, mechanical and corrosion properties. Secondary aluminum alloys can be obtained in the same high quality as the primary ones if production is appropriately organized; we refer here to collection and grading of the scrap not only by alloy, but also by form; storage of scrap and breakage in specially equipped premises; use of active methods to purify the scrap and liquid metal of detrimental metallic and nonmetallic impurities.

References: Istrin, M.A. [et al.], Vtorichnyye tsvetnyye metally [Secondary Nonferrous Metals], Part 2, Moscow, 1951; Al'tman, M.B., [et al.], Plavka i lit'ye legkikh splavov [Smelting and Casting Light Alloys], Moscow, 1956.

M.B. Al'tman

I-36a1

Manuscript Page No.	[Transliterated Symbols]
29	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = State All-Union Standard

ALUMINUM ALLOYS, SHAPING – alloys for the fabrication of semifinished products by mechanical working. A special class of the shaping aluminum alloys is formed by the SAS's – the sintered aluminum alloys, which include SAP (sintered aluminum powder). Aluminum shaping alloys occupy a dominant position among the aluminum alloys as regards production volume. In various countries, as much as 60-70% of all aluminum is used for production of aluminum shaping alloys. Together with an expansion of nomenclature, the dimensions of the semifinished products are increasing, with the closest possible approximation of their configuration to the finished product with the object of reducing the machining time and saving metal, which makes production considerably cheaper. Many aluminum shaping alloys possess high hot plasticity and not particularly high resistance to deformation, which makes it possible to obtain semifinished products with very complex shapes. In a number of countries, heavy equipment has been built for mechanical working of aluminum shaping alloys. The most powerful horizontal and vertical (up to 70,000 tons) presses have been put in operation in the USSR.

Aluminum shaping alloys are used to produce extruded shapes and tubes up to 15-30 m in length, sheets and plate up to 3 m wide and up to 6-12 m long, forgings and stampings weighing up to 5-6 tons, rods, wire and foil. Aluminum shaping-alloy structures can be built up from large subunits with a small number of joints. Aluminum shaping alloys are classified as follows on the basis of technological characteristics, uses, and physical and corrosion properties: decorative, corrosion resistant, riveting, forging, heat-resistant, alloys with special properties and self-hardening alloys. There are low-strength (below 30 kg/ /mm^2), medium-strength (30-45 kg/mm^2) and high-strength (above 45 kg/ /mm^2) aluminum shaping alloys.

Most low-strength aluminum shaping alloys are not strengthened by heat treatment and are used, as a rule, in the annealed state. These alloys include technical aluminum, AMts alloy, most alloys of the magnal type - AMg1, AMg2, AMg3, AMg4, and AMg5V; aluminum alloys of the Al-Mg-Si system - AD31, AD33 (which are strengthened by heat treatment); SAP-1 and SAS-1. Medium-strength alloys are strengthened by heat treatment and are used after tempering and natural or artificial aging (see Aging of Aluminum Alloys). These include the forging alloys AK2, AK4, AK4-1, AK6 and AK8; duralumins D1, D16, VD17, D19, VAD1 and M40; AMg6 magnal, the alloys AV and AD35 of the Al-Mg-Si system; the self-hardening alloys V92, ATsM, etc., and alloy D20. All high-strength alloys are strengthened very effectively by heat treatment and are used after tempering and, as a rule, artificial aging. These alloys include those of the Al-Zn-Mg-Cu system: V93, V95 and V96; alloy VAD23 and, to some extent, alloys D16, AK8, and others. Sheets and plates of low-, medium- and high-strength aluminum shaping alloys may be further strengthened by rolling.

Aluminum shaping alloys in the annealed state are characterized by an extremely large excess of ultimate strength over yield point (by a factor of two or more). All alloys of the Al-Mg system, up to and including AMg6, have relatively low yield points and are distinguished by high elongation. Naturally aged alloys retain the high elongation values; the ultimate strength and yield point are considerably higher than in the annealed alloys. Artificial aging does not influence the ultimate strengths of alloys in the various systems in the same way as natural aging: it increases it very sharply in alloys of the Al-Mg-Si system (AD31, AD33, AD35 and AV) and particularly in alloys of the Al-Cu-Mn and Al-Cu-Mn-Li-Cd systems (D20 and VAD23); it raises it, but not by very much, in alloys of the Al-Zn-Mg-Cu system (V93, V94, V95, V96); the ultimate strength is virtually unchanged in alloys of the Al-Cu-Mg system (D1, D16, VD17, D19). In alloys of most systems, however, artificial aging causes a sharp increase in yield point, bringing it close to the ultimate strength (the difference between them may amount to 1-5 kg/mm^2); the elongation is reduced by a factor of 2-3, although transverse necking remains quite high.

In artificially aged high-strength alloys, the elongation may decrease to 2.5-4% in the transverse direction. Experience has shown that with such elongation values, the structures perform successfully if sharp stress concentrators are eliminated and the process in which the semifinished products and structural elements are manufactured is strictly controlled. The elongation may be increased by using better-quality ingots (cast with water cooling rather than air cooling, as is sometimes the practice), and by selecting appropriate forging, stamping, rolling and extrusion conditions. In the artificially aged state, aluminum shaping alloys exhibit high strength and, as a rule, low technological plasticity, so that it is desirable to minimize operations involving deformation for semifinished products in this state (V95, V96 and other alloys); for alloy D16, it is advisable to perform all such operations before artificial aging, and for alloy VAD23, to conduct artificial aging on completely finished riveted units.

The higher the strength of aluminum shaping alloys, the greater is their sensitivity to stress concentrators (oriented perpendicular to the direction of force action), particularly in work under alternating-load conditions. Hence all structural components made from high-strength aluminum shaping alloys must have smooth contours; production notches (transverse to force action) are not allowable. Impact-strength values of the order of 1-5 kg-m/cm^2 in the longitudinal direction and 0.3-1.0 kg-m/cm^2 transverse are characteristic for aluminum shaping alloys of medium and high strength. However, brittle failure is not observed in aluminum shaping alloys, and they have no tendency to cold-shortness. If the structures are subjected directly (without shock absorption) to impact loads, a preliminary (experimental) check must be made to determine the possibility of using them under the given conditions.

Medium- and high-strength aluminum shaping alloys may be inclined to corrode under stress. For standard aluminum shaping alloys, this tendency is dependably eliminated by the use of a suitable production process in fabricating the semifinished products, by specification of and adherence to the necessary heat-treatment conditions, and by means of protective coatings. Certain groups of aluminum shaping alloys exhibit very high corrosion resistance; these include the decorative alloys, which are distinguished by excellent external appearance and can be polished and color-anodized (see Anodizing of aluminum alloys, Enamel anodizing of aluminum alloys). As a rule, alloys with high corrosion resistance have low strength, so that it is important to obtain a fine-grained structure in order to impart good external appearance to the workpieces. The surface may become rough if a coarse grain is formed, and particularly in cases of a coarse crystalline crust. In aluminum shaping alloys of medium and high strength, the appearance of a coarse grain and the coarse crystalline crust results in a decrease in strength and a danger of cracking during hardening. The coarse grain and coarse crystalline crust are eliminated by adjusting the chemical composition and the production conditions under which the semifinished products are fabricated and heat treated.

In certain aluminum shaping alloys, coarse segregations of intermetallic phases appear in the structure – these are the so-called intermetallides, which spoil the external appearance of the products, lower their corrosion resistance and increase their sensitivity to alternating loads. Intermetallides are eliminated by regulating the chemical composition of the alloys and the conditions under which the ingots are cast.

Aluminum rivet alloys are used in making rivets. These alloys possess high shear resistance and good plasticity, which ensures that the rivets can be given heads of regular shape without cracking. Some riveting alloys can be peened only in the freshly tempered state, during a limited period of time after tempering; alloys that can be headed in the aged state, with no restrictions on riveting time (alloys D18, V65, V94) are more convenient for mass production.

Forging aluminum alloys can be cast continuously in any necessary diameter and exhibit high plasticity in the hot state. Forging aluminum alloys of medium and high strength must have the proper levels of strength, plasticity and corrosion resistance. Critical stress-bearing forged components are usually studied very thoroughly when placed in production, in various directions and in various zones. The necessary level of properties is attained by the use of high-quality ingots and the proper production forging process (for example, by swaging and drawing of the blank). In forgings and stampings, and particularly for massive and complex-shaped types (as is the case with rolled and extruded semifinished products), cracking and peeling may occur. It is mandatory that these products be given a UZ [ultrasonic] inspection, together with an eddy-current test on the surface layers

Heat-resistant aluminum shaping alloys are, as a rule, used in the artificially aged state. Since these alloys heat up during use – especially over long periods, actually undergoing artificial aging in the process, it is advisable to stabilize them before they are installed in the structure.

The aluminum shaping alloys with special properties include: SAS-1, which has a low coefficient of linear expansion, and AMts-1, which exhibits a low temperature coefficient of resistivity.

The self-hardening aluminum shaping alloys are distinguished by a special property that is important for welding alloys – slow decay of the supersaturated solid solution and the ability to temper on cooling in air, which results in tempering of the welding zone during welding and subsequent hardening of this zone as a result of aging. These aluminum shaping alloys include V92, ATsM and others.

References: Voronov, S.M., Deformiruyemyye alyuminiyevyye splavy [Aluminum Shaping Alloys], Moscow, 1951; Legkiye splavy. Metallovedeniye, termicheskaya obrabotka, lit'ye i obrabotka davleniyem [Light Alloys. Physical Metallurgy, Heat Treatment, Casting and Mechanical Working], [Collection of articles], Moscow, 1958; Fridlyander, I.N. Vysokoprochnyye deformiruyemyye alyuminiyevyye splavy [High-strength Aluminum Shaping Alloys], Moscow, 1960; Baykov, D.I. [et al.], Svarivayushchiyesya alyuminiyevyye splavy [Aluminum Welding Alloys], Leningrad, 1959; Dobatkin, V.I., Slitki alyuminiyevykh splavov [Aluminum Alloy Ingots], Sverdlovsk, 1960; Deformiruyemyye alyuminiyevyye splavy [Aluminum Shaping Alloys], collection of articles edited by I.N. Fridlyander [et al.], Moscow, 1961; Teploprochnyy material ;iz spechennoy alyuminiyevoy pudry (SAP) [Hot-Strong Material Prepared from Sintered Aluminum Powder (SAP)], collection of articles edited by I.N. Fridlyander and B.I. Matveyev, Moscow, 1961; Stroitel'nyye konstruktsii iz alyuminiyevykh splavov [Aluminum Alloy Structures], [collection of articles], edited by

S.V. Taranovskiy, Moscow, 1962; Pavlov, S.Ye. Korroziya duralyumina [Corrosion of Duralumin], Moscow, 1949; Petrov, D.A., Voprosy teorii splavov alyuminiya [Problems in the Theory of Aluminum Alloys], Moscow, 1951; Voronov, S.M., Izbrannyye trudy po legkim splavam [Selected Works on Light Alloys], Moscow, 1957; Mikheyeva, V.I., Khimicheskaya priroda vysokoprochnykh splavov alyuminiya s magniyem i tsinkom [The Chemical Nature of High-Strength Alloys of Aluminum with Magnesium and Zirconium] Moscow-Leningrad, 1947; Romanova, O.A., Novyy zharoprochnyy deformiruyemyy alyuminiyevyy splav D20 [The New D20 Hot-Strong Aluminum Shaping Alloy], Moscow, 1958; Archakova, Z.N., Romanova, O.A., Fridlyander, I. N., Issledovaniye splavov sistemy Al-Cu-Li-Cd-Mn, pri komnatnoy i povyshennykh temperaturakh [Investigation of Alloys of the Al-Cu-Li-Cd-Mn System at Elevated Temperatures], "IAN SSSR. OTN. Metallurgiya i toplivo," Bulletin of the USSR Academy of Sciences, Technical Sciences Section, Metallurgy and Fuel], 1960, No. 4; 1962, No. 4; Livanov, V.A. [et al.], Otzhig distovogo al'kleda [Annealing Sheet Alclad], Moscow, 1940; Shilova, Ye.I., Alyuminiyevyy splav V65 dlya zaklepok [V65 Aluminum Rivet Alloy], Moscow, 1958.

I.N. Fridlyander

Manuscript Page No.	[Transliterated Symbols]
170	УЗ = UZ = ul'trazvukovoy = ultrasonic
171	САП = SAP = spechennaya alyuminiyevaya pudra = sintered aluminum powder

ALUMINUM BARS – round and shaped (square, hexagonal, etc.) semifinished products of aluminum and aluminum alloys. Bars of aluminum and its alloys are generally manufactured by pressing, although rolling is sometimes employed. Pressed bars are produced in diameters of from 5 to 300 mm or more and are supplied in the hot-pressed, annealed, and quenched states. Only bars with diameters of less than 50 mm are supplied in the quenched state. Round bars with diameters of up to 50 mm can be standardized by drawing. Shaped bars are standardized at inscribed-circle diameters of up to 40 mm. Standardized bars are produced to the 3rd, 4th and 5th precision classes, while other bars are produced to the 7th, 8th and 9th classes (GOST 4783-55). This procedure reduces the extent of the large-crystalline rim, but causes deterioration of surface quality. Bars with diameters of up to 120-150 mm can be manufactured by this method. Larger-diameter bars are produced only by direct pressing. The conformity of the characteristics of such bars to technical specifications is always at the discharge end. Macrostructure and fracture are checked at the draw end. Nonuniformity of characteristics must be eliminated when components are to be manufactured from pressed bars by stamping or forging.

The most uniform characteristics are obtained when bars are produced by rolling. Considering the difficulty of rolling cast ingots of certain alloys, pressed or forged blanks are often employed, although this reduces the efficiency of the rolling process. Bars up to 180 mm in diameter are manufactured by rolling.

References: Zholobov, V.V. and Zverev, G.I., Pressovaniye metallov [Pressing of Metals], Moscow, 1959.

B.I. Matveyev

ALUMINUM BRASS – a brass in which the main alloying element is aluminum. Brasses containing from 0.4 to 3.5% Al are used in industry. Aluminum displaces the boundaries of the α and β'-phases on the Cu-Zn diagram toward the copper side: 1% of Al is equivalent to 6% Zn (see Brass). Aluminum increases the strength, heat resistance and corrosion resistance of brass under atmospheric conditions and in sea water. The increase in corrosion resistance is accounted for by the formation of an oxide zone. The chemical composition of aluminum brasses is given in Table 1.

TABLE 1
Chemical Composition

Сплав 1	ГОСТ, ТУ 2	3 Содержание элементов (%)									
		Cu	Al	Zn	4 другие элементы	Pb	Fe	Bi	P	Sb	6 Сумма примесей
						5. не более					
7 ЛА 85-0,5	8 ПМТУ 1507-46	84—86	0.4—0.7	9 Остальное	—	0.03	0.01	0.002	—	0.005	0.3
10 ЛА 77-2	11 ГОСТ 1019-47	76—79	1.75—2.50		—	0.07	0.10	0.002	0.01	0.005	0.3
12 ЛАЖ 60-1-1	13 То же	58—61	0.75—1.50		0.75—1.50 Fe 0.1—0.6 Mn	0.40	—	0.002	0.01	0.005	0.7
14 ЛАН 59-3-2	» »	57—60	2.50—3.50		2.0—3.0 Ni	0.10	0.50	0.003	0.01	0.005	0.9

1) Alloy; 2) GOST, TU; 3) content of elements (%); 4) other elements; 5) not above; 6) total impurities; 7) LA 85-0.5; 8) PMTU 1507-46; 9) remainder; 10) LA 77-2; 11) GOST 1019-47; 12) LAZh 60-1-1; 13) same; 14) LAN 59-3-2.

Aluminum brasses have good mechanical working properties. They are shaped into rods (LAZh60-1-1, LAN59-3-2), tubing (LA77-2) and wire (LA85-0.5). The basic properties of aluminum brasses are listed in Tables 2 and 3.

Uniform braid and insignia are made from LA85-0.5 brass; LA77-2

TABLE 2

Mechanical Properties

Сплав 1	2 ГОСТ, ТУ	3 E (кг/мм²)	4 σ_b (кг/мм²)	δ (%)
			5 не менее	
6 8 ЛА 85-0,5	ЦМТУ 1507-46 7	—	30	35
9 ЛА 77-2	ГОСТ 2203-43 9	10500	38	23
10 ЛАЖ 60-1-1	ГОСТ 2060-60 11	10500	45	18
12 ЛАН 59-3-2	МПТУ 4212-53 13	10000	55	12

1) Alloy; 2) GOST, TU; 3) E (kg/mm^2); 4) σ_b (kg/mm^2); 5) not below; 6) LA 85-0.5; 7) TsMTU 1507-46; 8) LA 77-2; 9) GOST 2203-43; 10) LAZh 60-1-1; 11) GOST 2060-60; 12) LAN 59-3-2; 13) MPTU 4212-53.

TABLE 3

Physical and Technological Properties

Сплав 1	γ (г/см³) 2	$\alpha \cdot 10^6$ (1/°C)	3 λ (кал/см·сек·°C)	4 ρ (ом·мм²/м)	5 Темп-ра плавления (°C)	6 Темп-ра горячей обработки (°C)	7 Темп-ра отжига (°C)
ЛА 85-0,5 8	8,6	18,6	0,26	—	1020	800—850	650—700
ЛА 77-2 9	8,4	18,5	0,24	0,075	975	700—770	600—650
ЛАЖ 60-1-1 10	8,2	21,6	0,20	0,09	904	700—800	600—700
ЛАН 59-3-2 11	8,4	19,1	0,20	0,078	956	700—750	600—650

1) Alloy; 2) γ (g/cm^3); 3) λ (cal/cm·sec·°C); 4) ρ (ohms·mm^2/m); 5) melting point (°C); 6) hot working temperature (°C); 7) annealing temperature (°C); 8) LA 85-0.5; 9) LA 77-2; 10) LAZh 60-1-1; 11) LAN 59-3-2.

and LAN59-3-2 are used to fabricate condenser tubes, pipes, gears, bushings, etc.; components made from LAZh60-1-1 are used in the aviation industry and other industrial branches.

References: Gagen-Torn, V.O., Grashchenko, B.F., and Ivanov-Skoblikov, N.N., Mekhanicheskiye i tekhnologicheskiye svoystva alyuminiyevykh latuney [Mechanical and Technological Properties of Aluminum Brasses], "Tr. Vses. alyuminiyevo-magniyevogo in-ta," [Transactions of the All-Union Institute for Aluminum and Magnesium], 1939, [No.] 19, pages 132-49; Smiryagin, A.P., Promyshlennyye tsvetnyye metally i splavy [Indus-

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trial Nonferrous Metals and Alloys], 2nd edition, Moscow, 1956, pages 110-20; Spravochnik po mashinostroitel'nym materialam [Handbook on Mechanical Engineering Materials], Vol. 2, Moscow, 1959, pages 175-84.

A.V. Bobylev

Manuscript Page No.	[Transliterated Symbols]
175	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = State All-union Standard
	ТУ = TU = tekhnicheskiye usloviya = technical specifications
176	ЦМТУ = TsMTU = technicheskiye usloviya tsvetnoy metallurgii = nonferrous metallurgy technical specifications

ALUMINUM BRONZE – a bronze in which the main alloying element is aluminum. Alloys containing from 4 to 11% Al are of industrial importance (see Table 1).

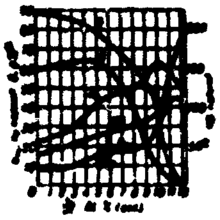

Fig. 1. Mechanical Properties of aluminum bronze as a function of aluminum content. a) σ_{pts}, σ_b, kg/mm^2; δ, ψ, %; b) % Al (by weight); c) HB, kg/mm^2; d) σ_{pts}.

The maximum solubility of aluminum in solid copper is 9.4%. Aluminum bronzes are distinguished by high plasticity and are easily worked; they have no tendency to liquation and flow readily, but show high volumetric shrinkage. Alloys containing more than 9.4% Al have a two-phased structure. Bronzes with a high aluminum content are distinguished by high strength and hardness coupled with low elongation (Fig. 1). Small quantities of iron, manganese or nickel introduced into aluminum bronze further increase its strength, inhibit recrystallization and refine the grain. The presence of iron, which delays the decay process of the β-solid solution, eliminates the phenomenon of "spontaneous annealing," which renders the alloy increasingly brittle. Aluminum bronzes containing more than 10% Al – particularly in the presence of nickel – are capable of dispersion hardening. Manganese improves the technological properties and corrosion stability of aluminum bronze. Sb, As, Bi, S and P impurities are detrimental, since they lower the mechanical properties of aluminum bronzes sharply and render mechanical working difficult; zinc is permissible up to 1.5%.

The corrosion resistance of aluminum bronze is superior to that of tin and tin-zinc bronzes. The single-phased bronzes (solid solutions)

TABLE 1

Chemical Properties of Aluminum Bronze and Semifinished Forms (after GOST 493-54)

Сплав 1	2 Содержание элементов (%)*												4	6 Полуфабрикаты и виды изделий
	Al	другие элементы	As	Sb	Sn	Si	Ni	Pb	P	Fe	Zn	Mn	сумм. примесей	
			5 не более											
7 БрА5	4—6	—	0,01	0.002	0.1	0.1	0.5	0.03	0.01	0.5	0.5	0.5	1.6	8 Ленты, полосы
9 БрА7	6—8	—	0.01	0.002	0.1	0.1	0.5	0.03	0.01	0.5	0.5	0.5	1.6	10 Ленты, полосы
11 БрАМц9-2	8—10	1,5—2,5Mn	0.01	0.002	0.1	0.1	0.5	0.03	0.01	0.5	1.0	—	1.7	12 Прутки, полосы, ленты
13 БрАМц9-2Л	8—10	1,5—2,5Mn	0.05	0.05	0.2	0.2	1.0	0.1	0.1	1.0	1.5	—	2.8	14 Фасонные отливки
15 БрАМц10-2	9—11	1,5—2,5Mn	0.05	0.05	0.2	0.2	1.0	0.1	0.1	1.0	1.5	—	2.8	16 Фасонные отливки
17 БрАЖ9-4	8—10	2—4Fe	0.01	0.002	0.1	0.1	0.5	0.01	0.01	—	1.0	0.5	1.7	18 Прутки
19 БрАЖ9-4Л	8—10	2—4Fe	0.05	0.05	0.2	0,2	1.0	0.1	0.1	—	1.0	0.5	2.7	20 Поковки и фасонные отливки
21 БрАЖМц10-3-1,5	9—11	2—4Fe 1,0—2Mn	0,01	0.002	0.1	0.1	0.5	0.03	0.01	—	0.5	—	0.75	22 Прутки, поковки, трубы, фасонные отливки
23 БрАЖС7-1,5-1,5	6—8	1—1.5Fe 1—1.5Pb	0.01	0.002	0.1	0.1	—	—	0.1	—	0.3	0.5	1.5	24 Фасонные отливки
25 БрАЖН10-4-4	9,5—11	3,5—5,5Fe 3,5—5,5Ni	0.01	0.002	0.1	0.1	—	0.02	0.01	—	0.3	0.3	0.8	26 Прутки, трубы
27 БрАЖН10-4-4Л	9,5—11	3,5—5,5Fe 3,5—5,5Ni	0.05	0.05	0.2	0.2	—	0.05	0.1	—	0.5	0.5	1.5	28 Поковки и фасонные отливки
29 БрАЖН11-6-6	10,5—11.5	5—6,5Fe 5—6,5Ni	0.05	0.05	0.2	0.2	—	0.05	0.1	—	0.6	0.5	1.5	30 Фасонные отливки

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*The base of the alloy is Cu.

1) Alloy; 2) Content of elements (%)*; 3) other elements; 4) total impurities; 5) not above; 6) semifinished products and workpiece forms; 7) BrA5; 8) ribbons, strips; 9) BrA7; 10) ribbons, strips; 11) BrAMts9-2; 12) rods, strips, ribbons; 13) BrAMts9-2L; 14) fancy-shaped castings; 15) BrAMts10-2; 16) fancy-shaped castings; 17) BrAZh9-4; 18) rods; 19) BrAZh9-4L; 20) forgings and fancy castings; 21) BrAZhMTs10-3-1.5; 22) rods, forgings, tubing, fancy castings; 23) BrAZhS7-1.5-1.5; 24) fancy castings; 25) BrAZhN10-4-4; 26) rods, tubing; 27) BrAZhN10-4-4L; 28) forgings and fancy castings; 29) BrAZhN11-6-6; 30) fancy castings.

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TABLE 2

Physicomechanical Properties of Aluminum Bronze

1 Свойства	2 БрА5		5 БрА7		6 БрАМц9-2		8 БрАЖ9-4		9 БрАЖМц10-3-1,5		10 БрАЖН10-4-4	
	3 ленты нагартованные	4 отливки	3 ленты нагартованные	4 отливки	7 прутки прессованные	4 отливки	7 прутки прессованные	4 отливки	7 прутки прессованные	4 отливки	7 прутки прессованные	4 отливки
11 σ_b (кг/мм²)	80	30	90	40	50	40	55	40	60	55	65	60
σ_s (кг/мм²)	50	10	60	15	25	20	28	21	30	22	35	28
E (кг/мм²)	11000	—	12000	—	10500	10000	11500	10500	—	10000	12500	11000
HB (кг/мм²)	180	60	180	70	130	110	150	100	160	110	180	170
δ (%)	5	50	3	60	25	20	15	10	12	10	5	5

1) Property; 2) BrA5; 3) cold-hardened ribbon; 4) castings; 5) BrA7; 6) BrAMts9-2; 7) extruded rods; 8) BrAZh9-4; 9) BrAZhMts10-3-1.5; 10) BrAZhN10-4-4; 11)(kg/mm²).

are more stable, particularly in solutions of sulfates, caustic alkalies and tartrate. Only stainless steels can be compared to the aluminum-iron-nickel bronzes as regards corrosion resistance in the atmosphere, in sea water and organic acids. In the presence of aluminum, the elec-

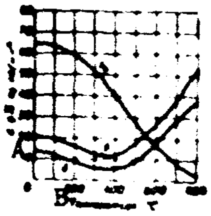

Fig. 2. Variation of mechanical properties of BrAZhN10-4-4 bronze at high temperatures A) δ, ψ %, σ_b, kg/mm²; B) temperature, °C.

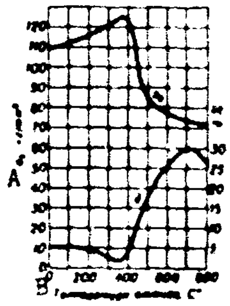

Fig. 3. Influence of annealing on the mechanical properties of bronze BrAZhN10-4-4. A) σ_b, kg/mm²; B) annealing temperature, °C.

trical and thermal conductivities of copper are reduced, but heat resistance rises due to the formation of a thin film of aluminum oxide on the surface; the latter protects it from further oxidation. The physicomechanical properties of the basic types of aluminum bronze are listed in Table 2. The strength of aluminum bronzes is considerably higher than those of the tin bronzes, and at the same time they exhibit high plasticity, good hot-working properties and, with Al contents below 7-8%, good cold-working properties as well. The various semifinished forms are shipped in the work-hardened or annealed state in the form of tubing, rods, strips and ribbon. Aluminum-bronze parts can be fabricated by the most economical methods – stamping, etc. The high foundry properties of all aluminum bronzes make it possible to obtain castings of any desired size. Aluminum bronzes with iron and nickel are distinguished by particularly high mechanical properties, corrosion resistance and heat resistance (Figs. 2-3); for example, at 500°, bronze BrAZhN10-4-4 has approximately the same mechanical properties (σ_b = 30 kg/mm^2, δ = 10%, 80 HB) as the tin bronzes at normal temperature. After heat treatment – quenching from 980° in water and subsequent dispersion hardening for 2 hours at 400° – the hardness and strength of the alloy increase; after tempering, the hardness of BrAZhN10-4-4 rises from 170-200 to 400 kg/mm^2. The specific gravity of aluminum bronze ranges from 7.4 to 7.9; the coefficient of linear expansion (α) at 20° is $16 \cdot 10^{-6}$-$18 \cdot 10^{-6}$ 1/°C. Due to the high mechanical properties and corrosion resistance, as well as their excellent machinability, aluminum bronzes are used for the fabrication of a wide variety of components in chemical engineering, aeronautical engineering and general mechanical engineering.

References: Bochvar, A.A., Metallovedeniye [Physical Metallurgy], 5th edition, Moscow, 1956; Smiryagin, A.P. Promyshlennyye tsvetnyye metally i splavy [Industrial Nonferrous Metals and Alloys], 2nd edition, Moscow, 1956.

O.Ye. Kestner

I-33a4

Manuscript Page No.	[Transliterated Symbols]
179	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = State All-union Standard

ALUMINUM CASTING ALLOYS – alloys intended for casting of shaped components. These ligatures can be divided into five groups, in accordance with their chemical composition and principal alloying element: 1) aluminum-silicon (AL2, AL4, AL9, AL4V and AL9V); 2) aluminum-magnesium (AL8, AL13, AL22); 3) aluminum-copper (AL7, AL7V, AL12, and AL19); 4) aluminum-silicon-copper (AL3, AL3V, AL5, AL6, AL10V, AL14V, and AL15V); 5) other alloys (AL1, AL11, AL16V, AL17V, AL18V, AL20, and AL21). For the chemical compositions of these alloys see Aluminum alloys. Alloys bearing the suffix "V" (AL3V, AL7V, etc.) are secondary; see Secondary aluminum alloys.

Aluminum casting alloys can be arbitrarily divided into three basic groups: 1) high- and medium-strength; 2) high-hot-strength (functioning at temperatures of up to 200-350°); 3) corrosion-resistant (functioning in salt water).

Aluminum casting alloys have a low specific gravity (2.5-2.75), high impact strength, and comparatively high electrical and thermal conductivity. Heat treatment increases the strength of the majority of aluminum casting alloys (see Heat treatment of aluminum alloys). The mechanical properties of all aluminum casting alloys are determined both by the content of alloying elements and by that of impurities. The State Standards consequently give the maximum permissible impurity content. Many metals which are alloying elements for certain ligatures have a detrimental influence on the properties of others. Thus, copper is an alloying element of AL3, AL5, and AL7, but an impurity in Al2, its content being restricted by its negative influence on corrosion resistance (see Corrosion of aluminum alloys). An admixture of zinc reduces the mechanical properties of Al-Si and Al-Cu alloys. Tin and lead substantially lower the melting temperature of these alloys, even when only tenths of a per cent are present. Silicon, which is an alloying element in AL2, AL4, AL9, et al., reduces the mechanical properties of Al-Mg alloys. Iron has a very detrimental influence on silumin, causing formation of a brittle Al-Si-Fe ternary phase, which crystallizes in laminar form. The presence of this brittle phse reduces the mechanical properties, especially the plasticity and impact strength, of Al-Si alloys. The positive influence of small additions of certain metals on the structure and properties of aluminum casting alloys must also be taken into account; these metals include manganese, which is incorporated into the quaternary phase Al-Si-Fe-Mn, a phase that crystallizes in round grains rather than laminae, and beryllium, which in magnesium-containing alloys forms a dense film of MgO•BeO at the surface of the molten metal and thus prevents diffusion of gases into the alloy. By reducing the quantity of metallic and nonmetallic impurities (using high-purity aluminum), adding small amounts of titanium, zirconium, and beryllium, and using the most effective refining methods and advanced casting techniques it is possible to increase the mechanical and other properties and the hermeticity of aluminum casting alloys materially.

References: Bochvar, A.A., Metallovedeniye [Metalworking], 5th Edition, Moscow, 1956; Al'tman, M.B., et al., Playka i lit'ye legkikh splavov [Melting and Casting of Light Alloys], Moscow, 1956.

M.B. Al'tman

III-38f

ALUMINUM FOIL — is a strip with a thickness from 0.05 mm (with a tolerance of 0.005 mm) to 0.2 mm (with a tolerance of 0.04 mm). The strip is from 10 to 460 mm wide (at a thickness from 0.055 to 0.04 mm), or from 10 to 600 mm wide (at a thickness from 0.05 to 0.2 mm). Aluminum foil is manufactured from the aluminum grades AD, AD1 (GOST 4784-48) and AV00, A00, A0, A1 (GOST 3549-55). It is used for the production of honeycomb structures, and capacitors, for heat insulation, for waterproofing, and for decorative and other purposes. It is available in rolls in annealed and cold hardened states, in diverse tints or with printed ornaments. The foil from the AMts alloy is produced in cold hardened state with a thickness from 0.05 to 0.1 mm and a width from 100 to 175 mm.

Ye.D. Zakharov

ALUMINUM FORGING ALLOYS – alloys distinguished by high plastic properties at hot-working temperatures and good foundry properties, which make it possible to obtain ingots of specified sizes and to make forged products of specified shape and dimensions. Aluminum forging alloys are used to make forgings and stampings with larger dimensions and more complex shape than any other material. This makes it possible to build structures from large subassemblies with a minimal number of members. An important advantage of certain aluminum forging alloys is the relatively high uniformity of their properties in the three mutually perpendicular directions, together with good hardenability of solid sections and low warpage during machining.

The aluminum forging alloys include AK6, AK6-1 and AK8 in the Al-Mg-Si-Cu system; alloys AK2, AK4 and AK4-1 in the Al-Cu-Mg-Fe-Ni system; alloy V93 in the Al-Zn-Mg-Cu system and alloy VD17 in the Al-Cu-Mg system. In addition to these forging alloys, forgings and stampings may be made from alloys AD, AD1, AMts, AMts1, AMg1, AMg2, AMg3, AMg4, AMg5V, AMg6, AD31, AD33, AD35, AV, D1, M40, V95, V96, D20, VAD23, SAP-1, SAP-2, SAS-1 (see articles on Medium-strength aluminum shaping alloys, High-strength aluminum shaping alloys, Heat-resistant aluminum shaping alloys, Sintered aluminum alloys and Sintered aluminum powder).

The forging alloys AK2, AK4, AK4-1 and V93 do not contain Cr, Mn, Zr or other additives that promote the appearance of the aluminum-alloy press effect and accelerate the decay process of the supersaturated solid solution of aluminum. As a result, the alloys are distinguished by relatively little property anisotropy and by good hardenability. Alloy V93 has the highest strength among all of the aluminum forging alloys, but softens rapidly on prolonged heating above 100°. It is more sensitive to notching under alternating load than alloys AK6 and AK4-1.

Alloys AK2, AK4, and AK4-1 have medium strength at room temperature and relatively high strength at temperatures up to 200-250°. After quenching in hot water, forgings and stampings of alloys AK2, AK4, AK4-1 and V93 show only insignificant warpage during machining. In many cases, they can be put through all machining operations (except for seating pads) before tempering.

Alloy AK6 can be used for stampings with extremely complex shapes and is one of the widely used forging alloys. Alloy AK6-1 is a modification of alloy AK6. Small additives of chromium and titanium make it possible to reduce the tendency toward the appearance of a columnar structure in ingots and coarse recrystallization structure in workpieces.

Alloy AK8 is stronger than alloy AK6, but a number of difficulties are encountered in its heat treatment (narrow temperature range of heating for quenching, which frequently results in overheating of workpieces or "nettling" - the appearance of chains of intermetallides along the grain boundaries, particularly in solid sections).

Alloys AK6, AK6-1 and AK8 are usually used in the tempered and artificially aged states, but in cases where it is necessary to elevate the plasticity of the metal, they may also be used after natural aging. In this case, the strength characteristics of these alloys, and the yield point in particular, drop noticeably.

Alloy VD17 is of medium strength at room temperature and has high hot strength (short and long term) at 200-250°. It is used chiefly for stamping and priming of compressor blades.

The properties of the forgings and stampings in the transverse direction, particularly through the thickness (height) are extremely important for evaluation of the forging alloys and the processes used in working them. The strength and particularly the plasticity values of the metal in this direction may be only a fraction of those in the longitudinal direction if the alloy or forging procedure has not been properly specified. When new types of stampings or forgings are being made, provision is made in advance for cutting out control specimens at various points on the workpiece in all three directions, in accordance with the possible distribution of the working stresses.

These alloys are frequently worked by a combined swaging and drawing-down process consisting of repeated swaging and drawing operations, with drawing before swaging in the direction perpendicular to the axis of the billet. Such working raises the strength characteristics and the plasticity of the material, particularly in the transverse directions. All forgings that will go on to fabrication of critical stress-bearing components should be subjected to this process.

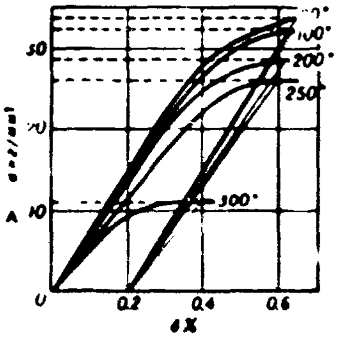

Fig. 1. Stress-strain curves to yield point at room and elevated temperatures for AK4 alloy. A) σ, kg/mm^2.

Rolled and extruded products can also be fabricated from any forging alloy that submits to casting and hot working. Thus, the production of sheet from AK6 and AK8 alloys has certain technological advantages: large ingots may be poured and rolled with less difficulty than in the

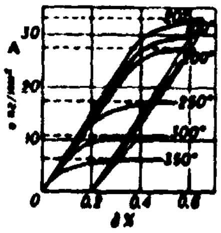

Fig. 2. Stress-strain curves to yield point at room and elevated temperatures for VD17 alloy. A) σ, kg/mm^2.

case of alloys D1 and D16. Sheets of alloy AK4-1 are distinguished by high fatigue strength up to 200°. Large shapes are fabricated from V93 alloy. These shapes have lower strength in the longitudinal direction and better properties in the transverse direction than alloy V95 shapes. The larges profiles, for which the initial billet is an ingot 1000-1100 mm in diameter, are produced considerably more easily from V93 than from V95 alloy.

Figures 1 and 2 show tension diagrams for alloys AK4 and VD17 as far as the yield point; Figs. 3 and 4 show creep curves for alloy VD17 at 250° and 300°; Figs. 5 and 6 show the fatigue-strength curves of AK4 and VD17, and Figs. 7 and 8 show the endurance curves of AK4-1 alloy after shot blasting. For the properties of the aluminum forging alloys, see Tables 1-13.

Corrosion resistance. Alloys AK6, AK6-1, AK8, AK2, AK4, AK4-1 and VD17 possess satisfactory corrosion resistance, but have a tendency to corrosion cracking; this applies particularly to AK6 in thin sections. The corrosion resistance of alloy V93 is practically the same as that of alloy V95. It is superior to alloys AK6, AK8 and AK4 as regards over-all corrosion resistance, but has a stronger tendency to corrosion cracking. Anodizing with chromate filling of the film provides dependable corrosion protection.

Heat treatment and mechanical working. To render the properties

TABLE 1

Mechanical Properties of Small Forgings and Stampings in the Tempered and Artificially Aged State*

Сплав A	$\sigma_{0,2}$	σ_b	δ_{10}	ψ	C $\tau_{ср}$	σ_{-1}** (кг/мм²) B	
	(кг/мм²) B		(%)		(кг/мм²) B	образец без надреза D	образец с надрезом E
АК6-1, АК6	30	42	13	40	26	13.0	8.0
АК8	38	48	10	25	29	12.5	–
АК2	28	44	9	–	27	12	–
АК4	32	39	10	25	–	13.5	7.0
АК4-1 . . .	28	42	13	26	–	13	–
F ВД17	29	43	10	–	–	16.0	9.0
G В93	48	52	10	25	–	13	8.0

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*At 20°, E = 7200 kg/mm², G = 2700 kg/mm² and μ = = 0.33.

**The endurance limit was determined in alternating bending of a rotating specimen: N = 2 x 10^7 cycles.

A) Alloy; B) (kg/mm²); C) τ_{sr}; D) smooth specimen; E) notched specimen; F) VD17; G) V93.

TABLE 2

Mechanical Properties of AK6-1 Alloy Stampings at Low and Elevated Temperatures

Состояние материала 1	Темп-ра испытания (°C) 2	σ_b (кг/мм²) 3	δ_{10}	ψ	σ_{-1}* (кг/мм²) 3	
			(%)		образец без надреза 4	образец с надрезом 5
Закаленный и искусственно состаренный 6	70	45	12.0	17.0	–	–
	+20	42	13.0	40.0	–	–
	+150	33	15	–	11.0	7.0
	+200	29	13	–	10.0	6.0

---

*The endurance limit σ_{-1} was determined in bending of a rotating specimen; N = 2 x 10^7 cycles.

1) State of material; 2) test temperature (°C); 3) (kg/mm²); 4) smooth specimen; 5) notched specimen; 6) tempered and artificially aged.

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TABLE 3

Mechanical Properties of Forged Semifinished Products (Tempered and Artificially Aged) of Alloy AK8 at Elevated Temperatures

A Темп-ра испытания (°C)	B Время выдержки (часы)	σ_b C (кг/мм²)	δ_{10} (%)
20	—	48	10
150	0.5	38	17
	100	37	15
175	0.5	35	18
	100	32	16
200	0.5	31	14
	100	26	19
250	0.5	20	17
	100	12	19
315	0.5	7	30
	100	6	50

A) Test temperature (°C); B) holding time (hours); C) (kg/mm²).

TABLE 4

Mechanical Properties with and Across Fiber of Large AK8 Alloy Forgings at 20°

A Состояние материала	B Вдоль волокна			D Поперек волокна					
				E по ширине			F по толщине		
	$\sigma_{0,2}$	σ_b	δ (%)	$\sigma_{0,2}$	σ_b	δ (%)	$\sigma_{0,2}$	σ_b	δ (%)
	C (кг/мм²)			C (кг/мм²)			C (кг/мм²)		
Закаленный и искусственно состаренный G	29—32	40—43	11—15	27—31	39—42	5—10	27—30	37—40	7—12

A) State of material; B) along fiber; C) kg/mm²; D) across fiber; E) width; F) thickness; G) tempered and artificially aged.

TABLE 5

Typical Mechanical Properties of Extruded AK4 Alloy Strips with and Across Fiber

A Направление вырезки образца	σ_b	$\sigma_{0,2}$	δ_5	ψ	σ_{-1}* (кг/мм²) B	
	B (кг/мм²)		(%)		C без надреза	D) с надрезом
Вдоль	43.0	36.0	10.5	20.5	13.5	7.0
Поперек . . .	42.5	36.0	6.5	9.0	13.0	3.5
По толщине .	39.0	36.0	5.0	6.0	—	—

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*The endurance limit σ_{-1} was determined in pure bending of a rotating specimen; $N = 2 \times 10^7$ cycles.

A) Cutting direction of specimen; B) kg/mm²; C) smooth; D) notched; E) lengthwise; F) crosswise; G) through thickness.

TABLE 6

Mechanical Properties of AK4 Alloy Extruded Rods at Low Temperatures

A Темп-ра испытания (°C)	B Образец без надреза			Образец с надрезом D	
	C σ_b (кг/мм²)	ψ	δ_5	E σ_{bN} (кг/мм²)	F ψ_N (%)
		(%)			
+20	43.0	20.0	9.0	68.0	1.8
−40	42.5	20.0	8.5	67.5	1.6
−70	42.0	20.0	8.5	67.0	1.4
−196	51.0	18.0	8.5	52.0	1.0

A) Test temperature (°C); B) smooth specimen; C) σ_b (kg/mm²); D) notched specimen; E) σ_{bN} (kg/mm²); F) ψ_N (%).

TABLE 7

Mechanical Properties of AK4 Alloy Extruded Strips at Elevated Temperatures

Темп-ра испытания (°C) A	E	B $\sigma_{пц}$	$\sigma_{0,2}$	σ_b	δ_{10}	ψ
	C (кг/мм²)				(%)	
20	7200	25.0	32.0	39.0	9.5	21.5
100	6800	25.0	31.0	38.0	9.0	22.5
150	—	23.5	30.5	35.5	9.5	24.5
200	6200	23.0	29.0	32.5	8.0	28.5
250	5900	18.0	25.0	28.0	8.0	31.5
300	5000	7.0	16.5	18.5	10.5	53.0
350	4200	4.0	5.0	7.5	33.5	79.5

A) Test temperature (°C); B) σ_{pts}; C) (kg/mm²).

TABLE 8

Mechanical Properties of AK4-1 Alloy Forgings at Elevated Temperatures

Темп-ра испытания (°C) A	Время нагрева (часы) B	σ_b (кг/мм²) C	δ_{10} (%)
20	—	40	18
150	0.5	37	19
	100	37	17
175	0.5	35.5	22
	100	36	18
200	0.5	32	16
	100	29	8
225	0.5	31	15
	100	24	10
250	0.5	29	18
	100	20	20
275	0.5	26	12
	100	18	25

A) Test temperature (°C); B) heating time (hours); C) σ_b (kg/mm²).

TABLE 9

Mechanical Properties of V93 Alloy Forgings Made from an Ingot 800 mm in Diameter (Tempering in Forgings)

Толщина поковки (мм) 1	2 По длине		По ширине 4		По толщине 5	
	σ_b (кг/мм²) 3	δ (%)	σ_b (кг/мм²) 3	δ (%)	σ_b (кг/мм²) 3	δ (%)
130	53	5.0	53	3.5	53	3.0
200	52	5.0	53	4.0	51	3.0
400	53	4.5	50	4.5	50	3.0

1) Forging thickness (mm); 2) lengthwise; 3) kg/mm²; 4) crosswise; 5) through thickness.

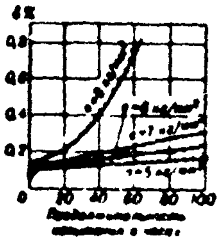

Fig. 3. Creep curves of VD17 alloy at 250°. A) Test time in hours; B) kg/mm².

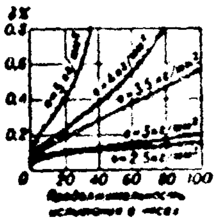

Fig. 4. Creep curves of VD17 alloy at 300°. A) Test time in hours; B) kg/mm².

TABLE 10

Mechanical Properties of V93 Alloy Forgings at Low and Elevated Temperatures

Температура (°C) A	$\sigma_{0.2}$ B	σ_b B	δ (%)
−70	48	50	7
+20	42	49	7
+100	41	44	8
+125	36	42	8
+150	38	40	6

A) Test temperature (°C); B) (kg/mm²).

TABLE 11

Endurance Limits of Extruded Semifinished Products of VD17 Alloy at 20°

Направление вырезки образцов A	σ_{-1} (кг/мм²) B, На гладких образцах C	σ_{-1} (кг/мм²) B, На образцах с надрезом D
Вдоль	16.2	9.3
Поперек	15.3	8.3

A) Specimen cutting direction; B) (kg/mm²); C) smooth specimen; D) notched specimen; E) lengthwise; F) crosswise.

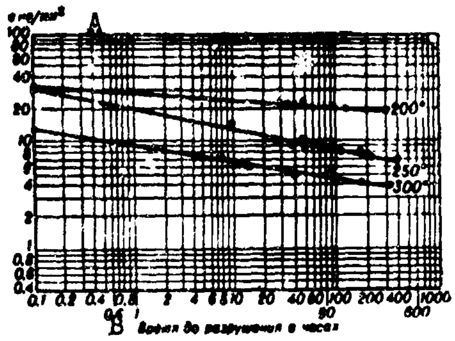

Fig. 5. Fatigue-strength curves of alloy AK4. A) kg/mm²; B) time to failure in hours.

TABLE 12

Physical Properties of Forging Alloys

Сплав A	B γ (г/см³)	C ρ (ом·мм²/м)	D λ (кал/см·сек·°C)	α·10⁶ (1/°C)	E c (кал/г°C)
АК6, АК6-1	2,75	0.041	0,42(25°) 0,45(400°)	21,4(20—100°) 35,6(400—500°)	0,19(50°) 0,24(400°)
АК8	2,8	0,043	0,38(25°) 0,43(400°)	25,5(20—100°) 24,5(20—300°)	0,20(100°) 0,26(400°)
АК2	2,8	0,047	0,37(25°) 0,43(400°)	22,3(20—100°) 24,2(20—300°)	0,18(100°) 0,24(400°)
АК4	2,77	0,050	0,35(25°) 0,41(400°)	21,8(20—100°) 24,9(20—300°)	0,20(100°) 0,25(400°)
АК4-1 ...	2,8	0,055	0,34(25°) 0,39(400°)	19,6(20—100°) 24,8(300—400°)	0,19(100°) 0,22(350°)
ВД17 F. .	2,75	0,055	0,32(25°) 0,41(400°)	23,6(20—100°) 26,9(300—400°)	0,20(100°) 0,23(400°)
В93 . . G. .	2,84	0,0408	0,39(25°) 0,39(400°)	24,1(20—100°) 40,7(300—400°)	0,19(20°) 0,27(400°)

A) Alloy; B) γ (g/cm³); C) ρ (ohms•mm²/m); D) λ (cal/cm•sec•°C); E) c (cal/g°C); F) VD17; G) V93.

uniform through the length, width and thickness of the workpiece, the blank should be given swaging-and-drawing in three (or two) mutually perpendicular directions. Alloys AK6 and AK6-1 forge easily from an extruded blank. The forging and stamping temperatures range from 380-470°. The critical strain lies in the range from 2-15%. The alloys should be deformed with more than 20% upsetting. They have lower plasticity in the case state. The forging and stamping temperature for the cast state ranges from 380 to 450°. Various types of complex-shaped forgings and stampings can be made from alloys AK6 and AK6-1. The heating temperature for quenching is 500-515°; cooling is in water and the pieces are artificially aged at 150-165° for 6-15 hours.

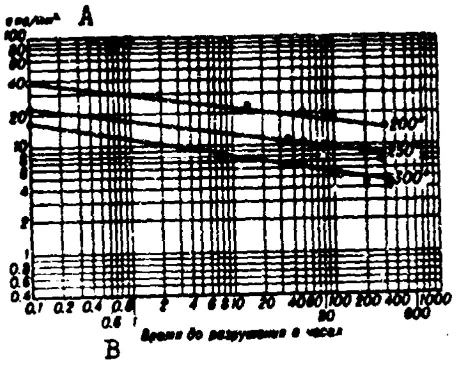

Fig. 6. Fatigue-strength curves of VD17 alloy. A) σ, kg/mm²; B) time to failure in hours.

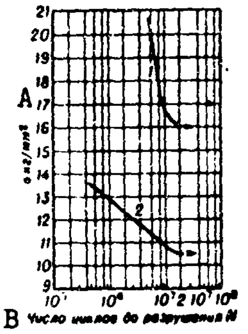

Fig. 7. Endurance curves of AK4-1 alloy in cantilevered bending of rotating specimens with shoulder ($\alpha_k = 1.85$). 1) Specimens with work-hardened surface; 2) specimens with polished surface. A) σ, kg/mm²; B) number of cycles to failure, N.

Alloy AK8 exhibits satisfactory hot plasticity. It can be used to make forgings and stampings with complex shapes. The heating temperature for quenching is 490-505°; cooling is in water and the pieces are artificially aged at 150-165° for 6-15 hours; natural aging for at least 4 days. Alloys AK6, AK6-1 and AK8 (and alloy VD17) are tempered in water at room temperature (when they are tempered in boiling water, the strength drops sharply). Hence considerable warpage during temper-

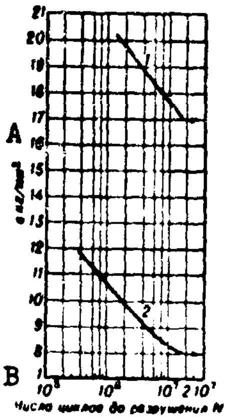

Fig. 8. Endurance curves of AK4-1 alloy in cantilevered bending of rotating specimens with semicircular notch (α_k = 2.2). 1) Specimens with shot-blasted surface; 2) specimens with polished surface. A) σ, kg/mm²; B) number of cycles to failure, N.

ing and subsequent machining is characteristic for pieces made from these alloys.

TABLE 13

Technological Data on AK2, AK4, AK4-1 and VD17 Alloys

1 Сплав	Темп-ра ковки и штамповки в прессованном состоянии 2 (°C)	Темп-ра нагрева под закалку (°C) 3	4 Искусственное старение	
			Температура 5 (°C)	Продолжительность (часы) 6
АК2 7	350—450	510—520	165—175	15—18
АК4	350—480	515—520	165—175	16
АК4-1	350—450	525—540	180—195	10
ВД17	350—450	495—505	165—175	16

1) Alloy; 2) forging and stamping temperature in extruded state (°C); 3) heating temperature for quenching (°C); 4) artificial aging; 5) temperature (°C); 6) time (hours); 7) VD17.

Alloys AK2, AK4, AK4-1 and VD17 possess satisfactory plasticity in the hot state and can be drop- and press-forged. The permissible degree of deformation in one pass under dynamic conditions is 60%, and under static conditions it is over 60%.

To reduce warpage, workpieces made from alloys AK4 and AK4-1 must be tempered in water at 90°. This lowers the strength of the alloys by more than 2-3 kg/m^2 [sic]. Alloy V93 possesses satisfactory plasticity in the hot state; it can be used to make the largest forgings and stampings, including complex-shaped stampings. To reduce warping of forgings and stampings during the tempering process and subsequent machining, the water temperature in the quenching bath must be raised to 70-80°. The strength characteristics of the alloy show virtually no change when the water temperature in the quenching bath is raised right up to 90°, but the elongation has a tendency to diminish.

All alloys of this group can be welded satisfactorily by spot and seam welding, but not by fusion welding. They are easily cut in machining.

Uses. Alloy AK2 is used to make pistons for internal-combustion engines; alloys AK4, AK4-1 and VD17 are used in compressor blades, in pillars, disks and wheels of turbojet and turbopropeller engines, engine pistons and other forged parts operating at high temperatures. Alloy AK4-1 can also be used in sheet form. Stamped and forged parts with complex shapes and average strength are produced from AK6 and AK6-1 alloys (engine subframes, fittings, rockers and fastening components); alloys AK8 and V93 are used for heavily stressed stampings and forged components, engine subframes, fishplates, and spar flanges; airplane undercarriage components are also made from V93 alloy. Recently, alloy AK8 has been supplanting alloys AK6 and V93. In cases when it is necessary to have very high corrosion stability, minimum warpage and minimum distortion of geometry during operation, untempered corrosion-resistant alloys such as AMg5V, AMg6, SAP-1, SAP-2, etc., should be used. Certain characteristics of the most important aluminum forging alloys are given in Table 14 as an aid to selection.

All large, solid and complex-shaped forgings and stampings must be given UZ [ultrasonic] inspection to detect internal flaws (cracking and

TABLE 14

Certain Characteristics of the Most Important Forging Alloys

Сплав 1	Прочность при 20° 2	Макс. диаметр слитка (мм) 3	Степень сложности получаемых штамповок 4	Температура применения (°C) 5	Коррозионная стойкость 6	Термич. обработка 7	Прокаливаемость 8	Поводки в процессе закалки и механич. обработки 9	Дополнительные хар-ки 10
АК6, АК6-1	Средняя 11	1100—1200	Наиболее сложные 12	До 150—180	Удовлетворительная 14	Закалка и старение естественное или искусственное 15	При толщине св. 200—300 мм — средняя 16	Существенные 17	—
АК8	Высокая 18	1100—1200	Средней сложности 19	То же 20	То же 20	То же 20	То же 20	То же 20	Чувствителен к перегреву при закалке 21
АК4-1	Средняя 11	1100—1200	Сложные 22	До 250 13	То же 20	Закалка и искусственное старение 23	Хорошая 24	Существенные, но незначительные при закалке в горячей воде (св. 90°) 25	—
В93 26	Высокая 27	1100	19 Средней сложности	До 100—120 13	То же 20	То же 20	То же 20	Незначительные 28	Закалка в воде при 70—80° 29
АВ 30	Средняя 11	500—600	Наиболее сложные 12	До 150—180 13	Повышенная 31	Закалка в воде, искусственное или естественное старение 32	При толщине св. 200—300 мм — средняя 16	Существенные 17	—
33 АД31, АД33, АД35	Невысокая и средняя 34	500—600	То же 20	То же 20	Высокая 18	То же 20	То же 20	То же 20	—
АД, АД1, АМг1, АМг2, АМг3, АМг4, АМг5В, АМг6 35	Невысокая и средняя 34	500—1100	Сложные и не очень сложные 36	То же 20	Высокая и повышенная 37	Отжиг 38	— 16	Минимальные 39	—
Д1 40	Средняя 11	До 800 13	Средней сложности 19	До 150 13	Удовлетворительная 14	Закалка и естественное старение 41	При толщине св. 200—300 мм — средняя	Существенные 17	—
В95, В96 42	Высокая 18	300—500	То же 20	До 100—120 13	То же 20	Закалка и искусственное старение 23	При толщине св. 200—300 мм — ниже среднего 43	Существенные, но при закалке в горячей воде — незначительные 44	—
Д20 45	Средняя 18	1100	То же 20	До 300 13	То же 20	То же 20	Хорошая 24	Незначительные 28	—
ВАД23 46	Высокая 18	500—600	Не очень сложные 47	До 160—180 13	То же 20	То же 20	То же 20	Существенные, но незначительные при закалке в горячей воде 44	—
САП-1, САП-2 48	Невысокая и средняя 34	—	Средней сложности 19	300—500	Высокая 18	Не обрабатываются 49	—	Минимальные 39	—

1) Alloy; 2) strength at 20°; 3) maximum ingot diameter (mm); 4) complexity of stampings produced; 5) temperature of use (°C); 6) corrosion

resistance; 7) heat treatment; 8) hardenability; 9) warpage in tempering and machining; 10) other characteristics; 11) average; 12) most complex; 13) up to; 14) satisfactory; 15) tempering and natural or artificial aging; 16) average at thicknesses above 200-300 mm; 17) substantial; 18) high; 19) average complexity; 20) same; 21) sensitive to overheating in tempering; 22) complex; 23) tempering and artificial aging; 24) good; 25) substantial, but insignificant for tempering in hot water (above 90°); 26) V93; 27) high; 28) insignificant; 29) tempering in water at 70-80°; 30) AV; 31) above average; 32) tempering in water, artificial or natural aging; 33) AD31, AD33, AD35; 34) low to average; 35) AD, AD1, AMg1, AMg2, AMg3, AMg4, AMg5V, AMg6; 36) complex and not highly complex; 37) high to above average; 38) annealing; 39) minimum; 40) D1; 41) tempering and natural aging; 42) V95, V96; 43) below average at thicknesses above 200-300 mm; 44) substantial, but insignificant on tempering in hot water; 45) D20; 46) VAD23; 47) not particularly complex; 48) SAP-1, SAP-2; 49) not machined.

lamination), eddy-current tests of the surface layers, and careful external inspection with a magnifying glass, particularly after the finished products have been anodized.

Together with the mandatory use of UZ inspection to find reject forgings and stampings with large laminations and double-skin areas, production measures should be taken to reduce the detrimental effects of lamination. As a rule, stampings have many advantages over forgings. Stampings permit the use of smaller-diameter ingots. As the ingot diameter increases, double skin and lamination become more frequent and their dimensions increase. Lamination and double skin are oriented strictly in the direction of the fiber; hence more successful orientation of the fiber with respect to the forces operating can be guaranteed in stampings. The stamping inspection chart should indicate the most heavily loaded sections, in which the fiber direction should not be perpendicular to the operating forces. The degree of deformation of the metal is also considerably higher in stampings, and this increases its strength under repeated and vibrating loads appreciably. In cases in which it is not possible to guarantee favorable orientation of the fibers in the dangerous sections of the stampings, UZ inspection of the corresponding zones is indispensable. If necessary to guarantee higher reliability of UZ inspection of the most heavily loaded zones, special production allowances should be made for removal after UZ inspection. The number and size of the permissible defects, their directions and locations are determined in each specific case by the designer.

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I.N. Fridlyander, T.K. Ponar'ina

Manuscript Page No.	[Transliterated Symbols]
190	ср = sr = srez = shear
192	н = n = nadrez = notch
192	пц = pts = proportsional'nost' = proportionality
197	УЗ = UZ = ul'trazvukovoy = ultrasonic

ALUMINUM FORGINGS – semifinished products obtained by free forging of an aluminum-alloy ingot or extruded bar between flat hammer blocks. The process is used to manufacture parts of experimental structures and for short-run production. On the basis of weight, these forgings are classified into two categories: up to 30 kg and over 30 kg. Maximum forging weight is determined by the capabilities of the forging and pressing equipment and the technological properties of the alloy (casting properties, making it possible to pour large-diameter ingots, satisfactory plasticity in the cast state). Forgings made from alloys with good technological properties (V93, AK6, AK8) measure up to 2000 × × 1500 × 500 mm^3 and weigh up to 4500 kg. The use of an extruded rod aids in the forging process, but reduces the maximum size of the forging. The mechanical properties of the forgings depend on the situation of the specimen with respect to the direction of metal flow under deformation. The best mechanical properties are displayed by specimens whose axis is parallel to the direction of maximum metal flow, i.e., along the length of the forging, in most cases; the properties along the forging width are somewhat poorer, and poorest of all along the thickness. Mechanical properties over the thickness of a forging may prove to be poorer than in the longitudinal direction (by 20-30% with respect to ultimate strength and by a factor of 3-4 with respect to relative elongation). The degree of forging property degradation in the transverse direction depends on the quality of the initial bar and the deformation configuration during forging. An omnidirectional forging configuration is used to improve these properties. In order to reduce warping, large forgings made from aging alloys are given a complete annealing prior to mechanical working, and a strengthening heat treatment is used after preliminary peeling.

Ye.D. Zakharov

ALUMINUM PANELS - monolithic, ribbed, and sheet semifinished products. They are used in heavily loaded and light-weight structures in areas such as ship and aircraft building.

Aluminum panels up to 1000 mm or more wide and up to 15 m or more long are manufactured by pressing in horizontal hydraulic presses with forces of 5000, 12,000, and 20,000 t and by stamping in vertical hydraulic presses with forces of from 35,000 to 75,000 t. Production of panels by pressing has a number of advantages over stamping; the former method can be used to obtain rib configurations that cannot be achieved by the latter technique (T-shaped ribs). Moreover, equipment of considerably lower power can be employed in pressing. Thus, for example, stamping of a panel 700 mm wide and 12 m long in a vertical press requires a force of 150,000 t, while pressing in a horizontal press requires a force of 5000 t. There are several procedures for manufacturing pressed aluminum panels:

1) V- or U-shaped, where the width of the panel somewhat exceeds the diameter of the container; 2) linear, where a round or flat container is used and the width of the panel is less than the container diameter; 3) tubular, where the width of the panel considerably exceeds the container diameter. Panels obtained by the second and third methods are straightened along the genetrix after pressing.

The table presents data on possible panel widths for pressing in 5000 and 12,000 t presses.

When the press force is raised to 20,000 t and a container 1200 mm in diameter is used panels up to 2500 mm wide can be obtained by the

Усилие пресса (т) 1	Форма контейнера 2	Диаметр или сечение контейнера (мм) 3	Прямой способ 4	U-образный способ 5	Прессование ребристых труб 7	
			макс. ширина панели (мм) 6		диаметр трубы 8	ширина панели 9
					(мм)	
9000	10 Круглый	360	330	560	250	780
		500	460	780	390	1220
	11 Плоский	200×600	500	—	—	—
12000	Круглый	650	590	1000	520	1620
		800	740	1200	650	2080
	Плоский	200×940	880	—	—	—

1) Press force (t); 2) container shape; 3) container diameter of cross-section; 4) linear method; 5) V-shaped method; 6) maximum panel width (mm); 7) pressing of ribbed tubes; 8) tube diameter; 9) panel width; 10) round; 11) flat.

tubular method. Pressed panels have thicknesses of 4-6 mm. It is possible to manufacture panels that very in cross-section along their length, using the tubular method. In this case the punch has a predetermined taper, which permits variation of the inside diameter of the tube as the metal moves by. Panels can also be produced with end pieces, their production technology being similar to that employed for shapes with end pieces (see Aluminum shapes of varying cross-section). However, pressing can only be used to produce monolithic panels with longitudinal (running in the pressing direction) ribs. Panels with longitudinal and transverse ribs are manufactured in comparatively small sizes (up to 2-2 m long). They are fabricated by stamping in vertical presses with forces of 30,000 and 70,000 t. Curved panels can also be produced by stamping. The height of the ribs depends to a considerable extent on the stamping pressure, the die geometry, and the deformation temperature. Thus, for example, in stamping an initial blank of D16 alloy 15 mm thick at a pressure of 40 kg/mm^2 the maximum height of a trapezoidal rib is 42.5 mm, while at a pressure of 16 kg/mm^2 it is only 15 mm. Stamping flat ribs by forcing the metal through an undercut groove (similar to a mold) under the same pressure increases rib height by 30-35%. Panels are stamped in two or three operations, depending on the complexity of the ribs. Pressed and stamped panels are delivered after heat treatment and straightening. Pressed panels are straightened on stretching machines, while stamped panels are straightened in gauging dies. The mechanical characteristics of pressed and stamped panels are equivalent to those of ordinary semifinished products obtained by these methods.

References: Zholobov, V.V., Zverev, G.I., Pressovaniye metallov [Pressing of Metals], Moscow, 1959.

B.I. Matveyev

ALUMINUM PIPES – are made from aluminum and its alloys; have a round or fancy hole along the length. By their configuration they are divided into 3 groups: smooth, fancy (rectangular, square, hexagonal, etc.) and ribbed (with longitudinal or transverse ribs. Smooth pipes are made by pressing (extrusion) of the pipe blank with subsequent cold rolling, drawing or only hot or cold extrusion. In the hot pressed state, due to the retention of the press effect (see Press Effect of Aluminum Alloys) the strength characteristics of the pipes are higher. Smooth pipes can also be made by rolling a strip into a pipe blank with subsequent welding of the longitudinal or spiral joint. Lately round aluminum pipes of large diameter are obtained by rolling hollow ingots into strips which are rolled up into rolls. These rolls are unrolled at the location where the finished pipes are to be placed into a strip up to 100 m and more long a under the action of internal pressure they take on the correct shape of a round pipe. Shaped pipes are made by drawing through an intricately shaped drawing die and extrusion through a reed female die. In extrusion through the reed female die the deformed metal, being separated by the knife-like part of the bit, forms the internal void of the pipe, is joined by pressure and then welded in the cavity zone. Extrusion by this method requires a high degree of deformation and a high temperature. Usually fancy pipes are made from alloys with a high plasticity (AV- D1, D16). Ribbed pipes with longitudinal ribs are made by extrusion, while those with transverse ribs are made by rolling on special rolling mills. Smooth and fancy pipes, as ribbed pipes, can be made with a wall thickness variable over the length (with respect to the inside diameter) by extrusion, using a tapered bit.

Pipes can have a stepped change in the inside diameter at a specified length. The outside diameter can change only at one of the pipe ends. Here the outside diameter can only be increased. Aluminum pipes are made with diameters of 3-4 mm up to 300 mm and more. In extrusion by the use of the metal counterflow method it is possible to obtain diameters up to 1500 mm; here the extruding force should be by a factor of 2 and more lower than when extruding by the direct method. The length of such pipes does not exceed 1.5-2 meters. Pipes with diameters from 90 to 300 mm can be made by the direct extrusion method with a wall thickness of not less than 2-5 mm. Cold rolled pipes from 10 to 80 mm in diameter are made with wall thicknesses of 1.0-1.5 mm, and pipes 2-15 mm in diameter are made by cold impact extrusion with a wall thickness within the limits of 0.2-0.5 mm. In the as-supplied state pipes can be annealed (M) from the D1, D6, D16, AV, AMG, AMts, AD and AD1 alloys; quench hardened (T) from the D1, D6, D16, and AV alloys; semihardened (P) from the AMg alloy; hardened (N) from the AMg, AMts, AD and AD1 alloys. Quench hardened pipes are straightened with a residual deformation of 1.5-2.5%. In order to prevent the residue of saltpeter from settling on the internal walls and pipes and avoid the sharp drop in corrosion resistance which this produces, the pre-quench heating is performed in vertical air furnaces with a forced air circulation. The pipes are inspected for specific mechanical properties, are tested in longitudinal compression and flattening in amounts of 3% from a melt batch for round pipes and of 20% for fancy pipes after heat treatment. The longitudinal compression testing is performed in the cold state in pipe sections whose length is equal to twice the outside diameter. Annealed pipes from brand AD and AD1 aluminum withstand, without forming cracks, the longitudinal compression test up to half of the initial length. Pipes from the AMg alloy withstand transverse flattening without forming cracks until the pipe walls meet, while hardened and semihardened pipes withstand it until the walls approach one another through a distance equal to four times the wall thickness. The pipe material should not have a coarsely-grained structure.

B.I. Matveyev

ALUMINUM PLATES - semifinished products obtained by rolling a flat ingot, forged slab, or pressed strip on smooth cylindrical rolls and having a thickness of more than 10 mm. They have a maximum width of 2500 mm and a maximum length of 10,000 mm. The maximum plate thickness and weight are governed by the maximum weight of the ingot or slab. Plates more than 30 mm thick rolled from flat slabs have markedly reduced characteristics through their cross-section. when plates are used in the fabrication of components intended to operate in a volumetrically stressed state it is necessary to check the plate characteristics in all three directions. Use of a forged slab or pressed blank insures more uniform characteristics in all directions, but reduces maximum plate weight. Plates intended for the manufacture of especially critical components should be fabricated from ingots cast with water cooling only or from forged slabs. In rolling plates from flat ingots of certain alloys (AMg6, etc.) the ingot is subjected to technological plating with pure aluminum in order to improve its surface; the thickness of the plating should not exceed 1.5% of the plate thickness. It is possible to produce laminated plates (bimetallic or polymetallic) consisting of two or more layers of different aluminum alloys, which are welded to one another during rolling.

In order to eliminate or reduce warping caused by quenching, freshly quenched plates are straightened under tension sufficient to produce 1-2% elongation. The figure shows a machine for tension-straightening freshly quenched plates with lengths of up to 15 m, widths of up to 3 m, and thicknesses of up to 150 mm. During rolling or

Machine for tension-straightening plates.

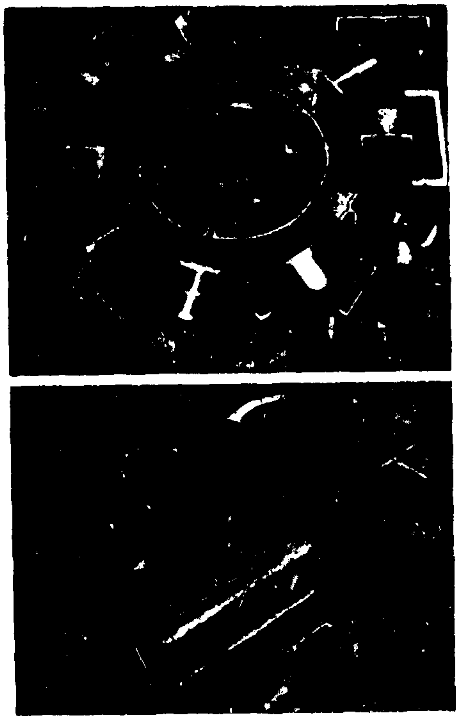
heat treatment plates may develop internal cracks that do not appear at the surface; in order to detect such defects the plates must be checked ultrasonically.

References: Sheet Metal Inds, 1958, Vol. 35, No. 372, page 300.

Ye.D. Zakharov

ALUMINUM SHAPES — semifinished products of aluminum and aluminum alloys with a large length-to-cross-section ratio. The cross section of a shape may be constant or may vary over its length (shapes of varying cross section), ranging from very simple to very complex (Figure). Aluminum shapes are manufactured from sheets by pressing, stamping, rolling, and bending. Pressing can be employed to produce shapes of diverse configuration and size, utilizing simple equipment. Pressed shapes fabricated from certain aluminum alloys have elevated strength characteristics as a result of the press effect (see Press effect in aluminum alloys). Pressing in horizontal hydraulic presses is the principle method employed in the manufacture of aluminum shapes. Pressed shapes can be divided into three groups in accordance with their cross-sectional configuration: open shapes, hollow shapes, and shapes of varying cross-section.

Shapes of the 1st and 3rd groups are pressed both with and without lubrication. Shapes obtained by pressing with lubrication have a small large-crystalline rim, a more uniform structure, and more uniform characteristics along their length than shapes pressed without lubrication. Pressing of shapes with lubrication is not, however, a common procedure, since it produces an unsatisfactory surface quality (roughness and embedded graphite residues) and thus a greatly reduced corrosion resistance. Shapes of the 2nd group are pressed only without lubrication, since when a lubricant is present the metal does not fuse before being removed from the mold. Shapes can be classified in the following manner in accordance with as-delivered condition: annealed (M), quenched and naturally aged (T), and quenched and artificially aged (T1). Shapes are delivered after tension straightening (to a residual deformation of 2-4%). Pressed shapes are produced with a flange thickness of from 1 mm to 350 mm or more. Normal- and high-precision shapes are also produced.



Expanded shapes with various cross sections.

The warping of a shape about its longitudinal axis cannot exceed 2° per running meter over any segment. Shapes with a flange thickness of from 4 to 10 mm can be subjected to smooth bending over a radius of curvature <4 mm per running meter, while those with a flange thickness of more than 10 mm cannot be bent through a radius of curvature of more than 2 mm per running meter. Shapes can have a large-crystalline rim if their mechanical characteristics satisfy the requirements imposed by TU. The size of this rim can be somewhat reduced by regulating the chemical composition of the alloy and the pressing regime. Aluminum shapes obtained by pressing have nonuniform characteristics along their length and through their cross section as a result of very nonuniform flow of the metal during pressing. The ultimate strength of the shape increases by 5-6 kg/mm^2 from the discharge end to the starting end, while its elongation decreases. The minimum characteristics set by TU for aluminum shapes consequently respond to the discharge end. The nonuniformity of characteristics in shapes is also affected by the total geometric deformation. The smaller this deformation, the greater is the nonuniformity of characteristics through the cross section and along the length of the shape. The least nonuniformity is obtained at a total deformation of 90%. The temperature at which the ingots are heated before pressing affects the mechanical characteristics of the finished shapes. The influence of heating temperature on mechanical characteristics is slight at deformations of more than 80%; nonuniformity of characteristics increases with heating temperature at deformations of less than 75%. The characteristics of a shape are lower in the central portions of its cross section than at its periphery in this case. Nonuniformity of characteristics decreases as the temperature is reduced. The optimum pressing temperature for the soft alloys AD, AD1, AMg, AMg3, AMts and AV and all types of pure aluminum is 350-450°, while that for the hard alloys D18, D3P, D1, D6, AMg5, AK2, AK4, AK5, AK6, AK8, V95, VAD23, D19, D20, etc. is 350-400°. Higher pressing temperatures permit a reduction in pressure, but the pressing rate is also reduced and the surface quality of the shapes deteriorates. Hard-alloy ingots are usually subjected to homogenization heating at temperatures near the quenching temperature. Homogenization greatly reduces the anisotropy of characteristics in pressed shapes. The flow rate during pressing is considerably higher for soft alloys than for hard alloys (being 0.3-1 m/min for the latter). The flow rate has no effect on the mechanical characteristics of the finished shapes. Shapes obtained by bending sheets have a number of advantages, including thin walls (less than 1 mm thick), low tolerances, uniformity of characteristics through their cross sections, and a comparatively simple production technology.

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B.I. Matveyev

ALUMINUM SHAPING ALLOYS WITH SPECIAL PROPERTIES – SAS-1 sintered aluminum alloy, which has a reduced coefficient of linear expansion, and AMtsM-1 alloy, which has a low temperature coefficient of electri-

TABLE 1

Typical Mechanical Properties of Semifinished Products of AMtsM-1 Alloy (at 20°)

Вид и размер полуфабриката 1	Состояние материала 2	3 В продольном направлении		5 В поперечном направлении	
		4 σ_b (кг/мм²)	δ (%)	σ_b (кг/мм²)	δ (%)
Полосы 6 толщиной 10 мм	литые . 7 . .	17.0	20.0	16.5	21.0
Листы толщиной 0.5–1.0 мм 8	нагартованные	32.0–33.0	2.0	30.0–32.0	2.0

1) Type and size of semifinished product; 2) state of material; 3) longitudinal; 4) kg/mm^2; 5) transverse; 6) strips 10 mm thick; 7) cast; 8) sheets 0.5-1.0 mm thick; 9) cold-worked.

TABLE 2

Typical Electrical Properties of Semifinished Products of AMtsM-1 Alloy (at 20°)*

Электрич. свойства 1	Нагартованные, нагрев при 200° в течение 16 час., охлаждение на воздухе 2	Нагартованные, нагрев при 300° в течение 3 час., охлаждение на воздухе 3	Нагартованные, нагрев при 300° в течение 16 час., охлаждение на воздухе 4
ρ при 20° (ом·мм²/м) . 5 . .	0.119	0.114	0.100
Температурный коэфф. электросопротивления (0–100°) 6	$0.67 \cdot 10^{-3}$	$0.95 \cdot 10^{-3}$	$1.22 \cdot 10^{-3}$

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*Sheets 1.0 mm thick.

1) Electrical properties; 2) cold-worked, annealed at 200° for 16 hr, and air-cooled; 3) cold-worked, annealed at 300° for 3 hr, and air-cooled; 4) cold-worked, annealed at 300° for 16 hr, and air-cooled; 5) ρ at 20° (ohm·mm^2/m); 6) temperature coefficient of electrical resistance (0-100°).

cal resistance.

AMtsM-1 alloy contains 2.0-4.5% Mn and is prepared from pure Al. The low temperature coefficient of electrical resistance of this alloy is attributable to formation of a supersaturated solid solution of Mn in Al as a result of quenching from the liquid state. The billet for production of sheets is a strip 6-12 mm thick, which is cast directly in a special apparatus, the crystallized metal being rapidly cooled. Annealing at temperatures above 200° causes decomposition of the supersaturated solid solution of Mn in Al and reduces the electrical characteristics of the alloy. Rolling of thinner sheets (up to 0.5 mm) and stamping are carried out with cold metal or at temperatures below 200°. Tables 1 and 2 show the mechanical and electrical properties of semifinished products of AMtsM-1 alloy.

AMtsM-1 alloy has a high corrosion resistance, close to that of pure Al and substantially higher than that of unplated duralumin. It is easily stamped when cold. In order to avoid deterioration of the electrical properties of the alloy straightening should be carried out with cold metal or at temperatures below 200°. This alloy is used for electronic devices requiring a reduced temperature coefficient of electrical resistance at temperatures of from below zero to +200°.

For information on SAS-1 alloy see Sintered aluminum alloys.

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in collection Metallurgicheskiye osnovy lit'ya legkikh splavov [Metallurgical Principles of the Casting of Light Alloys], Moscow, 1957.

I.N. Fridlyander

ALUMINUM SHEET is produced by rolling a flat ingot, forged slab or pressed bar on smooth cylindrical rolls. Sheets are obtained by hot rolling (hot-rolled), hot rolling with subsequent cold cold rolling (cold-rolled). The dimensions of the sheet produced are: thickness from 0.5 mm (allowable deviation 0.1 mm) to 10 mm (allowable deviation 0.5 mm); width 1000-2000 mm, length to 7000 mm. If required, sheet can be produced with width to 2500 mm and length to 10,000 mm. Sheets made from alloys which are not strengthened by heat treatment are delivered annealed (for example, AMtsM), half-hard (for example, AMtsP), hard (for example, AMtsN). Sheets from the alloys which are strengthened by heat treatment are delivered annealed (for example, D16M); solution treated and naturally aged (for example, V95T1, D16T); solution treated and artifically aged (for example, V95T1, D16T1); strain hardened after solution treatment and natural aging (for example, D16TN); highly strain hardened (degree of cold deformation 15-20%) after solution treatment and natural aging with subsequent artificial aging (for example, D16T1N1, D19T1N1); strain hardened after solution treatment and artificial aging (for example, V95T1N). With regard to the surface finish, the sheets are divided into structural and facing. Facing sheets are produced with higher requirements on the quality of the surface finish. Their designation includes the letter "V" (for example, D16TNV). Sheet made from the D1, D16, V95 alloys can be produced without cladding. In this case the designation includes the letter "B" (D16B). Sheets made from these alloys of thickness 0.8-4 mm with heavy cladding (7.5% on each side) have a designation with the letter "U." Surface defects of the sheets (scratches, nicks, worn spots, wrinkles, imprints from the rolls, spots, stripes, etc.) are permitted in the limits established by the specifications. Delaminations which do not extend to the surface of the sheet can be detected by untrasonic inspection.

Ye.D. Zakharov

ALUMINUM SHEET OF VARIABLE SECTION (tapered sheet). Variation of the cross section of the sheet along the length can follow a linear law, some curved law, or periodic, i.e., power laws.

An economical method of producing sheets with variable section is rolling and this method is the most widely used; this method can produce sheets only with a uniform variation of the cross section area. Other methods are machining on milling machines, etching in concentrated solutions of alkalis and acids. The first two methods permit producing sheets with both uniform and periodic, power, variation of the cross section.

The following form of sheets of variable section cross are rolled: with one-sided taper, with one-sided taper with a region of constant section; with bilateral taper with the presence of a region of constant section in the center of the sheet. The width of the sheets produced industrially is 800 mm and more, maximal length is 5 meters. The maximal thickness of the sheets is 10 mm and the minimal is 1 mm.

The maximal permissible taper is $<$ 1 mm/running meter. The tolerance on the sheet thickness is ± 0.2 mm, the width tolerance is ± 1 mm, the length tolerance is ± 5 mm. Sheets can be produced from all the wrought aluminum alloys. They are delivered in the solution treated and aged condition and also in the strain hardened condition.

With regard to metal structure, mechanical properties, and also the quality and magnitude of the cladding layer, the sheets of variable section made from the corresponding aluminum alloys do not differ from the sheets of constant section.

II-95kl

Mechanical Properties of Sheets of Variable Section Made From the D-16 Alloy

Состояние поставки 1	σ_b	$\sigma_{0,2}$	δ
	2 (кг/мм²)		(%)
3 Закаленные и состаренные	41,5	27,5	18
4 Нагартованные	43,5—46,5	34—35	10—8

1) Delivery state; 2) (kg/mm^2); 3) solution treated and aged; 4) strain hardened.

Reference: Shor E.R., Novyye protsessy prokatki [New Rolling Processes], M., 1960.

B.I. Matveyev

ALUMINUM WIRE. This wire is produced from several types of aluminum alloys and is intended for the manufacture of rivets, electrical leads, electrodes for fusion-welding aluminum alloys, etc. Wire with a round cross-section is most commonly used; it is obtained by rolling and drawing round blanks. Pressed blanks are generally employed in the manufacture of rivet wire (1.6-10 mm in diameter), although rolled blanks are also permissible. Cast blanks are used principally in the production of electric leads and small-diameter welding wire.

Wire with a d = 4 mm or less intended for mechanized welding can be delivered in chemically purified form in hermetically sealed containers and is suitable for direct utilization in automatic and semiautomatic welding equipment (GOST 7871-63).

Ye.D. Zakharov

AMBER – is a fossil resin of conifers of the Tertiary period; it is amorphous. Its composition is very complex and inconstant, and corresponds approximately to the formula $C_{10}H_{16}O_4$, and contains in the average (in %) 79 C, 10.5 H, and 10.5 O, and also small quantities of sulfur and ash as impurities. The color turns from straw-yellow to cherry and darkbrown; the Mohs hardness is 2-3; the refraction index is 1.530-1.547; the melting point is 250-300°, the decomposition temperature is 370-380°; amber obtains a negative electric charge when rubbed; it is very translucent to x-rays. The specific volume resistance is 10^{17}-10^{19} ohm•cm; the dielectric constant is 2.7-3.0; the bending strength (of pressed amber) is 180-600 kg/cm^2; the coefficient of dielectric loss is 0.002-0.009; the heat conductivity is $21 \cdot 10^{-4}$ w/cm. Amber is partially soluble in certain organic solvents, its solubility being as follows (in %); 11.3 in methanol; 11.5 in carbon tetrachloride; 14.3 in ethanol; 16.9 in turpentine oil; 17.5 in chloroform; 18.8 in ethyl ether; 21.3 in benzene; 23.3 in acetone; 24.2 in amylol; 30.0 in amyl acetate, and 32.1 in bitter-almont oil (benzaldehyde). Alkalis and acids (including hydrofluoric acid) do not almost affect amber. Sulfuric (concentrated) acid and concentrated solutions of tin chloride and chlorine water affect amber by corroding the surface. Amber softens and may be pressed when heated at 140-200° (in the absence of air). Pressed amber is composed of fine grains and chippings of natural amber which are heated and pressed at 3000 kg/cm^2; the properties of pressed amber are almost similar to those of natural amber. Dry distillation of amber yields succinic acid (up to 2%), oil (15-20%), colophony (up to 60-65%), and water. Melted amber is a low-melting substance (t_{pl} = 180°) obtained by dry distillation at a temperature about 420°; it is higher soluble in organic solvents than natural amber.

Amber is used as follows: as an insujating material in a number of electric devices (mainly pressed amber); in the manufacture of dishware (beakers, dishes, etc.) which is chemically resistant to hydrofluoric acid and alkalis; in the preparations of succinic acid, oil, varnishes, colophony, medicinal preparations, paints, etc.; and in the manufacture of artistic commodities and jewelry (mouth-pieces, brooches, beads), etc.

References: Rybin, A.A., Yantar', yego obrabotka i primeneniye [Amber, Its Treatment and Application], "Byul. tekhn. inform. po kamneobrabotke i yuvelirnomu proizvodstvu" [Bulletin of Technical Informations on Stone Processing and Jewelry], 1954, 7th Issue, No. 1, pages 1-14; Raykin, B.L., Yantar' [Amber], "Samotsvety. Byul. tekhn.-ekonomn. inform. TsNILKS" [Gems. Bulletin of Technical and Economical Information of the Central Scientific Research Laboratory of Gem Stones], 1960, No. 1(3), pages 55-62.

V.I. Fin'ko

Manuscript Page No.	[Transliterated Symbols]
224	ЦНИЛКС = TsNILKS = Tsentral'naya nauchno-issledovatel'skaya laboratoriya kamney samotsvetov = Central Scientific Research Laboratory of Gem Stones

AMETHYST - see <u>Quartz</u>.

AMINOPLASTS - plastics (reactoplasts) based principally on urea-formaldehyde and melamine-formaldehyde resins and organic or mineral additives. They are produced in accordance with GOST 9359-60. Carbamide resins are obtained by polycondensation of the amides of monobasic acids with aldehydes. Cellulose sulfite, nitrocellulose (linters), cellulose-sulfite paper, various types of asbestos, talc, mica, etc., are used as additives. Aminoplasts are produced as pressed powders (types A and B, melalit, K-77-51, K-78-51), fibers (melavoloknit, VEI-11, VEI-12, MFK-20), laminar materials (decorative laminar plastics), and plastic foam (mipor). Pure carbamide resins are used for manufacturing cements (KM-1, KM-3, KM12 and MF-17). Pressed powders and fibrous materials are produced by mixing a resin solution or aqueous resin condensate with the filler and then drying and grinding the mixture. An accelerator (urotropin), a dye (organic or mineral), and a lubricant (zinc stearate) are also added to the composite. When mineral dyes (litapon, barium sulfate, etc.) are used the resultant products are opaque. Laminar plastic is manufactured by impregnating cellulose-sulfite paper with aqueous resin condensate (MM-54-U) and then drying it at 110-120°. Pressing is carried out in multistage hydraulic presses at 140-150°. The inner layers of the plastic are usually paper, cloth, or veneer impregnated with phenol-formaldehyde resin; the outer, decorative layer is of paper impregnated with a carbamide resin. Articles are fabricated from pressed powders and fibers by direct pressing. The pressing temperature is 140-150° for materials based on urea-formaldehyde resin and 150-160° for materials based on melamine-formaldehyde resin; the pressing pressure is 250–1200 kg/cm², depending on the type of material (powder or fiber) and the geometric complexity of the product. The holding time in the press-form is approximately 1 min at a product-wall thickness of 1 mm. It is recommended that the press-powder be briquetted before pressing. Mipor is produced by mixing an aqueous emulsion of urea-formaldehyde resin with a poor-forming agent and consolidating the mixture in molds at 20–40°. Carbamide resins are colorless, so that materials based on them can be dyed any color, including light tints.

Physical, Mechanical, and Electrical Characteristics of Aminoplasts

Свойства 1	2 Прессматериал				
	аминопласт 3	мелалит 4	мела-волокнит 5	К-78-51 МФК-20 ВЭИ-11 6	слоистый пластик 7
Удельная ударная вязкость (кг·см/см²) 8	5–10	5–10	9–15	4–15	8–12
9 Предел прочности при статич. изгибе (кг/см²)	600–800	600–800	600–800	200–500	900–1000
10 Твердость по Бринелю (кг/мм²)	30–50	30–50	25–40	20–30	23–25
11 Теплостойкость по Мартенсу (°C)	100–120	120–160	160–180	не менее 150	130–150
12 Водопоглощение (%)	0.2–0.6	0.1–0.5	0.1–0.5	0.1–0.3	3–4
13 Удельное поверхностное сопротивление (ом)	10^{10}	10^{10}–10^{11}	10^{10}–[illegible]	не менее 10^{11}	[illegible]
14 Электрич. прочность (кв/мм)	12–14	14–16	12–18	2–12	32–33
15 Дугостойкость (сек)	—	—	—	60–180	—

1) Properties; 2) press-material; 3) aminoplast; 4) melalite; 5) melavoloknit; 6) K-78-51, MFK-20, VEI-11; 7) laminar plastic; 8) specific impact strength (kg·cm/cm²); 9) ultimate strength on static bending (kg/cm²); 10) Brinell hardness (kg/mm²); 11) thermostability by Martens's method (°C); 12) water absorption (%); 13) specific superficial resistance (ohms); 14) dielectric strength (kv/mm); 15) arc resistance (sec); 16) no less than.

Aminoplasts are stable when exposed to light, have no odor, resist the action of weak acids and alkalies, oils, gasoline, alcohol, acetone, etc., and are decomposed by concentrated acids and alkalies. Aminoplasts based on urea-formaldehyde resin are hygroscopic, their moisture content varying with that of the air, a phenomenon accompanied by development of internal stresses in the material. These plastics consequently age rapidly when the air temperature and humidity often vary over a wide range; this is manifested in the appearance of a network of fine cracks and in yellowing of the material. When urea-formaldehyde plastics are boiled in water for 30 min they absorb up to 4% of the water and release formaldehyde. Aminoplasts based on melamine-formaldehyde resin are water-stable, are unharmed by boiling in water, and have a higher mechanical strength, dielectric properties, chemical stability, and thermostability than urea-formaldehyde plastics. Aminoplasts, especially those based on melamine-formaldehyde resin, have a high arc resistance (when exposed to an electric arc they release nitrogen, which extinguishes the arc). Aminoplasts based on urea-formaldehyde resin are used to fabricate components which need not meet rigorous requirements for dielectric properties and mechanical strength (switches, sockets, telephone housings, etc.). Decorative laminar plastic is widely employed for interior trim and furniture; mipor is one of the best heat and sound insulators. Aminoplasts based on melamine-formaldehyde resin are used for electrical mining equipment, arc-extinction chambers, and other apparatus, as well as for articles which must function in hot liquids and steam.

A new production method has been proposed for increasing the quality and speeding up the manufacture of aminoplasts; this technique permits continuous production of aminoplasts at temperatures of up to 160° and rates 60–100 times as rapid as under ordinary conditions. Aminoplasts manufactured by this method have a higher water resistance and less tendency to age.

The table shows the physical, mechanical, and electrical characteristics of the most common pressed types of aminoplasts.

References: Barg, M., Tekhnologiya sinteticheskikh plasticheskikh mass [Technology of Synthetic Plastics], Leningrad, 1954; Ullmans Encyklopaedie der technischen Chemie,

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Vol. 3, Munich-Berlin, 1953; Petrov, G.S., Karbamidnyye smoly i pressovochnyye kompozitsii [Carbamide Resins and Extruded Composites], Moscow, 1940; Gorbunov, V.N., Rydvanova, S.S., Kinetika reaktsii kondensatsii mocheviny s formal'degidom pri vysokikh temperaturakh , "PM," [Kinetics of the Condensation Reaction Between Urea and Formaldehyde at High Temperatures, PM, 1960, No. 4; Gorbunov, V.N., Konstruktsionnyye sloistyye plastiki na osnove steklovolokna i bumagi, v kn. [Laminar Structural Plastics Based on Fiberglass and Paper] in book: Plastmassy v mashinostroyenii [Plastics in Machine Building], Moscow, 1959.

V.N. Gorbunov, V.Z. Mayevskaya, and S.M. Perlin

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ANDALUSITE, Al_2SiO_5 – a mineral of the silicate class; it is identical in composition and application to sillimanite and kyanite, from which it differs in lattice structure and certain physical properties. Andalusite often contains a small admixture of Fe_2O_3 and sometimes as much as 7% MnO (this is a variety of andalusite known as viridine or manganandalusite). This mineral can be gray, yellow, brown, red, or dark green (viridine) in color and may in rare instances be colorless. Andalusite is usually found in acicular crystals. It does not decompose in acids. It has a Mohs hardness of 7-7.5, a specific gravity of 3.1-3.2, and a heat capacity of 0.77 cal/g·°C at 0° and 1.20 cal/g·°C at 1200°. At 1325-1410° andalusite is converted to mullite and silica glass, but, in contrast to kyanite and sillimanite, its volume remains unchanged. This mineral is employed in the production of refractory ceramic products; clear, finely colored andalusite is used in jewelry.

P.P. Smolin

ANDESITE – see <u>Natural acid-resistant materials</u>.

III-2U

ANGLE OF TWIST - plasticity characteristic of metallic wire, which is determined by performing and <u>industrial test</u> in torsion and which gives an idea about the ability of the metal to undergo plastic deformation in constant or intermittent torsion. The angle of twist is determined over a computational length, which is equal to 100 diameters of the wire being tested, but nlt less than 50 and not more than 500 mm. One twist is defined as one complete (360°) turn of the rotating end of the specimen being tested.

In torsion tests (GOSTs 3565-58, 1545-42) the term angle of twist or torsion angle is defined as the difference in simultaneous turning angle of two cross sections at the computational length of the specimen under test.

References: Shaposhnikov, N.A., Mekhanicheskiye ispytaniya metallov [Mechanical Testing of Metals], <u>2nd</u> edition, Moscow-Leningrad, 1954.

Yu.S. Danilov.

Manuscript Page No.	[Transliterated Symbols]
232	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standard = All-Union State Standard

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ANID – a synthetic heterogenous-chain fiber obtained by polycondensation of the salt AG (hexamethylene diamine and adipic acid in a ratio of 1:1). It is produced in the USSR (as an ordinary and reinforced filamentous thread), in the United States, in England (under the name nylon 66), and in other nations. Its physical and mechanical properties are as follows: specific gravity of fiber – 1.14; moisture content under standard conditions – 3.4-3.8%, at 20° and 95% relative humidity – 5.8-6.1%; breaking length – 35-38 (65-70) km (henceforth the figures in parentheses are for reinforced thread); loss of strength when wet – 7.8-13.5 (6.4-12.2)%, when skeined – 1-1.1 (5.6-12.7)%; short-term tensile strength – 40-44 (74-79) kg/mm^2; maximum elongation when dry – 23-32 (14-16)%, when wet – 26-34 (14-16)%; modulus of elasticity – 230-320 (370-450) kg/mm^2; modulus of torsion – 4500-5400 (7400-8200) kg/cm^2; elasticity during extension by 4% – 100 (100)%, during extension by 10% – 98.0-98.5 (96-99)%; durability (resistance to repeated bending in a DP apparatus at 110 cycles per min under a load of 5 kg/mm^2) – 11-15 thousand (28-37 thousand) bends; wearability (number of cycles under a load of 30 g) – 1-1.1 thousand (3.7-4 thousand); resistance to ultraviolet irradiation (loss of strength after irradiation for 20 hr) – 23.7-32.2 (36.3-47.9)%. For other properties and uses of anid see Nylon 66 and Polyamide fiber.

References: Demina, N.V., et al., KhV, 1960, No. 5.

E.M. Ayzenshteyn

ANIMAL GLUE — is the product of the treatment of diverse materials of animal origin; it has a high adhesive property. Depending upon the raw material, the animal glues are subdivided into glutin, casein, albumin and combined glues.

The glutin glues are subdivided into: hide glues, from the hypodermic layer of the animal hide, and into bone and fish glue. Glutin glues form stable joints when wood is glued, but they have a low resistance to water and rot readily. Dry glutin glue is supplied in form of plates, tablets, lamellas or powder, and glue with a water content of 50-60% is available as jelly. The bonding strength of hide glue (GOST 3252-46) must be not less than 100 kg/cm^2 shearing strength for the "extra," "highest" and "first" grades. Casein, the main substance of the casein glues, is obtained from skimmed milk. Waterproof glues are obtainable by treatment of casein with the oxides of certain heavy -tals and alkaline earth metals. Alkalis and sodium salts are added to casein glues in order to prolong its working life. The bonding strength, the waterproofness, the viscosity and other properties of the glues depend on the quantity of alkali, lime and water. Casein glues are subdivided into glues mixible in liquid state, and in powdered glues. The former may be prepared on the place of application. The casein glue is waterproof and possesses a high bonding strength (not less than 130 kg/cm^2 in the shearing test); its working life is 5-7 hrs. Powdered glues are composed of dry components and are prepared in special shops by mixing the powder with water. Powdered casein glues make for joints of a higher strength than the glutin glues, but their water resistance is limited, and they are easily affected by fungi. Albumin glues provide higher water-resistant joints than the casein glues, but the joints swell and are affected by microorganisms. Combined glues are composed from albumin and casein and possess a higher bonding strength than albumin and casein glues. Animal glues are used in the wood-working, paper and textile industries.

References: Berdinskikh I. P., Skleivaniye drevesiny [The Gluing of Wood], Kiev, 1959; Adgeziya, klei, tsementy, pripoi [Adhesion, Adhesives, Cements and Solders], translated from English, Moscow, 1954.

D. A. Kardashev

ANISOTROPIC MATERIALS - materials with some or all of their properties varying in different directions. They usually exhibit anisotropy with respect to the majority of their physical (mechanical, optical, thermal, magnetic, etc.) and chemical characteristics. Anisotropic materials may be monocrystals, textured polycrystalline bodies, fibrous and foam materials, reinforced concrete, plastics with laminar fillers (getinaks, textolite, stekloplast), etc. Amorphous materials also become anisotropic in directional force fields. Liquids are anisotropic during flow and when they contain so-called liquid crystals, whose molecules are oriented relative to one another under certain conditions (paraoxyphenetole, cholesterol benzoate, etc.). The properties of anisotropic materials are characterized as a function of geometric direction by polar diagrams (Fig. 1) or by the vector of the property in question. The degree of anisotropy is determined by the composition and internal structure of the material. Heterodesmic crystals are the most anisotropic, their particles having different types of chemical bonds with varying energy in different directions. Such materials are often characterized by a laminar or fibrous (linear) structure. For example, carbon in the form of graph[illegible] heterodesmic laminar crystal, exhi-

Fig. 1. Polar diagram of anisotropy of strength in a copper monocrystal (after Chokhral'skiy).

bits substantially greater anisotropy than diamond, a homodesmic covalent crystal. Composite materials with nonuniform filling in different directions, such as reinforced concrete beams, laminar plastics, etc., are highly anisotropic.

Utilization of anisotropy makes it possible to reduce the consumption of materials and to improve structural quality. Thus, for example, transformers with cores of anisotropic textured steel in which the external magnetic field coincides with the direction of greatest magnetizability in the material are approximately 20-40% better than transformers with cores of untextured hot-rolled steel. Anisotropy opens up broad possibilities in tool making and automation.

Mechanical anisotropy is manifested in the dependence of elasticity constants, strength indices, plasticity, and viscosity on the direction in which parts of crystals undergo plastic slip along selected crystallographic planes and the directions in which the crystals fracture along certain crystallographic planes, the cleavage planes. A clear example of anisotropy of mechanical properties is furnished by mica and asbestos crystals, which are easily split into thin sheets and fibers. Even crystals with a high degree of lattice symmetry exhibit marked anisotropy of mechanical properties. Thus, the modulus of normal elasticity of iron monocrystals at room temperature varies from 1350 kg/mm^2 for direction [100] to 2900 kg/mm^2 for direction [111]; copper specimens cut parallel to the diagonal of the lattice unit are 3 times as strong as specimens cut parallel to the edge of the cube (35 and 12 kg/mm^2), the anisotropy of residual deformation being still greater. Utilization of mechanical anisotropy makes it possible to assemble lighter, stronger structures. Anisotropic fiberglass with $\sigma_b = 50$ kg/mm^2 both along and across the sheet tears at an angle of 45° under a stress of 22 kg/mm^2. Paper is 1.5-2 times stronger along the roll than across it. Three-layer, three-millimeter plywood of birch veneer has a strength of no less than 7.5 kg/mm^2 along the fibers of the outer layers and of 2.5 kg/mm^2 at an angle of 45°. Polymer fibers and foams are also highly anisotropic. Production technology has a large influence on anisotropy. Preliminarily extended (oriented) polymer materials are 2-3 times as strong as unoriented materials. Cast alloys (not subjected to controlled crystallization) usually exhibit little anisotropy. Anisotropy of mechanical properties increases with the degree of reduction (the ratio of the cross-sectional area of the original workpiece to that of the drawn billet; Fig. 2). This is especially clearly reflected in the impact strength a_N, plasticity δ, ψ, fatigue strength σ_w, and fracture resistance S_k; the coefficients of plastic-deformation resistance, σ_s and σ_b, vary less as a function of the direction in which the specimen is cut. Anisotropic materials are often quantitatively characterized by the coefficient of anisotropy α, which is the ratio of the properties along the fibers to those across the fibers. It must be noted, however, that the lowest values are not always obtained in the transverse direction; in annealed carbon steel, nickel ferrite, etc., the lowest values are observed at an angle of 60–70° to the deformation direction (Fig. 2). Anisotropy of strength and plasticity in metals such as steel is associated not so much with textural deformation as with orientation in the deformation direction of nonmetallic carbide, nitride, sulfide, etc., phases, dislocation networks, adsorbed gases, etc. After reduction anisotropy consequently depends to a large extent on the chemical and, especially, the phase composition (Fig. 3). Homogeneous alloys are less anisotropic than heterogeneous alloys Alloys smelted in purer form, as by the vacuum method, are less anisotropic at a given reduction than those produced by electrosmelting. Electric steel is less anisotropic than open-hearth steel. All other conditions being equal, steels exhibit a nonuniform rise in anisotropy as their strength increases (at low annealing temperatures). Rolled billets are more anisotropic than pressed billets. Thus, according to the experiments of N.I. Korneyev, et al., the impact strength of longitudinal duralumin samples is identical to that of pressed specimens, while that of transverse rolled specimens is only a bit more than half as much. Liquation intensifies anisotropy after reduction. The anisotropy of deformed materials is utilized by designing structures in which the maximum tensile stresses coincide with the direction of the fibers.

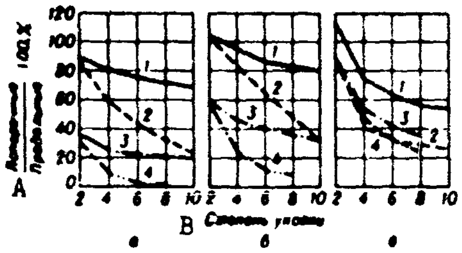

Fig. 2. Influence of degree of reduction and liquation on anisotropy of mechanical properties in steel: a) ψ; δ; c) a_N; 1) No pronounced liquation (electric steel); 2) the same (open-hearth steel); 3) marked liquation; 4) very marked liquation (after Coupette). A) (transverse/longitudinal)·100%; B) degree of reduction.

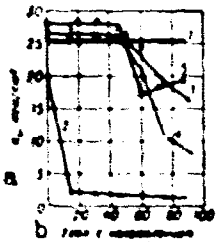

Fig. 3. Change in impact strength of ferrite (0.03% C) as a function of cutting direction: 1) 0.5% Si; 2) 1.1% Si; 3) 0.09% S; 4) 0.09% S + 1.1% Mn; 5) 3.45% Ni. a) a_K, kg-m/cm^2; b) angle to forging direction, degrees.

Micromechanical testing has recently become quite important in evaluating anisotropic materials.

Optical anisotropy (OA) is manifested in birefringence, optical activity, i.e., rotation of the plane of polarization, dichroism, dependence of polarization on direction, and a number of other phenomena. It can be natural (crystals) or artificial (induced by mechanical deformation or magnetic or electric fields). Induced optical anisotropy may persist, as in tempered glass, or may disappear when the inducing field is removed (Kerr effect). Optically anisotropic materials are used as light polarizers and analyzers of the Nicol-prism (Iceland spar) and polaroid (polyiodides, quinine sulfate, polyvinyl alcohol) types, as light modulators in Kerr cells (nitrobenzene, o-nitrotoluol, et al.), and for photoelastic investigations of the stress state of various structures in models of glass, plastic, etc. Optical anisotropy is utilized in chemical analysis of petroleum products, etc.

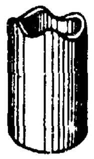

Fig. 4. Scalloping formed during deep drawing of textured (anisotropic) sheet metal with a face-centered cubic lattice.

Fig. 5. Deformation of cold-worked uranium samples cut in rolling direction under cyclic thermal stress: a – before; b – after 3000 cycles at 50-500° (after Chiswick and Kelman).

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Thermal anisotropy is manifested in the direction of the coefficients of thermal conductivity and thermal expansion. It is especially pronounced in laminar (e.g., graphite) and chain (e.g., tellurium) structures. The maximum increase in crystal size takes place in the direction of the weakest bonds. A slight decrease in size may occur in the direction perpendicular to this in the aforementioned substances.

Anisotropy of electrical conductivity and magnetic properties is also important. For example, $FeCl_2$, $CoCl_2$, and other metamagnetic compounds are ferromagnetic in some directions and paramagnetic in others. The natural anisotropy of anisotropic materials can be utilized, but it is often intensified artificially or even induced by special technological processing. For example, holding a ferroelectric ceramic in an electric field increases the piezoelectric modulus in the field direction and such a ceramic can be used as a piezoelement. Thermomagnetic treatment of magnico and supermalloy greatly improves their magnetic characteristics along the applied field. Anisotropy sometimes has undesirable consequences in the processing and exploitation of anisotropic materials. Thus, deep drawing produces 4 scallops on the upper edge of sheet metal with a cubic lattice and 6 scallops on that of sheets with a hexagonal lattice (Fig. 4). Each scallop corresponds to a direction in which the deformation resistance is relatively low. Metals with anisotropic mechanical and thermal properties undergo marked deformation during cyclic heat transfer (Fig. 5).

References: Mes'kin, V.S., Osnovy legirovaniya stali [Principles of the Alloying of Steel], Moscow, 1959; Fridman, Ya. B. and Ratner, S.I., ZL, 1945, Vol. 9, No. 2-3; Coupette, W., Stahl und Eisen, [Steel and Iron], 1941, Vol. 61, No. 45, page 1013, No. 46, page 1036.

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ANNEALING OF STEEL - heat treatment employed to soften steel and facilitate machining for plastic deformation, as preparation for further heat treatment, and to produce given mechanical characteristics. Annealing can be classified as high (or complete), incomplete, low, complete isothermal, or incomplete isothermal (see Figure). High (or complete) annealing consists in heating the steel to a temperature 30-50° above its upper critical point Ac_3 and then slowly cooling it. Incomplete annealing involves heating to somewhat above the lower critical point Ac_1 and subsequent slow cooling. Low annealing (high tempering) consists in heating to slightly below the lower critical point Ac_1, more or less prolonged holding at this temperature, and subsequent cooling, usually in air. Isothermal annealing differs from high and incomplete annealing in the fact that, after preliminary heating to a

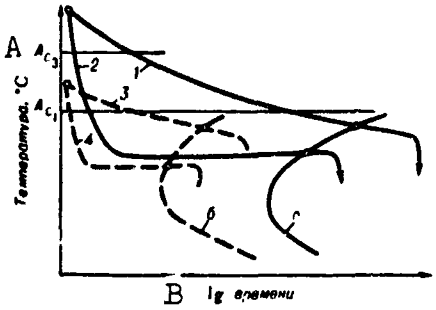

Figure. Graphs of high annealing, complete isothermal annealing involving heating to above the critical point Ac_3, incomplete annealing, and incomplete isothermal annealing involving heating to above the critical point Ac_1. a, b) Curves showing completion of austenite decomposition when steel is heated to temperatures above the critical points Ac_3 and Ac_1 respectively; 1) high annealing; 2) complete isothermal annealing; 3) incomplete annealing; 4) incomplete isothermal annealing. A) Temperature, °C; B) lg time.

temperature above Ac_3 or Ac_1, the component or semifinished product is held for a definite time during cooling at a temperature somewhat above the lowest austenite-stability temperature (approximately 100° below Ac_1) and then cooled in air. The complete recrystallization necessary to correct the structure of overheated steel takes place only during complete (or complete isothermal) annealing; incomplete annealing results in only partial recrystallization, while low annealing produces no recrystallization at all. Cold-worked structural steel usually recrystallizes during all types of annealing, provided that the appropriate holding time is employed. The cooling rate during complete and incomplete annealing and the holding time during isothermal annealing should ensure decomposition of the austenite in the perlitic-transformation zone. The higher the transformation temperature, the lower is the hardness of the steel. A reduction in the heating temperature during incomplete or incomplete isothermal annealing of alloy steel leads to a lower austenite stability in the perlitic-transformation zone than complete annealing and consequently accelerates the annealing process. An increase in the degree of alloying increases the stability of the austenite and thus necessitates use of slower cooling rates or prolongation of the holding time during isothermal annealing. When the steel is highly alloyed the stability of the austenite is so greatly enhanced that all forms of annealing involving heating to above the critical point Ac_1 or Ac_3 become unsuitable; low annealing of sufficient duration is employed in this case. The hardness of the steel decreases as the low-annealing temperature is raised, although the hardness of high-alloy steel may rise sharply if the critical point Ac_1 is accidentally reached. High or complete isothermal annealing, which ensures a structure consisting of laminar perlite and ferrite, is generally utilized to improve the machinability of low-alloy steel containing less than

0.5% carbon. Incomplete or incomplete isothermal annealing is employed instead of high annealing to accelerate the premachining heat treatment of medium-carbon alloy steel. High-carbon steel has optimum machinability when it has a granular-perlite structure, which is obtained by incomplete annealing involving heating to somewhat above the critical point Ac_1 and subsequent slow cooling. Such annealing is sometimes called spheroidization. In order to produce the maximum quantity of granular perlite high-carbon steel is occasionally subjected to swing or cyclic annealing, which consists in repeated heating to and cooling from a temperature near Ac_1. In some cases, high-carbon steel is low-annealed to increase its machinability. In order to improve its plastic deformation steel is subjected to low or incomplete annealing in order to obtain a granular-perlite structure. Low or incomplete annealing is generally employed for cold-worked steel. Complex cooling cycles are often used to ensure maximum softening of high-alloy structural steel: the steel is heated to a temperature above Ac_1 but below Ac_3, cooled to a temperature below the minimum austenite-stability point (450-550°), reheated to somewhat above the minimum austenite-stability point (650-670°), and held at this temperature until the austenite has completely decomposed; it is then recooled to 450-550° in order to reduce austenite stability at 600-670°. Slow cooling over the temperature range 650-450° causes temper brittleness in many alloy steels, which leads to a decrease in viscosity. This brittleness can be completely eliminated by subsequent quenching of the steel. In order to avoid Temper brittleness of steel during annealing further cooling in air after the austenite transformation has been completed is recommended.

References: Gulyayev, A.P., Termicheskaya obrabotka stali [Heat Treatment of Steel], 2nd Edition, Moscow, 1960.

Ya.M. Potak

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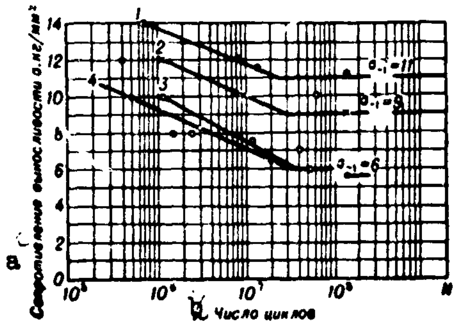
ANODIZING OF ALUMINUM ALLOYS (anodic oxidation, anodic polarization) – an electrochemical process for obtaining a protective film (usually of aluminum oxide) on the surface of aluminum alloys. In anodizing the component is immersed in an electrolyte and connected to the positive pole of a current source (anode). When current is passed to the anode active oxygen is released, reacting with the aluminum to form an oxide film on its surface. In contrast to galvonic metallic coatings, an anodic coating is deposited not on the outer surface of the component, but beneath the previously formed oxide film, i.e., at the boundary between the aluminum and the oxide film. In addition to increasing corrosion resistance and the adhesion of subsequent coats of lacquer, anodizing imparts hardness, wearability, and electrical and thermal insulating properties to the surface layer of the metal, while subsequent treatment in dye solutions gives it the requisite color. Anodizing can be employed for checking the quality of aluminum-alloy components, for



Durability curves for specimens of AMg alloy 6.5 mm in diameter bend-tested at a rotation speed of 1010 rpm for $150 \cdot 10^6$ cycles: 1) As-delivered, after rolling; 2) sulfuric acid anodizing at 20° with a bichromate-film filler; 3) heavy anodizing in a 20% H_2SO_4 electrolyte, without subsequent polishing; 4) the same, polished. a) Durability σ, kg/mm²; b) number of cycles.

protecting aluminum mirrors against tarnishing, and for ensuring good adhesion of galvonic coatings to the surface of the component. Depending on the requirements which it must meet, the component is subjected to various types of preanodizing surface treatment, prime among which are degreasing, pickling, and mechanical, chemical, and electrochemical polishing. Only a few electrolytes are of commercial significance (Table 1). Anodizing intended to provide corrosion protection is usually carried out in sulfuric or chromic acid.

The sulfuric-acid process is used for surface-treating aluminum components and plated and unplated deformed and cast aluminum alloys with a porosity of no more than 3 points. When a current of 40-45 amp•min/dm^2 is passed through aluminum, deformed low-alloy aluminum alloys (AMg1, AMg2, AMg3, AD31, AD33, etc.), or plated aluminum alloys a film approximately 10 μ thick is formed; a film approximately 5 μ thick is deposited on cast and unplated high-alloy deformed alloys. It is possible to obtain films of different thicknesses by varying the applied current. A film thickness of 20-25 μ is best for components which will not be given lacquer coatings, being intended for use in the open air (structural elements – window-frames, doors, trim), while a thickness of 15 μ is best for components of this type which will be used in dry, heated rooms. A thickness of 10 μ is recommended for articles (e.g., the skin of aircraft, machine components, etc.) which will be lacquered and used in the open air and a thickness of 5 μ for articles of this type which will be used in heated rooms. In order to increase its corrosion resistance the anodic film is shrunk in hot 5% potassium dichromate or, if a colorless film is desired, in hot water. Anodic films on components fabricated from deformed high-alloy and cast alloys should be shrunk only in potassium dichromate. Lacquering substantially improves the protective properties of the anodic film.

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TABLE 1

Electrolytes and Regimes Used in Anodizing

Анодирование 1	2 Электролит		Режим анодирования 5				Толщина пленки (мк) 10	Назначение 11
	Состав 3	Концентрация 4 (г/л)	6 Плотность тока (а/дм²)	Напряжение 7 (в)	Температура 8 (°C)	Выдержка 7 (мин.)		
Сернокислотное 12	H_2SO_4	100—250	0.5—2.5	10—25	13—25	10—60	5—25	Защита от коррозии; декоративная отделка; подслой лакокрасочного покрытия 19
Толстослойное (твердое) 13	H_2SO_4	180—350	2.3—6	20—120	от −10 до 0	60—240	30—200	Защита от износа и коррозии; получение тепло- и электроизоляц. покрытий 20
Обычное хромовокислотное 14	CrO_3	30—50	0.2—1.6	0—40 40	32—42	15 45	2—6	Защита от коррозии полированных деталей, а также деталей с точными размерами, выявление пороков металла 21
Ускоренное хромовокислотное . . . 15	CrO_3	90—100	0.3—2.7	0—40 40	35—40	5—10 25	2—3	Защита от коррозии; подслой лакокрасочного покрытия 22
Щавелевокислотное . . . 16	$(COOH)_2$	30—50	1—2	30—35	30—40	15—30	8—15	Декоративная отделка; защита от коррозии; подслой лакокрасочного покрытия 23
Фосфорнокислотное . . . 17	H_3PO_4	100—350	1.3—4.0	20—60	30—35	1—10	0.3—3	Улучшение сцепления гальванопокрытий 24
Борнокислотное 18	$H_3BO_3 + Na_2B_4O_7$	90—150	до 2.5	230—250	70—95	25—35	0.2—0.3	Электроизоляц. покрытие конденсаторов; защита алюминиевых зеркал от потускнения 25

1) Anodizing; 2) electrolyte; 3) composition; 4) concentration (g/liter); 5) anodizing regime; 6) current density (amp/dm^2); 7) voltage (v); 8) temperature (°C); 9) holding time (min); 10) film thickness (μ); 11) purpose; 12) sulfuric-acid; 13) heavy; 14) ordinary chromic-acid; 15) accelerated chromic-acid; 16) oxalic-acid; 17) phosphoric-acid; 18) boric-acid; 19) corrosion protection, decorative finish, underlayer for lacquering; 20) wear and corrosion protection, production of thermal and electrical insulating coatings: 21) corrosion protection for polished and precisely dimensioned components, detection of defects in metal; 22) corrosion protection, underlayer for lacquering; 23) decorative finish, corrosion protection, underlayer for lacquering; 24) improvement of galvonic-coating adhesion; 25) insulating coatings of capacitors, tarnish protection for aluminum mirrors.

The chromic-acid process, which is more expensive and more complex, is carried out in 3, 5, and 10% solutions of CrO_3 and is intended principally for corrosion protection of components with low dimensional tolerances or polished surfaces (in 3% CrO_3 surface cleanness is not altered by more than ± 0.05 μ and size is not changed by more than ±2 μ) and components fabricated from cast alloys with a porosity of more than 3 points (5 and 10% CrO_3). This anodizing method is not recommended for alloys containing more than 4.5% copper. Films up to 10 μ thick can be obtained on pure aluminum and films 2-3 μ thick can be deposited on alloys. A chromic-acid film is softer and more elastic than a sulfuric-acid film and causes no decrease in fatigue strength; the resultant corrosion resistance is somewhat higher than for a sulfuric-acid film of equal thickness. Films produced by this technique require no filler. Chromic-acid anodizing permits detection of defects (cracks, pores, etc.) in the metal.

Heavy anodizing in sulfuric acid is carried out at low electrolyte temperatures (from 0° to −10°) in order to obtain heat-insulating layers (for the piston bottoms of internal-combustion engines, etc.) and electrical insulation coatings (usually with an additional coating of an insulating varnish). It is intended for components which will be subject to friction and erosive factors. When the component is internally cooled the hardest, thickest (up to 200 μ) films are obtained on pure aluminum and its homogeneous alloys (AMg, AV, etc.). Alloys containing silicon (AL2, AL4, AL9) or small quantities of copper (type V95, etc.) are easily anodized, while those containing more than 4.5% copper (D16, D1, D20, etc.) are more difficult to anodize. The recommended film thicknesses are 50-60 μ (before honing) for components which will be subject to friction and erosive factors, 100 μ for heat-insulating coatings, and 20-40 μ or more (depending on the desired resistance) for electrical insulating coatings. Heavy anodizing increases the size of the component by approximately half the thickness of the deposited film. The microhardness of the film is approximately 250-500 kg/mm^2. Heavy anodizing reduces the cleanness of surface treatment from class 9 to class 5 or even class 4. In order to improve surface cleanness the film is honed and polished mechanically. The reduction in fatigue strength depends on the anodizing method, the thickness of the film, and the type of alloy. Thus, for example, heavy anodizing reduces the fatigue strength of AL4 alloy (80 μ) by 12%, of AMg alloy (170 μ) by 45%, and of AK6 alloy (100 μ) by 33%.

TABLE 2

Formulas and Regimes for Staining of Anodic Films with Organic Dyes

Наименование красителей (для алюминия) 1	ТУ или ГОСТ 2	Концентрация (г/л) 3	Выдержка (мин) 4	pH	Температура (°C) 5	Светопрочность (баллы) 6
7 Желтый 53	31 ГОСТ 7767—55	1	15	6—7	50—60	3
Желтый 3	ТУ У637-55	1,5	15	5—7	50—60	3
Желтый 43	22 —	1	15	6—7	50—60	5
8 Оранжевый 2Ж	ТУ У636-55	1	15	6—7	20—25	4
Оранжевый	23 ВТУ У179-51	1—3	15	4—5	20—25	5
Оранжевый К	ГОСТ 7437—55	1	15	5—7	50—60	3
9 Алый	24 ГОСТ 6135—52	1	15	4—5	50—60	4
Бордо	ВТУ ГАП-У487-53	0,5—1	15	4—5	20—25	3
10 Рубиновый	—	1	15	5—6	50—60	5
Фиолетовый 11	ГОСТ 1197—41	1	15	6—7	50—60	4
12 Фиолетовый К	—	1	15	4—5	50—60	5
Фиолетовый С	—	1	15	5—6	50—60	5
13 Бирюзовый	ГОСТ 7468—55	0,5—2	15	6—7	50—60	5
Голубой З	—	1	15	3—4	50—60	5
14 Голубой К	25 ТУ У637	0,5—2	15	4—5	50—60	5
15 Синий 2К	ТУ МХП 3429-52	1	15	5—7	50—60	4
16 Зеленый Ж	ВТУ У488-54	1	15	3—4	50—60	3
Зеленый С	ГОСТ 7570—55	1	15	5—7	50—60	4
17 Коричневый 18	ВТУ У377-52	1	30	4—5	50—60	3
Черный	ВТУ У265-51	5	30	4—5	20—25	5
20 Золотой (смесовой)	—	—	1—2	5,5—7	4	—

1) Dye (for aluminum); 2) TU or GOST; 3) concentration (g/liter)· 4) holding time (min); 5) temperature (°C); 6) light-fastness (points); 7) yellow; 8) orange; 9) blood red; 10) claret; 11) ruby; 12) violet; 13) turquoise; 14) blue; 15) deep blue; 16) green Zh; 17) green S; 18) brown; 19) black; 20) gold (mixed); 21) GOST; 22) TU U; 23) VTU U; 24) VTU GAP-U; 25) TU MKhP.

The oxalic-acid process is employed principally to produce electrical insulating coatings (followed by treatment with electrical insulating varnishes).

Decorative (chromatic) anodizing colors the component. Before anodizing the component is subjected to mechanical, electrochemical, or chemical polishing. The higher the purity of the aluminum, the better are its decorative properties. It is recommended that components with a mirror finish be fabricated from aluminum of no less than type

A00. A somewhat less intense luster can be obtained with aluminum of types A0 and A1 and AMg and AD31 alloys. The clear, colorless films needed for staining are formed by anodizing in a sulfuric-acid electrolyte. The film thickness should be 5-8 μ for light hues and 10-15 μ for dark hues. Such films are porous in structure and can be stained (filled) by a dye. Anodizing in oxalic-acid and chromic-acid electrolytes produces opaque films. Enamel-like films are formed in electrolytes containing salts of Ti, Zr, and Th. The films are stained with organic dyes (which cover a broad range of bright hues, but are not sufficiently light-fast or thermostable; Table 2) or inorganic pigments (which cover a small range of dull hues, but are light-fast and thermostable).

Light anodizing is used to produce thin nonporous (barrier) films of high resistance and is employed in the manufacture of electrical capacitors and rectifiers and for protecting aluminum mirrors against tarnishing. Anodizing intended to improve the adhesion of galvonic coatings is usually carried out in phosphoric acid.

References: Shreyder, A.V., Oksidirovaniye alyuminiya i yego splavov [Oxidation of Aluminum and Its Alloys], Moscow, 1960; Golubev, A.I. Anodnoye okisleniye alyuminiyevykh splavov [Anodic Oxidation of Aluminum Alloys], Mow, 1961; Vernik, S., Pinner, R., Khimicheskaya i elektroliticheskaya obrabotka alyuminiya i yego splavov [Chemical and Electrolytic Treatment of Aluminum and Its Alloys], Leningrad, 1960.

N.A. Makarov

ANODIZING OF MAGNESIUM ALLOYS – an electrochemical process for obtaining a protective film on the surface of magnesium alloys. Such anodizing is usually carried out in alkaline or acid electrolytes, using direct or alternating current. The metal to be protected serves as the anode. The films produced by anodizing serve principally to pro-

TABLE 1

Anodizing Methods (alternating current)

Электролит 1		4 Плотность тока (а/дм²)	Напряжение на электродах ванны (в) 5	Темп-ра электролита (°C) 6	Продолжительность процесса (мин) 7	Цвет покрытия 8	Толщина покрытия (мк) 9
состав 2	количество 3						
	16	10 Метод № 1					
11 Едкое кали 12 Гидроокись алюминия 13 Трифосфат натрия Фтористый калий 14 15 Перманганат калия	120 г/л 30 » 34 » 34 » 19 »	1—5	17 До 100	25—30	60—90	18 Коричневый	35
		Метод № 2					
19 Хромовая кислота 20 Фтористоводородная кислота (50%-ная) 21 Фосфорная кислота (45%-ная) 22 Аммиак	25 г/л 23 25 мл/л 50 » 160—180 мл/л	1,6	До 380	75—95	12	24 Зеленый	25
		29 Метод № 3*				30	
25 Бифторид аммония 26 Двухромовокислый натрий 27 Фосфорная кислота (85%-ная)	250—300 г/л 60—80 » 60—70 мл/л	5—6 (начальная) 28	75—95 (в зависимости от сплава)	70—80	30—45	От светло-зеленого до темно-зеленого	30—50

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*Magnesium alloys can also be anodized with direct current by this method.

1) Electrolyte; 2) composition; 3) quantity; 4) current density (amp/ /dm²; 5) voltage at bath electrodes (v); 6) electrolyte temperature (°C); 7) process time (min); 8) coating color; 9) coating thickness (μ); 10) method No. 1; 11) potassium hydroxide; 12) aluminum hydroxide; 13) sodium triphosphate; 14) potassium fluoride; 15) potassium permanganate; 16) g/liter; 17) up to; 18) brown; 19) chromic acid; 20) hydrofluoric acid (50%); 21) phosphoric acid (85%); 22) ammonia; 23) ml/liter; 24) green; 25) ammonium difluoride; 26) sodium dichromate; 27) phosphoric acid (85%); 28) initial; 29) depending on alloy; 30) from light green to dark green.

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TABLE 2

Certain Physical and Chemical Properties of an Anodic Film Obtained by Method No. 3

1 Примерный химич. состав	2 Уд. вес ($г/см^3$)	3 Толщина (мк)	4 Отношение объема пор к объему пленки	5 Теплостойкость (°C)	Адгезия 6 к лакокрасочным покрытиям (баллы)		9 Микротвердость ($кг/мм^2$)
					до увлажнения 7	после увлажнения 8	
Сложное соединение, содержащее Cr^{3+}, PO_4^{3-}, F^- 10	3	30–50	0.4	350	5	5	200–300

1) Typical chemical composition; 2) specific gravity (g/cm^3); 3) thickness (μ); 4) ratio of pore volume to film volume; 5) thermostability (°C); 6) adhesion to lacquer coating (points); 7) before moistening; 8) after moistening; 9) microhardness (kg/mm^2); 10) complex compound containing.

tect magnesium alloys against corrosion. Table 1 shows new methods for the anodizing of magnesium alloys, while Table 2 shows certain physical and chemical properties of an anodic film. The composition and properties of anodic films are determined by the character and ratio of the components of the electrolyte, the process regime, and the elements present in the alloy. Films consisting primarily of magnesium hydroxide are formed in alkaline electrolytes. The films obtained in acid electrolytes usually consist of insoluble phosphates, chromates, and fluorine compounds. Anodizing can be used to produce high-quality films up to 60 μ thick. Anodic films, especially those obtained by the new methods (see Table 1), have material advantages over chemical films (see Oxidation of magnesium alloys): they have better protective properties, greater hardness, and better wearability. Some anodic films are thermostable. Inorganic and organic fillers materially improve the protective properties of such films. The principal drawbacks of this process are the fact that it is impossible to anodize assembled units, the complexity of the process, and the low elasticity of the film. Anodic films are employed for corrosion protection when high hardness and thermostability are required in addition to protective properties.

References: Timonova, M.A., Yershova, T.I., in collection: Korroziya i zashchita metallov [Corrosion and Protection of Metals], Moscow, 1962, pages 166-179; Andreyeva, M.A., Rozov, M.N., Tr. Vses. alyuminiyevo-magniyevogo instituta [Transactions of the All-Union Aluminum-Magnesium Institute], 1960, No. 44, pages 228-247; Kennedy, A.J., and Sollars, A.R., Aircraft Engng, 1960, Vol. 32, No. 371; McNeill, W., Wick, R., J. Electrochem. Soc., 1957, Vol. 104, No. 6; Barbian, H.A., Mater. and Methods, 1954, Vol. 39, No. 1; Light Metal Age, 1954, Vol. 12, No. 3-4, pages 12-13.

M.A. Timonova

ANODIZING OF TITANIUM ALLOYS - an electrochemical process for obtaining a protective film on the surface of titanium alloys. This process is usually carried out in alkaline or acid electrolytes (H_2SO_4, HNO_3, CrO_3, KOH, etc.) at a current density of 0.5-1.5 amp/dm^2 and voltages increasing from 10-15 to 80-100 v. The anodic film thus formed apparently consists of anatase and varies in thickness from a fraction of a micron to 2.5 μ, depending on the type of electrolyte and the anodizing time and temperature. The thickest, densest films are obtained in 18% H_2SO_4 at a current density of 0.5 amp/dm^2, a temperature of 80°, and a process time of 2-8 hr. The anodic films have good protective properties in H_2SO_4, HCl, and other media. Anodizing can be employed to improve the antifriction properties of titanium alloys only in conjunction with preliminary water-sand blasting of the friction surface and subsequent application of a varnish based on BF-2 glue, etc. When there is a continuous supply of lubricant such processing furnishes a coefficient of friction of 0.06-0.07 at a speed of 0.4 m/ /sec under loads of no more than 40 kg/cm^2.

References: Richaund, H., "Metal Finish," 1957, Vol. 3, No. 25, page 10.

ANTEGMIT – a chemically stable anticorrosion, antifriction (self-lubricating), heat-conducting material produced as a press-powder based on phenolic resin and graphitized material. Three types of antegmit are manufactured (see Table). Small-size products fabricated from ATM-1 are pressed in the same manner as phenol-formaldehyde powders, while large-size products are formed in open molds with a vibration compactor. In order to increase their chemical resistance and thermostability the finished products are heat-treated, which leaves their configuration

Physical and Mechanical Properties of Antegmit

Показатели 1	2 Марка		
	АТМ-1	3 АТМ-10 (ТАТЭМ-0)	4 АТМ-1Г (ТАТЭМ-Г)
5 Удельный вес	1.8	1,74	1.74
Предел прочности (кг/см²) 6			
7 при растяжении	180—220	90—120	60—80
при статич. изгибе 8	400—500	260	200
9 при сжатии	1000—1200	550	450
10 Удельная ударная вязкость (кг·см/см²)	2,75—3,5	1,7	1,6
Теплостойкость по Мартенсу (°C) 11			
12 в присутствии воздуха	170	400	600
в инертном газе 13	170	2000	2000
14 Термостойкость	22 Воспринимают любые температурные колебания в пределах теплостойкости		
15 Теплопроводность (ккал/м·час·°C)	30—35	80—85	90—120
Теплоемкость (ккал/кг·°C) 16	0,18	—	—
17 Коэфф. линейного расширения	$0,85\cdot10^{-5}$	$0,25\cdot10^{-5}$	$0,22\cdot10^{-5}$
Удельное электрическое сопротивление (ом·см) 18	$(5-6)10^{-3}$	$1,6\cdot10^{-3}$	$1,2\cdot10^{-3}$
19 Проницаемость для воздуха при толщине 5 мм	25 23 Не проницаемы		
	24 До 5 *атм*	До 5 *атм*	До 3 *атм*
20 Коэфф. трения без смазки	0,12	—	—
21 Обрабатываемость на станках	26 Легко обрабатываются режущим инструментом		

1) Index; 2) type; 3) TATEM-0; 4) ATM-1G (TATEM-G); 5) specific gravity; 6) ultimate strength (kg/cm²);7) under tension; 8) under static bending; 9) under compression; 10) impact strength (kg•cm/cm²); 11) Martens' thermostability (°C); 12) in air; 13) in inert gas; 14) thermostability; 15) thermal conductivity (kcal/m•hr•°C); 16) heat capacity (kcal/kg•°C); 17) coefficient of linear expansion; 18) specific electrical resistance (ohms•cm); 19) permeability to air of 5-mm thickness; 20) coefficient of friction without lubricant; 21) machinability; 22) response to all temperature fluctuations within thermostable range; 23) impermeable; 24) up to; 25) atm; 26) easily cut.

and impermeability unchanged, but reduces their mechanical strength.

Dissolved ATM-1 in any concentration is stable in solutions of almost all acids, ammonia, and metal salts at temperatures up to and including the boiling point; it is also stable in amyl, isopropyl, and methyl alcohol, gasoline, dichloroethane, chlorobenzene, sulfuric acid (75% to 120°), hydrogen chloride (to 105°), and sulfuric anhydride (to 120°). At 20° it is stable in 5% nitric acid, 10% mercuric nitrate, copper sulfate, 5% potassium persulfate, and acetone. It is unstable in alkalies, media containing active bromine, chlorine, or fluorine, and strong oxidizing agents. ATM-10 and ATM-1G are stable in the same media as ATM-1, although ATM-1G is more resistant to oxidizing agents and media containing active chlorine. Graphitized material containing a phenol-formaldehyde binder modified by polyvinyl chloride is alkali-stable. Antegmit is easily cut, but sharp projections must be avoided; external and internal threads (large threads) should have rounded crests and spacings. Antegmit must be cut in shallow passes with a hard-alloy tool. It is best to assemble the finished product with cold-setting cement (arzamite-4 or arzamite-5). Antegmit is used for manufacturing lined reaction apparatus, tubes, fittings, electrolytic baths, shielded-tube heat exchangers, sprinkling and combined sulfuric-acid condensers with counterflow tubes and of the "tube within a tube" type, the bearings of worm conveyors, the bearings of roller conveyors for furnaces, the precipitating electrodes of electric filters, bubblers, etc. Equipment fabricated from antegmit is cheaper than that manufactured from lead, while enameled antegmit is cheaper than Faolite.

References: Sagalayev, G.V., Antegmit i yego primeneniye [Antegmit and Its Applications], Moscow, 1959.

M.S. Krol'

ANTICORROSION COATINGS. In addition to protecting metals and alloys against corrosion, these coatings serve a number of other functions (increasing hardness and wear resistance, imparting the desired decorative qualities and color to manufactured products, improving the flow-by characteristics of aircraft components, etc.). We may distinguish metallic and nonmetallic anticorrosion coatings; the latter category also includes protective films. Metallic anticorrosion coatings can be divided into anodic and cathodic. In a given medium the electrochemical potential of anodic coatings is more negative than that of the metal to be protected. Anodic coatings consequently prevent corrosion both mechanically and electrochemically; when the coating is damaged only the coating itself and not the metal is destroyed. Zinc and cadmium are typical anodic coatings for steel (Fig. 1). The potential ratic is reversed for cathodic coatings, which cannot furnish electrochemical protection; when a cathodic coating is damaged the medium (electrolyte) destroys the exposed areas of the base metal (Fig. 2). Use of cathodic coatings is justified by their high chemical resistance, hardness, and good decorative qualities. Chromium, copper, nickel, and tin are used as cathodic coatings for steel. Coatings of this type are rarely employed for aluminum and magnesium alloys.

Before application of any coating the surface of the component is carefully cleaned by mechanical or physicochemical means: sand blasting, grinding, polishing, brushing (scratch-brushing), pickling in acids, machine washing, and degreasing with alkalies and organic solvents. Electromechanically excited ultrasound has recently come into use for

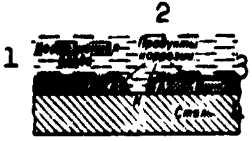

Fig. 1. Anodic coating (corrosion diagram): A) Anode; K) cathode. 1) Corrosive medium; 2) corrosion products; 3) zinc; 4) steel.

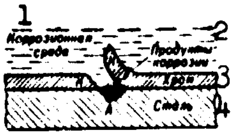

Fig. 2. Cathodic coating (corrosion diagram): A) Anode; K) cathode. 1) Corrosive medium; 2) corrosion products; 3) chromium; 4) alloy.

surface-cleaning small components; this technique provides better cleaning and is more economical than other methods. Metallic anticorrosion coatings can be applied in various ways. The hot method is based on immersion of pickled components in molten protective metal (Sn, Zn, Al), which wets the workpiece and, after the excess has drained off, crystallizes on the surface in a thin layer. This method is most widely employed for depositing hermetic layers, for tin-plating and zinc-plating steel sheets, wires, or welded assemblies, and for protecting components against gas corrosion, as in the deposition of molten stellite or nichrome on the valve faces of internal-combustion engines.

The most common galvonic method is based on liberation of metal from an electrolyte under the action of an electric current. The production of thin coatings, including anticorrosion coatings (usually no more than 50 μ thick), is called electroplating. The workpiece serves as the cathode and a plate of the protective metal as the anode. Acid or cyanide baths containing salts of the appropriate metals are usually used as the electrolyte. The advantages of this technique include high coating quality, retention of the structure and properties of the base metal as a result of the fact that no heating is involved, and ease of process control, which is effected by varying the electrolyte composition, the temperature, and the current density; the thickness of the plating layer is determined by the metal-deposition time. The mechanical properties of the workpiece sometimes deteriorate as a result of application of a galvonic coating: plasticity at elevated temperatures, fatigue strength, and impact strength are reduced. Automatic and semi-automatic devices are widely employed for zinc-, cadmium-, chromium-, nickel-, copper-, and tin-plating, as well as for application of rare or precious metals (Ag, Au, Pt, Rh, Pd, In, etc.). Galvonic application of alloys is also possible (bronze- and brass-plating, etc.). The thickness of galvonic coatings varies over a wide range, depending on their composition and structure and the operational conditions. For example, zinc and cadmium coatings are 35-50 μ thick for severe conditions and no more than 10 μ thick for mild conditions. Gold, rhodium, and indium coatings rarely exceed 0.5-1 μ in thickness.

The protective properties of anticorrosion coatings are determined by their thickness, their behavior with respect to the corrosive medium in question, and their physicochemical properties. Zinc coatings furnish good protection under atmospheric corrosion conditions. Cadmium provides better protection against salt water. Nickel coatings are resistant to air, certain weak acids, alkalies, and fuel-combustion products. Chromium coatings are highly resistant to moist air, nitric and certain organic acids, alkalies, many salt solutions, hydrogen sulfide, etc. However, since they are often porous and are cathodic with respect to steel, chromium coatings give reliable protection only when the steel has an undercoat of copper and nickel. Use of multilayer coatings is also recommended if the metal of the anticorrosion coating adheres poorly to the base metal or alloy. Lead coatings have a high resistance to sulfuric acid and sulfur-containing gases. Tin coatings have a high chemical resistance; the corrosion products of this metal are harmless to the human body and it is consequently widely employed for plating purposes in the foodstuffs industry. Gold and platinum coatings are extremely stable and break down only in a mixture of hydrochloric and nitric acids (aqua regia). Copper coatings are often used as underlayers in nickel-, chromium-, gold-, and silver-plating. The table gives examples of the use of galvonic coatings. The contact method for application of anticorrosion coatings is based on deposition without an electric current, as a result of displacement of metals from solutions of their salts. This technique is used to produce coatings of tin on brass and steel, of gold on silver, and of copper, nickel, and silver on steel. They are most frequently decorative, being very thin and having low protective characteristics. Among the methods for liberating the protective metal from solution is chemical nickel-plating, which is based on reduction of nickel salts by hypophosphite. The principal advantage of this method is the fact that it permits deposition of a protective layer of uniform thickness on components with complex surfaces. Anticorrosion coatings of high-melting metals (tantalum, niobium, etc.) can also be obtained by decomposition of their volatile haloid salts by thermal dissociation or reduction with hydrogen.

Dispersion metallization (the Schoope process) is carried out with a special metallizer, a "pistol" (Fig. 3), which disperses the molten protective metal by means of compressed air; the metal is melted with an electric arc or oxyacetylene flame or by induction heating. This technique permits rapid covering of large surfaces with protective metal after assembly has been completed. However, the protective layer obtained is of low density and strength and not completely uniform. Only anodic coatings (e.g., zinc, cadmium, or aluminum on steel) are applied by the dispersion method for corrosion protection. Coatings of

Galvonic Anticorrosion Coatings (recommended applications)

Protective Metal	Corrosive Medium	Typical Types of Products Protected and Purpose of Coating
Zinc	Air, fresh water at temperatures of up to 70°, closed rooms with moderate humidity contaminated with sulfur-containing gases and combustion products, gasoline, kerosene;	Steel sheets, strips, and wire, components of machinery and mechanisms, tubing, tables, braces, standards, fasteners (bolts, nuts, rivets, screws), food containers, threaded components with precise tolerances
Cadmium	Moist sea air, salt water, hot fresh water, chloride-containing solutions	Components and mechanisms (primarily for marine aviation and ship-building), high-stress steel aviation components, standards, springs, electrical contacts, fasteners and threaded components with precise tolerances for tight assembly
Nickel	Air, closed rooms with moderate humidity	Usually with a copper underlayer for protective-decorative coatings on chemical-apparatus components, medical instruments, terminals to which copper or aluminum leads are to be attached, bronze springs, membranes, gears, components with precise tolerances, fasteners
Chromium	Moist air, hot oxidizing gaseous media	Often with an underlayer of copper and nickel or nickel for protective-decorative coatings on fittings for railway rolling stock, trolley cars, trolley buses, and omnibuses, automobile parts, precision instruments, medical instruments, widely used everyday products, components which must function under friction, gun barrels
Tin	Weakly acid media, foodstuffs	Iron sheets (manufacture of tin plate), components of instruments and radio equipment which are to be soldered, contacts, components with precise tolerances, storage containers, food containers, pots, copper cable (for protection against the action of sulfur during vulcanization)
Lead	Sulfuric acid, air containing sulfurous gases	Tubing, vessels for sulfuric acid, baths, storage batteries

Protective Metal	Corrosive Medium	Typical Types of Products Protected and Purpose of Coating
Copper	Rarely used as an independent anticorrosion coating, generally employed as an underlayer for nickel-, chromium-, gold-, and silver-plating and for subsequent oxidation or chemical staining	
Silver	Moist air, alkaline media, hydrochloride solutions	Chemical apparatus, electronic and radio components, contacts, reflecting devices (mirrors, projectors, reflectors, headlights)
Gold, platinum	Air, aggressive chemical media	Chemical vessels, watch components, components of precision measuring instruments
Antimony	Salt water, moist sea air	Substitute for cadmium coatings
Indium	Organic acids formed during oxidation of lubricants	Bushings of lead-bronze bearings
Rhodium	Air containing sulfurous gases	Protection of silver coatings against tarnishing

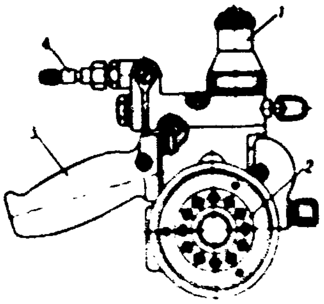

Fig. 3. Gas metallizer: 1) Dispersion head; 2) compressed-air turbine; 3) handle; 4) connecting tube for compressed-air supply.

nickel, lead, tin, copper, bronze, and stainless steel are used primarily for decorative purposes.

A new method has recently been developed for applying protective coatings with a plasma disperser (Fig. 4). A flare is produced in the plasma burner by the interaction of the plasma gas (e.g., a mixture of hydrogen with 5-10% nitrogen) with the electric arc, this resulting in

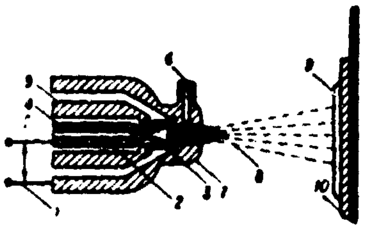

Fig. 4. Plasma disperser (diagrammatic): 1) dc power supply; 2) electrode; 3) arc; 4) plasma; 5) coolant; 6) powder suspended in through-flowing gas; 7) nozzle; 8) gas stream; 9) dispersed material; 10) workpiece.

dissociation and ionization of the gas; the temperature reaches ~17,000°. Nitrogen containing dispersed metal is forced through the plasma-flame zone; the resultant gas stream is directed at the workpiece, where a protective layer is deposited. Plasma anticorrosion coatings have a lower porosity, higher strength, and lower oxide content than coatings produced by the usual dispersion method. This technique is employed for applying high-melting metals (niobium, tantalum), high-hot-strength zirconium and hafnium borides, vanadium carbide, etc. The thermal-diffusion method is based on diffusion of the protective metal into the surface of the workpiece, heating the latter. Vaporized metal is used for this purpose in some cases and volatile compounds of the metal in question are used in others. The diffusion layer is 0.02-0.1 mm thick. Diffusion metallization with vaporized zinc (sherardization) is carried out in closed rotating drums containing nuts, bolts, washers, hardware, and zinc turnings. A thin zinc-enriched diffusion layer is formed on heating.

Gaseous chrome-plating, calorizing (aluminum-plating), and silicon-coating* of steel, etc., are based on the reaction of appropriate haloid compounds ($CrCl_2$, $AlCl_3$, $SiCl_4$) with iron at high temperatures to form active atoms of the elements in question (Cr, Al, and Si), which diffuse into the workpiece. These methods are used primarily to increase the hot strength of alloys, i.e., to raise their resistance to gaseous corrosion by formation of high-quality protective films on oxidation. Silicon coating can be employed to increase the hot strength of high-melting molybdenum-based alloys. One drawback of the diffusion method is the fact that brittle metallic compounds, such as FeZn, $FeAl_3$, and FeCr [FeCr (σ-phase) is formed principally during chromium diffusion-plating of austenitic chrome-nickel steels] are formed in the intermediate zones, reducing the resistance of the protective layer to dynamic stresses. The thermodiffusion methods also include anticorrosion nitrogen-coating of steel components, which is effected by heating them in an ammonia atmosphere (at 650° for 3 hr). The nitrogen-enriched layer thus formed is distinguished by high hardness and corrosion resistance in water; this method is recommended for components which must function both in corrosive medium and under friction, e.g., for water-pump shafts.

The thermomechanical method consists in welding a layer of protective metal to the workpiece during hot rolling and is employed for sheets and wire. For example, this method is used to produce duralumin sheets plated on both sides with pure aluminum; the plating layer on each side amounts to 2-5% of the thickness of the base sheet. Plating of duralumin is widely utilized in aircraft construction; it is an example of anodic coating and is a very effective means of increasing the corrosion resistance of duralumin in active aqueous media and under atmospheric conditions. This technique is also employed to produce bimetallic products, such as iron sheets plated with stainless steel, copper, or brass, and for corrosion protection of cartridge cases.

Nonmetallic anticorrosion coatings include lacquers and paints, plastics, rubber, bitumen, and oxide and salt film. Temporary corrosion protection is provided by anticorrosion greases. Lacquers and paints are the most widely employed coatings, being simple to apply, long-acting, easily renewed, and economical. They can be divided into three categories: primers, fillers, and paints (enamels) and finish lacquers. Plastic anticorrosion coatings include polyethylene, fluoroplasts, viniplasts, nylon, and materials based on phenol-aldehyde (bakelite) and epoxy resins. They are highly water- and acid-resistant and are used for lining various types of containers and galvonic baths, for shielding electrical leads, cables, etc., and, primarily, in the chemical industry. Faolite, which is highly plastic and easily formed or rolled into sheets, is very widely used. Fluidization, in which suspended plastic particles are deposited on the workpiece in a bath under the action of a stream of compressed air, is commonly employed. Certain plastics can also be applied in a pseudcannealed layer by eddy sintering. Bitumen or asphalt is used for corrosion protection of subterranean installations, principally piping. These materials are applied in the molten state; in order to prevent slippage the coated pipes are wrapped in strips of cloth or paper. Rubber-based composites make good anticorrosion coatings (rubberizing). Rubberizing and coating with chlorinated rubber provide effective protection against the action of acids and other chemical reagents.

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B.K. Vul'f

ANTIFRICTION CAST IRON – is a wear-resistant cast iron capable of running in, by friction on metal (see Wear-resistant cast iron). Antifriction cast iron is used in the construction of bearings and other friction joints. The high specific properties of the antifriction cast iron are determined first of all by its microstructure, the pearlite – ferrite ratio in the metal base, and also by the quantity and size of the graphite inclusions. The microstructure of the antifriction iron depends on the chemical composition and the heat treatment. The great majority of antifriction iron grades are low-alloy and non-alloy iron grades. Copper-bearing or high-alloy antifriction iron with an austenite base is used in some cases.

TABLE 1

Chemical Composition of Non-Alloyed Antifriction Cast Iron (GOST 1585-57)

1 Группа	2 Марка	3 Содержание элементов (%)									
		C	Si	Mn	P	S	Cr	Ni	Ti	Cu	Mg
Серые 4	5 АСЧ-1	3,2—3,6	1,6—2,4	0,6—0,9	0,15—0,20	<0,12	0,2—0,35	0,2—0,4	—	<0,7	—
	АСЧ-2	3,2—3,8	1,4—2,2	0,4—0,7	0,15—0,40	<0,12	0,2—0,4	0,2—0,4	0,1	0,3—0,5	—
	АСЧ-3	3,2—3,8	1,7—2,6	0,4—0,7	0,15—0,40	<0,12	≤0,3	≤0,3	0,1	0,3—0,5	—
Высокопрочные 6	7 АВЧ-1	2,8—3,5	1,8—2,5	0,5—1,2	≤0,2	<0,03	—	—	—	≤0,7	0,03
	АВЧ-2	2,8—3,5	2,2—2,7	0,5—0,8	≤0,2	<0,03	—	—	—	—	0,03
Ковкие 8	9 АКЧ-1 АКЧ-2	2,6—3,0	0,8—1,3	0,3—0,6	≤0,15	<0,12	<0,06	—	-	—	—

1) Group; 2) grade; 3) percentage of elements; 4) gray; 5) ASCH-; 6) high-strength; 7) AVCH-; 8) malleable; 9) AKCh-.

TABLE 2

Chemical Composition of Copper-Bearing Antifriction Iron (AMTU 294-58)

Чугун 1	2 Содержание элементов (%)						
	C	Si	Mn	P	S	Cr	Cu
				не более			
4 Ковкий ЧМ-1,3	2,3—3,0	0,5—1,1	0,6—1,2	0,2	0,08	<0,15	1,0—1,5
5 Серый ЧМ-1,8	2,8—3,6	1,3—1,9	0,6—0,9	0,3	0,10	0,2—0,4	1,5—2,0

1) Cast iron; 2) percentage of the elements; 3) not more than; 4) malleable ChM-; 5) gray ChM-.

TABLE 3

The Limits of Working Conditions for Antifriction Iron Parts

Чугун 1	HB (кг/мм²) 2	Состояние вала 3	Уд. давление p (кг/см²) 4	Скорость скольжения v (м/сек) 5	p·v (кгм/см²·сек) 6
АСЧ-1	180—229	Термически обработанный 11	0,5—90	2,0—0,2	1—18
7 АСЧ-2	190—229	То же 12	1—60	3,0—0,75	3—45
АСЧ-3	160—190	Сырой 13	1—60	3,0—0,75	3—45
АВЧ-1	210—260	Термически обработанный	5—120	5—1	25—120
8 АВЧ-2	167—197	Сырой	—	—	—
АКЧ-1	197—217	Термически обработанный	5—120	5—1	25—120
9 АКЧ-2	167—197	Сырой	—	—	—
10 ЧМ-1,3	187—262	Термически обработанный	до 200	до 1	до 200
ЧМ-1,8	207—262	То же	до 5	до 25	до 125

1) Cast iron; 2) kg/mm²; 3) condition of the shaft; 4) specific pressure p(kg/cm²); 5) sliding rate v(m/sec); 6) p•v (kgm/cm²•sec); 7) ASCH-; 8) AVCH-; 9) AKCh-; 10) ChM-; 11) heat treated; 12) the same; 13) raw.

Exact junction of the friction surfaces of the parts, absence of bending, continuous high-quality lubrication, and clearancces increased by 15-30% in comparison to the standards for bronze (an increase by 50% of the clearances is necessary when the bearing is considerably heated) are necessary to obtain reliable service with antifriction iron. Moreover, the friction surfaces must have a sufficient roughness in order to improve the run in. The run in is carricd out in idle state with a gradually increasing working load. The run in is improved by a preliminary pickling of the finished antifriction iron parts in a 10% solution of nitric acid for 1-1.5 minutes and a subsequent impregnation in hot spindle oil for 15-20 min. This treatment not only increases the micro-roughness of the friction surfaces (0.25-0.8 micron), but prevents the formation of cold-hardened or seized spots during the run-in process, and due to the continuous oil film increases the wear-resistance by eliminating the contact between themetal surfaces in friction. The following groups of antifriction iron are distinguished: gray, high-strength (magnesium-alloy), malleable, and austenitic cast iron. The chemical composition of nonalloyed cast iron grades for castings utilized in bearing units is listed in Table 1, that of the copper-bearing cast iron (according to AMTU 294-58) is quoted in Table 2. Austenitic cast iron of the ZhChNDKh15-7-2 grade, alloyed with nickel (15%), copper (8%), and chromium (2%), and other cast irons of this type, belonging to the corrosion-resistant and heat-resistant cast irons of the Ni-Resist type (see Corrosion-resistant cast iron and Heat-resistant cast iron), are used for parts which work at higher temperatures under wearing and corrosive conditions, e.g., for sleeves of fuel pumps, distributor valves, etc.

Antifriction iron parts used for service in combination with hardened or normalized shafts (Table 3) must be made of a pearlitic antifriction iron of the ASCh-1, ASCh-2, AVCh-1, and ChM-1,8 grades, which contain in the visual field of a polished section at least 85% pearlite, and the AKCh-2 and ChM-1,3 grades containing 100% pearlite; parts used for service with non-heat-treated (raw) shafts must be made of a pearlite-ferritic antifriction iron of the grades ASCh-3 (more than 60% pearlite), AVCh-2 (more than 50% pearlite), and AKCh-2 (35-80% pearlite). The AKCh-2 grade may be a ferrite-pearlitic or a pearlite-ferritic iron, depending on its pearlite content.

The austenitic cast iron of the ZhChNDKh15-7-2 grade may work at sliding speeds of up to 20 m/sec and at specific pressures of up to 25 kg/cm^2.

Gray, high-strength, and malleable antifriction iron is used in the manufacture of parts of tool-machines and forging equipment, in automobile and tractor building, in agricultural machine building, and in other branches.

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A.A. Simkin

Manuscript Page No.	[Transliterated Symbols]
267	АСЧ = ASCh = antifriktsionnyy seryy chugun = antifriction gray iron
267	АВЧ = AVCh = antifriktsionnyy vysokorpochynny chugun = high-strength antifriction cast iron
267	АКЧ = AKCh = antifriktsionnyy kovkiy chugun = malleable antifriction cast iron
268	ЧМ = ChM = chugun medistyy = copper-bearing cast iron
269	АМТУ = AMTU = aviatsionno-metallurgicheskoye tekhnicheskoye usloviye = Aviation-Metallurgical Technical Specification

I-73a

ANTIFRICTION CERMETS -- cermets with high durability and a low coefficient of friction. They are produced by powder metallurgy as bushings and bearings of two types, monometallic and bimetallic. Monometallic products are fabricated entirely from cermets and include bronze-graphite and ferrographite. Bimetallic products consist of a steel base to which a cermet layer is applied; a variant consists in applying a layer of 60% copper and 40% nickel and another, working layer of 6% tin, 6% antimony, and 88% lead to a steel base. The middle layer is applied by powder metallurgy and the working layer by impregnation.

The antifriction cermet employed in bimetallic bearings consists of lead bronze

TABLE 1

Properties of Lead Bronze

Свойства 1	2 Показатели свойств
Плотность (г/см³) . . 3 .	8.4—8.6
HB (кг/мм²) . . 4	25—28 или 12—15
δ (%)	3.5
α·10⁶ в интервале 20—100° (1/°C) . . 5 . . .	12—14
Коэфф. трения по стали со смазкой . . 6 . . .	0.005

1) Property; 2) value; 3) density (g/cm3); 4) HB (kg/mm^2); 5) $\alpha \cdot 10^6$ over the range 20–100° (1/°C); 6) coefficient of friction over lubricated steel; 7) or.

TABLE 2

Applications of Antifriction Cermets

Вид изделий 1	2 Область применения
Вкладыши биметаллич из свинцовистой бронзы 3	5 Автомобилестроение — подшипники коленчатого вала, станкостроение—крупные подшипники
Вкладыши трехслойные 4	6 Автомобилестроение — подшипники коленчатого вала форсированных автомобильных двигателей, упорные шайбы

1) Type of product; 2) applications; 3) bimetallic lead-bronze bearings; 4) three-layer bearings; 5) automobile construction (crankshaft bearings), machine building (large bearings); 6) automobile construction

(crankshaft bearings for fuel-injection engines, thrust collars).

containing 70-72% copper and 28-30% lead.

Three-layer bearings with a cermet underlayer have a fatigue strength 2-3 times that of bimetallic bearings of lead bronze. The permissible loading reaches 150 kg/cm^2.

For applications of other antifriction cermets see Bronze graphite.

References: Rakovskiy, V.S., and Saklinsky, V.V., Metallokeramika v mashinostroyenii [Cermets in Machine Building], Moscow, 1956; Saklinskiy, V.V., Tekhniko-ekonomicheskaya effektivnost' tekhnologii poroshkovoy metallurgii, "Vestn. mashinostroyeniya," [Technical-Economic Efficiency of Powder-Metallurgy Technology, [Herald of Machine Building], 1961, No. 6; Saklinskiy, V.V., Khazov, V.A., Izgotovleniye trimetallicheskoy lencheskoy linii, [Manufacture of Trimetallic Sheets for Bearing Linings on Automatic Production Lines, Moscow, 1960 (TsITEIN. Peredovoy nauch.-tekhn. i proizv. opyt [Advanced Scientific-Technical and Production Experience], No. M 60-296/13. Report 3, No. 13).

V.V. Saklinskiy

ANTIFRICTION MATERIALS – materials usually employed for sliding bearings, bushings, and similar components, which generally function under friction against metal, primarily in the presence of lubricants, and ensure low friction, i.e., have antifriction properties or are antifrictional. A low coefficient of friction depends on the combined properties of the contact surfaces of the two components. The presence or absence of lubricants and their properties, the conditions at the friction surface (kinematic, force, temperature), the quality of the surface finish, and other factors. In addition to antifriction properties, the requirements usually imposed on components which must function under friction include mechanical strength, durability, corrosion resistance in a given medium, workability, etc. It is often impossible to find a material which simultaneously satisfies these different, sometimes contradictory requirements and two or more materials with different properties are consequently combined in a single component, such as bimetallic bushings with a steel base and a working layer of an antifriction plastic, bearings of porous hard bronze with a filler of polytetrafluorethylene (referred to by the technical designation fluoroplast-4 in the USSR and as teflon in England and the United States), a material which provides low friction without lubricants, cast-iron piston rings with a thin working layer of tin, etc.

One phenomenon which causes high friction between metals in direct contact (with the surfaces absolutely clean and with no oil films, oxides, or contaminants), grabbing, involves formation of simple metallic bonds where projecting irregularities come into contact; grabbing is responsible for the sticking of contact surfaces in friction which results in damage. Lack of grabbing is one of the most important indications of antifriction properties in a given combination of materials. The principal method for reducing friction and eliminating wear (including its most dangerous manifestation, grabbing) in machinery is the use of lubricants, completely separating the contact surfaces with the liquid film formed during hydrodynamic lubrication or with a boundary film of the lubricant. The properties of these materials which promote formation or maintenance of the lubricant film between the contact surfaces are among those responsible for antifriction characteristics. In cases where a lubricant cannot be used to separate the friction surfaces and a load is applied (partially or completely) between them, i.e., in metallic contact, grabbing and sticking of steel components are avoided by giving them antifriction properties through superficial chemical heat treatment (nitriding, sulfiding, parkerizing, oxidation) and, in some cases, by application of metallic coatings (brass-plating, etc.). A similar function is served by lubricating oils containing chemically active antiscratching additives: during friction surface treatment of the steel occurs when the surface temperature rises to the initiation temperature of the chemical reaction between the additive and iron. Antifriction properties can also be imparted to steel by application of solid lubricants (graphite, molybdenum disulfide, polytetrafluorethylene) to the contact surfaces. Antifriction materials include metals, which are used principally in working with lubricants (certain types of cast iron, alloys based on copper, aluminum, zinc, cadmium, tin, and lead, porous materials obtained from powdered metals by the cermet method, metallized coatings, and coatings of certain plastic metals), plastic and resinous materials for working with water as a lubricant, metal-plastic composites for working without lubricants, and graphite-based composites for working without lubricants. The majority of these materials are employed for sliding bearings (see Bearing materials).

M.M. Krushchov

ANTIFRICTION PLASTICS – textolite, laminar ligneous plastics, polyamides (caprone, anid), fluoroplast-4, and other plastics used in machine components subjected to friction. These materials are used for bearings, guides, bushings, sleeves, etc. The advantages of bearings of antifriction plastic include high fatigue strength, absorption of impact and vibration, and little damage to the contact surfaces in imperfect friction. Their drawbacks include less precise mechanism operation (variation in shaft-axis position) as a result of the fact that antifriction plastics are less rigid than metals, the necessity of running-in a bearing before it will regain its original dimensions after the load is removed, and the change in bearing dimensions as a result of absorption of moisture.

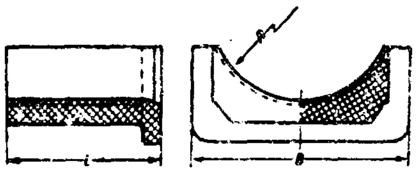

Fig. 1. Single-piece extruded bearing.

Textolite bushings and bearings are used in various branches of machine building and tool making; textolite 2 and 2B has the best antifriction properties, withstanding pressures of up to 300-350 kg/cm^2 when lubricated with water and having a maximum sliding speed of 5-8 m/sec. Textolite 3, PTK, PT, etc., is also employed. Bearings of various shapes are manufactured by hot pressing (Fig. 1). Laminar textolite, which is produced in the form of plates, is widely used for the split bearings of rolling equipment. Bearings of the laminar ligneous plastics DSP-B and DSP-V are used in water-driven turbines, naval equipment, rolling

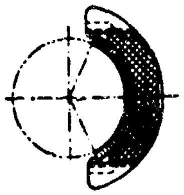

Fig. 2. Longitudinally-assembled plastic bearing.

stands operating under light and moderate regimes, the closing mechanisms of locks and floodgates, hydraulic pumps, etc.; these materials can withstand pressures of up to 200 kg/cm^2 when lubricated with water and of up to 20-40 kg/cm^2 when heavy lubricants are used. Bushings or bearings of textolite or DSP are assembled from individual elements (Figs. 2 and 3). In designing bearings of ligneous plastics assembly should be "face-wise," the veneer layer lying perpendicular to the shaft cross-section. The elements of split bearings fabricated from trapezoidal bars of DSP are used only with their layers arrayed radially. The lateral surfaces are machined in such fashion that the bars can be placed in polygonal tubes (Fig. 4). The coefficient of friction of textolite and DSP is 0.002-0.015 when water serves as the lubricant and 0.03-0.1 when a mineral lubricant is used. The quantity of water needed to lubricate a bearing is 0.05-0.75 liters/cm^2 per min, depending on working conditions.


Fig. 3. Transversely-assembled plastic bearing.

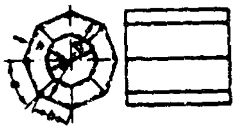
Fig. 4. Assembly of bars to produce bushing.

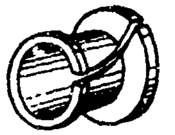
Fig. 5. Nylon bushing with compensating slit and flange.

Caprone (polycaprolactam) bearings with wall thickness of 1.5 mm or less function reliably at pressures of up to 80-120 kg/cm^2, speeds of up to 3.5 m/sec, and temperatures of no more than 100-120°. Caprone (nylon) bushings with narrow slits (Fig. 5) to compensate for changes in size resulting from variations in temperature and humidity are also employed. Low-viscosity mineral oil is used as a lubricant. The pressure on bearings fabricated from other polyamides should be reduced when lubricating with water. Caprone bearings can function at pressures of up to 5 kg/cm^2 under dry friction; the Brinell hardness of caprone is 10 kg/mm^2. The surface hardness of caprone bearings is roughly halved by heating. The coefficient of friction against steel is 0.17-0.20 without lubricants, 0.014-0.020 with lubricating oil, and 0.02-0.05 with water. The gaps in caprone and other plastic bearings should be somewhat larger than those in metal bearings; the relative clearance should be approximately 0.003-0.006.

Bearings fabricated wholly from plastic deform under stress, swell in water, and have a low thermal conductivity. These drawbacks can be eliminated or somewhat reduced by lining the bearings with a thin layer of plastic (caprone, polyamide P-68, finely cut cloth, etc.). Lining methods include eddy deposition of films, pressure casting (for finely cut cloth and wood), cementing of a plastic film to the surface of the metal, etc. The most productive method is eddy deposition (immersion of a metallic component heated to a temperature above the melting point of the plastic in powdered plastic agitated by a stream of air); the plastic layer is easily renewed by relining. In pressure casting the lining material is finely cut thin cloth impregnated with bakelite lacquer. Longitudinal and transverse channels are made on the inner surface of the bearing for attachment of the lining, which is 2.5-6 mm thick. Bearings lined with finely cut textolite are used under loads of up to 300 kg/cm^2 in rolling and hydraulic equipment lubricated by water. Bearings coated with polyamide and polyurethane films (0.1-0.5 mm thick) are used at pressures of up to 200 kg/cm^2 and are oil-lubricated. Bearings of fluoroplast-4 (teflon) have a very low coefficient of dry friction (0.04-0.06) and can be used without lubricants or with limited lubrication at pressures of up to 4-5 kg/cm^2; this material is deformed at high pressures. The high antifriction and anticorrosion properties and frost- and heat-resistance (maximum working temperature – +250°) of fluoroplast-4 porous bearings are fabricated from fluoroplast impregnated bronze; such bearings can withstand pressures of 30–50 kg/cm^2 or more. Bearings can be fabricated from teflon and fiberglass (the fiberglass serves as a base and prevents material deformation of the teflon); there are also three-layer bearings based on porous pin bronze impregnated with a mixture of teflon and lead. According to the data available, such bearings can be used at pressures of up to 280 kg/cm^2 and temperatures of up to 200–280°. In addition to sliding bearings, antifriction plastics are used in friction guides for various machine tools and mechanisms (textolite has been found to give the best results). Roller bearings fabricated wholly or partly from plastics (plastic rollers and metal rings or vice versa) are used at low speeds (up to 2 m/sec).

References: Al'shits, I.Ya. Verzhbitskiy, N.F., Zomer, E.F., Opory skol'zheniye, [Sliding Bearings], Kiev–Moscow, 1958; Platonov, V.F., Podshipniki iz poliamidov [Polyamide Bearings], Moscow, 1961.

I.Ya. Al'shits

ANTIMONY BRONZE – bronze in which the picture alloying element is antimony.

Chemical Composition of Antimony Bronzes

Сплав 1	2 Содержание основных элементов (%)					
	Sb	P	Ni	Zn	Pb	Cu
3 БрСуФ 6-1	4,7—6,2	0,4—0,9	—	—	—	8 Остальное
БрСуСФ 6-12-0,3 4	4,5—6,0	0,1—0,3	—	—	10—14	То же
5 БрСуН 6-2	5,2—6,3	—	2—3	—	—	9 »
БрСуНЦСФ 3,5-3,5-3,5-20-0,2 6	3—4	0,15—0,3	3—4	3—4	18—22	»
7 БрСуН 7-2,5	7	—	2	—	—	»

1) Alloy; 2) content of basic elements (%); 3) BrSuF 6-1; 4) BrSuSF 6-12-0.3; 5) BrSuN 6-2; 6) BrSuNTsSF 3.5-3.5-3.5-20-0.2; 7) BrSuN 7-2.5; 8) remainder; 9) the same.

The phase diagram of antimony bronze resembles that of copper-tin alloys. The greatest solubility of antimony in copper at the eutectic temperature (645°) amounts to 10.4%. As the temperature is reduced the solid-solution region becomes narrower and the antimony content amounts to ~4% at 250° (2.6% on later investigation). Antimony bronze has a broad crystallization range, is not greatly oxidized during casting, fills the mold well, and has a low linear shrinkage and a weak tendency (especially tin bronzes) toward dispersed shrinkage porosity. Antimony casting bronzes alloyed with phosphorous, lead, nickel, and zinc have good mechanical and very good antifriction characteristics. Antimony bronze is a fully satisfactory substitute for tin bronzes in critical friction components (see Casting bronze). The table shows the chemical composition of antimony bronzes.

References: Mal'tsev, M.V., Diagramma sostoyaniya i prevrashcheniya pri raspade -tverdogo rastvora v sisteme med'-sur'ma [Phase Diagram of

III-148s1

Copper-Antimony System and Transformations During Decomposition of the -solid solution], in book: Struktura i lit'ye splavov tsvetnykh metallov [Structure and Casting of Nonferrous Alloys, Moscow, 1945; Antifriktsionnyye splavy [Antifriction Alloys], Moscow, 1956.

O.Ye. Yestner

AQUAMARINE – see Beryllium.

ARALAK – see Protein fiber.

ARBITRARY YIELD STRENGTH – the stress at which the residual deformation reaches a definite predetermined value. In determining this factor the most common tolerance for residual elongation (on extension and bending) or shrinkage (on compression) is 0.2% of the calculated specimen length; when this tolerance is used for the change in linear dimensions the residual shear amounts to 0.3%. As a rule, the arbitrary torsional yield strength is consequently determined with a residual shear tolerance of 0.3%.

Arbitrary Tensile, Compressive, Warping, and Bending Yield Strengths for Certain Structural Materials

Материал 1	2 Состояние материала	3 Пределы текучести (кг/мм²) при:			
		4 растяжении ($\sigma_{0,2}$)	5 сжатии ($\sigma_{0,2сж}$)	6 смятии ($\sigma_{0,2\,см}$)	7 изгибе ($\sigma_{0,2изг}$)
8 Сталь 30ХГСА	17 Закаленный и отпущенный при 500°	105	106	—	134
	18 Закаленный и отпущенный при 200°	125	140	—	160
9 Алюминиевые сплавы:					
10 Д16	19 Естественно состаренный	30	32	35	—
11 В95	20 Искусственно состаренный	44	47	54	—
12 В96	20 Искусственно состаренный	65	70	—	90
13 Титановые сплавы: ВТ1	Отожженный 21	40	42	—	—
14 ВТ5	Отожженный 21	69	75	90	96
15 Магниевые сплавы:					
МА2	В состоянии поставки 22	16	11	—	20
МА8	Отожженный 21	15	11	14	—
16 ВМ65-1	Искусственно состаренный 20	25	19	—	—

1) Material; 2) state of material; 3) yield strength (kg/mm^2) on; 4) extension ($\sigma_{0.2}$); 5) compression ($\sigma_{0.2szh}$); 6) warping ($\sigma_{0.2sm}$); 7) bending ($\sigma_{0.21zg}$); 8) 30 KhGSA steel; 9) aluminum alloys; 10) D16; 11) V95; 12) V96; 13) titanium alloys: VT1; 14) VT5; 15) magnesium alloys; 16) VM65-1; 17) quenched and tempered at 500°; 18) quenched and tempered at 200°; 19) naturally aged; 20) artifically aged; 21) annealed; 22) as-delivered.

In some cases the arbitrary yield strength is determined with a higher residual-deformation tolerance (0.3, 0.5, 1.0%, etc.). The magnitude of the tolerance is indicated by the subscript on the letter designating the yield strength, e.g., $\sigma_{0.2}$, $\sigma_{0.5}$, $\sigma_{0.3}$, etc.

The arbitrary tensile, compressive, warping, bending, and torsional yield strengths are calculated from the following formulas:

$$\sigma_{0,2}=P_{0,2}/F_0;\ \sigma_{0,2\text{сж}}=P_{0,2\text{сж}}/F_0;$$
$$\sigma_{0,2\ \text{см}}=P_{0,2\ \text{см}}/da;$$
$$\sigma_{0,2\ \text{изг}}=M_{0,2\text{изг}}/W\ \text{and}\ \tau_{0,3}=M_{0,3\text{кр}}/W,$$

where $P_{0.2}$ and $M_{0.2izg}$ are respectively the axial load (in kg) and the bending moment (in kg-cm or kg-mm) at which the residual elongation reaches 0.2%, $M_{0.3kr}$ is the torsional moment (in kg-cm or kg-mm) at which the residual shear reaches 0.3%, F_0 is the cross-sectional area of the specimen in mm^2 or cm^2, d is the aperture diameter in mm or cm, a is the specimen thickness in warping tests in mm or cm, and W is the moment of resistance in mm^3 or cm^3.

For low- and medium-strength structural steels (after annealing, normalization, and high tempering) and many aluminum and titanium alloys the arbitrary tensile and compressive yield strengths are virtually identical (Table). In high-strength steels the compressive yield strength is generally 10-15% higher than the tensile yield strength. The arbitrary compressive yield strength of magnesium alloys is usually lower than their tensile yield strenth. The arbitrary warping yield strength of steels and aluminum and titanium alloys is 10-25% higher than their tensile or compressive yield strength, while that of magnesium alloys is higher than their compressive yield strength and somewhat lower than their tensile yield strength. The majority of structural materials have an arbitrary bending yield strength 25-40% higher than their tensile yield strength. This is due to the fact that the bending yield strength is calculated on the basis of an elastic stress distribution over the specimen cross section and not on the basis of the actual curve showing the hardening of the material in the elastic-plastic region (see Specific strength).

S.I. Kishkin-Ratner

II-119G

ARC RESISTANCE (spark resistance) - ability of a material to resist erosion which takes place under the action of electrothermal and electric processes. The arc discharge has a plasma temperature of 7000°, is distinguished by a continuous thermal effect on the material. Hence the arc resistance of a material depends primarily on its melting temperature. As opposed to an arc, a spark discharge has a higher temperature, of the order of 10,000°K, is distinguished by a short-duration thermal effect on the material, nonuniform distribution of heat supplied to thematerial, overheating and melting of individual sections of the material. Hence the spark resistance of a material depends not only on the melting temperature, but also on the specific heat, heat transfer coefficient, the materials, structure, the force created by the electron motion, on the shock wave; the electrode polarity, etc. For the regime: discharge energy 0.125 joules, discharge voltage U_r = 30 volts current amplitude I_a = 250 amps, medium - diesel oil, the approximate values of the electric spark resistance of various materials relative to the resistance of steel which is taken as unity, comprise: 6.0 for magnesium, 4.0 for aluminum, 1.6 for brass, 1.1 for copper, 1.0 for steel, 0.8 for nickel, 0.6 for titanium, 0.5 for molybdenum and 0.3 for tungsten.

References: Stall, D.R., Tablitsy davleniya parov individual'nykh veshchestv (Tables of Vapor Pressures of Individual Substances), translated from English, Moscow, 1949; Slavinskiy, M.P., Fiziko-khimicheskiye svoystva elementov (Physicochemical Properties of Elements), Moscow, 1952; Lazarenko, B.R. and Lazarenko, N.I., Fizika iskrovogo sposoba obrabotki metallov (Physics of Spark Machining of Metals), Leningrad, 1957; Spravochnik po elektrotekhnicheskim materialam (Handbook of Electrical Engineering Materials), vol. 1, part 1, Moscow - Leningrad, 1958.

V.V. Korolev

ARDIL – see <u>Protein fiber</u>.

ARMATURE STEEL – steel for structural reinforcing units and for reinforcement of concrete structures. It is produced in hot-rolled rods with periodic shapes (with projections forming a triple thread, with two longitudinal ribs, etc.) of St5, following Group 1 of GOST 380-60. The plasticity of armature steel is tested by cold bending. It is also used in the form of cold-flattened rods of St0, St2, St3, St4, and St5 steels with periodic shapes and special hollows, following Group 1 of GOST 380-60. When better weldability is required steel with a standardized chemical composition is used (Paragraph 4, GOST 380-57). St0, St2, St3, and St4 steels should have an ultimate strength of no less than 45 kg/mm^2 and a yield strength of no less than 35 kg/mm^2; the corresponding figures for St5 steel are 60 kg/mm^2 and 50 kg/mm^2. Cold bending to 90° is carried out around a mandrel whose thickness equals three times the diameter of the rod before flattening. Hot-rolled round armature steel wire is manufactured from the Martensitic steels M09kp, M12kp,

Mechanical Properties of Armature-Steel Wire

1 Диаметр проволоки (мм)	2 σ_b (кг/мм², не менее)	3 δ (%, не менее) (образцы с расчетной длиной 100 мм)	4 Перегиб на 180°	
			5 диаметр оправки (мм)	6 число перегибов (не менее)
2.5	200	2	20	10
3.0	190	2	20	8
4.0	180	3	20	6
5.0	170	3	20	4
6.0	160	3	20	3
7.0	150	3	30	3
8.0	140	4	30	3
10.0	100	4	30	2

1) Wire diameter (mm); 2) σ_b (kg/mm^2, no less than); 3) δ (%, no less than; specimens with a calculated length of 100 mm); 4) 180° bending; 5) mandrel diameter (mm); 6) number of bends (no less than).

M18kp, and M18a and the Bessemer steel B09kp. Hot-rolled bars of carbon steel are used in certain special cases, following GOST 535-58. Carbon steel wire is used for prestressed reinforced concrete structures, following GOST 7348-55 (see Table).

M.L. Bernshteyn, I.N. Kudin

ARMCO IRON – iron containing very small quantities of carbon and other elements. Its chemical composition (according to GOST 3836-47) is: $\leq 0.04\%$C, $\leq 0.20\%$, Si, $\leq 0.20\%$ Mn, $\leq 0.030\%$ S, $\leq 0.025\%$ P, $\leq 0.15\%$ Cu. Armco iron has low ultimate and yield strengths and a very high plasticity. The mechanical properties of bars (according to Ferrous Metallurgical Technical Specification 2900-56) are as follows: $\sigma_b \geq 27$ kg/mm^2, $\sigma_{0.2} = 12$ kg/mm^2, $\delta_{10} \geq 26\%$, $\psi \geq 60\%$, HB(d_{otn}) ≥ 5.2 mm. The mechanical properties of Armco iron at elevated temperatures are shown in Table 1 and its magnetic properties in Table 2.

TABLE 1

Typical Mechanical Properties of Armco Iron (bars) at Elevated Temperatures

Темп-ра (°C) 1	σ_b	$\sigma_{0,2}$	δ_{10} (%)
	2 (кг/мм²)		
20	30	20	—
300	37	25	15
500	15	14	19
650	9	5	20
800	5	4	8

1) Temperature (°C); 2) kg/mm^2.

Its physical properties are as follows: $\gamma = 7.85$ g/cm^3; $\alpha = 12.9 \times 10^{-6}$ (25-300°), $14.7 \cdot 10^{-6}$ (25-500°) 1/°C; $\lambda = 0.131$ (100°), 0.124

TABLE 2

Magnetic Properties of Armco Iron (according to GOST 3836-47, no less than)

Сталь 1	2 Коэрцитивная сила (э, не более)	3 Макс. магнитная проницаемость (гс/э)
Э 4	1.2	3500
ЭА 5	1.0	4000
ЭАА 6	0.8	4500

1) Steel; 2) coercive force (oersteds no more than); 3) maximum magnetic permeability (gausses/oersted); 4) E; 5) EA; 6) EAA.

(200°), 0.116(300°), 0.087(600°) cal/cm•sec•°C; c = 0.106 (25°), 0.124 (200°), 0.132 (300°), 0.178(600°) cal/g•°C.

Despite its high plasticity at room temperature, Armco iron may become brittle as a result of extreme ferrite-grain growth or when its oxygen content is increased; in the latter case the brittleness is accompanied by fracture along the grain boundaries. Armco iron may also be brittle at low temperatures. The cold-brittleness temperature of this metal depends principally on the size of the ferrite grains. As a result of its high plasticity Armco iron can be subjected to deep stamping, beating, and bending; it is only very slightly less susceptible to cold plastic deformation than copper and is good for all types of welding. Armco iron exhibits reduced plasticity over the temperature range 850-1150° and hot pressure working is consequently begun at 850° or at 1250-1300°. This metal is used for manufacturing various electromagnetic mechanisms requiring a low coercive force and a high magnetic induction; in many cases it is employed for deep-stamped components. Armco iron often is used as the initial material (charge) for production of alloy steel. It is expedient to employ the vacuum method in producing Armco iron for the electronics industry, since it permits a substantial reduction in power consumption.

References: Mes'kin, V.S., Osnovy legirovaniya stal; [Principles of Steel Alloying], Moscow, 1959.

ARMOR STEEL – steel used in the manufacture of armor plate to protect tanks, military ships and aircraft, engineering equipment, etc., from artillery shells, shrapnel, and small-arms fire.

Armor steel usually contains chromium (up to 2.5%), nickel (up to 3%), molybdenum (up to 0.6%), vanadium (up to 0.2%), manganese (up to 1.5%), and silicon (up to 2%); the content of carbon and specific complexes is determined by the requirements imposed on the armor plate for which it is to be used. The following factors are taken into account in selecting the composition of armor steel: 1) the thickness of the armor. As this factor increases the strength which must be imparted to the armor steel decreases. While thin armor (20 mm) must have a high ultimate strength, thick armor (200 mm) has a substantially lower ultimate strength and viscosity becomes the principal index. 2) the type of shell to which the armor will be exposed. Repulsion of armor-piercing shells impacting perpendicularly requires an armor steel which can be specially heat treated to produce a heterogeneous armor with mechanical properties that vary through the thickness of the plate: high hardness (600 HB) in the forward-facing surface layers and high strength and viscosity in the rearward layers. When the shells will impact at a large angle to the perpendicular the armor steel must combine high strength and high viscosity in a homogeneous armor plate. Protection against shrapnel and mines requires an armor steel with maximum impact strength at a given ultimate strength. 3) Production technology. Fabrication of armor-plate components from rolled sheets and plates or by casting requires an armor steel which satisfies the requirements of these production processes. The armor steel used in welded assemblages, where the armor is a load-bearing element, must exhibit satisfactory weldability after heat treatment and minimal warping after quenching and be suitable for cold-straightening after final heat treatment of the plate. Armor steel which does not satisfy these requirements can be used for suspended armor.

The armor plate used to produce heterogeneous armor with variable mechanical properties differs quite widely in composition and properties. Thus, the cementable armor steel used for this purpose has a carbon content determined by the required strength and viscosity of the base metal and the alloying necessary for hardening of armor of a given thickness and for production of a carbide zone in the forward-facing layers as dictated by the interaction of shell and armor. Armor steel with a uniform composition must have a carbon and alloying-element content such that it is possible to obtain armor with variable mechanical properties by employing the following types of heat treatment: single-sided quenching by single-sided heating (induction, gas, in salts, etc.) after preliminary heat treatment, single-sided cooling of a uniformly heated armor plate, a combination of single-sided heating and single-sided cooling, differential quenching, step-wise and isothermic quenching, and single-sided annealing. The armor steel used for laminar armor must permit casting of laminar ingots, pack rolling, and other lamination methods (see Multilayer steel).

N.M. Sklyarov

ARNEL – a triacetate fiber produced in the United States. See Triacetate fiber.

ARTIFICIAL FIBER – fibers from natural polymers (cellulose, cellulosic esters and proteins) whose macromolecules have an extended shape, and the polymers proper or their derivatives are soluble in accessible solvents. Artificial fibers include viscose, acetate, cuprammonium and protein fibers; viscose fibers are the most extensively used. They are used in the textile, tire, commercial rubber and radio engineering branches of industry.

G.G. Finger

ARTIFICIAL FIBER FROM CELLULOSE ESTERS – fibers from complex esters of cellulose and from organic (acetic) acids. See Acetate Fiber, Triacetate Fiber.

L. S. Gal'braykh

ARTIFICIAL LEATHER – see Leather-substituting Materials.

ARTIK TUFF – see Natural acid-resistant materials.

I-84a

ASBESTINE – a white, often porous rock, a variety of talc. In addition to talc, it contains an admixture (up to 25%) of short-fibered tremolite and a varying admixture of carbonates. Asbestine is used as a filler in the production of paints and papers; its fibrous particles give it an increased mechanical strength and elasticity and prevent precipitation of the pigment during prolonged storage of paints. Laboratory tests in the USSR on the use of asbestine as a filler in anti-crusting dies in the casting of nonferrous metals have yielded positive results.

References: Trebovaniya promyshlennosti k kachestvu mineral'nogo syr'ya [Industrial Specifications for Mineral Raw Materials], No. 1; Arshinov, V.V., Sokolov, P.N., Tal'k [Talc], Leningrad, 1945; Idem, 2nd Edition, No. 1; Chernosvitov, Yu.L., Tal'k and profillit [Talc and Prophyllite], Moscow, 1961.

P.P. Smolin

ASBESTOS – a mineral of the serpentine or amphibole group with a fibrous structure, called chrysotile asbestos and amphibole asbestos respectively; it splits into strong, extremely fine fibers under mechanical stress. The diameter of the elementary fiber (crystal) approximates that of the asbestos molecule, which gives us grounds for regarding asbestos as a mineral polymer. Even a highly distended fiber consists of an enormous number of elementary fibers under actual conditions. In chemical composition asbestos minerals are hydrated silicates of magnesium, iron, calcium, and sodium. The principal characteristics used in distinguishing the groups of asbestos are water content (from 13 to 14.5% in chrysotile asbestos and from 1.5 to 5% in amphibole asbestos) and the index of refraction (less than 1.6 in chrysotile asbestos and more than 1.6 in amphibole asbestos); the amphibole group includes 5 types of asbestos: crocidolite, amosite, anthophyllite, actinolite, and tremolite. Chrysotile asbestos is the principal commercial mineral, accounting for more than 95% of the world asbestos production and more than 99% of that of the USSR. Crocidolite, amosite, and anthophyllite are industrially the most important of the amphibole asbestos group. The production and consumption of actinolite and tremolite are negligible.

Chrysolite asbestos is a hydrated magnesium silicate, its theoretical composition being expressed by the formula $H_4Mg_3Si_2O_9$. The actual composition of various deposits differs from the theoretical composition by inclusion of FeO (which substitutes isomorphically in the MgO crystal lattice) and contamination with other oxides (Fe_2O_3, Al_2O_3, CaO, etc.). This mineral is completely and rapidly dehydrated at 700°, which causes structural breakdown and loss of mechanical strength. Complete dehydration of chrysotile asbestos occurs within one year on prolonged heating at 550°. This type of asbestos melts at ~1550° and has an index of refraction of 1.50-1.55; its specific gravity varies from 2.4 to 2.6, depending on its crystallization-water and iron contents. A normal fiber is easily broken down into extremely fine elastic fibrils. Fibers with reduced elasticity (semibrittle and brittle fibers) are encountered in deposits of chrysotile asbestos. When elasticity is normal the mechanical strength of this mineral is high along the fiber axis; it reaches 365 kg/mm^2 in fibers which have not undergone deformation and which have a prismatic shape and a lustrous surface. The fibers are deformed during mining and processing and this causes their strength to decrease to 60-80 kg/mm^2. The modulus of elasticity of a normal fiber ranges from $15.8 \cdot 10^5$ to $21 \cdot 10^5$ kg/cm^2. Semibrittle and brittle fibers are easily split and less strong. When their fibrils are loosened semibrittle fibers lose a large part of their strength and brittle fibers break up (the latter are of no practical value). Fiber length reaches 50-75 mm, but the majority of fibers are less than 3 mm long. Chrysotile asbestos is not acid-resistant, but alkalies have little effect on it (Table).

The quality of commercial chrysotile asbestos has been standardized by GOST7-60. The principal qualitative indices are average fiber length and texture (degree of fluffiness), content of nonfibrous rock inclusions in the form of dust and small fragments, and absence of the brittle variety. Commercial asbestos is divided into grades and types in accordance with fiber length and texture and contamination with rock. The Soviet asbestos industry produces eight grades with the following average fiber lengths in mm: Grade 0 – more than 18, Grade 1 –

16, Grade 2 – 12, Grade 3 – 9, Grade 4 – 5.5, Grade 5 – 2, Grade 6 – 1.0, Grade 7 – fractions of a millimeter. The fiber texture of chrysotile asbestos is classified as hard, semihard, and soft. The more compact the fibers in a given grade, the higher the quality of the asbestos. More than 80% of the entire Soviet production of chrysotile asbestos is used in the manufacture of structural and insulating materials and products (asbestos-cement roofing, siding, and sheathing tiles and sheets, asbestos-cement water and gas pipe, channels, and ventilator housings, asbestos-cement wall panels, sanitary enclosures, cooling-tower components, and special-purpose products, asbestos-asphalt floor tiles and asbestos cements, asbestos insulating materials, e.g., asbestos cardboard and asbestos-magnesium, asbestos-dolomite, and asbestos-diatomaceous materials and products, and asbestos-bitumen roofing and waterproofing materials). Asbestos filters are used in the chemical industry. The majority of chrysotile asbestos of grades 3, 4, 5, 6, and 7 is used in the production of asbestos structural and insulating products and materials. The next basic group consists of asbestos materials and products used in machine building, electronics, and heating plants. These can be subdivided into: 1) textiles produced from the longest-fibered grades of chrysotile asbestos, up to grade 3 (asbestos yarn, thread, and cloth products). As much as 20% cotton fiber is added to increase product strength; in manufacturing certain types of fabric asbestos yarn is twisted with metal wire; 2) formed articles produced from Grades 3-6, with organic and inorganic binders added.

The principal products manufactured from chrysotile asbestos are: 1) friction products – molded brake shoes produced from a mixture of asbestos and synthetic rubber, woven brake bands impregnated with bitumen or oil, woven or molded asbestos-bakelite brake linings, which are pressed on latex synthetic rubber or molded or rolled on synthetic rubber, friction rings of woven asbestos-bakelite, asbestos-bakelite molded or pressed on synthetic latex, or asbestos-bakelite cardboard, and friction plates of woven asbestos or asbestos cardboard impregnated with bakelite. 2) woven and rolled asbestos packing glands, annular packings (cups of cut asbestos fabric, cut asbestos-aluminum rings). 3) asbestos packings: asbestos-steel sheets, paronite (asbestos-rubber sheets), cut strips of asbestos fabric, metal-wire-reinforced asbestos linen, cut and ruled (see Reinforced linen), asbestos-cardboard packings, feronite (packing sheets consisting of asbestos, rubber, a filler, and a metal grid). 4) asbestos electrical-insulating materials: insulating paper and cardboard, sheets of insulating asbestos fabric, electronit (asbestos-rubber sheets), bulk electronit. 5) asbestos heat-insulating materials: asbestos cord, asbestos insulating paper, asbestos-magnesium cord, beaten asbestos fiber. 6) asbestos filter materials: filter fiber, filter plates, sterilization plates.

Solubility of Asbestos Minerals in Acids and Alkalies

Асбестовые минералы 1	2 Потери веса (%) после 528-часовой обработки при 26° 25%-ным раствором				
	HCl	CH_3COOH	H_3PO_4	H_2SO_4	NaOH
Хризотил-А. 3.	56 00	24.04	58.45	56.00	[illegible].03
Крокидолит-А. 4.	3.14	1.02	3.91	3.48	1.20
5 Амозит-А.	12.0	3.08	11.83	11.71	6.82
6 Антофиллит-А.	2.13	1.04	3.29	2.90	1.77

1) Asbestos minerals; 2)loss of weight (%) after treatment for 528 hr in 25% solution at 26°; 3) chrysotile asbestos; 4) crocidolite asbestos; 5) amosite asbestos; 6) anthophyllite asbestos.

Crocidolite asbestos is a fibrous variety of riebeckite and has the theoretical composition $3H_2O \cdot 2Na_2O \cdot 6\ (Fe, Mg)\ O \cdot 2Fe_2O_3 \cdot 17SiO_2$; it has a hardness of 4, an index of refraction of 1.7, a specific gravity of 3.2-3.3, a mechanical strength somewhat higher than that of chrysotile asbestos, and an average fiber length greater than that of chrysotile asbestos.

Amosite asbestos is a hydrated ferromagnesium silicate with an irregular chemical composition; it has a hardness of 5.5-6, an index of refraction of 1.64, a specific gravity of 3.1-3.25, and a mechanical strength one-third that of crocidolite asbestos. Its acid- and alkali-resistance are satisfactory, but somewhat lower than that of crocidolite asbestos (Table). Amosite asbestos has the longest fibers of the simple types of asbestos, the fiber length reaching 300 mm (averaging from 12 to 70 mm); the fibers are, however, less elastic, more rigid, and more difficult to split than those of crocidolite asbestos.

Anthophyllite asbestos is a ferromagnesium hydrosilicate with the chemical composition $(Mg, Fe)_7 \cdot Si_8O_{22} \cdot (OH)_2$; it has an index of refraction of 1.61, a specific gravity of 2.85-3.11, and a very high chemical stability (Table). This permits its use in asbestos filters, in chemical laboratories, and in certain chemical manufacturing processes.

Crocidolite asbestos is used in the production of chemically stable asbestos products in the chemical industry (linings, packings, filters, etc.) and as an additive to chrysotile asbestos in the manufacture of asbestos-cement products and heat-insulating materials. Amosite asbestos is used in the same types of products as crocidolite asbestos, except in textiles. Anthophyllite asbestos is employed primarily in the production of equipment for the chemical industry and, in certain countries, as an additive to chrysotile asbestos in the manufacture of asbestos-cement products.

References: Trebovaniya promyshlennosti k kachestvu mineral'nogo syr'ya [Industrial Specficati[illegible] for Mineral Raw Materials], No. 5, Sokolov, P.N. and Shneyder, [illegible], Asbest [Asbestos], Moscow, 1959;

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Sinclair, W.E., Asbestos, Its Origin, Production and Utilization, London, 1955.

N.N. Sokolov

ASBESTOS CARDBOARD – is a fireproof insulating material whose main component is the fiber of chrysotile asbestos. It is delivered in sheets (dimensions of the sheets in mm: 500 × 900; 900 × 1000, and 1000 × 1000). The thickness of the cardboard is 2-10 mm, the heat conduction coefficient at 20° is 0.18-0.21 kcal/hr·m·degree. It is used for the protection of wood constructions against fire, as a lining for industrial furnaces, for the heat insulation of pipelines and hot surfaces with temperatures from 150 to 500°, as a packing material in flanges of the connection pipelines of petroleum refineries and other plants. In connections with a low pressure up to 16 kg/cm^2 and temperatures up to 300°, the asbestos cardboard is used as a soft packing. At higher pressures, up to 40 kg/cm^2, and at temperatures up to 300-450°, asbestos-metallic packings are used, consisting of a soft corrugated metal shell and a filler from asbestos cardboard.

The physicomechanical properties of asbestos cardboard are listed in the Table.

TABLE

1 Показатели	2 Норма
3 Объемный вес (г/см³)	1,0–1,3
4 Прочность (кг/см², не менее):	
5 вдоль	12
6 поперек	6
7 Влажность (%, не более)	3
8 Потеря в весе при прокаливании (%, не более)	15

1) Indices; 2) standard; 3) weight by volume (g/cm^3); 4) strength (kgf/cm^2, not less than); 5) along; 6) across; 7) moisture (not more than); 8) loss in weight after calcination (%, not more than).

It is delivered according to GOST 2850-58.

References: Kitaytsev V.A., Tekhnologiya teploizolyatsionnykh materialov [Technology of Heat-Insulating Materials], Moscow, 1959; Neftyanoye oborudovaniye [Equipment for the Petroleum Industry], Vol. 5, Moscow, 1958.

Ye.G. Vagina

ASBESTOS CORDS AND ASBESTOS THREAD – are manufactured from chrysotile-asbestos fibers combined with cotton. The types and the characteristics of the cords are listed in the Table.

Types and Characteristics of Asbestos Cords

1 Диаметр шнуров (мм)	2 Вес 1 пог. м (г), не более	1 Диаметр шнуров (мм)	Вес 1 пог. м (г), не более
3 Асбестовый шнур		4 Асбомагнезиальный шнур	
3	10	13	95
4	15	16	130
5	20	19	190
6	25	22	215
8	60	25	290
10	90	28	420
13	125	32	440
16	175	5 Асбопухшнур	
19	260	20	180
22	290	25	120
25	380	30	380

1) Cord diameter (mm); 2) weight of the running meter (g), not more than; 3) asbestos cord; 4) asbestos-magnesia-cord; 5) asbestos-cotton-cord.

Asbestos thread is manufactured with diameters of 0.5 to 2.5 mm. Asbestos cords and asbestos thread with a diameter of up to 6 mm are twisted from one or more single yarns; such with a diameter greater than 6 mm are manufactured from asbestos thread, varn or rove entwined with asbestos thread or yarn. Asbestos-magnesia cord is manufactured by entwining asbestos thread around a core composed of magnesia and asbestos draw thread. Asbestos-cotton cord is formed from a core of carded asbestos and cotton fibers and entwined with asbestos or cotton thread. The loss in weight after roasting at 700° must not surpass 32% for asbestos cord and asbestos thread, and 22.5% for the cover braiding of the asbestos-magnesia cord; the coefficient of heat conductivity is 0.080 for asbestos-cotton cord; 0.100-0.128 for asbestos cords with a core of asbestos-cotton cord, and 0.150 kcal/m•hr•°C for asbestos cords with an asbestos-cord core. Asbestos cords are used as a packing to stuff boxes of objects used to work in a nonaggressive medial; asbestos-magnesia cord and asbestos-cotton cord are used as a basic heat insulation. Asbestos cord is used as a heat-resistant packing material to seal manholes, flanges, molds for steel casting, etc. Asbestos cord and asbestos thread can be used for a long time at tempera tures which do not exceed 400°.

N.T. Dodonov

ASBESTOS FABRIC – is made by interweaving warp and weft asbestos threads on a loom; according to GOST 6102-52.9 brands are produced. In addition to fabrics provided for in the GOST, the industry produces sealing, asbestosmetallic and asbestosglass fabrics in accordance with individual TU. The characterization of fabrics is presented in the table.

Indicators of Asbestos Fabrics

Марка 1	Ширина (мм) 2	Толщина (мм, не более) 3	Вес 1 м² (г, не более) 4	Разрывная нагрузка полоски 50×100 мм (кг, не менее) 5		Потери при прокаливании при 700° (%, не более) 6
				по основе 7	по утку 8	
АТ-1	1040	1,6	1000	65	27	29,0
АТ-2	1040	1,9	1100	50	17	32,0
АТ-3	1040	2,9	1500	42	12	32,0
АТ-4	1040	3,5	1900	42	14	32,0
АТ-5	1040	3,2	1900	68	25	32,0
АТ-6	1550	3,8	3400	250	150	19,0
АТ-7	1520	2,5	1600	80	60	23,5
АТ-8	1500	3,5	2000	75	100	23,5
АТ-9	1500	3,5	2000	70	45	32,0
ОТ-1	1100	1,5	1200	50	50	32,0
ОТ-2	1100	1,5	1600	70	70	32,0
ОТ-2/35	1100	2,0	1800	100	50	32,0
НМ-10	1080	1,6	1200	95	25	32,0
НМ-12	1080	1,2	900	55	14	32,0
АСТ-1	1040	2,3	1200	90	40	27,0
АСТ-4	1040	3,5	1600	70	25	32,0

1) Brand; 2) width (mm); 3) thickness (mm, not more than); 4) weight of 1 m^2 (g, not more than); 5) rupture length of a 50 × 100 mm strip (kg, not less than); 6) losses on calcining at 700° (%, not more than); 7) NM; 8) AST.

Following are the uses of asbestos fabrics: the AT-1, AT-2 and AT-3 fabrics are used as a filler in making heat resistant asbestos plastics for electrical insulation and construction purposes; AT-4 is used in the production of rubberized items of industrial equipment (asbestos lining strips, rolled up packing gland material, packing rings and V-shaped rubber packing rings) and as heat insulation of surfaces up to 300°; AT-5 is used as a filler in making friction linings and clutch rings for automotive and other engines; it is made from asbestos yarn with brass wire and is impregnated in various compounds; AT-6, which is distinguished by high mechanical strength and a low cotton content is used as diaphragms in electrolitic processes as well as for heat insulation of surfaces up to 600°; AT-7 is used as a sheating material in the production of mats with loose fillers; the mats are used for heat insulation of surfaces up to 500°; AT-8 and AT-9 are used as heat insulation up to 400 and 300°, respectively. The OT,1, OT-2 and OT-2/35 sealing fabrics are distinguished by high elongation at break and are used in making shock absorbing pads for special mechanisms. The NM-10 and NM-12 asbestosmetallic fabrics (with brass wire) are used in making asbestos textolite and engine gaskets. The AST-1 and AST-4 asbestos-glass fabrics (with a continuous nonalkaline glass thread) are distinguished by a high mechanical strength, heat resistance and low weight and are the replacements, respectively, of the AT-7 and AT-8 asbestos fabrics. The thermal conductivity coefficient (λ) of the AT-6, AT-7, AT,8, AT-9, AST-1 and AST,4 fabrics, which is determined by the pipe method, when not less than 3 layers are placed, can be expressed, depending on the average temperature (t_{sr}), by the formula:

$$\lambda = 0{,}120 + 0{,}000201_{cp} \cdot \text{kcal/m-hour-°C}$$

References: Poyarkov, A.S., Vovoya tekhnologiya pryadeniya azbesta [The New Asbestos Spinning Technology], Moscow, 1959.

N.T. Dodonov

Manuscript Page No.	[Transliterated Symbols]
312	ТУ = TU = tekhnicheskiye usloviya = technical specification
312	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = All-Union State Standard
312	AT = AT = azbestovaya tkan' = asbestos fabric
312	OT = OT = obtyuratornaya tkan' = sealing fabric

312 ACT = AST = azbosteklyanaya tkan' = asbestosglass fabric

313 cp = sr = srednyaya = average

ASBESTOS FIBER - is produced of three types: beaten, combed and filter fiber. Beaten fiber is serpentine asbestos, which corresponds in its starting state to GOST 7-60, treated in a vertical opener for separation of fibers. Asbestos of grades 3-5 with rough, semirough and soft textures is used for obtaining beaten fibers. Beaten fiber is produced according to: TU MKhP 323-N (grades 3-5); TU 35-KhP-381-61 (Zh-3-40, P-3-50, P-3-60, P-3-70, M-5-60); TU MKhP ShAU 41-54 (Zh-3-40, P-3-60, P-30-70). The losses due to firing of processed fiber at 700° should not exceed 14% and the moisture content should not be higher than 6%; it is used for filling of insulation mats and in the pure form for thermal insulation and as a component part of insulation mixtures.

Combed fiber differs from beaten fiber by its greater fiber length and the degree of separation. It is produced from rough texture grade 1-3 serpentine asbestos. The fiber is processed by edge-runner mills, vertical opener and a carding machine. Combed fiber is used as a heat-resistance reinforcing filler in the production of plastic materials and should meet the following basic requirements: hygroscopic moisture up to 4%, losses due to firing at 700° up to 15%, iron content of the asbestos up to 4%. The combed fiber is produced according to TU ShAU 52-55 from brand Zh-3-40 asbestos and according to VTU-35-KhP-383-61 from brand Zh-1-50 and Zh-1-38 asbestos.

Filter fiber represents a homogeneous mixture of grade 4 serpentine asbestos and bleached sulfite pulp, separated in a beater into thin fibers. Filter fiber is produced according to TU MKhP 331-N, brands being YaK-1, YaK-2 and YaK-3, and has the following characteristics:

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TABLE

	ЯК-1 1	ЯК-2	ЯК-3
2 Потеря веса при прокаливании при 700° (%) . .	26—34	68—78	55—65
3 Влажность (%) . .	До 8 4	До 8 4	До 8 4
Применяется для фильтрации жидкостей . 5 .	Быстро-текущих 6	Вязких	Средней вязкости 8

1) YaK; 2) weight loss when fired at 700° (%); 3) moisture content (%); 4) up to; 5) used for filtering of fluids; 6) free-flowing; 7) viscous; 8) of medium viscosity.

E. S. Popova

ASBESTOS FRICTION MATERIALS - materials used in the manufacture of elements of braking units intended to absorb the kinetic energy of operating machines (to half movement) or to transfer motion from one part of a machine to another. Asbestos friction materials and products consist of asbestos, powdered fillers (barite, iron minium, ground quartz, corundum), binders (bitumen, linseed, tung, and perilla oils, synthetic rubber, latex, phenol-formaldehyde resins), metal filaments or rods, and other additives. Under operating conditions asbestos friction materials are subject to static and dynamic stresses, the high temperatures produced during friction, and wear. Asbestos friction materials and products fabricated from them should have a high, stable coefficient of friction and a high wear-resistance, but should not scratch or abrade the surface with which they are in contact. A decrease in coefficient of friction during operation at elevated temperatures makes braking devices unreliable. The principle types of asbestos friction materials and their compositions and applications are shown in Table 1 and their physical and mechanical properties in Table 2; Tables 3 and 4 show the thermal and pressing properties of certain asbestos friction materials.

Investigation of various asbestos friction materials has shown that each of them has a critical temperature above which the coefficient of friction drops off sharply. Thus, the majority of materials with rubber binders have critical temperatures of 220-250°, while those based on phenol-formaldehyde resins have critical temperatures of 260-280°. The binders of 6KKh-1 and 7KF-31 burn off at temperatures above

TABLE 1

Principal Types of Asbestos Friction Materials and Their Compositions and Applications

Марка 1	2 Состав	3 Применение
6КХ-1 4	Синтетич. каучук, асбест, окись цинка, железный сурик 10	Тормозные накладки грузовых автомобилей, лебедок 15
7КФ-31 5	Синтетич. каучук, крезольная смола, окись цинка, латунная стружка 11	Кольца сцепления грузовых автомобилей 16
6КВ-10 6	Синтетич. каучук, асбест, окись цинка, железный сурик 10	Вальцованная лента для дорожных машин 17
КФ-3 и КФ-3М 7	Волокнистый асбест, пропитанный резольной смолой 12	Фрикционные накладки и колодки 13
КФ-3Г 8	Волокнистый асбест, пропитанный фенолформальдегидной смолой, графит 13	Детали, обеспечивающие фрикционное демпфирование при вибрациях в условиях сухого трения по нержавеющей стали. Коэфф. трения не стабилен 19
К-217-57П 9	Асбест, пропитанный резольной смолой, латунная стружка 14	Фрикционные накладки и кольца экскаваторов 20
К-15-6	Асбест, пропитанный резольной смолой, барит, электрокорунд, латунная стружка 24	Материал с повышенным и стабильным коэфф. трения для гусеничных машин 29
ТФ-2 (К-15-13)	Асбест, резольная смола, латунная стружка, барит 25	Тропикостойкие фрикционные кольца с повышенной прочностью на удар 30
Ретинакс: ФК-16Л (К-236-58) ФК-24А	26 Фенольная смола, модифицированная канифолью, асбест, латунная стружка, барит Фенольная смола, модифицированная канифолью, асбест, барит (без латунной стружки) 27	Тормозные устройства шагающих экскаваторов, буровых лебедок, ФК-16Л — в тормозных устройствах самолетов 31
Лента тормозная асбестовая	Асбестовая ткань, сплетенная из асбестовых нитей и латунной проволоки, пропитанная битумом (тип А), льняным, тунговым или др. маслом (тип Б), термообработанные 28	Накладки в различных тормозных механизмах, тип Б в основном в механизмах тракторов и автомобилей 32

1) Type; 2) composition; 3) application; 4) 6KKh-1; 5) 7KF-31; 6) 6KV-10; 7) KF-3 and KF-3M; 8) KF-3G; 9) K-217-57P; 10) synthetic rubber, asbestos, zinc oxide, iron minium; 11) synthetic rubber, cresol resin, zinc oxide, iron minium; 12) fibrous asbestos impregnated with resol resin; 13) fibrous asbestos impregnated with phenol-formaldehyde resin, graphite; 14) asbestos impregnated with resol resin, brass rod; 15) brake linings for trucks and winches; 16) clutch collars for trucks; rolled belting for road-building machinery; 18) friction linings and shoes; 19) components intended to provide-damping of vibration in dry friction over stainless steel; coefficient of friction unstable; 20) friction linings and collars for excavators; 21) TF-2 (K-15-13); 22) retinaks: FK-16L, (K-236-58), FK-24A; 23) asbestos brake bands; 24) asbestos impregnated with resol resin, barite, corundum, brass rod; 25) asbestos, resol resin, brass rod, barite; 26) phenolic resin modified with colophony, asbestos, brass rod, barite; 27) phenolic resin modified with colophony, asbestos, barite (without brass rod); 28) asbestos fabric woven of asbestos thread and brass wire, impregnated with bitu-

men (type A) or linseed, tung, or other oil (type Б), and heat-treated; 29) material with high, stable coefficient of friction for caterpillar machinery; 30) friction collars with high impact strength for tropical use; 31) braking devices for walking excavators and drill winches; FK-16L – braking devices for aircraft; 32) linings for various braking mechanisms; type B – principally in tractor and automobile mechanisms.

TABLE 2

Physical and Mechanical Properties of Asbestos Friction Materials

1	2	3	4	5	6				12	13	14	15
					7	8	9	10				
					11							
16	2.37	24	0.42–0.45	—	29 570	—	—	730	30	0.12	—	196
17	—	21–28	0.32–0.36	0.04–0.06	[illegible]	300–420	370–400	—	9–11	—	—	—
18	2.24	49	0.37	0.2	470	—	—	—	27.1	—	—	—
19	1.75–1.85	30	0.31	1.0	Не менее 700	—	200–270	1000	Не менее 21	0.3	0.1	200
20	1.95	30	0.3	—	» 600	—	200–400	800	» 10	0.3	0.1	200
21	1.75–2.1	30	0.35	—	—	—	—	—	» 12	0.3	—	300
22	2.12	2[illegible]	0.33	—	Не менее 550	—	150–250	850–1900	» 9	0.18–0.30	0.0–0.8	200
K-15-8	2	25	0.35–0.38	—	» 700	—	—	1000	» 10	[illegible]	0.3	200
23	2.2	30	0.25–0.28	—	1000	—	—	1000	» 21	[illegible]	0.4	300
24												
25	2.44	до 40	0.36–0.40	0.1	до 670	до 520	315	до 1400	9–12	0.35	0.3	—
26	2.4	до 50	0.33–0.36	0.13	—	до 400	230	до 1000	5–8	0.35	0.3	—
27		—	0.35–0.45	0.15–0.20	—	—	—	—	—	—	—	—

1) Type; 2) specific gravity; 3) Brinell hardness (kg/mm²); 4) coefficient of friction (no less than); 5) wear over 2 hr (mg); 6) short-term resistance to; 7) static bending; 8) shear; 9) tension; 10) compression; 11) kg/cm²; 12) impact strength (kg·cm/cm²); 13) water absorption (g/dm², no more than); 14) oil resistance (%); 15) Martens thermostability (°C, no less than); 16) 6KKh-1; 17) 7KF-31; 18) 6KV-10; 19) KF-3; 20) KF-3M; 21) KF-3G; 22) K-217-57P; 23) TF-2 (K-15-13); 24) retinaks; 25) FK-16L (K-236-58); 26) FK-24A; 27) asbestos brake bands; 28) up to; 29) no less than.

TABLE 3

Thermal Properties of Certain Asbestos Friction Materials

1	2		
	3	4	5
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

1) Index; 2) Type; 3) KF-3; 4) FK-16L; 5) FK-24A; 6) coefficient of linear expansion, $\alpha \cdot 10^{-6}$; 7) heat capacity (kcal/kg·°C); 8) thermal conductivity (kcal/m·hr·°C).

250°, while K-217-57P is resistant to 300°. Exceptions to this rule are retinaks, K-15-6, and TF-2 (K-15-13). The coefficient of friction of retinaks drops at 180°, but stabilizes at 200-350°; on prolonged exposure to high temperatures the coefficient of friction increases with no marked reduction in durability. K-15-6 and TF-2 (K-15-13) have stable coefficients of friction which remain almost unchanged at sliding speeds of up to 30 m/sec and loads of up to 10 kg/cm^2. TF-2 is stable under tropical conditions. At temperatures of up to 900° the coefficients of friction of K-15-6 and TF-2 are somewhat higher than that of retinaks. Products fabricated from asbestos friction materials should not crack, exfoliate, or crumble when drilled or countersunk under rivets or when riveted to metal shoes or disks. Such products can be classified as net, woven, molded, pressed, or rolled, depending on the process employed in their manufacture. More than 50 asbestos friction materials have been assigned names.

TABLE 4

Pressing Properties of Certain Asbestos Friction Materials

Марка 1	2 Текучесть по Рашигу (мм)	3 Усадка расчетная (%, не более)
4 КФ-3	120—180	—
5 КФ-3М	120—180	0.6
6 К-217-57П	70—190	—
К-15-6	90—200	0.2
7 ТФ-2	140—180	0.2
8 ФК-16Л	110—180	0.2

1) Type; 2) Raushig yield (mm); 3) calculated shrinkage (%, no more than; 4) KF-3; 5) KF-3M; 6) K-217-57P; 7) TF-2; 8) FK-16L.

References: Povysheniye effektivnosti tormoznykh ustroistv. Svoystva friktsionnykh materialov [Increasing the Efficiency of Braking Devices. Properties of Friction Materials], collection of articles, Moscow, 1959; Bulanov, A.A., Friktsionnyye materialy [Friction Materials], Moscow. 1958; Chichinadze, A.V., Troyanovskaya, G.I., Temperaturnoye pole, koeffitsivent treniya i iznos friktsionnykh par [Temperature Field, Coefficient of Friction, and Wear of Friction Pairs], Moscow, 1957.

M.S. Krol'

ASBESTOS PAPER — a roll material manufactured from chrysotile asbestos fiber with starch added as a binder. Cellulose or synthetic latex is added to the mass for certain types of paper. The asbestos-fiber content of this material ranges from 76 to 96%. Several types of asbestos paper have been developed: heat-insulating, waterproofing, membrane, electrial-insulating, and calendar-roll.

Heat-insulating asbestos paper (GOST 2630-44) is produced in rolls 670, 950, and 1150 mm wide and 0.3, 0.4, 0.5, and 0.65 mm thick and in sheets 1000 × 950 mm in size and 0.5, 1.0, and 1.5 mm thick. The weight of 1 m^2 of paper 0.65-1 mm thick is no more than 1250 g; its coefficient of thermal conductivity is 0.1350 kcal/m•hr•°C. The loss during heating at 700-750° is no more than 17%. The tearing length for paper 0.65-1 mm thick is no less than 160 m along the fibers and 70 m across them. This paper is used at temperatures of no more than 500°. Waterproofing asbestos paper (TU MKhP 64-N) is manufactured with an admixture of cellulose and produced in rolls 950 mm wide and 0.65 mm thick. It is impregnated with oxidized petroleum bitumens (gidroizol) and used as a waterproofing layer for subterranean and other structures, as an anticorrosion covering for metal pipes, and to protect the surface of foundations from moisture. The asbestos base of gidroizol makes it rotproof and comparatively fire-resistant. The impregnability of this paper is determined from its ability to absorb kerosene, which should be no less than 72%. The weight of 1 m^2 of this material is no less than 400 g; its loss in weight on heating at 700-750° is no more than 30%, while its tensile strength is no less than 450 g/mm^2. Asbestos membrane paper (TU MKhP 258-55p) is used for membranes in the electrolysis of aqueous solutions of the chlorides of alkaline metals. It should have a definite strength and porosity. It is produced in rolls 915 and 950 mm wide and 0.65 mm thick and has a tearing length of no less than 360 m along the fibers and 180 m across them; 1 m^2 of the paper weighs 450-600 g. The transverse permeability of 1 m^2 of a single layer to water is 2000-3000 cm^3/min at 20° and 700 mm H_2O. The latest electrolyzer designs utilize a layer of asbestos fiber instead of asbestos paper. Electrical-insulation asbestos paper (GOST 9426-60) is produced in thicknesses of 0.2, 0.3, 0.4, 0.5, 0.8, and 1.0 mm, with corresponding breakdown voltages of 1200, 1400, 1700, 2000, 2300, and 2500 v. Varnish-impregnated paper is used for between-turn insulation in coils and in the manufacture of laminated plastics. Impregnation promotes an increase in electric strength from 3-5 kv/mm to 5-10 kv/mm, in deep resistance from 10^8 to 10^{10}-10^{11} ohms/cm, and in specific skin resistance from 10^7 to 10^9-10^{10} ohms. The bulk weight of this paper does not exceed 0.5 g/cm^3, while its loss in weight on heating at 700-800° is no more than 25%. The Fe_3O_4 content of such paper is no more than 3.4%. Calendar asbestos paper (TU MKhP 3921-55) is intended for lining the calendar rolls used in the manufacture of capacitor paper. In order to give this paper high strength and elasticity semipulped cotton and synthetic latex are added to it. The final rolls contain paper 720, 800, and 1080 mm wide and 0.2-0.3 mm thick, whose tearing length is no less than 450 m in either direction (longitudinal or transverse). Its loss in weight on heating at 700-800° is 34-40%.

References: Kitaytsev, V.A., Tekhnologiya teploizolyatsionnykh materialov [Technology of Heat-Insulation Materials], Moscow, 1959; Spravochnik po elektrotekhnicheskim materialam [Handbook of Electrical

Materials], Vol. 1, Part 1, Moscow, 1958; Stender, V.V., Diafragmy dlya elektroliza vodnylh rastvorov [Membranes for Electrolysis of Aqueous Solutions], Moscow-Leningrad, 1948.

Ye.G. Vagina

ASBODINE - see Bulk electronite.

ASBOPLASTIC – a plastic material reinforced with a filler of asbestos fibers, used in the manufacture of components with a high heat-resistance and mechanical strength. Asboplastics are divided into the following groups: laminar plastics, asbovoloknits, and true asboplastics based on asbestos fiber or mats preliminarily molded into the product. Parallel-fiber asbestos of filamentous crystals is the primary raw material in the production of asboplastics. The physical and mechanical properties of asboplastics depend on the type of resin and its content. The resin content is generally 30-45%. Phenol-formaldehyde, melamine, silicoorganic, and furfuryl resins are most commonly employed as the

Physical and Mechanical Properties of Asboplastics Based on Different Resins

Показатели 1	Смолы 2						
	фенолформальдегидная 3			7 кремнийорганическая			8 меламиновая
	пластик на основе матов 4	асболит * 5	асбоволокнит 6	пластик на основе матов 4	асболит 5	асбоволокнит 6	асболит 5
Удельный вес . 9 . .	1.8	1.5—1.83	1.95	1.6—1.7	1.65	1.8—1.9	1.75-1.85
Водопоглощение за 24 час. (%) . 10 . .	—	0.3—5.0	0.5—1.0	—	1	0.1—1	0.4—5
Предел прочности (кг/см²) 11							
при растяжении 12 . .	3150—3900	800—2800	250—1000	1750—2250	1000	200—1250	2450—2860
при статич. изгибе 13	3500—3900	700—2450	800—1200	1750—2450	1400	620—1200	1100—2100
Теплостойкость по Мартенсу (°C) . . . 14 . .	250	160—200	20—30	250	250	250—350	100—200
Пробивное электрич. напряжение (кв/мм) 15 .	—	4.0	1.1—2.5	—	6—7	2-4	2.5—5

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*A laminar plastic based on asbestos paper or asbestos board.

1) Index; 2) resin; 3) phenol-formaldehyde; 4) plastic based on mats; 5) asbolite; 6) asbovoloknit; 7) silicoorganic; 8) melamine; 9) specific gravity; 10) water absorption over 24 hr (%); 11) ultimate strength (kg/cm²); 12) under tension; 13) under static bending; 14) Martens thermostability (°C); 15) breakdown voltage (kg/mm).

binders in asboplastic production, unsaturated polyester and polyepoxy resins and suspensions of polytetrafluorethylene being used less frequently.

The Table shows the principal properties of various asboplastics.

The mechanical properties of asboplastics are rather stable under the action of moist air and water; these materials have an elevated thermostability (being resistant up to 500°). Asboplastics, which do not contain organic fillers, are resistant to tropical conditions. The fatigue strength of asbolite under bending (10^6 cycles) is approximately 500 kg/cm^2. Products are fabricated from laminar asboplastics by machining or molding. Large-size articles are manufactured from asbovoloknit mats with parallel fibers, which are produced on asbestos-combing machines. Binder-impregnated mats are pressed into complex products under pressures of up to 15 kg/cm^2.

Asbovoloknit, or Faolite, is used in the manufacture of large-size pipes, armatures, and other products. Articles are fabricated from the asbovoloknits K-6, K-41-5, KF-3M, etc., by direct pressing and extrusion under pressures of 500–600 kg/cm^2 and at temperatures of 145–160° for sheets based on phenol-formaldehyde resins and 160–210° for sheets based on silicoorganic resins.

Asboplastics are used in the manufacture of rotary-pump blades, friction clutches for hydraulic drives, panels for mounting electrical controls operating at low voltages, etc. Commutators for small electrical equipment, contactors, switches, and other components are manufactured from the asbovoloknits K-6, K-41-5, etc. Press materials of type KF-3, etc., are used for hot pressing of brake shoes for subway cars and other components. The coefficient of friction of unlubricated asboplastic at a specific pressure of 10 kg/cm^2 and a speed of 0.4 m/sec is 0.3-0.35, as determined on an "Amsler" machine. Asboplastics, which are distinguished by high strength and rigidity, are used in the manufacture of large-size structural components (elements of aircraft wings and rudders, glider components, elements of free-standing tanks, etc.). As a result of their high heat resistance plastics based on asbestos mats are widely used for thermal protection of rocket nosecones, heat insulation of rocket engines, and heat-insulating shielding.

References: Shugal, Ya.L., Baranovskiy, V.V., Sloistyye plastiki [Laminated Plastics], Moscow-Leningrad, 1953; Kiselev, B.A., Ukh, 1960, Vol. 29, No. 6, pages 796-808; Armirovannyye plastmassy v raketnoy tekhnike [Reinforced Plastics in Rocket Technology], Ekspress informatsiya [Information Bulletin], 1958, No. 46 (Nos. 136-139), 137-138.

B.A. Kiselev

ASBOSTEEL SHEETS - a product fabricated from two sheets of a special asbestos-latex paper joined by an intermediate framework of perforated steel. Both sides of the sheet are coated with a layer of lamellar graphite. This product is intended for sealing gaskets at the points where tractor-engine components are joined. The gaskets should not adhere to metallic surfaces or be permeable to water, gases, or oil. The sheets are 1.75 mm thick, 50 mm wide, and 50-875 mm long. The sheet lengths most in demand are 675 and 875 mm. The absorption capacity of asbosteel sheets over a 4-hr period at 20° is no more than 7% in water, 15% in oil, and 17% in gasoline. The loss resulting from roasting of an asbestos layer separated from the steel framework is $\leq$40% at 700-800°; the tensile strength is ~250 kg/cm^2 along the sheet and ~320 kg/cm^2 across it. The residual shrinkage through the sheet is ~20% under a load of 250 kg/cm^2 and ~25% under a load of 500 kg/cm^2. Gaskets fabricated from asbosteel sheets will function in water, oil, and hot gases at temperatures of up to 350° and pressures of up to 100 kg/cm^2.

S.I. Chernyshev

ASBOTEXTOLITE – a laminar pressed sheet material consisting of layers of asbestos fabric impregnated with a synthetic-resin solution. It is produced in tiles and sheets of varying thickness and is also molded into complex products. Production of asbotextolite involves asbestos fabric based on chrysotile asbestos fiber of types KV-6, KV-30, AT-1, etc., and phenol-formaldehyde resins (melamine and silicoorganic

Physical and Mechanical Properties of Asbotextolite Based on Various Resins

Показатели 1	2 Смолы		
	3 фенол-формальдегидная	меламиновая 4	кремний-органическая 5
Удельный вес 6	1.4–1.8	1.75–1.85	1.7–1.8
Водопоглощение за 24 часа (%) 7	0.4–3.0	0.4–5.0	0.2–2.0
8 Предел прочности (кг/см²)			
при растяжении 9			
вдоль основы 10	400–900	450–860	410
поперек основы 11	600–850	—	—
при сжатии 12			
перпендикулярно слоям 13	1260–3150	1890–3500	2250
вдоль слоев 14	1400–1500	—	—
при статич. изгибе 15			
вдоль основы 10	700–2450	1150–1680	840
поперек основы 11	700–980	—	—
Теплостойкость по Мартенсу (°C) 16	200–250	[illegible]–200	300
Пробивное электрич. напряжение (кв/мм) 17	0.5–2.5	2.5–5.0	—

1) Index; 2) resin; 3) phenol-formaldehyde; 4) melamine; 5) silicoorganic; 6) specific gravity; 7) water absorption over 24 hr (%); 8) ultimate strength (kg/cm²); 9) under tension; 10) along base; 11) across base; 12) under compression; 13) perpendicular to layers; 14) along layers; 15) under static bending; 16) Martens thermostability (°C); 17) breakdown voltage (kv/mm).

resins are less frequently used). The resin content of the impregnated fabric amounts to 38–43%. Asbotextolite sheets and tiles based on phenol-formaldehyde resins are pressed at a temperature of 150–160° and a pressure of 90–110 kg/cm^2. The Table shows the physical and mechanical properties of asbotextolite based on various resins.

The coefficient of friction of unlubricated asbotextolite based on phenol-formaldehyde resin is 0.3–0.38 at a pressure of 10 kg/cm^2 and a speed of 0.4 m/sec; when lubricating oil is used the coefficient of friction drops to 0.05–0.07. Under these same conditions the wear over 1 kg amounts to 2–5 mg under dry friction and 1–2 mg when lubricating oil is used. The Brinell hardness of this material is 30–45 kg/mm^2. Asbotextolite based on phenol-formaldehyde resin has an oil and gasoline absorption not exceeding 1%. The loss of weight produced by soaking specimens in hot mineral oil for 6 hr at 125° does not exceed 3%. Most components fabricated from asbotextolite are produced by machining. It is recommended that blanks of plastic based on phenol-formaldehyde resin be heat-treated at 130° for 12 hr. Asbotextolite up to 1.5 mm thick can be cut with a guillotine without preliminary heating; sheets up to 3 mm thick can be cut after preliminary heating. Carborundum abrasive wheels 300–350 mm in diameter and 3–6 mm thick are also used for cutting asbotextolite; this operation is carried out at a cutting speed of 3000–3600 m/min, feeding the material to the wheel at a rate of 0.01–0.6 m/min. A number of flat components are fabricated from asbotextolite up to 3 mm thick by stamping. This plastic can be lathed and milled. Cutters of high-speed steel or with blades of hard alloys are used for lathing. Large-size asbotextolite products are manufactured from impregnated asbestos fabric by vacuum or autoclave molding. Liquid binders containing little or no solvent are most frequently employed in this case. Articles produced by autoclave molding have a higher mechanical strength and are more fully monolithic than those produced by vacuum molding. Asbotextolite is used for thermal protection and heat-insulation of various structural elements in rocket and aviation technology and as a thermostable, electrical-insulating, and friction material in instrument building and plant construction. It is also employed as a panel material, in the assembly of electrical control units, in low-voltage electrical circuits, for wedges and braces for turbogenerator rotors, etc. Asbotextolite is capable of functioning for prolonged periods (a number of years) at temperatures of up to 155°.

References: Shugal, Ya.L. and Baranovskiy, V.V., Sloistyye plastiki [Laminated Plastics], Moscow-Leningrad, 1953.

B.A. Kiselev

ASBOVINYL – a plastic consisting of a mixture of pulverized asbestos and the binder lac ethinol. Freshly prepared asbovinyl (Departmental Technical Specification MKhP-3190-53) has the consistency of putty and is applied to a clean surface with a spatula (it is best to use several layers, alternating 3 or 4 layers of asbovinyl with a layer of pure ethinol). The total coat thickness should be 10–12 mm. Asbovinyl hardens when heated or at room temperature; the polymerization time is 3-4 weeks at room temperature and approximately one hour at 90°. Thermal decomposition of the polymerization products sets in at 105°. The physical and mechanical properties of this plastic include: specific gravity – 1.4-1.5, ultimate strength – 150-215 kg/cm^2 under tension and 160 kg/cm^2 under compression, working temperature – 95-110°. Asbovinyl is similar to faolite in physical and mechanical properties, but adheres better to metals, ceramics, concrete, and other materials; it is distinguished by high chemical stability in many aggressive media (nonoxidizing mineral and organic acids, dry and moist gases, alkalies, fresh and salt water, salt solutions, and many organic solvents and compounds). The chemical stability of asbovinyl in these media extends over the temperature range 50-110°, but it decomposes under the action of oxidizing agents and certain organic solvents. The principal shortcoming of asbovinyl is its instability during storage. In order to improve its properties this plastic is modified with epoxy, furyl, and other synthetic resins, which increase its ultimate strength under compression to 240-350 kg/cm^2 and reduce its polymerization time to 2 days at room temperature.

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Asbovinyl is an anticorrosion lining material. It is used in the chemical industry to protect structures and apparatus employed in the production of sulfuric and sulfurous acids, sulfur dioxide, and weak nitric acid at temperatures of up to 100°. It is also used for corrosion protection of equipment in metallurgy, machine building, and tool making; in nonferrous metallurgy it serves as a substitute for lead in electrolytic baths; in the wood pulp industry it replaces nonferrous metals and stainless steel in equipment exposed to acetic acid; in the cellulose-paper industry it serves as a substitute for ceramic-tile and lead linings (in tapping vessels, baths, coolers, scrubbers, etc.). Asbovinyl is employed for protection against gas corrosion in gas pipes and reinforced concrete structures.

E.G. Gashnikov

ASBOVOLOKNIT – a heat-resistant pressed material based on asbestos impregnated with synthetic resins. Phenolic, silicoorganic, carbamide, etc., resins can be used as the binder.

Phenolic asbovoloknit type K-6 is a composite based on fibrous asbestos impregnated with an emulsified resol-phenol-formaldehyde resin and various additives (talc, a lubricant, etc.). The impregnated material is cold-rolled without friction and vacuum-dried at 80-95°; externally it is a film no more than 1.5 mm thick and has a guaranteed stor-

Physical, Mechanical, and Dielectric Properties of Silicoorganic Asbovoloknit Materials

Показатели 1	2 Марка	
	К-41-5	КМК-218
Объемный вес (г/см^3) 3	1,8—1,9	1,6—2,0
Уд. ударная вязкость (кг·см/см^2) 4	15—20	3,8—6,2
5 Временное сопротивление статическому изгибу (кг/см^2)	500—720	370—490
6 Предел прочности (кг/см^2)		
при сжатии 7 8	1320—1420	1200—1470
при растяжении	600	—
9 Теплостойкость по Мартенсу (°С)	>350	>350
Водопоглощение (%) 10	0,25	—
11 Твердость по Бринеллю (кг/мм^2)	19	20
Уд. объемное электросопротивление (ом·см) 12	$8\cdot10^{11}$—$8\cdot10^{12}$	$5\cdot10^{10}$—$4\cdot10^{12}$
Уд. поверхностное электросопротивление (ом) 13	$1\cdot10^{16}$—$5\cdot10^{12}$	$1,8\cdot10^{10}$—$1\cdot10^{12}$
Электрич. прочность (кв/мм) 14	3.5	4.4
Дугостойкость (сек.) 15	5—60	>180
Тангенс угла диэлектрич. потерь		
17 при 50 гц 16	0,53	0.34
при 10^6 гц 18	0,256	0,075—0,15
Диэлектрич. постоянная 19		
при 50 гц	110	62,6
при 10^6 гц	7,15	5,6—5,8
Текучесть по Рашигу (мм) 20	140—180	—
Усадка (%) 21	0,6—1,6	—

1) Index; 2) type; 3) specific gravity (g/cm^3); 4) impact strength (kg··cm/cm^2); 5) short-term static bending resistance (kg/cm^2); 6) ultimate strength (kg/cm^2); 7) under compression; 8) under tension; 9) Martens thermostability (°C); 10) water absorption (%); 11) Brinell hardness (kg/mm^2); 12) deep electrical resistance (ohm·cm); 13) skin resistance (ohms); 14) electric strength (kv/mm); 15) arc resistance (sec); 16) tangent of angle of dielectric loss; 17) at 50 cps; 18) at 10^6 cps; 19) dielectric constant; 20) Raushig yield (mm); 21) shrinkage (%).

age life in a dry heated room at a temperature of no more than 25°. Finished products are fabricated from phenolic asbovoloknit by hot compressive pressing at 170-200° and a pressure of 450 kg/cm^2. The Raushig yield of this material is 110-190 mm and its theoretical shrinkage is 0.1-0.2%. A metal reinforcing armature is easily introduced into asbovoloknit during pressing. The material can be drilled, sawn, etc. External and internal threads, inscriptions, and numerals are applied during pressing. Phenolic asbovoloknit has the following properties: specific gravity – 1.95; impact strength – no less than 20 kg•cm/cm^2; short-term static bending resistance – no less than 800 kg/cm^2; ultimate strength on compression – no less than 800 kg/cm^2; short-term tensile strength – 200-250 kg/cm^2; relative elongation – 0.1-0.13%; modulus of elasticity – 150-250•10^3 kg/cm^2; Brinell hardness – 30 kg/mm^2; Martens thermostability – no less than 200°; coefficient of linear expansion – 25-28•10^{-6}•1/°C; thermal conductivity – 0.45-0.5 kcal/m•hr••degrees; heat capacity – 0.28-0.3 kcal/kg•degrees; water absorption over 24 hr – 0.5%; oil resistance – 0.16-0.22%; gasoline resistance – 0.4-0.7%; skin resistance – no less than 10^{10} ohms; deep resistance – no less than 10^{10} ohms•cm; electric strength – no less than 1.5 kv/mm; tangent of angle of dielectric loss at 50 cps – 0.88. K-6 undergoes little aging, although its strength and dielectric indices decrease at elevated temperatures or on prolonged soaking in water; it can be used at temperatures of up to 100°. This material is recommended for manufacture of components with high mechanical strength and heat resistance (high- and low-voltage commutators, terminal blocks, electrical panels requiring soldering of leads, sliding components, etc.). Pressed products should be heated at 120° ± 5° for 6 hr. For the pressed materials K-18-56 and K-18-53, which have a powdered asbestos filler, see Phenolic press-powders.

Silicoorganic asbovoloknit has high mechanical strength, exceptional thermostability, and good dielectric properties (Table). It is produced as types K-41-5, which is based on phenolypolysiloxane resin, and KMK-218, which is based on methylpolysiloxane resin. Products pressed from silicoorganic asbovoloknit are heat-treated to obtain good strength and dielectric characteristics. The physical, mechanical, and dielectric properties of silicoorganic asbovoloknit are altered by high temperatures. Thus, the ultimate strength under compression of K-41-5 drops to 20% of its initial value over the temperature range 20-300°; the ultimate strength under compression of KMK-218 is little affected. The values of the ultimate strength under static bending and the manner in which it changes are similar for these two materials, but the relative decrease in this index over the temperature range up to 350° is 69% for K-41-5 and 42% for KMK-218. The impact strength of KMK-218 drops to 54% of its initial value when the temperature is raised to 350°. The strength of both materials decreases during prolonged thermal aging. The drop in ultimate strength under static bending for K-41-5 is 15% of the initial value at 200° and 35% at 300° (after aging for 300 hr); the comparable figures for KMK-218 are 16% at 200° and 35% at 400°. Impact strength is little affected at 200° and is substantially reduced at 400°. The high values obtained for the tangent of the angle of dielectric loss and the dielectric constant make it impossible to use K-41-5 and KMK-218 for manufacturing components for high-frequency radio equipment. The deep resistance of both materials decreases by 1 or 2 orders of magnitude as the temperature is raised from 20° to 100°, but remains virtually unchanged when it is further increased. Thermal aging of K-41-5 (at 200° or more) causes a sharp drop in deep resistance, both under normal conditions and when the material has been kept in a moist atmosphere. Aging of KMK-218 at 200° and 300° increases its specific resistance under normal conditions, but has virtually no effect on this index when the humidity at 300° is high. The working temperature for both materials is 300-350°, but they can withstand higher temperatures in single-use products. K-41-5 has a higher mechanical strength than other silicoorganic press materials and is employed as a heat-resistant electrical insulating and general-purpose material in the manufacture of fittings, housings, and components for instruments and electronic equipment subject to constant heating to 200° or more. KMK-218 has the highest arc resistance and is the most resistant to prolonged exposure to high temperatures; it is used in the manufacture of labyrinthine arc-extinction chambers, switches for high-power direct current, terminal blocks, and other electrical-insulating products which involve direct contact with an electric arc or operation at high temperatures. This material is capable of withstanding the combined action of tropical humidity and temperatures and growths of fungi and molds.

For carbamide asbovoloknit see Aminoplasts.

References: Pik, I.Sh., Pressovochnyye i podelochnyye plasticheskiye materialy [Plastic Pressing and General-Purpose Materials], Moscow-Leningrad, 1951; Steklotekstolit i drugiye konstruktsionnyye plastiki [Steklotextolite and Other Structural Plastics], Collection of articles edited by Ya.D. Avrasina, Moscow, 1960; Plastmassy v mashinostroyenii [Plastics in Machine Building], collection of articles edited by V.K. Zavgorodniy, Moscow, 1959.

M.S. Krol'

ATMOSPHERE RESISTANCE – the ability of materials to withstand the combined action of atmospheric factors: water vapor, rain, wind, dust, oxygen, ozone, solar radiation, and variations in air temperature. The latter two factors are of special importance for polymer materials. Radiant energy both affects the polymer itself and activates oxygen, ozone, and water. This activation results in formation of atmospheric oxygen, hydrogen peroxide, excited oxygen molecules, etc., substances which intensify oxidative processes and consequently accelerate Destruction and Structuring, i.e., lead to accelerated aging and decomposition of the material. Atmospheric aging is specifically accelerated by the presence of mechanical stresses. This is especially important for resin products, which crack under the action of atmospheric ozone when stressed (see Ozone resistance of polymer materials). In the case of materials which absorb large quantities of light (those with dark coloration) the rise in the temperature of the illuminated object may also play a material role. In some cases this factor is of decisive influence in reducing the atmosphere resistance of polymer materials. The breakdown of cellulose materials, cotton fiber, paper, synthetic polyesters, and other polymers is often due to hydrolysis under the influence of radiation. Ultraviolet light may convert the water absorbed by the fibers to hydrogen peroxide (the bleaching action of sunlight), which gradually destroys the fibers. Polyamides, polyesters, polysaccharides, and, particularly, polyolefins, including rubber and resins, are highly susceptible to the action of the atmosphere. Atmosphere resistance can be increased by adding specific antioxidants, light-filtering substances which do not permit radiation to reach the sensitive areas of the material, or hydrophobic substances to the polymer. The requirements imposed on the different additives are extremely diverse and depend on the nature of the polymer, the conditions under which the material will be exposed to the atmosphere, the latitude, etc. An effective increase in atmosphere resistance is occasionally achieved by use of appropriate coatings. Special requirements are imposed on materials intended to function under Arctic conditions and in the upper layers of the atmosphere. Resistance to ultraviolet radiation is very important in the latter case. Ozone resistance plays a special role in the lower layers, particularly during the spring and summer. For the atmosphere resistance of metals see the article on corrosion of metals.

N.N. Lezhnev

ATMOSPHERE-RESISTANT LACQUER AND PAINT COATINGS are coatings which are resistant to the action of atmospheric factors (solar radiation, oxygen, air moisture, temperature, etc.). These coatings include the perchlorvinyl, polyacrylic, pentaphthalate, alkyd-melamine, epoxy and certain others.

The perchlorvinyl(PKhV) lacquer and paint atmospher-resistant coatings have good atmosphere, water resistance and chemical stability and are widely used for painting of ships, aircraft, helicopters, agricultural machines, various metal structures, items used in the oil, highway and transport machine construction, which are used in severe atmospheric conditions, for example, in a humid tropical climate. These coatings retain their properties over a wide range of temperatures from minus 70° to plus 90-100°. Essential deficiencies of the PKhV coatings are the change of color under atmospheric action and the very weak bonding with the metallic surfaces, therefore they are applied on surfaces which have undergone preliminary priming. For the ferrous metals use is made of 138-A, AG-10c, AG-3a, FL-03K primers; for the nonferrous metals use is made of the AG-3a, AG-10c, FL-03Zh and ALG-14 primers. The PKhV enamels are applied primarily with paint sprayers, are dried at 15-25° for 2-2.5 hours. The enamels are thinned to working consistency with the R-5 thinner (12-14 seconds on the VZ-4 viscosimeter).

The polyacrylic lacquer and enamel coatings have excellent resistance to aging under atmospheric conditions. They differ from the other atmosphere-resistant paint and lacquer coatings in stability of the color in the aging process, particularly the lacquer coatings which provide good protection for metallic items thanks to their color achromatism, transparency and resistance to sunlight. As a result of their high vapor penetrability (water swelling is slight) the polyacrylic lacquer films are not suitable for protection against corrosion of the metals which have limited corrosion resistance. The polyacrylic lacquers are used primarily for painting various structures made from aluminum and its alloys, and the enamels are used for the painting of aluminum and other alloys and also for certain grades of steel. The polyacrylic lacquer and enamel coatings are suitable at temperatures from minus 50° to plus 180°. Deficiencies of the coatings are the tendency to some softening at elevated temperature (60° and above) and limited resistance to various forms of fuel. The chemical industry produces the 9-32, 9-32f and AS-82 polyacrylic lacquers, the AS-1sp and AS-81 white enamels. The lacquers and enamels are applied using paint sprayers. In order to improve the adhesion of the lacquers to aluminum surfaces the aluminum and its alloys are first anodized. The enamels are applied over the AG-3a, AG-10s, ALG-14 and other primers (for more detail see Lacquer and Paint Coatings for Aluminum Alloys). The coatings are dried at 15-25° for 1-1.5 hours. The lacquers and enamels are thinned to working consistency using the R-5 thinner (12-14 seconds on the VZ-4 viscosimeter).

The pentaphthalic enamels are atmospheric resistant and are used for painting items located in the open air. The properties of the enamels depend on the drying regime. After drying at 100-120° they have high adhesion, hardness, atmospheric resistance; with drying under natural conditions all the properties deteriorate. These enamels are widely used for painting trolley buses, all-metal railway cars, autobuses, and also various equipment. To improve the protective properties the enamels are applied on previously primed surfaces. The FL-03-K, 138, FL-03Zh and other primers are used. The chemical industry produces the PF enamels in a large assortment of colors (GOST 6465-53). The enamels can be applied using all the methods customary in painting technology. The enamels are thinned to working consistency using the RS-2 thinner (TU MKhP 1763-52).

Alkyd-melamine enamels (GOST 9754-61) have good decorative qualities, water resistance, hardness, elasticity, good protective properties, are atmospheric and sunlight resistant. They are suitable for painting products which are used under conditions of a humid tropical climate. The enamels are applied using a paint sprayer. The coatings are stable after drying of the first coat for 30 minutes at 130-140°, the second coat for 50 minutes. The enamels are used primarily for painting bodies and components of passenger automobiles, motorcycles, etc. The chemical industry produces the enamels in a large assortment of colors. They are thinned to working consistency (24-26 seconds on the VZ-4 viscosimeter) using the 651 solvent (TU MKhP 4537-56).

In the case of inadequate adhesion, the atmosphere-resistant coatings in themselves give poor protection to the metal from corrosion. Therefore, as a rule, they are applied over surfaces which have undergone preliminary preparation and priming. In the selection of the coatings account is taken of the operating conditions, for example, items subjected to the direct effect of solar radiation are painted with enamels of light tones with high gloss or with enamels of an aluminum color which have a high coefficient of reflection. In the case of products operating under conditions of high dust content, use is made of coatings with high hardness (alkyd-melamine, epoxy, etc.). In an atmosphere contaminated with industrial gases and vapors it is most advisable to use the perchlorvinyl enamels.

Equipment operated in regions with high humidity is protected by coatings having low vapor and water permeability (perchlorvinyl, phenol-formaldehyde, alkyd-butyric). The external appearance of items operating under atmospheric conditions is of very great importance, from this point of view the best enamels are the auto enamels made on an alkyd-melamine base and the pentaphthalic enamels.

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I.I. Denker

ATTACHMENT OF RUBBER TO THE METALS (bonding of rubber with the metals) is widely used in the fabrication of rubber-metallic details. The methods of attachment of rubber to the metals are divided into two basic groups: those associated with vulcanization of the rubber (hot attachment) and those not associated with vulcanization of the rubber (cold attachment). During hot attachment, the unvulcanized rubber is attached to the metal in the vulcanization process with the aid of cements, a layer of brass or ebonite. During cold attachment, the vulcanized rubber is attached to the metal by special cements. For the fabrication of rubber-metallic details which carry significant loads, for example, aircraft engine mount supports, auto engine mounts or for the mounting of precision instruments subject to vibration, use is made of hot attachment of the rubber to the metals to create a bond of high strength. Cold attachment of rubber to the metals is used for creation of less-strong bonds which are used for coating various equipment with rubber to provide sound absorption, thermal insulation, etc.

In industry the rubber-metallic details are attached by means of brass; this method is based on the capability of the rubber mixtures which can be vulcanized in contact with a lyaer which electrochemically deposited on the metallic framework of the brass to form a strong bond with it. The attachment of the rubber to the framework which is covered with the brass layer is accomplished in forms, in a press whose plates are heated with steam or by means of electrical current. In this case the vulcanization of the rubber proceeds simultaneously with its shaping and attachment to the metal. The forms may be filled with rubber under pressure for this same purpose. The strength of the attachment of the rubber to the brass in tear tests (40-60 kg/cm^2) depends on the form of the crude rubber used as the basis for the preparation of the rubber, the rubber composition, the quality of the brass deposited and the care with which the entire process is carried out. The attachment using a brass layer is resistant to impact, vibration, is thermally resistant to 130-150° and oil and gas resistant if the rubbers used are heat, gas and oil resistant. The method is suitable primarily for the attachment of rubber to steel framwork on which there has been plated a good and strong layer of brass.

A strong bond of the rubber with the metal cannot be obtained with vulcanization of the rubber mixture in contact with a steel framework which is not covered with a layer of brass. For these cases there have been developed and utilized in industry special cements on the basis of the cyclized, chlorinated and oxidized crude rubbers, synthetic resins, organic isocyanates, and also combined cements based on the materials listed. The basis of the cements from the cyclized crude rubber is thermoprene, which is obtained by action of sulfuric acid or organic sulfo acids on natural crude rubber along with heating. For the attachment of rubber to the metals,use is made of solutions of thermoprene in benzene of 10-15% concentration. The tear strength of the attachment of rubber to the metals using thermoprene is 10-25 kg/cm^2. Vulcanized rubber can also be attached to metal with the aid of the thermoprene cement. Wide usage is made for attachments of cements based on the natural and synthetic chlorinated crudes, which have adhesive properties to the metals and rubbers. In the process of the vulcanization of the rubber, these cements are capable of creating a strong bond of the resin with the metal, for example, the cement 201. The tear strength of the attachment using this cement is from 30 to 60 kg/cm^2. The bond is thermally stable to 120-130°. The bond is resistant to impact, vibration and has limited resistance to the action of solvents and oils. The DT-2 cement based on the oxidized crudes is recommended for the attachment to metals of the rubbers based on the crudes SKB and SKS-30. The tear strength of the bond obtained with the aid of this cement is 20-40 kg/ /cm^2.

The cement VDU-3 which is used for the attachment of rubbers based on the SKN crude to metals is a solution of a mixture of the VDU resin and carbon black mixture of the SKN-40 crude in acetone and benzene. The tear strength of the attachment using this cement is 40-50 kg/cm^2. This same group includes the cements MAS-1 and KT-15 with heat resistance of the attachment to 200-300° which are used for the attachment to metals of the high temperature-resistant silicone rubbers. In industry widest use is made of the Laykonat cement based on organic isocyanate which permits attachment of rubbers of all the industrial forms of the crudes to the most varied metals (this cement is known abroad under the label of Desmodur R). The tear strength of the rubber-metal attachments obtained with the aid of these cements is 40-60 kg/cm^2. The Leykonat bond is heat resistant to 130-150°, has excellent resistance to the action of organic solvents and oils. Compounded cements are prepared on the basis of materials having good adhesive properties. Thus, the widely know Tie-Ply cement is created on the base of the chlorinated and hydrochlorinated crudes. The attachment of rubber to the metals for fabrication of rubber-metal details by means of ebonite is not used in view of the brittleness of the latter. The ebonite bond is used in industry in rubberizing chemical equipment. Cold attachment of vulanized rubber to metal at ordinary temperature with the aid of special cements has found wide application in various branches of industry. It does not require special equipment, forms, heating, etc. The strength of the bond of the rubber with the metal in this case is considerably less than the strength obtained with hot bonding. The cements 88 (based on Sevanit) and 88-n (based on Nairit) used for cold attachment of rubber to metals is heat resistant to 60-70°. The tear strength of the rubber-metal bond 24 hours after cementing must be no less than 11 kg/cm^2, and the delamination strength must be no less than 2 kg/cm^2. Bonding using these cements is not resistant to the action of solvents and has limited resistance to oils. In addition to the 88 and 88-n cements, use is made of the SN-57 and SN-58 cements with thermal resistance of the attachment to 70-80°, but with lower bond strength than in the case of the 88 and 88-n cements. The glue 3300 of the 88-n type which is more resistant to oils and gasoline is also known. The rubbers which are being bonded by the cold setting cements must not contain significant quantities of softeners and plasticizers (no more than 5-10 parts by weight to 100 parts of crude).

Any method of attachment of rubber to the metals requires cleaning of the metal surface of rust, scale, oils, lubricants, etc., and other contaminants. The metal surface is cleaned by dry or wet sand (sand blasting), steel or iron shot (shot blast cleaning), wire brushes, emery cloth and etchants.

Infrequent use is made of mechanical attachment of rubber to the metals which is based on securing the rubber in openings of the metal framework in the process of vulcanization of the rubber.

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S.K. Zherebkov

I-94a

AUSTENITE— a solid solution in which γ-iron is the solvent, having a face-centered cubic lattice structure. In iron-carbon alloys the solute is carbon, whose maximum content in austenite reaches 2% (at a temperature of 1130°). In addition to carbon, the austenite in alloy steels may contain certain alloying elements.

No austenitic phase is present in carbon steel at equilibrium at temperatures below 723°; this phase may be present in small quantities at room temperature in quenched carbon steel, taking the form of so-called residual austenite. Homogeneous austenite with a polyhedral structure may be fixed even during normalization in alloy steels with a sufficiently high content of alloying elements (e.g., nickel, manganese, etc.). Austenite is nonmagnetic; it has a higher density than the other basic structural constituents of steel, a moderate hardness and ultimate strength, a low elastic limit, and a high viscosity.

Austenite is named for the English metallurgist W. Roberts-Austen.

A.F. Golovin

AUSTENITIC-FERRITIC STAINLESS STEEL is a group of chrome-nickel or chrome-manganese steels whose structure consists of austenite and δ-ferrite. The relationship between the amount of the ferritic and austenitic phases at high temperatures depends on the content of the chromium, nickel, manganese and other alloying elements, and also on the tempering temperature (900-1300°) (Fig. 1). It has been established that the best combination of mechanical properties and corrosion resistance of austenitic-ferritic stainless steel is obtained after tempering at 950-1000° with rapid cooling. Use of higher tempering temperature (above 1100°) increases the amount of the ferrite and reduces the amount of the austenite (Fig. 1). With subsequent heating at 550-900° there is a reverse separation of the austenite from the ferrite in the form of widmanstatten figures (Fig. 2). The austenitic-ferritic stainless steels which are quenched from high temperatures are more prone to separation of the σ-phase and structural changes which lead to the appearance of intercrystalline corrosion (Fig. 3). Extended heating 475° makes the steel prone to embrittlement and destruction by selective corrosion (Fig. 4). For this reason use of the austenitic-ferritic steels for operation above 350-400°, is not recommended, and during welding several precautions must be observed to avoid excessive heating of the metal adjacent to the weld seam. The mechanical properties of the austenitic-ferritic stainless steels depend on the relationship of the amount of the ferritic and austenitic phases and the degree of their refinement. A high silicon content in the austenitic-ferritic stainless steels increases the amount of the ferritic component and improves the ultimate and yield strengths at room temperatures. The chrome-nickel steels with low nickel content (OKh21N5T, 1Kh21N5T, OKh21N6M2T) have higher strength properties than the chrome-nickel steel of purely austenitic type. The two-phase structure also improves the strength of the weld seam, which is of great practical importance.

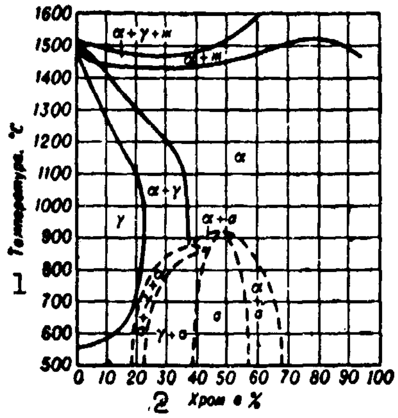

Fig. 1. Effect of chromium on phase position in alloys with iron containing 8% Ni. 1) Temperature, °C; 2) chrome in percent.

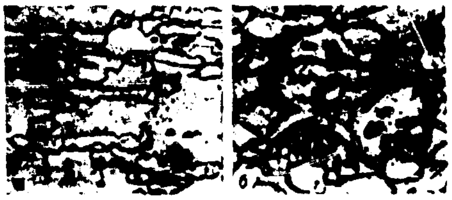

Fig. 2. Structure of OKh21N5T steel: a) After quenching from 1000° into water; b) after quenching from 1200° into water and 2-hour heating at 750° (lamellar segregations of secondary austenite from the ferrite are seen).

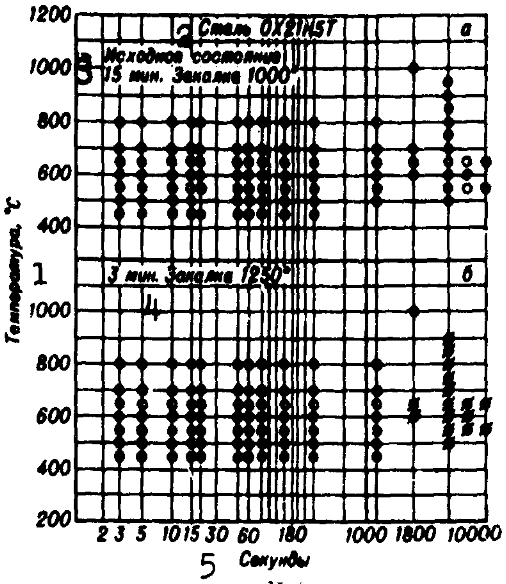

Fig. 3. Effect of temperature and time on tendency of OKh21N5T steel to intercrystalline corrosion: a) After quench from 1000° in water (hold for 15 min); b) after quench from 1250° in water (hold 3 min); o) specimens destroyed by intercrystalline corrosion; o) specimens destroyed by intercrystalline corrosion; o) specimens withstood intercrystalline corrosion testing per GOST 6032-58 (AM method). 1) Temperature, °C; 2) OKh21N5T steel; 3) initial condition, 15 min, quench from 1000°; 4) 3 min, quench from 1250°; 5) seconds.

Fig. 4. Structure-selective corrosion of 1Kh21N5T steel in solution of copper sulfate and sulfuric acid after water quench from 980° and 2-hour temper at 550°.

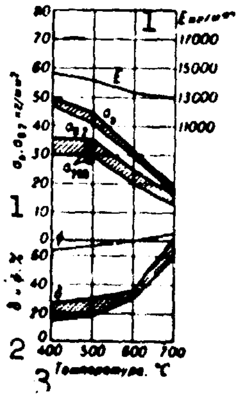

Fig. 5. Variation cf mechanical properties of 1Kh21N5T steel with test temperature. 1) σ_b, $\sigma_{0.2}$ kg/mm²; 2) and; 3) temperature, °C.

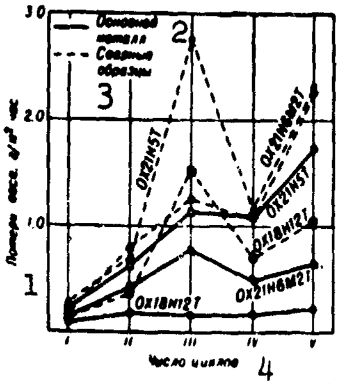

Fig. 6. Variation of corrosion resistance of basic metal and welded specimens of various steels as a function of number of cycles in boiling 65% nitric acid. Each cycle is 48 hours of boiling. 1) Weight loss, g/m^2-hr; 2) base metal; 3) welded specimens; 4) number of cycles.

TABLE 1

Chemical Composition of Sustenitic-Ferritic Chrome-Nickel Stainless Steels

Сталь по ГОСТ 1	Заводская марка 2	3 Содержание элементов (%)					
		C	Si	Mn	Cr	Ni	4 др. элементы
0X21H5T	5 ЭП53	<0.08	<0.8	<0.8	20—22	4.8—5.8	Ti (0.3—0.6)
1X21H5T	ЭИ811 6	0.09—0.14	<0.8	<0.8	20—22	4.8—5.8	Ti (%C—0.02) 5, но не более 0.8 7
0X21H6M2T	ЭП54	<0.08	<0.8	<0.8	20—22	5.5—6.5	Ti (0.2—0.5) Mo (1.8—2.5)
0X20H14C2	ЭИ732	<0.08	2—3	<1.5	19—22	12—15	
X20H14C2	ЭИ211	<0.2	2—3	<1.5	19—22	12—15	

1) Steel per GOST; 2) factory designation; 3) element content (%); 4) other elements; 5) EP; 6) EI; 7) but no more than.

TABLE 2

Mechanical Properties and Heat Treatment of Austenitic-Ferritic Stainless Steels

Сталь по ГОСТ 1	Заводская марка 2	Полуфабрикат 3	ГОСТ или ТУ 4	Термич. обработка 5	σ_b (кг/мм²) 6	$\sigma_{0,2}$ (кг/мм²) 6	δ (%)	$a_н$ (кгм/см²) 7
0Х21Н5Т	ЭП53 11	8 Тонкий лист	ГОСТ 5582—61	Закалка с 1000—1080° на воздухе, в воде	65	—	20	—
		12 Толстый лист 13	ЧМТУ 62-58	10 Закалка с 980—1050° на воздухе, в воде	65	30	20	—
	14	Пруток	ГОСТ 5949—61 9	Закалка с 980—1050° на воздухе 15	60	35	25	—
1Х21Н5Т	ЭИ811	Тонкий лист	ГОСТ 5582—61	Закалка с 1000—1080° в воде, на воздухе	65	—	18	—
		17 Проволока	ЧМТУ 201-60	16 Закалка с 900—1000° в воде, на воздухе	70	35	20	6
		Пруток	ГОСТ 5949—61	Закалка с 980—1050° на воздухе	65	40	20	6
		Толстый лист	ЧМТУ 62-58	Закалка с 950—980° в воде 19	70	45	25	6
	20	Трубы	ЧМТУ 142-58	Закалка с 900—1000° на воздухе, в воде	70	—	20	—
0Х21Н6М2Т	ЭП54	Тонкий лист	ГОСТ 5582—61	Закалка с 1000—1080° на воздухе, в воде	70	—	18	—
		Пруток	ГОСТ 5949—61	Закалка с 980—1050° на воздухе	65	35	20	—
0Х20Н14С2	ЭИ732 18	Пруток	ГОСТ 5949—61	Закалка с 1000—1100° на воздухе, в воде	55	25	40	10
Х20Н14С2	ЭИ211	Пруток	ГОСТ 5949—61	Закалка с 1000—1150° на воздухе, в воде	60	30	35	—
		Тонкий лист	ГОСТ 5582—61	Закалка с 1000—1080° в воде, на воздухе	60	—	40	—

1) Steel per Gost; 2) factory designation; 3) mill product; 4) GOST or TU: 5) heat treatment; 6) (kg/mm^2); 7) a_n (kgm/cm^2); 8) thin sheet; 9) GOST; 10) quench from – in air, in water; 11) EP; 12) thick sheet; 13) ChMTU; 14) rod; 15) quench from – in air; 16) quench from – in water, in air; 17) wire; 18) EI; 19) quench from – in water; 20) tube.

TABLE 3

Typical Mechanical Properties of 1Kh21N5T Steel*

Состояние материала 1	2 σ_b (кг/мм²)	2 $\sigma_{0,2}$ (кг/мм²)	δ_{10} (%)	3 Число перегибов	Проба по Эриксену (мм) 4
5 После закалки с 950—1000° на воздухе . . .	70—85	52—60	22—32	4—6	8.8
После нагартовки в холодном состоянии . . . 6	90—115	70—90	8—20	2—3	7

*Sheet thickness 1:5 mm.

1) Material condition; 2) σ_b (kg/mm^2); 3) number of bends; 4) Erichsen test (mm); 5) after air quench from; 6) after work hardening in cold condition.

TABLE 4

Mechanical Properties of Weld Joints of Hot Rolled Sheets*

1 Вид сварки	σ_b	$\sigma_{0,2}$	2 Число загибов или угол загиба	
	3 (кг/мм²)		4 продольный образец	5 поперечный образец
6 Основной материал	78	55	10	5
7 Электродуговая сварка с обмазанной электродов	70	51	8	180°
8 Аргонодуговая сварка	75	65	9	180°

*Sheet thickness 3 mm.

1) Form of welding; 2) number of bends or bend angle; 3) (kg/mm^2); 4) longitudinal specimen; 5) transverse specimen; 6) parent material; 7) electro-arc welding with coated electrodes; 8) argon-arc welding.

TABLE 5

Corrosion Resistance of 1Kh18N9T and Type 20-12-Si Steels in Boiling 60% Nitric Acid

1 Сталь	2 Термическая обработка	3 Потери веса (г/м²·час)				
		4 один цикл *	5 два цикла	6 три цикла	7 четыре цикла	8 пять циклов
9 20-10-Ti (типа 1Х18Н9Т)	Закалка с 1050° в воде 10	0.23	0.62	0.4	0.32	0.29
	То же и отпуск в течение 2 час при 650° 11	1	7.3	7.6	7.8	6.7
	То же и отпуск в течение 50 час при 650°	0.8	3.2	2.9	3.4	2.8
20-12-2.3 Si с 0.10% С 12	Закалка с 1050° в воде	0.7	1.16	2	2.4	2.1
	То же и отпуск в течение 2 час при 650°	14	28	15	19	—

*Each cycle is 48 hours stay in the boiling acid.

1) Steel; 2) heat treatment; 3) weight loss (g/m^2-hr); 4) one cycle*; 5) two cycles; 6) three cycles; 7) four cycles; 8) five cycles; 9) (type 1Kh18N9T); 10) water quench from 1050°; 11) same and tempering for 2 hours at 650°; 12) with.

0Kh21N5T, 1Kh21N5T, and 0Kh21N6M2T chrome-nickel austenitic-ferritic stainless steels. At high temperatures the 1Kh21N5T steel has relatively low mechanical properties which decrease rapidly with heating above 500° (Fig. 5). The steel welds well using various welding methods: spot, manual electric-arc and argon-arc with the use of weld wire made from steel of the same composition or from chrome-nickel steel of the 18-8 and 18-8-with-niobium types.

In the heat treated condition the OKh21N5T and 1Kh21N5T steels have high corrosion resistance in oxidizing media, very close to the resistance of the chrome-nickel austenitic stainless steel of the 18-8 type with niobium. When tested per GOST 6032-58, weld joints made from the OKh21N5T and 1Kh21N5T steels using the TsL-11 electrode (1Kh18N9B weld wire) do not have intercrystalline corrosion in the thermally affected zone. However corrosion of the putting type in boiling 65% nitric acid is about the same as for the 1Kh18N9T steel. The variation of the corrosion rate of these steels and weld joints in 65% nitric acid as a function of the number of cycles of 48-hour boiling is shown in Fig. 6. The OKh21N6M2T steel also belongs to the austenitic-ferritic stainless steel group, but thanks to the molybdenum additive it has higher corrosion resistance in several media in which the 18-12 type chrome-nickel steel with molybdenum is used. This steel has higher tendency to precipitation of the σ-phase, and also to embrittlement at a temperature of 475° as a result of the large quantity of ferritic-forming elements present. After water quench from 1000° it has high corrosion resistance in several media and is not prone to intercrystalline corrosion even with quite long exposure. Quenching of the OKh21N6M2T steels from high temperatures (1200°) leads to the appearance of a tendency to intercrystalline corrosion directly after quenching, and also after tempering.

The austenitic-ferritic stainless steels based on the systems Fe — Cr — Mn or Fe — Cr — Mn — Ni, which have about the same properties as the chrome-nickel austenitic-ferritic stainless steels just considered, find some application in the US.

High manganese content (more than 10%) in the chrome-manganese steels and high chrome content in the chrome-manganese-nickel steels lead to very severe embrittlement as a result of precipitation of the intermetallic σ-phase.

The chrome-nickel-silicon austenitic-ferritic stainless steels include the chrome-nickel-silicon steels of the austenitic-ferritc type, which as a result of the two-phase structure have higher mechanical properties than the 18-8 type austenitic chrome-nickel steels, high corrosion resistance, low tendency to carbonization, better casting properties, but greater tendency to embrittlement as a result of precipitation of the σ-phase. At the same time the high silicon content has an unfavorable effect on hot pressure working, reduces the plasticity in the hot condition. The type 20-10 chrome-nickel steel with silicon (4%) shows somewhat better corrosion stability in dilute solutions of hydrochloric and sulfuric acids, but poorer corrosion resistance in boiling solutions of 60 and 60% nitric acid. Table 5 shows the corrosion resistance of the 1Kh18N9T and type 20-10 chrome-nickel steels with silicon in boiling 60% nitric acid. These data indicate the unfavorable effect of silicon addition on the corrosion resistance of steel in nitric acid of this strength.

TABLE 6

Mechanical Properties of 18-10 Steel With 3.5% Si

Обработка 1	σ_b (кг/мм²) 2	δ_5	ψ
		(%)	
3 Литье	62	14	13
4 Литье + выдержка в течение 40 мин. при 1050° в воде	70	36	40
5 Кованая сталь	85	44	58
6 Кованая сталь + выдержка в течение 40 мин. при 1050° в воде	83	53	70

1) Treatment; 2) σ_b (kg/mm^2); 3) cast; 4) cast + soak for 40 min at 1050°, water quench; 5) wrought steel; 6) wrought steel + soaking soak for 40 min at 1050°, water quench.

The refinement of the cast structure of steel with silicon leads to increase of σ_b with simultaneous improvement of the plasticity. Heat treatment at 1050° also has a favorable effect, increasing the strength and plasticity of the cast and wrought material.

Technological characteristics. The austenitic-ferritic stainless steels have severe anisotropy of properties along and across the direction of rolling when the deformation is performed predominantly in some one direction during their production. The two-phased structure of the steel also has an unfavorable effect on hot pressure working, particularly in the fabrication of seamless tubing, therefore in hot pressure working it is necessary to observe narrow heating temperature ranges and lower degrees of deformation.

The 0Kh21N5T and 1Kh21N5T steels are used to replace the 1Kh18N9T steel for the fabrication of corrosion-resistant detail parts. The 0Kh21N5T steel is recommended for replacement of the Kh17N13M3T (Kh18N12M2T) chrome-nickel-molybdenum steel as a corrosion-resistant material which is stable in acetic, lactic, oxalic, phosphoric acids and other aggressive media.

The 0Kh20N14S2 and Kh21N14S2 steels serve for the fabrication of scale-resistant tubing, furnace conveyors, cementation boxes, hangars and supports in steam boilers. The type 20-10 steels with silicon may find application in fabricating elements for high strength structures.

References: Khimushin, F.F., Nerzhaveyushchiye stali (Stainless Steels), Moscow, 1963; Babakov, A.A. KhP, 1959, No. 4; Khimushin, F.F., in book: Puti ekonomii nerzhaveyushchikh staley (Ways of Economizing Stainless Steels), Seminar Transactions, Moscow, 1960 (Moscow House of Scientific-Technical Propaganda im. F.E. Dzerzhinskiy, coll. 1) Kuznetsov, V.V., Kachestvennaya stal' (High-Quality Steel), 1935, No. 7, p. 5.

F.F. Khimushin

II-26N

AUSTENITIC STAINLESS STEEL is steel alloyed with chromium, nickel, and manganese which retains the structure of the γ-solid solution (austenite) with cooling from high temperature to room temperature and below. In contrast with ferritic stainless steel, austenitic stainless steel is nonmagnetic, has moderate hardness and strength, low yield point and high plastic properties (δ and $\psi \geq 50\%$). In application to the austenitic stainless steels quenching is the heat treatment operation which fixes the austenitic structure. With nickel or manganese content in the steel which is not adequate for the formation of a purely austenitic structure, intermediate structures are obtained: austenite + ferrite, austenite + martensite, and others. In steel of the system Fe — Cr — Mn, as a result of the lower effectiveness of the manganese in the formation of the austenitic structure the austenite + ferrite or austenite + martensite regions are more developed (Fig. 1).

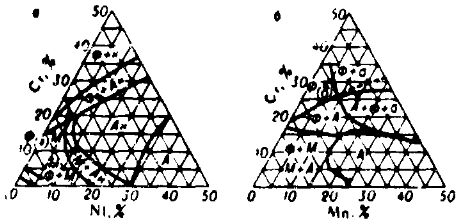

Fig. 1. Ternary diagrams: a) system Fe — Cr — Ni; b) system Fe — Cr — Mn A — stable austenite; A_n — unstable austenite; Ф — ferrite; $Ф_\delta$ — δ-ferrite; M — martensite; K — carbides; σ — intermetallide σ-phase.

Introduction into the composition of chrome-nickel steel of various elements causes a change of position on the state diagrams of the phases γ, α and $\gamma + \alpha$. Increase of the chrome content, introduction of titanium, niobium, silicon, tantalum, aluminum, and molybdenum promote the formation of the ferritic phase. Increase of the nickel content, introduction of nitrogen, carbon, manganese, on the other hand, promote expansion of the region of existence of the austenite and increase its stability. With respect to the efficiency of their austenite-forming effect, the alloying elements are arranged in the following sequence (with indication of the nominal coefficients): carbon (30), nitrogen (26), nickel (1), manganese (0.6-0.7), copper (0.3). The ferrite-forming elements are: aluminum (12), vanadium (11), titanium (7.2-5), silicon (5.2), niobium (4.5), molybdenum (4.2), tantalum (2.8), tungsten (2.1), chromium (1).

Long-term heating of the austenitic steels at 700-900° or slow cooling from high temperatures causes the formation of the hard and brittle intermetallide σ-phase, which can lead to a very severe loss of ductility. Heating the steel above 900° eliminates this phenomenon, providing for transition of the brittle σ-phase into a solid solution. Separation of the σ-phase (Fig. 2) may take place directly from the austenite or from the ferrite which is formed after the $\gamma \rightarrow \alpha$ transformation. The austenitic stainless steel which has the σ-phase in the structure is more prone to cracking as a result of the action of temperature changes. The degree of effectiveness of the influence of the alloying elements on the reduction of the martensitic transformation temperature increases in the following order: silicon (0.45), manganese (0.55), chromium (0.68), nickel (1), carbon or nitrogen (27).

The stability of the austenitic structure in the chrome-nickel steel is also associated with the change of solubility of carbon (carbides) in the γ-solid solution at various temperatures. Separation of the carbides from the γ-solid solution as a result of heating to 650-800° increases the martensitic transformation temperature.

Separation of the carbides from the solid solution (austenite)

Fig. 2. Separation of σ-phase in the ferrite of type 18-8 steel with titanium after quenching from 1250° and 2-hour heating at 800°.

causes a change in it of the concentration of the alloying elements, which can cause partial structural transformation and change of the ma magnetizability, particularly in alloys lying near the boundary between the regions of the γ and α-phases. This transformation takes place preferentially along the grain boundaries, where there is the greatest depletion of carbon and chromium from the solid solution, which makes the steel prone to intercrystalline corrosion. Under the action of aggressive media such a steel decomposes rapidly, even more rapidly with higher carbon content. Protracted heating at 500-700° causes a tendency to intercrystalline corrosion of steel even with very low carbon content (0.017-0.03%). To prevent this phenomenon, additions are made to the austenitic chrome-nickel steels of such strong carbide-forming elements as titanium or niobium. With regard to intercrystalline corrosion, the austenitic stainless steels are divided into the following groups: those which have high tendency to intercrystalline corrosion with heating to 450-750° (OKh18N10, OKh18N11, Kh18N9, 2Kh18N9, 2Kh13N4G9, Kh14G14N, Kh17G9AN4, Kh17AG14); those which are not prone to intercrystalline corrosion (OKh18N10T, Kh18N9T, OKh18N12T, 1Kh18N12T, OKh18N12B, Kh14G14N3T). Steels of the first group cannot be used above 400-450° in aggressive media. For operation in aggressive media parts must be subjected to heat treatment (austenitic quench from 1000-1100° into water) after welding (except for spot and seam welding). Steels of the second group may be used at high temperatures and in weld joints. The austenitic stainless stells of the intermediate group (OOKh18N10, OOKh17G9AN4, OKh17N5G9BA) with short duration heating in the course of 5-30 minutes do not develop a strong tendency to intercrystalline corrosion. This permits performing welding without danger of onset of intercrystalline corrosion in the weldment in the thermally effected zone if the welding is performed rapidly enough. The lower the carbon content in this steel (0.03-0.06%), the more resistant it is to intercrystalline corrosion.

TABLE 1

Chemical Composition

Сталь по ГОСТ 5632–61 1	Заводская марка 2	3 Содержание элементов, %					
		C	Si	Mn	Cr	Ni	4 др. элементы
00X18H10 5	ЭИ842	0,04	0,8	1–2	17–19	9–11	—
0X18H10 6	ЭЯ0	0,07	0,8	1–2	17–19	9–11	—
0X18H11	ЭИ684	0,06	0,8	1–2	17–19	10–12	—
X18H9	ЭЯ1	0,12	0,8	1–2	17–19	8–10	—
2X18H9	ЭЯ2	0,13–0,21	0,8	1–2	17–19	8–10	—
0X18H10T	ЭИ914	0,08	0.8	1–2	17–19	9–11	7 Ti>5C до 0,6%
X18H9T	ЭЯ1T	0,12	0,8	1–2	17–19	8–9,5	Ti>5 (%C–0,02) до 0,7%
X18H10T	ЭЯ1T	0,12	0,8	1–2	17–19	9–11	То же
0X18H12T	—	0,08	0,8	1–2	17–19	11–13	Ti>5C 8 до 0,6%
X18H12T	—	0.12	0,8	1–2	17–19	11–13	Ti>5 (%C–0,02) до 0,7%
0X18H12Б	ЭИ402	0,08	0,8	1–2	17–19	11–13	Nb>8C до 1,2%
2X13H4Г9	ЭИ100	0,15–0,3	0,8	8–10	12–14	3,7–4,7	—
X17Г9AH4	ЭИ878	0,12	0,6	8–10,5	16–18	3,5–4,5	0,15–0,25% N
X14Г14H	—	0,12	0,8	13–15	13–15	1–1,5	—
X14Г14H3T	ЭИ711	0,1	0,8	13–15	13–15	2,5–3,5	Ti>5 (%C–0,02) до 0,6%
X17AГ14	ЭИ213	0.15	0,8	13,5–15,5	16–18	0,6	0,3–0,4 N
0X17H5Г9БA 9	ЭИ55	0,08	0,6	8–10	16–18	4,5–5,5	0,8 Nb 0,18–0,25 N
X17H13M2T	ЭИ448	0,1	0,8	1–2	16–18	12–14	0,3–0,6 Ti 1,8–2,5 Mo 0,02 S 0,035 P
X17H13M3T	ЭИ432	0,1	0,8	1–2	16–18	12–14	0,3–0,6 Ti 3 –4 Mo 0,02 S 0,035 P
0X17H16M3T	ЭИ580	0,08	0,8	1–2	16–18	15–17	0,3–0,6 Ti 2 –3,5 Mo 0,02 S 0,035 P
0X23H28M2T	ЭИ628	0,06	0,8	0.8	22–25	26–29	0,4–0,7 Ti 1,8–2,5 Mo 0,02 S 0,035 P
0X23H28M3Д3T	ЭИ943	0,06	0,8	0.8	22–25	26–29	0,4–0,7 Ti 2,5–3 Mo 2,5–3,5 Cu 0,02 S 0,035 P

1) Steel per GOST 5632-61; 2) factory designation; 3) content of elements, %; 4) other elements; 5) EI842; 6) EYa; 7) to; 8) same; 9) EP.

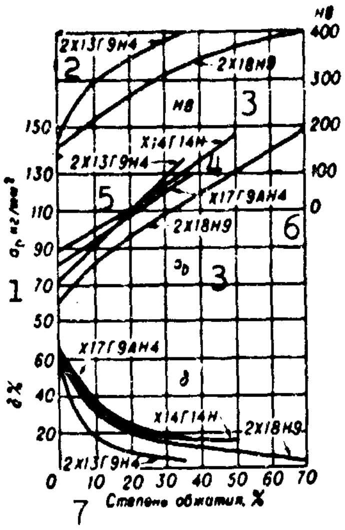

Fig. 3. Variation of mechanical properties of austenitic stainless steel as a function of degree of reduction with cold rolling of 1.5-2-mm-thick sheet. 1) σ_b kg/mm^2; 2) 2Kh13G9N4; 3) 2Kh18N9; 4) Kh14G14N; 5) 2Kh13G9N4; 6) Kh17G9AN4; 7) degree of reduction, %.

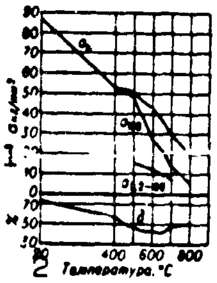

Fig. 4. Variation of mechanical properties of Kh13N4G9 steel with temperature increase. 1) σkg/mm^2; 2) temperature, °C.

The strength of chrome-nickel steel may be increased considerably by strain hardening during cold rolling, drawing, stamping. Here σ_b may reach 120 kg/mm^2 for sheet and strip, $\sigma_{0.2}$ increases to 100-120 kg/mm^2, at the same time the plastic properties drop, δ falling from 50-60% to 10-18% (see Fig. 3). However this plasticity is adequate for part fabrication. For wire σ_b increases to 180-260 kg/mm^2. In comparison with the ferritic and semi-ferritic stainless steels, the austenitic stainless steels have higher mechanical properties at elevated temperatures (Figs. 4, 5).

Type 18-8 chrome-nickel steel (OOKhk8N10, OKh18N10, Kh18N9, 2Kh18N9). Steels with low carbon content (00Kh18N10 and 0Kh18N10) are used primarily as welding electrode wire. The lower the carbon content in the welding wire, the higher the corrosion resistance of the weld seam. Steels Kh18N9 and 2Kh18N9 have a strong tendency to intercrystalline corrosion even with brief heating in the moderate temperature range, therefore after welding the parts are subjected to an austenitic structural quench. The steels Kh18N9 and 2Kh18N9 are used primarily in the work-hardened condition for the fabrication of high strength parts for aircraft and autos which are joined by electric spot or seam welding.

TABLE 2

Mechanical Properties (No Less Than)

Сталь по ГОСТ 5632—61 1	Заводская марка 2	Полуфабрикат * 3	Термич. обработка 4	HB	σ_b	$\sigma_{0,2}$	δ	ψ
				5	(кг/мм²)		(%)	
00Х18Н10	ЭИ842	6 Лист	7 Закалка с 1050—1080° в воде 8	—	55	—	45	—
		Пруток 9	Закалка с 1050—1100° на воздухе, в масле или в воде 10	135—170	45	18	40	20
0Х18Н10	ЭЯ0 0Х18Н9	Лист	Закалка с 1050—1080° в воде 8	—	52	—	45	—
		Пруток	Закалка с 1050—1100° на воздухе, в масле или воде 10	135—185	48	20	40	55
0Х18Н11	ЭИ684	Лист	Закалка с 1050—1080° в воде или на воздухе 11	—	52	—	35	—
Х18Н9	ЭЯ1 1Х18Н9	Лист	Закалка с 1050—1080° в воде 8	—	55	—	35	—
		Пруток	Закалка с 1050—1100° на воздухе, в масле или воде 10	135—200	58	20	40	55
2Х18Н9	ЭЯ2	Лист	Закалка с 1050—1100° в воде или на воздухе	—	60	—	35	—
		Пруток	Закалка с 1050—1100° в воде или на воздухе	160—200	59	22	40	55
0Х18Н10Т	ЭИ914	Лист	Закалка с 1050—1080° в воде или на воздухе	—	52	—	40	—
		Пруток	Закалка с 1050—1100° на воздухе, в масле или воде	140—180	50	20	40	55
Х18Н9Т и Х18Н10Т	ЭЯ1Т	Лист	Закалка с 1050—1080° в воде или на воздухе	—	56	—	[illegible]	—
		Пруток	Закалка с 1050—1100° на воздухе, в масле или воде	135—185	55 (Х18Н9Т)	—	—	—
					52 (Х18Н10Т)	20	40	55
0Х18Н12Т	—	Лист	Закалка с 1050—1080° в воде или на воздухе	—	52	—	35	—
Х18Н12Т	—	Лист	Закалка с 1050—1080° в воде или на воздухе	—	55	—	35	—
		Пруток	Закалка с 1050—1100° на воздухе, в масле или воде	[illegible]—180	55	20	40	55
0Х18Н12Б	ЭИ402 Х18Н11Б	Лист	Закалка с 1050—1080° в воде или на воздухе	—	54	—	40	—
		Пруток	Закалка с [illegible] на воздухе, в масле или воде	150—200	50	18	40	55
2Х13Н4Г9	ЭИ100	Лист	Закалка с 1080—1120° в воде	—	65	—	40	—
		Пруток	Закалка с 1100 ± 30° в воде или на воздухе	160—200	65	25	35	45
Х17Г9АН4	ЭИ878	Лист	Закалка с 1050—1080° в воде	—	70	—	40	—
Х14Г14Н	—	Лист	Закалка с 1050—1080° в воде	—	По согласованию 13			
		Пруток	Закалка с 1000—1080° в воде	160—210	70	30	35	50
Х14Г14Н3Т	ЭИ711	Лист	Закалка с 1050—1080° в воде или на воздухе	—	70	—	35	—
		Пруток	Закалка с 1000—1080° в воде или на воздухе	160—210	70	30	35	50
Х17АГ14	ЭП213	Лист	Закалка с 1050—1080°	—	70	—	35	—
0Х17Н5Г9БА	ЭП55	Лист	Закалка с 1000—1080° в воде	160—210	80	40	35	—
Х17Н13М2Т Х17Н13М3Т	ЭИ448 ЭИ432	Лист	Закалка с 1050—1080° в воде или на воздухе	—	54		35	—
		Пруток	Закалка с 1050—1100° охлаждение в воде, масле или на воздухе	12 —	52	12	54	55
0Х17Н16М3Т	ЭИ580	Лист	Закалка с 1050—1080° в воде или на воздухе	—	54		35	—
		Пруток	Закалка с 1050—1100° охлаждение в воде, масле или на воздухе	—	50	20	35	45
0Х23Н28М2Т	ЭИ628	Лист	Закалка с 1050—1080° в воде или на воздухе	—	55	—	35	—
		Пруток	Закалка с 1100—1150° охлаждение на воздухе, в масле или в воде		По согласованию			
0Х23Н28М3Д3Т	ЭИ943	Лист	Закалка с 1050—1080° в воде или на воздухе		55		35	
		Пруток	Закалка с 1100—1150° в воде, масле или на воздухе		По согласованию			

*GOST 3582-61 for sneet, GOST 5949-61 for rod.

1) Steel per GOST 5632-61; 2) factory desigantion; 3) mikk product*; 4) heat treatment; 5) (kg/mm²); 6) sheet; 7) rod 7 quench from; 8) in water; 9) rod; 10) in air, oil or water; 11) in water or air; 12) cooled in water, oil, or air; 13) by agreement.

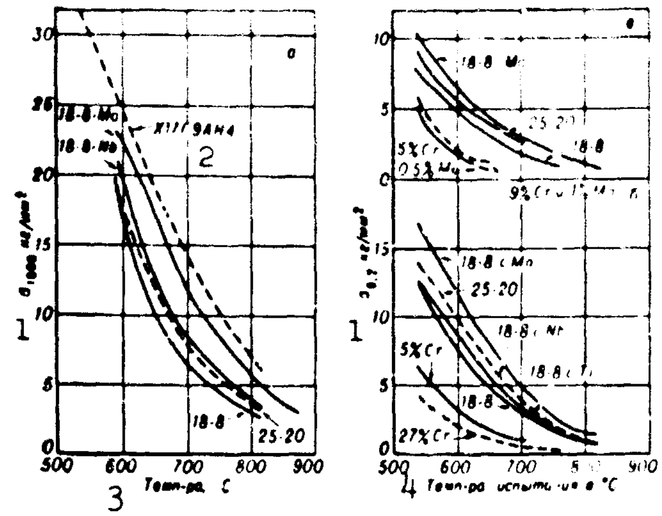

Fig. 5. Stress rupture strength after 1000 hours σ_{1000} (a) and creep limits $\sigma_{1\%-10,000}$ (b), $\sigma_{1\%-100,000}$ (c) of chrome-nickel austenitic stainless steel at elevated temperatures. 1) σ_{1000} kg/mm^2; 2) Kh17G9-AN4; 3) temperature, °C; 4) temperature of test in °C.

The chrome-manganese-nickel steel Kh14G14N with chrome content 12-14% is prone to intercrystalline corrosion during welding and after heating in the dangerous temperature range. It is used for parts in equipment requiring high plasticity and nonmagnetizability. In corrosion resistance it is close to the 12-14% chrome steels. It surpasses the 18-8 type steel in strength after tempering. It is satisfactorily welded by manual and automatic spot and roller welding with the use of weld wire from the type 18-8 stainless chrome-nickel steel. Heat treatment of the steel after welding (other than spot welding) is established as a function of the carbon content by control tests of weld specimens for intercrystalline corrosion per GOST 6032-58.

The 2Kh13G9N4 steel is used for fabrication of high-strength structures, primarily from cold rolled profiled strip. The strength and hardness of this steel increase with cold deformation more strongly than for the type 18-8 chrome-nickel steel. Therefore in cold rolling of strip large degrees of deformation must not be permitted in order to avoid excessive loss of plasticity.

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This steel operates reliably under [illegible] and is widely used in the foodstuffs industry. It retains high mechanical properties to 450°. It has a tendency to intercrystalline corrosion, therefore it serves primarily for the fabrication of parts whose joining is accomplished with the aid of spot or roller welding. For the same reason, high cooling rates must be used in the heat treatment of cold rolled strip.

Chrome-manganese-nickel steels with 17-19% chrome and nitrogen added (Kh17AG14 and Kh17G9AN4) have high resistance to atmospheric corrosion and in oxidative media. For parts which are fabricated using arc, argon-arc, gas and atomic hydrogen welding, it is necessary to use a steel with low carbon content (0.03-0.05%) and control the process strictly to avoid a tendency to intercrystalline corrosion in the weld joints. For parts fabricated using spot or roller welding, parts which are heat treated after welding, and for parts operating in atmospheric conditions, it is possible to use a steel of this type with higher carbon content.

TABLE 3

Mechanical Properties of Kh17AG14 Steel at Low Temperatures

Темпера (°C) 1	σ_b	$\sigma_{0,2}$	δ	ψ	3 a_k
	2 (кг/мм²)		(%)		(кгм/см²)
−50	115	56	72	60	26
−100	126	74	55	38	22
−196	150	122	8	10	8

1) Temperature (°C); 2) (kg/mm²);
3) (kg/cm²)

The Kh17AG14 steel is markedly strengthened with cold rolling and is used for commercial equipment and as a nonmagnetic material.

The 18-8 type chrome-nickel steels with addition of titanium or niobium (Kh18N9T, Kh18N10T, OKh18N10T, OKh18N12T, OKh18N12B). Addition of titanium or niobium reduces the tendency of the steel to intercrystalline corrosion. Titanium and niobium form stable carbides of the TiC and NbC type, in this case the chrome which is useful for increasing the corrosion resistance does not enter into the composition of the carbides and is retained in the solid solution. Titanium is introduced into the steel in an amount greater than carbon by a factor of 4-5.5, and niobium by a factor of 8-10 times. When the titanium or niobium content in relation to carbon is at the lower limit the steel is not always resistant to intercrystalline corrosion, particularly in long-term service at moderate temperatures (500-800°). This is caused by the effect of the nitrogen which is always present in the steel and binds part of the titanium into nitrides, and also by the effect of heat treatment. Overheating the steel during heat treatment (above 1100°) or welding is considered harmful, particularly in those cases when the relationship between the titanium and carbon is at the lower limit indicated by the formula $Ti \geq 5(\%C - 0.02)$. In this case the 1Kh18N9T steel which has been quenched from a temperature above 1150° acquires a tendency to intercrystalline corrosion. In the case of normal heat treatment regimes (quenching from 1050°) and in the case of short-time heating, it is necessary that the ratio of titanium or niobium to carbon be respectively no less than 5 and 10. For long-duration service of parts at 500-750° it is important that these ratios be no less than 7-10 for titanium and 12 for niobium. To reduce the tendency of the steel to intercrystalline corrosion, a major reduction of the carbon content to 0.03-0.05% is advisable. The corrosion resistance of welded joints made from steel of this type depends on the titanium and carbon content in the base metal and in the weld seam. Since titanium burns up markedly during welding, for the electrodes use is made of special coatings in which the titanium appears in the form of ferrotitanium in order to compensate for the loss of titanium in the welding wire. Generally, use is made of welding wire made from the 18-8 type chrome-nickel steel without titanium, but with a very low ($\leq$0.06%) carbon content (steels OKh18N9 and OKh18N10) or electrodes made from the 18-12 type steel with niobium (OKh18N12B). In weld joints made from the 1Kh18N9T steel operating in media containing nitric acid it is possible to have corrosion of the pitting type resulting from the high (>0.06%) carbon content in the steel. Therefore equipment components for nitric acid production are made from the OKh18N10T steel with carbon content 0.06%. In addition, this steel has higher over-all corrosion resistance.

In the deposited metal of the weld seam of a joint of steel with titanium, having a two-phase structure $\gamma + \alpha$, it is possible to have the $\alpha \rightarrow \sigma$-transformation with long-term heating in the range of moderate temperatures (650-800°), which makes the weld seam very brittle. A stabilizing anneal at a temperature of 850-900° is recommended in order ti restire tge toughness of the weld seam and to increase the corrosion resistance. It is also very useful for relieving strain hardening and eliminating stress corrosion cracking in boiling magnesium chloride and other media containing chlorine ions.

The type 18-8 chrome-nickel steels with titanium and niobium are widely used for fabricating detail parts operating at 600-800°. Figure 6 shows the effect of tempering temperature on the stress rupture strength of the OKh18N10T and OKh18N12B steels at a test temperature of 800° and a stress of 8 kg/mm^2, and also the resistance to thermal cycling with a temperature gradient $\Delta t = 800° - 20°$. From Fig. 6 we see that high tempering temperatures should not be used for detail parts operating in conditions of frequent thermal cycling.

The OKh17N5G9BA chrome-manganese-nickel steel with niobium added has high resistance to intercrystalline corrosion and high corrosion

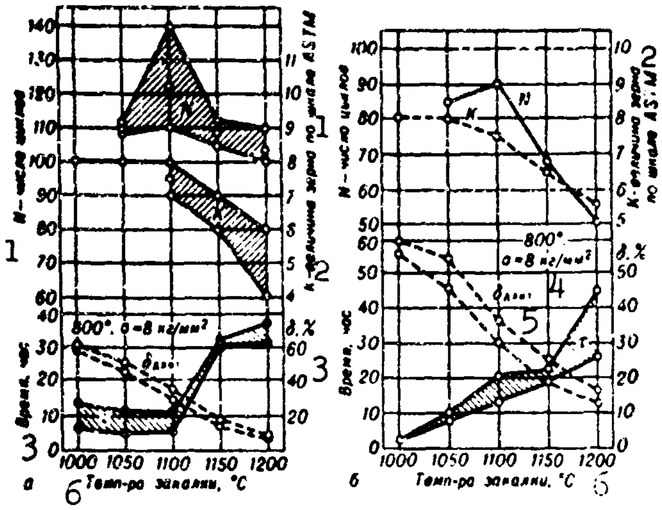


Fig. 6. Strength of OKh18N10T (a) and OKh18N12B (b) steels with temperature cycling (number of cycles to failure) and stress rupture strength (time to failure in hours) as a function of tempering temperature. 1) Number of cycles; 2) grain size per ASTM scale; 3) time, hours; 4) σ = 8 kg/mm^2; 5) stress rupture; 6) tempering temperature, °C.

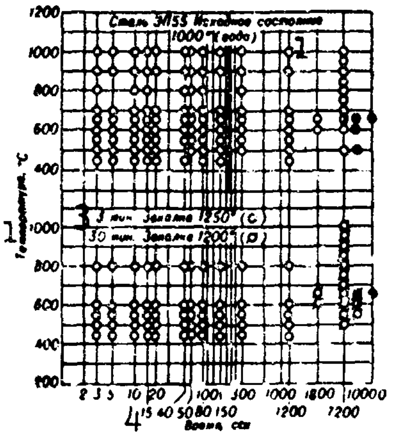


Fig. 7. Tendency of OKh17N5G9BA steel to intercrystalline corrosion per GOST 6032-58 (AM method) as a function of time and temperature: ● — steel prone to intercrystalline corrosion; ○ — steel not prone to intercrystalline corrosion. 1) temperature, °C; 2) EP55 steel, as delivered, 1000° (water); 3) min. temper at; 4) time, sec.

resistance in weldments operating in nitric acid. It does not have complete immunity to intercrystalline corrosion under long-tem action of critical temperatures, and has a tendency to intercrystalline corrosion after long-term heating at 500-750° (Fig. 7). At high temperature it has approximately the same mechanical properties as the type 18-8 chrome-nickel steel.

II-26N11

The Kh14G14N3T steel has high strength and high plasticity, is not prone to intercrystalline corrosion, and may be used to fabricate weld parts without subsequent heat treatment. The mechanical properties of this steel may be improved by rolling in the cold condition. Heating in the temperature range 500-700° does not alter the mechanical properties of the steel at room temperatures. The steel is produced in the form of bar, sheet, and strip, welds well by all forms of welding with the use of weld wire made from type 18-8 steel with or without niobium.

The chrome-nickel-molybdenum steels Kh17N13M2T and Kh17N13M3T are used to fabricate equipment for producing synthetic fertilizers, in the paper industry, in chemical machinery construction, and in the petroleum refining industry. These steels demonstrate high corrosion resistance to sulfuric, boiling phosphoric, formic and acetic acids, while the steels with an increased molybdenum content are also resistant in hot solutions of bleaching powder. Steels with increased carbon content (>0.07%) acquire a tendency to intercrystalline corrosion with welding and slow cooling, and also under conditions of long-term heating in the moderate temperature range. With short-term heating in the moderate temperature range (welding), satisfactory results are obtained with the use of a steel with a carbon content less than 0.07%, or still better no higher than 0.03-0.04%. Steels with titanium additions are not prone intercrystalline corrosion with higher carbon content. Addition of molybdenum to the chrome-nickel steels increases the corrosion resistance in dilute solutions of sulfuric acid and imparis the corrosion resistance in boiling 65% nitric acid (Fig. 8). The chrome-nickel-molybdenum steels weld well with the use of weld wire of the same composition.

As a result of the addition of molybdenum and a high nickel content, the 0Kh23N28M2T chrome-nickel-molybdenum steel has high corrosion

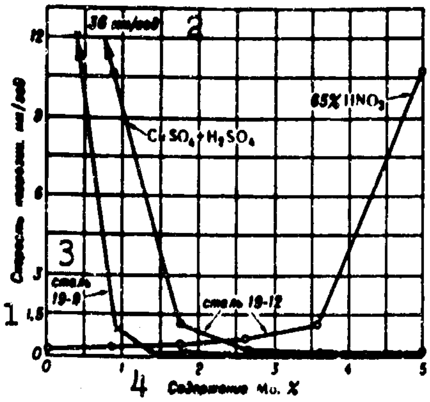


Fig. 8. Effect of molybdenum on corrosion rate of type 19-9 and 19-12 chrome-nickel steels in boiling 65% nitric acid after austenitic tempering and also in acidified solution of copper sulfate. 1) Corrosion rate, mm/year; 2) mm/year; 3) steel; 4) Mo content, %.

resistance in dilute solutions of sulfuric acid (to 20%) at temperatures not over 60°, in phosphoric acid containing fluorine compounds, and other highly aggressive media. It is used in detail parts of machinery for producing synthetic fertilizers. After an austenitic tempering, the steel has moderate strength and high plasticity, welds well by argon arc welding using electrodes of the same composition. In spite of the titanium content, the steel has a tendency to intercrystalline corrosion after short-time heating at 650° if the ratio of the titanium content to the carbon content is less than seven.

The 0Kh23N28M3D3T chrome-nickel-molybdenum steel is used quite successfully for condensers in the production of sulfuric acid by the tower process, for exhausters in producing fluosilicic acid, and also for vacuum tanks in producing concentrated fertilizers, has properties which are typical for the austenitic steels, welds well with the use of material of the same composition. In welding it is important to adhere to the temperature and time provided for in the specifications, avoiding extended heating in the moderate temperature range ot eliminate any possible tendency to intercrystalline corrosion.

The precessing properties of the austenitic stainless steels are

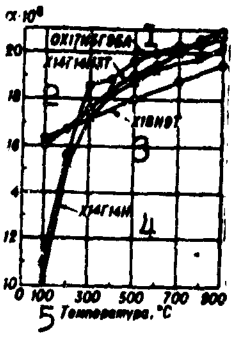


Fig. 9. Variation of coefficient of linear expansion of austenitic stainless steel as a function of temperature. 1) OKh17N5G9BA; 2) Kh14G14N3T; 3) Kh18N9T; 4) Kh14G14N; 5) temperature, °C.

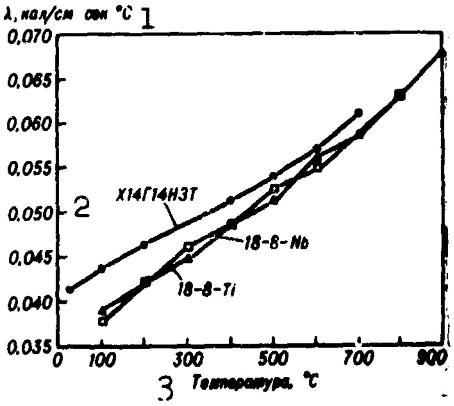


Fig. 10. Variation of coefficient of thermal conductivity of austenitic stainless steel as a function of temperature. 1) λ, cal/cm-sec-°C; 2) Kh14G14N3T; 3) termperature, °C.

completely satisfactory, pressure working is performed at 1150-850°, while for steels with copper the range for hot working si somewhat narrower (1100-900°). At high temperatures the austenitic stainless steels are more subject to grain growth than the steels of the martensitic and ferritic classes. At room temperature austenitic stainless steel has a high coefficient of linear expansion, increasing with increase of heating temperature (Fig. 9) and a high coefficient of thermal conductivity (Fig. 10). However at high temperatures the difference between α and ρ for austenitic stainless steel and the ferritic class steel diminishes. Therefore heating of austenitic stainless steel at lower temperatures must be performed slowly, while at high temperatures (above 800°) it must be done rapidly.

II-26N14

References: Khimushin F.F., Nerzhaveyushchiye stali (Stainless Steels), Moscow, 1963; Khimushin F.F., Kachestvennaya stal' (High-Quality Steel), 1934, No. 4; 1935, No. 1; Khimushin F.F. and Kurova O.I., ibid, 1936, No. 6; Khimushin F.F., Ratner S.I., Rudbakh Z.Ya., Stal' (Steel), 1939, No. 8 page 40; Medovar B.I., Svarka khromonikelevykh austenitnykh staley (Welding Chrmome-Nickel Austenitic Steels), 2nd edition, Kiev- Moscow, 1958; Metallovedeniye i termicheskaya obrabotka stali (Metal Science and Heat Treatment of Steel), Handbook, 2nd edition, Vol. 2, Moscow, 1962; Schaeffler A.L, "Metals progr." 1949, v. 56, No. 5, p. 680; Post C.B., Eberly W.S., "Trans. Amer. Soc. Metals", occurrence and effects of sigma phase, Phil., 1951 (ASTM. Special techn. publ., No. 110); Symposium on evaluation tests for stainless steels, [N.Y.], 1950 (ASTM. Special techn. publ., No. 93); Rosenberg S.J. Darr J. H., "Trans. Amer. Soc. Metals," 1949, v. 41, p. 1261; Krivobok V.N., Linkoln R.A., ibid, 1937, Vol. 25, No. 3.

F.F. Khimushin

I-95a

AUSTENITIZATION - conversion of the initial structure of steel to austenite by heating to a temperature above the critical limit. Austenitization is necessarily entailed by the processes involved in the heat treatment of steel, which are based on phase recrystallization: quenching, annealing, and normalization.

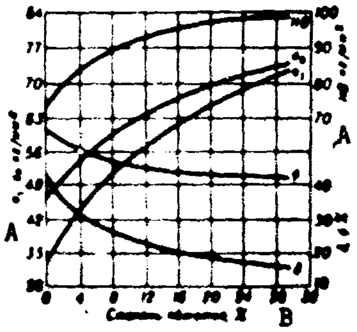
A.F. Golovin

I-96a

AUTOADHESION (self adhesion) - adhesion of two identical polymers, accompanied by mutual diffusion of the polymer chains and individual links. The strength of the autoadhesion bond increases with time, approximating the cohesive strength (see Cohesion).

G.M. Bartenev

AUTOMATIC STEEL – free-cutting steel. Used in the fabrication of machined components with a view to high productivity of the machining equipment, especially automatic and semiautomatic types. **Distinguished** by unusually high sulfur content, which is necessary for formation of inclusions, chiefly of manganese sulfide; these inclusions, arrayed along the fiber, facilitate cutting by assisting in breaking and easy removal of the chip. Automatic steel contains the amount of manganese necessary to bind the sulfur; if the sulfur content is increased, the manganese content is also raised. In many automatic steels made in the USA, lead is added as an alloying element to improve cutting. The chemical compositions of domestic automatic steels are listed in Table 1.



Influence of work-hardening on the mechanical properties of steel A12 (0.13% C; 0.6-0.9% Mn; 0.16-0.23% S; 0.09-0.13% P). A) kg/mm^2; B) upsetting ratio, %.

Automatic steels are produced in rod form. To increase the mechanical properties and improve cutting, automatic steels are frequently shipped in the work-hardened state. This reduces the energy required for plastic deformation in chip formation. The mechanical properties of automatic steels in the as-delivered state are listed in Table 2.

I-5a1

TABLE 1

Chemical Composition

Сталь 1	2 Содержание элементов (%)					3 ГОСТ, ТУ
	C	Si	Mn	S	P	
A12	0.08—0.16	0.15—0.35	0.6—0.9	0.08—0.20	0.08—0.15	ГОСТ 1414—54 5
A20	0.15—0.25	0.15—0.35	0.6—0.9	0.08—0.15	≤ 0.06	6 То же
A30	0.25—0.35	0.15—0.35	0.7—1.0	0.08—0.15	≤ 0.06	• •
A35	0.30—0.40	0.15—0.35	0.7—1.0	0.08—0.15	≤ 0.06	7 ЧМТУ 4934-55
A40Г 4	0.35—0.45	0.15—0.35	1.2—1.55	0.18—0.30	≤ 0.05	8 ГОСТ 1414—54

1) Steel; 2) content of elements (%); 3) GOST, TU; 4) A40 g; 5) GOST 1414-54; 6) same; 7) ChMTU 4934-55; 8) GOST 1414-54.

TABLE 2

Mechanical Properties (after GOST 1414-54)

a Сталь	b Состояние материала (прутков)	c σ_b (кг/мм²)	d δ	ψ	e HB (мм)
			(%, не менее)		
A12	f Горячекатаные, d до 200 мм	42—57	22	36	≥ 4.75
	g Холоднотянутые нагартованные, d 3—20 мм	60—80	7	—	4.65—4.1
	h То же, d 20—30 мм	55—75	7	—	4.65—4.1
	То же, d 30—100 мм	52—70	7	—	4.65—4.1
A20	f Горячекатаные, d до 200 мм	46—61	20	30	≥ 4.63
	g Холоднотянутые нагартованные, d 3—20 мм	62—82	7	—	4.65—4.1
	h То же, d 20—30 мм	57—75	7	—	4.65—4.1
	То же, d 30—100 мм	56—73	7	—	4.65—4.1
A30	f Горячекатаные, d 5—200 мм	52—67	15	25	≥ 4.43
	g Холоднотянутые нагартованные, d 3—20 мм	64—84	6	—	4.50—4.05
	То же, d 20—30 мм	60—80	6	—	—
	h То же, d 30—100 мм	55—77	6	—	—
A40Г	i Горячекатаные, d 5—200 мм	60—75	14	20	≥ 4.2
	j Холоднотянутые, d 3—100 мм (после высокого отпуска) . .	60—80	17	—	4.5—4.0

a) Steel
b) State of material (rods)
c) kg/mm²
d) not below
e) mm
f) hot-rolled, d below 200 mm
g) cold-drawn work-hardened, d from 3 to 20 mm
h) same
i) hot-rolled, d from 5 to 200 mm
j) cold-drawn, d from 3 to 100 mm (after high tempering).

Typical mechanical properties of unworkhardened A12 steel at elevated temperatures are given in Tables 3 and 4.

I-5a2

TABLE 3

Mechanical Properties of Steel A12

Темп-ра (°C) A	σ_b	$\sigma_{0,2}$	δ_5 (%)
	B (кг/мм²)		
20	45	30	38
400	41	17	36
480	32	17	38
535	26	16	[illegible]
595	10	10	57

A) Temperature (°C); B) kg/mm².

TABLE 4

Creep Limit (kg/mm^2) of annealed A12 Steel

Скорость деформации (мм/мм в час) A	B Темп-ра (°C)			
	425	480	535	595
10^{-7}	13.7	9	2	0.5
10^{-6}	19	12	4	1.2

A) Deformation speed (mm/ /mm per hour); B) temperature (°C).

The influence of cold deformation on the mechanical properties of A12 steel are shown in the figure. The critical point A_{c_1} for automatic steels of all types is 730°, and the A_{c_3} for steels A12, A20 and A30 are 875°, 865° and 845°, respectively.

Automatic steels are forged in the temperature range from 1200 to 950°. They submit poorly to welding. In many cases, parts made from low-carbon automatic steels (A12 and A20) are given chemicothermal machining (case-hardening or cyaniding), quenched in water or caustic soda solution, and low-tempered. After such processing, the surface hardness RC of the components is 56-60. Parts made from steel A30, A35 or A40g can be refined by quenching with subsequent high tempering.

References: Spravochnik po mashinostroitel'nym materialam [Handbook on Mechanical Engineering Materials], Vol. 1, Moscow, 1959; Assonov, A.D., Tekhnologiya termicheskoy obrabotki detaley avtomobilya, [Heat-Treatment Technology for Motor-Vehicle Components], Moscow, 1958; Prokoshkin, D.A., Al'tman, A.B., "Stal'," [Steel], 1941, No. 1.

Ya.M. Potak

I-4a

AVIAL (aviation aluminum) – a deformable aluminum alloy; type designation AV. Composition: Mg 0.45-0.9%; Si 0.5-1.2%; Cu 0.2-0.6%; Mn 0.15-0.35% (or Cr in the same quantity); Fe no more than 0.5%; Zn no more than 0.1%. The alloy exhibits high plasticity and satisfactory corrosion resistance and is used extensively in fabrication of complex-shaped components of medium strength, particularly forgings and stampings. Helicopter rotor blades, profiles and skin panels for airframe structures, forged engine components, and the like are fabricated from avial. In cases where the corrosion-resistance specifications are more rigorous, the copper content is lowered to 0.1%. Moreover, limiting the copper content in avial changes its technological properties substantially, but lowers the ultimate strength by 2 kg/mm^2. Avial (with copper) is used as a forging alloy (the old type designation for the forging version of avial was AK5 alloy).

References: Voronov, S.M., Protsessy uprocheniya splavov alyuminiy magniy-kremniy i ikh novyye promyshlennyye kompozitsii [Work-Hardening Processes of Aluminum-Magnesium-Silicon Alloys and Their New Industrial Compositions], Moscow, 1946; Edel'man, N.M. Alyuminiyevyye splavy v grazhdanskom stroitel'stve [Aluminum Alloys in Civil Engineering], in book entitled: Stroitel'nyye konstruktsii iz alyuminiyevykh splavov [Aluminum Alloy Structures], edited by S.V. Taranovskogo, Mowcow, 1962.

I.N. Fridlyander.

BABBITT – an alloy based on tin or lead and intended for bearing linings. In addition to tin and lead, the principal components of babbit are antimony and copper. Some types of lead alloys contain nickel, arsenic, cadmium, tellurium, calcium, sodium, magnesium, and certain other additives. Babbit is distinguished by a low melting temperature, a comparatively low hardness, and an especially heterogeneous structure, which gives it good antifriction properties. Ready-made alloy ingots of various types of babbit are generally employed for bearing linings. When pure metals are used the highest-melting are taken in the form of ligatures. The lining process should provide tight adhesion between the antifriction alloy and the steel bearing housing, which is achieved by special preparation of the bearing and maintenance of the proper lining temperature. After lining the bearing is bored out to the requisite size. The lining layer is usually 0.5–4 mm thick (up to 10–12 mm for large bearings). A layer of babbit in a bearing ensures rapid running-in to the rotating counterbody. Running-in is effected by plastic deformation of the surface layers of the soft alloy base, which consists of lead or tin and the metals partially dissolved in it; during this process the hard, brittle crystals of antimony and other compounds present at the friction surface are easily broken down and forced into the plastic base under overloads, thus reinforcing it. Running-in causes the babbit friction surface to acquire a shape corresponding to that of the rotating counterbody and imparts to it the necessary durability as a result of a certain cold-working and a redistribution of its solid structural components. Babbit is named after the

American inventor of the first alloy of this type, I. Babbit (see Tin babbit).

References: See article entitled Lead babbit.

O.Ye. Kestner

BAKELITE – see Cast phenoplast.

BAKELIZED PAPER TUBES AND CYLINDERS – laminated products from impregnated or varnished paper which are used in electrical devices. Products with an inside diameter up to 80 mm are called <u>tubes</u>, while products up to 3 m in diameter are called <u>cylinders</u>. Varnished paper is coated on one side by phenolformaldehyde resin (28-35% of the paper, by weight). Products from this paper are made by winding it into appropriate mandrels through a system of rolls heated to 140-160°; the resin melts and glues together the individual layers. Impregnated paper contains up to 55-60% of resin. Products from it are usually made in 2 stages. First the blank is cold-wound and then it is rolled on a machine with hot rolls.

After winding, the tubes and cylinders are heat treated at 130-140° for 2-24 hours and more in ordinary dryers or by using high-frequency current. The heat-treated products are removed from mandrels on a capstan. Varnished paper products are additionally coated by bakelite varnish. When making capacitor insulators aluminum foil is placed between the paper layers.

Bakelized paper tubes [illegible] cylinders from varnished paper are characterized by the following indicators: specific gravity 1.15, ultimate strength (kg/cm^2) i[illegible]tic flexure 800, in compression along the layers 400, in cleaving 20; the specific electrical resistivity at 70° after drying for 4 hours is 10^{10}-10^{11} ohms, electrical strength perpendicular to the layers 10 kv/mm, dielectric permittivity at 50 cps after drying at 70° for 4 hours is 4.5-5, tangent of dielectric losses angle at 50 cps after drying at 70° for 4 hours is 0.02-0.03. Bakelized paper tubes and cylinders can be, as in the case of Getinaks, machined by various means (drilling, milling, grinding, turning, etc.). Bakelized paper tubes and cylinders from varnished paper (GOST 8726-58) are used in transformer oil at temperatures from -40° to 105° and at standard humidity. Bakelized paper tubes and cylinders from impregnated paper have better electrical insulation properties than those from varnished paper, particularly under elevated humidity conditions; they are used for making cores of induction coils for high-frequency circuits.

References: Shugal, Ya.L. and Baranovskiy, V.V., Sloistyye plastiki [Laminated Plastics], Moscow-Leningrad, 1953; Spravochnik po elektrotekhnicheskim materialam [Handbook of Electrical Engineering Materials], Vol. 1, Part 1, pages 250-53, Moscow-Leningrad, 1958.

B.A. Kiselev

Manuscript Page No.	[Transliterated Symbols]
385	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = All-Union State Standard

BALINITE - see Ligneous laminar plastics.

II-54M

BALLOON MATERIALS are fabrics with polymer films, used for the fabrication of envelopes of stratosphere ballonns, free and tethered aerostats, dirigibles, pontoon and sports boats, diving suits, gas bags and other gas containers. The basic requirements of the balloon materials are: suitable strength, tensile deformation within specfied limits, impermeability to gas, and in the case of aeronautical balloon material minimal weight as well. The structural portion of the balloon material, supplying the strength, is fabric made from cotton, silk, Kapron or other fibers, covered with a film which is impermeable to gas. Widest usage has been made of rubber films made from natural or synthetic rubbers, various lacquer and other synthetic materials. Some products consist of a single gastight layer which fulfills the functions of the structural portion and the gas-retaining layer, for example, pilot balloons whose enevelopes are made from rubber, polyethylene and polyethyleneterephthalate. The balloon materials are divided into one-, two-, three-, and many-layer materials; with respect to nature of the gas-restraining layer we differentiate rubberized, lacquered, and so on. The two-layer balloon materials are divided into parallel-backed and diagonal-backed types. Balloon material of the first type consists of two fabric layers whose threads have the same direction (parallel layers). In the balloon materials of the second type the diagonal layer consists of strips (wedges) of fabric cut at an angle of 45°. The threads (warp and fill) of one layer are also placed at an angle of 45° to the threads of the neighboring layer, which increases the tear strength of the fabric by several times. As a rule, in the three-layer material two fabric layers are parallel and one is diagonal. The gastightness of the balloon materials depends basically on the nature of the film-forming polymer and the temperature (see Gas Permeability).

Reference: Reytlinger S.A., Gazopronitsayemost' vysokomolekulyarnykh soyedineniy (Gas Permeability of High Molecular Compounds), UKh, 1951, Vol. 20, No. 2.

I-5b

BARITE (heavy spar) – the rhombic or rhombic-dipyramidal mineral $BaSO_4$; crystals tabular in direction (001) predominate. The Mohs hardness of this mineral is 3.5 and its specific gravity is 4.50. Its indices of refraction are: $n_g = 1.648$, $n_m = 1.637$, and $n_p = 1.636$. It is distinguished by its high chemical stability. Barite is found in hydrothermal, metasomatic, and sedimentary deposits, as well as in zones of erosion.

The clear, colorless crystals of barite are used in optical instruments. In order to provide protection against x-radiation barite is used to coat the walls of x-ray rooms and is incorporated into rubber gloves, etc.As a result of its chemical stability, particularly with respect to sulfuric acid, barite is used as a lining and insulating material in the chemical industry. Baryta white is resistant to chemicals and light. Barite is a constituent of lithopone (a white pigment). It is used as a weighting compound in clay solutions encourtered in drilling and in the petroleum industry, increasing the specific weight of such solutions from 1.10–1.12 to 1.25–1.75 or more. When incorporated into glass barite increases its refractive index, improves its luster, and makes it more transparent to ultraviolet light. This mineralis used as a filler in the production of photographic papers.

References: Dena, Dzh. et al., Sistema minerologii [Systems Minerologia], translated from English, Vol. 2, Part 1, Moscow, 1953, pages 482–488; Trebovaniya promyshlennosti k kachestvu syr'ya [Industrial Specifications for Raw Materials], No. 11; Lyubimov, A.L., Barit i viterit [Barite and Witherite], Moscow-Leningrad, 1946.

V.V. Shcherbina

I-2b

BASALT – an effusive volcanic rock, with a composition characterized by approximately equal quantities of basic plagioclase and ferromagnesium minerals, principally augite. Its chemical composition is as follows (%): SiO_2 – 49.87, Al_2O_3 – 15.96, FeO – 6.47, Fe_2O_3 – 5.47, MgO – 6.27, CO – 9.09, Na_2O – 3.16, K_2O – 1.55, P_2O_5 – 0.46, TiO_2 – 1.38, and MnO – 0.32. The small-, medium-, and large-grained varieties of basalt are called dolerite, while the fine-grained variety is called anamesite. Basalt somewhat altered by secondary hydrothermal and other processes is called diabase, or diabasic porphyrite. Basalts with an elevated content of K_2O (4–10%), which in special cases is bonded to an alkali (orthoclase) or unsaturated silicate (nepheline, melilite, etc.), are included among the alkaline basaltoids. In engineering the basalts are sometimes referred to as fully crystalline analogs of the gabbro type. Basalt is used industrially in the natural state and after remelting or recrystallization.

Basalt has a specific gravity of 3 (2.7–2.3 for remelted basalt), a porosity of 0.5–1.5%, and a water-absorption of 0.2–0.4% by weight and 0.5–1.1% by volume; the compressive strength of dry basalt is 2640–3200 kg/cm^2, of wet basalt 2500 kg/cm^2, of remelted basalt 3000–5000 kg/cm^2, and of fine-grained varieties up to 9150 kg/cm^2. Remelted basalt has a wear resistance of 840 kg/mm^2. The short-term fracture resistance of remelted basalt is 460–600 kg/cm^2, while its short-term bending resistance is 450–520 kg/cm^2 (1000 kg/cm^2 in isolated cases). The coefficient of volumetric compression for basalt is $18 \cdot 10^{-8}$ at $p =$ $= 2000$ kg/cm^2 and $15 \cdot 10^{8}$ at $p = 10{,}000$ kg/cm^2; the corresponding figures for diabase at the same pressures are $15 \cdot 10^{-8}$ and $12 \cdot 10^{-8}$. The coefficient of thermal expansion of basalt is $6.3 \cdot 10^{-7}$ at 20-100°, $9 \cdot 10^{-7}$ at 100-200°, and $12 \cdot 10^{-7}$ at 200-300°. The coefficient of thermal expansion of remelted basalt varies from $11 \cdot 10^{-7}$ to $16 \cdot 10^{-7}$ over the temperature range 100-900°. Basalt well withstands sharp temperature changes in the range 25-600°. The heat capacity of basalt (joules/g) is 0.85 at 0°, 1.04 at 200°, 1.14 at 400°, 1.32 at 800°, and 1.49 at 1200° or more. The average heat capacity of diabase at 20-1320° is 0.285. The thermal conductivity of basalt is $5.01\text{-}5.06 \cdot 10^{-3}$ cal/cm•sec•°C over the temperature range 0-400°, while its melting temperature varies from 1150° to 1350° (averaging 1250°), depending on its composition. Its viscosity over the temperature range 1150-1400° varies from 37,900 to 140 poises. The magnetic susceptibility of basalt, $\underline{k}$, is 4.5 electromagnetic units per cm^3. Its electric strength is 32 kv/cm, while that of remelted basalt is 57 kv/cm. Basalt glass has an electrical conductivity of $4 \cdot 10^{-9}$ and a dielectric constant of 12. This rock is resistant to the majority of acids and bases, including HNO_3, H_2SO_4, NaOH, KOH, and aqua regia. The loss in weight over a 2-hr period amounts to 0.00-0.0.96% for exposure to boiling reagent and 0.00-0.067% for exposure to cold reagent. The high strength, wear resistance, and chemical stability of basalt are utilized commercially. Basalt glass has good electrical-insulating properties. The chemically industry uses primarily remelted basalt (linings for chemical apparatus and large-size components for special equipment). The electrochemical industry employs remelted basalt in the manufacture of insulating bases for storage batteries. The electronics industry uses principally hyaline or vitreous varieties of remelted basalt (line and support insulators for high- and low-voltage grids). In the mining industry remelted basalt is used for the linings of pneumatic tubes, ball mills, etc. In powder metallurgy basalt is used for pouring casting molds. This rock is incorporated into certain types of ceramics (as a substitute for clay). In the paper industry basalt fiber obtained by remelting is used in the manufacture of paper and cardboard.

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V.V. Nasedkin

BAUSHINGER EFFECT – a decrease in resistance to plastic deformation after preliminary plastic deformation of opposite sign; for example, tensile yield strength is reduced by prior compressive deformation. This effect is named after the German scientist I. Baushinger. It is little affected by the purity of the material, being observed in monocrystals of aluminum, brass, iron, and zinc and in polycrystals of iron, various steels, aluminum and its alloys, sodium and its alloys, lead, and nickel, as well as in sodium chloride and other nonmetallic compounds. The extent of the Baushinger effect (evaluated from the decrease in the elastic limit when the sign of the load is changed) reaches 15-30% in low-temper steels, 10-20% in aluminum alloys, and 40-50% in high-temper steels and magnesium alloys; this effect is very small in large-grained iron, copper, and aluminum. Repetition of the load cycle causes adaptation of the material and reduces the influence of subsequent cycles (see Fatigue). The Baushinger effect can be reduced by low tempering. It is caused by the oriented microstresses which develop after plastic deformation as a result of the differing properties of the internal zones (grains and mosaic blocks) and boundary regions (grain and mosaic-block boundaries). The Baushinger effect is of great practical importance when the plastic deformations during technological processing and under operating conditions are opposite in sign, as when tubes and bars operate under compression after being tension-straightened. It is necessary to take into account the decrease in yield strength and elastic limit resulting from the Baushing effect and, where possible, to eliminate it. This phenomenon has a material influence on fatigue fracture. The great danger involved in Symmetric stress cycles is due to the Baushinger effect (see Imperfect elasticity, Internal friction).

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Ya.B. Fridman

BEARING BRONZE – bronze intended for the manufacture of bearings and othercomponents which must function under sliding friction. Bronzes of varying composition (lead, tin, antimony, etc.) are used, depending on operating conditions (see Bearing materials, Tin bronze, Lead bronze, and Antimony bronze).

O.Ye. Kestner

BEARING MATERIALS - materials used in the manufacture of sliding bearings and having antifriction characteristics. They can be classified as metallic or nonmetallic. Metallic bearing materials include Babbitts, alloys based on copper (bronzes), zinc, and aluminum, and certain types of cast iron; nonmetallic materials include certain types of plastic, wood-based materials, graphite materials, and rubbers. A number of bearing materials combine different types of substances (metals and plastics, graphite materials and metals, etc.).

Tin- or lead-based babbitts. The distinctive features of all babbitts are their good workability, their ability to "absorb" solid particles, and the fact that they do not grab when paired with steel. Their drawbacks include low mechanical characteristics at temperatures of 100° or above, low thermal conductivity, and a comparatively low fatigue strength. Tin babbitts are more convenient to produce, more easily cast on steel, less subject to oxidation, and noncorrosible. When fatigue-tested by cyclic bending under equal loads tin and lead babbitts (of the same hardness) exhibit the same number of cycles to fracture; Lead babbitts have an advantage when fatigue-tested by cyclic bending with equal degrees of deformation, since their modulus of elasticity is substantially lower. Babbitts are used in bearings in the form of a layer cast on a housing of bronze, brass, steel, or cast iron. Strongest adhesion of the cast babbitt layer to the housing is obtained with a special casting process, which includes cleaning and tinning of the housing surface. Thin-walled bearings for light-automobile engines are fabricated by stamping from bimetallic strips produced by continuous casting of babbitt on a standardized moving steel strip. The fatigue strength of the babbitt layer increases as its thickness decreases; in the bearings of some modern automobile engines this layer is 0.1 mm or less thick.

When the surface of the bushing is properly prepared and the facing layer is correctly cast the babbitt and the housing metal (bronze, steel, cast iron) are strongly bonded over their entire contact surface, which makes it possible to reduce the thickness of the babbitt layer considerably. Mechanical fastening of the babbitt to the bushing (by providing the bushing with grooves and holes that are filled by the babbitt during casting) is suitable only for lightly loaded bearings.

Another bearing material consists of a grooved steel strip to which a porous layer of metal containing 60% Cu and 40% Ni is applied by powder metallurgy. The pores in this layer are filled with soft babbitt (e.g., one containing 3% Sn, 4% Sb, and the remainder lead). The third, "working" layer thus formed on the copper-nickel layer has a thickness of the order of 0.05 mm. This material is employed in the mass production of automobile-engine bearings and exhibits good workability and a substantially higher fatigue strength than ordinary babbitts.

Copper-based bearing materials. These alloys include Tin bronzes, Lead bronzes, tin-lead bronzes, and certain others. Tin bronzes are used for bearings intended to operate under high specific loads at low sliding speeds, while tin-lead bronzes of types OS8-12 and OS6-16 are employed for medium loads and speeds. Lead bronzes (25% or more Pb) are used for extremely heavily loaded bearings, being cast in a layer on steel (by casting of individual bearings, casting of bronze on a moving steel strip, or production of a bronze layer on a steel strip from powdered copper and lead by powder metallurgy, subsequently fabricating bearings from the bimetallic strip by stamping). Lead bronzes are less workable and less capable of "absorbing" solid particles than babbitts, but have a higher permissible working temperature and fatigue strength. In order to raise the fatigue strength of lead babbitt a total of 1-2% tin is added. Of the lead-free bronzes Antimony bronze has the highest antifriction characteristics, which approximate those of tin bronzes. Rolled bronzes with a low lead content (e.g., BrOTsS 4-3-4) and copper-zinc alloys (tombac, brass containing 69% Cu and 4% Pb) are also employed for bearings intended to operate at low speeds and loads.

Zinc-based bearing materials are used as replacements for tin-lead bronzes in bearings. Type TsAM9-1.5 alloy is used commercially as a substitute for bronze in the shaft and journal bearings of locomotives. For heavily loaded bearings TsAM9-1.5 is cast on a steel base, whose surface is preliminarily zinc-plated. Although the hardness of zinc alloys at room temperature is higher than that of the bronzes which they replace, this difference decreases as the temperature rises, since the hardness of zinc alloys drops more rapidly. Zinc alloys can also be used in the plastically deformed state, in which case they have higher mechanical characteristics.

Aluminum-based bearing materials have come into wide use in connection with the development of aluminum alloys that approximate the characteristics of babbitts and of methods for plating steel with them. Table 1 shows the composition of the best-known aluminum-based bearing materials. They can be subdivided into pliable alloys, which are used for facing the working surfaces of steel bearing housings, and alloys for the production of monometallic bearings or bushings consisting of only one material. Alloys of the first type, which are employed in automobiles (Moran, Glasier) and tractors (ASM, XB-80), are applied to

TABLE 1

Bearing Materials Based on Aluminum Alloys

1 Сплав	2 Среднее содержание основных компонентов, кроме алюминия (%)					4 Твердость HB (кг/мм²)	5 Страна преимущественного применения
	Sn	Cu	Ni	Mg	3 Др. элементы		
6 АСМ	—	—	—	0.8	4.75 Sb	28	12 СССР
7 Моран 400 *	—	—	—	—	4 Si; 1.2 Cd	40	США 13
8 Алкоа XA 750	6.5	1	0.5	—	2.5 Si	65	То же 14
9 Алкоа XB-80 S	6.5	1	0.5	—	1.5 Si	50	″
Глесье 10	20	1	—	—	—	27	Англия 15
11 KS 927	12	0.5	0.5	0.4	0,3 Si, 0.5 Pb	30	ФРГ 16

* Used with running-in coating.

1) Alloy; 2) average content of basic components other than aluminum (%); 3) other elements; 4) hardness, HB (kg/mm^2); 5) country of primary use; 6) ASM; 7) Moran; 8) Alcoa XA 750; 9) Alcoa XB-80 S; 10) Glasier; 11) KS 927; 12) USSR; 13) USA; 14) the same; 15) England; 16) Federal Republic of Germany.

steel by rolling bundles containing both metals. Bearings are fabricated from the resultant bimetallic strips by stamping; bearings and bushings are produced from KhA750 alloy by casting. Individual casting of bearings or bushings on steel housings is also employed (e.g., with KS927 alloy), this process being referred to as "alfining."

Pliable aluminum-based bearing materials have a higher fatigue strength and thermal conductivity, better high-temperature mechanical characteristics, and a lower specific gravity than babbitts. Their drawbacks include complexity of production, a lower capacity for running-in, less ability to "absorb" solid particles, and the need to use a very hard shaft with a very smooth surface. A better capacity for running-in is obtained by galvanizing the surface of the aluminum alloy with a thin layer (of the order of 25 μ) of a lead-tin alloy (up to 8% tin is added to the lead in order to make the plating corrosion-resistant). Glasier alloy has extremely high antifriction characteristics and a definite structure (individual tin inclusions) obtained by special annealing after plastic deformation; this alloy is used without a lead-alloy surface coating. In the USA XA750 alloy is employed in the manufacture of bearings and bushings, replacing tin and tin-lead bronzes. In installing monometallic aluminum-alloy bearings in steel or cast-iron housings it is necessary to keep in mind the difference in their coefficients of linear expansion, which may cause development of severe stresses and plastic deformation of the aluminum alloy during operational heating. After the bearing has cooled the shaft clearance may be reduced, causing grabbing. This phenomenon must also be taken into account in selecting the layer-thickness ratio for bimetallic bearings utilizing aluminum alloys.

Cermet (self-lubricating) bearing materials are produced in the form of porous bushings by sintering blanks preliminarily pressed (in press-forms) from suitably treated powdered metals, usually with a small amount of graphite added. The degree of porosity is generally about 25%. The finished bushings are grooved under pressure (the working surface should not be cut) and impregnated with oil in a vacuum. These materials are used principally for small bearings intended to operate under light loads without lubrication. Their service life is limited by the lubricant reserve in the layers adjoining the friction surface. Iron-graphite bearings can withstand greater loads than bronze-graphite bearings at lower sliding speeds; their chief drawback is their high susceptibility to corrosion.

Cast iron for bearings intended to operate under light loads at low speeds should, in the cast state (gray iron), have a microstructure that insures the requisite antifriction characteristics (medium- or coarse lamellar perlite, no free ferrite or free cementite, graphite of medium grain size, and a phosphide eutectic in the form of isolated inclusions). The Brinell hardness of such cast iron ranges up to 240 kg/mm^2. Cast iron containing globular graphite can be used if it is given a perlitic structure by heat treatment, but it has lower antifriction characteristics.

Plastic-based bearing materials are classified by type of resin, filler, physical characteristics, production technology, use of components in structures, and operating conditions. Plastics based on thermoreactive phenol-formaldehyde resins with fillers of cloth (textolite), plywood (lignofol'), or sawdust are used in bearings copiously wetted with water and operated at low speeds. Textolite is employed as a substitute for bronze in rolling-stand bearings. Thermoplastic plastics, such as polyamides (nylon, capron) and polytetrafluorethylene (fluoroplast-4), are also used for bearings. Polyamide bushings and

TABLE 2

Physicomechanical Characteristics of Thermoplastic Plastics for Bearings

1 Свойства	2 Капрон	3 Найлон	4 Политетрафторэтилен	5 Материал ДВ	6 Материал ДQ
7 Твердость по Бринеллю (кг/мм²)	7,5	6,5	2,8	—	-
8 Коэфф. термич. расширения (1/°С)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9 Коэфф. теплопроводности (кал/см·сек·°С)	[illegible]	[illegible]	[illegible]		[illegible]
10 Верхний температурный предел применения материала (°С)	75	75	[illegible]	[illegible]	[illegible]

1) Characteristic; 2) capron; 3) nylon; 4) polytetrafluorethylene; 5) DV; 6) DQ; 7) Brinell hardness (kg/mm^2); 8) coefficient of thermal expansion (1/$^{\circ}$C); 9) coefficient of thermal conductivity (cal/cm·sec·$^{\circ}$C); 10) maximum permissible working temperature ($^{\circ}$C).

TABLE 3

Physicomechanical Characteristics of Thermoreactive Plastics for Bearings

1 Свойства	2 Лигностон	3 Лигнофоль	4 Текстолит
5 Твердость по Бринеллю (кг/мм²)	11–14	[illegible]	[illegible]–35
6 Набухание (объемное) в воде при 15° за 24 час (%)	[illegible]	1–2	[illegible]

1) Characteristic; 2) lignoston; 3) lignofol'; 4) textolite; 5) Brinell hardness (kg/mm^2); 6) distension (volumetric) in water at 15° over 24 hr (%).

bearings are produced by pressure casting or machining of cast blanks, as well as in the form of thin coatings (e.g., 0.1 mm thick) on metallic bases. They are intended to operate with oil or water lubrication. Fluoroplast-4 has a lower coefficient of friction than other plastics at low sliding speeds without lubrication, retaining this property at temperatures of from -200 to +260°. Bearing materials of the following types utilize fluoroplast-4 (teflon): 1) bars and tubes are produced by pressing and sintering a mixture of teflon and a powdered bronze, lead, or graphite filler. Bushings are then machined from the resultant blanks. This material (designated as DQ in England) has a high coefficient of linear expansion and low mechanical strength; 2) a layer of tin-bronze beads containing 11% Sn is applied to a steel strip (the bead diameter is 0.1 mm and the layer thickness is 0.3 mm) and fixed by sintering. The pores between the beads (approximately 30% of their volume) are filled with a mixture of teflon and approximately 20% by volume dispersed lead, a working layer of plastic about 25 μ thick being left on the surface. Threaded bushings (which are pressed into the bearing housings) are stamped from these strips (designated as DV in England).

Wood-based bearing materials. Natural wood, pressed wood, and lignofol' are used in the manufacture of bearings. The natural woods used include lignum vitae (with a specific gravity of 1.3 g/cm^3 and a resin content of approximately 30%). Pressed wood (lignoston) is produced by special processing (of birch in the USSR) consisting of impregnation with glucose (or other substances that reduce water absorption), hot pressing, and heat treatment. Lignofol' (a laminated wood plastic) consists of a number of layers of birch veneer (of the order of 1 mm thick) arranged in such fashion that the fiber directions of adjacent layers are at right angles; these layers are impregnated with a phenol-formaldehyde resin and pressed under conditions that cause polycondensation of the resin. The principal drawback of pressed wood is its substantial water absorption. Wood-based bearing materials are employed in the bearings of rolling stands, water turbines, and marine propellers, with copious water lubrication. Bearings of lignoston and lignofol' generally take the form of a steel casing within which plates of the wood material are fastened, with their butts toward the shaft surface. Lignofol' is used as a substitute for more expensive textolite in rolling-stand bearings. Lignofol' bearings have a higher permissible load and working temperature than lignoston bearings. Tables 2 and 3 show certain of the physicomechanical characteristics of plastic bearing materials.

Graphite-coal bearing materials are produced by pressing and heat-treating a mixture of petroleum coke and a coal-tar resin, a small amount of natural graphite being added. These materials are employed for bearings intended to operate at temperatures of up to 480° under light loads in air. The porosity of graphite-coal materials makes it possible to impregnate them with metals or resins to give them special properties. Metal-graphite-coal materials can withstand specific loads of up to 25 kg/cm^2 when operating in air and up to 40 kg/cm^2 when lubricated; their maximum working temperature depends on the characteristics of the impregnating material.

Rubber is used as a bearing material with water lubrication under light loads and at low speeds. It is fastened to the working side of a metal bearing or bushing in the form of a layer with a row of longitudinal grooves to supply water to the friction surface. The bearing working temperature is 50-70°.

Other bearing materials. Cadmium-based alloys are sometimes used for sliding bearings, having a maximum permissible load intermediate between that for tin babbitts and that for lead bronze; these alloys are used for automobile-engine bearings in the USA. Silver is employed for the extremely heavily loaded bearings of certain types of aircraft piston engines. Production of bearing materials with a wide range of characteristics will be associated with broader utilization of powder-metallurgical methods and the development of metallization technology.

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M.M. Khrushchov

BEINITE – a structure formed by the intermediate conversion products of austenite. See Steel.

BELTING – a strong, linen-woven technical fabric used in the manufacture of rubberized conveyor and elevator belts, flat drive belts, and subway straps (GOST 2924-45; TU MLP 714-50). Belting is produced from tightly twisted cotton thread; the stronger types are produced from long-fibered cotton with a fiber length of 33-35 mm and the strongest types from synthetic fibers. Belting produced from medium-fibered cotton is used as a filter material. This fabric is classified as loose- or close-woven, depending on its tightness. The Table shows its physical and mechanical properties.

Physical and Mechanical Indices

Бельтинги 1	Толщина (мм) 2	Прочность на разрыв (кг) полоски 50×200 мм 3		Вес 1 м² ткани (г) 6
		основа 4	уток 5	
ОПБ-5 7	2.5±0.3	640	420	1500±200
ОПБ-6 7	2.4±0.3	640	350	1400±200
ОПБ-12	2.3±0.3	480	210	1100±150
820	1.9±0.1	305	134	820
930	2.0±0.1	355	134	930

1) Belting; 2) thickness (mm); 3) tensile strength (kg) of 50 x 200 mm strips; 4) warp; 5) woof; 6) weight of 1 m^2 of fabric (g); 7) OPB.

Cotton belting is manufactured from No. 12 thread; threads consisting of from 4 to 7 filaments are used for the warp and woof. Close-woven belting (OPB-6, OPB-6, and OPB-12) is produced from thin-fibered cotton thread No. 35, using 30 filaments for the warp and from 24 to 30 filaments for the woof. The elongation under tension is no more than 32% along the warp and 12-14% along the woof. Belting is produced in various widths, ranging from 750-1450 mm for the ordinary fabric to

1100-2100 mm for the extra-strong fabric. Linen-woven cotton cord-woof fabric is used for the flat rubberized belts of railway generators; this material is produced with a warp of stretched, heat-fixed double-twisted 37/27/3 cord and a woof of No. 37 thread with 23 filaments. The strength of a 50 x 200 mm strip of this fabric is no less than 660 kg along the warp and 250 kg along the woof; its elongation under tension is 30% along the warp and no more than 20% along the woof. This material has a thickness of no more than 2.8 mm and weighs 1600 ± 80 g per m^2. It is manufactured in widths of 78 and 96 cm.

S.Ye. Strusevich

III-1U

BENDING ANGLE – plasticity characteristic of metallic materials (strips, sheets, wire, bar stock, pipes, shapes) which is determined by performing industrial tests: bending, folding, flanging, double roofing joint. The bending angle is specified for each kind of tests in applicable GOSTs or TU for the material. A sign showing that the material has withstood the specified bending angle is the absence of cracks, tears and cleavages in the material.

References: Shaposhnikov, N.A., Mekhanicheskiye ispytaniya metallov [Mechanical Testing of Metals], 2nd edition, Moscow-Leningrad, 1954.

Yu.S. Danilov

Manuscript Page No.	[Transliterated Symbols]
409	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standard = All-Union State Standard
409	ТУ = TU = tekhnicheskiye usloviva = technical specifications

BENDING TEST – is a statical checking of materials at which the specimen is set up two supports and loaded with one (a) or two (b) concentrated forces as it is shown in the Fig. The bending test is used to determine the strength and the plastic properties of materials, and also as a technological checking of the plasticity of the material, its ability to be pressed, the quality of welding joints, etc. (OST 1683, OST 1684, OST 1685). If the tests are carried out with machines provided with recording devices (IMCh-30, IM-4A, for example, designed by the TsNIITMASh, and others), the bending curve is obtained in the coordinates "bending of the specimen v.s. force" which permits one to determine the conditioned yeild strength $\sigma_{0.2}$ and the bending strength σ_b using the formulas which are valid for the calculation of stresses in the range of elastic deformations. The maximum bending deflection or the bending angle of the specimen before cracking occurs is taken as a characteristic of the plasticity (a crack may not occur even at a bending angle near to 180° when high-plastic materials are tested). The bending test is particularly used frequently for brittle materials (for casts from gray iron and wrought iron, for example, GOST 2055-43), because it secures a good reproducibility of the results in contrast to other testing methods, especially the monoaxial tensile test, which gives a wide scattering of the results owing to the high sensibility of brittle materials to the skewing of the specimens in the machine clamps. The toughness of a metal and its sensibility to sharp cracks may be judged based on the character of the final section of the bending curve of notched specimens.

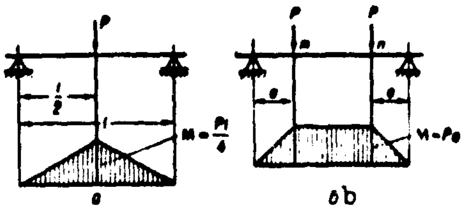

Fig. Typical schemes of the loading of specimens in the bending test and the corresponding lines of the bending moment (M): a) Transversal bending of the specimen; b) pure (circular) bending within the section mn of the length of the specimen.

References: Shaposhnikov N.A., Mekhanicheskiye ispytaniya metallov [Mechanical Tests of Metals], 2nd edition, Moscow-Leningrad, 1954; Drozdovskiy B.A., Fridman Ya.B., Vliyaniye treshchin na mekhanicheskiye svoystva konstruktsionnykh staley [Effect of Cracks on the Mechanical Properties of Strcutural Steels], Moscow, 1960.

I.V. Kudryavtsev, D.M. Shur

BENDING TEST – determination of the ability of a metal to withstand bending when cold or hot. Bending tests are standardized and are employed for sheets, various rectangular and round blanks (OST 1683), and tubes (GOST 3728-47), as well as to determine the quality of welded joints (OST 1685), nonquenchability (OST 1684), and hot-shortness (OST 1683).

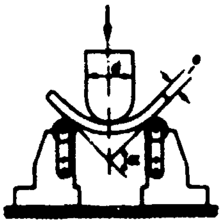

Fig. 1

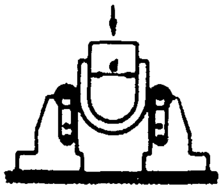

Fig. 2

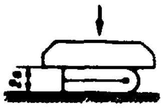

Fig. 3

Fig. 4

The size and the shape of the specimen are defined by the GOST and technical specifications in accordance with the type of material and its purpose. However, it is necessary in all cases to retain the surface layer of the metal and the specimen thickness is consequently taken as the thickness of the material _a_, its width is taken as twice the thickness of the material 2a (see Fig. 3) but no less than 10 mm, and its length is taken as 5a + 150 mm, usually being oriented perpendicular to the rolling direction. The specimens are cut cold and sharp fins are removed. The central portion of the specimen should be free of markings, glue, notches, and hammer marks.

Bending tests are conducted on machines which permit compressive loading and have devices for bending the specimen (cross pieces with roller supports and a mandrel). The roller supports should prevent warping of the specimen. The radius of curvature of the mandrel around which the specimen is bent is usually a multiple of the thickness of the test material, ranging from 1 to 4 times this thickness. The width of the mandrel should be greater than that of the specimen.

We can distinguish three types of bending tests: 1) bending to fracture or cracking and determination of the bending angle (Fig. 1); 2) bending around the mandrel until the sides of the specimen are parallel (Fig. 2); 3) complete bending, i.e., until the sides of the specimen touch (Fig. 3).

A bending test consists in smooth loading of the specimen under an increasing load until the type of bend stipulated in the standards for technical specifications is obtained.

Tubes no more than 114 mm in diameter are subjected to bending tests consisting in smooth bending of the specimen (Fig. 4) by any method that permits the outside diameter of the tube to remain at no less than 85% of its initial value over the entire length of the specimen. The bending angle is usually taken as 90°, while the other angles are stipulated in the technical specifications.

Specimens which survive bending tests should not show separation, tearing, fracture, or cracking (see Technological testing).

Yu.S Danilov

BENDING TEST INVOLVING ALTERNATE BENDING (alternate-bending test) – determination of the ability of metal wire, strips, and sheets to undergo cold plastic deformation by bending. The alternate-bending test consists in bending a specimen held vertically in a special device alternately 90° to the left and right until it fractures or until the number of cycles set by standard requirements for technical specifications is reached.

One cycle is assumed to be bending through 90° and rebending through 90° (i.e., returning the specimen to its initial position). The cycle during which fracture occurs is not counted. The number of cycles per minute should not exceed 60. Alternate-bending tests are standardized for wire with diameters of from 0.8 to 7.0 mm (GOST 1579-63) and for strips and sheets with thicknesses of up to 5 mm (OST 1688). In testing sheets up to 0.5 mm thick and wire up to 1.5 mm in diameter it is permissible to use a tensioning attachment, which ensures that the specimen is pressed tightly against the bushings (rollers) of the device.

Specimens which survive bending tests should not exhibit separation, exfoliation, tearing, cracking, or fracture of the base material or surface coatings (see Technological testing).

References: Shaposhnikov, N.A., Mekhanicheskiye ispytaniya metallov [Mechanical Testing of Metals], 2nd Edition, Moscow-Leningrad, 1954.

Yu.S. Danilov

I-29I

BENDING TEST OF DISCS RESTING ON THE CIRCUMFERENCE – is one of the methods to evaluate the disruption strength (Fig. 1). It is applicable only to the destruction of discs along radial directions which in the case of structural steels is usually attained by testing in liquid nitrogen medium (Fig. 2). Generally, the thickness of the disc is equal to 5-6 mm. A stressed state near to a biaxial stress is established in the disc during the test, and, therefore, more favorable conditions for the determination of the brittleness are given. Such tests of discs are especially recommended for a comparative evaluation of materials used for spherical and cylindrical shells operating under internal pressure. The calculation of the breaking stresses in the case of absent plastic bending is carried out using the formula

$$\sigma = \frac{3P}{8\pi h^2}\left[4 - (1-\mu)\left(\frac{b}{a}\right)^2 + 4(1+\mu)\ln\left(\frac{a}{b}\right)\right],$$

where P is the breaking load, h is the thickness of the disc, μ is the Poisson's ratio, a is the radius of the support of the disc, and b is the radius of the contact area of the punch.

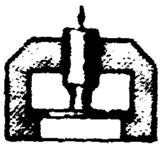

Fig. 1. Scheme of the bending test of discs resting on the circumference.

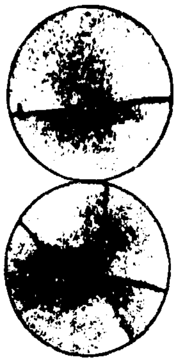

Fig. 2. Discs from 30KhGSA steel after brittle destruction in liquid nitrogen.

References: Fridman Ya. B., Roytman I.M., "Zavodskaya laboratoriya," 1948, No. 10.

S.I. Kishkina-Ratner

BERYL – a mineral of the silicate class, the beryllium silicate $Be_3Al_2[Si_6O_{18}]$, containing admixtures of alkalies, water, helium, and oxides of Ca, Mg, Mn, Fe, Cr, and V. The simplest crystals are elongated six-sided prisms combined with a pinacoid; tabular crystals, granular masses, etc., are also encountered. Beryl is brittle and has an intense glassy luster, a Mohs hardness of 7.5-8, a specific gravity of 2.63-2.91, a $t°_{pl}$ of 1420°, a coefficient of thermal expansion of $26 \cdot 10^{-7}$ (20-1000°), and a dielectric constant of 6.8-7.6; its indices of refraction are n_m = 1.568-1.602 and n_p = 1.564-1.595. It has a dispersion of 0.014. The only acid which reacts with beryl is fluoric acid. The following color varieties of beryl are distinguished: 1) true beryl – blue, greenish-blue, yellow, yellowish-green, green, brown, milky white, and occasionally reddish; cloudy, opaque crystals and granular masses; 2) emerald – bright green as a result of an impurity of Cr^{3+}; unflawed, opaque varieties with a uniform rich color are very rarely encountered and are highly prized as gem stones; paramagnetic; 3) aquamarine – clear, greenish-blue hues ranging from almost colorless to pure greenish-blue and deep blue; the color is due to an impurity of Fe^{2+}; precious stone; 4) vorobyevite (morganite) – reddish or yellowish-red as a result of an impurity of Mn^{2+}; contains cesium; 5) rosterite – colorless, in short prismatic or tabular crystals; 6) heliodor – clear, golden-yellow, principally as a result of an admixture of Fe^{2+}, but possibly of Fe^{3+}; gem stone.

The ewelry trade values emeralds, which are more expensive than diamonds when of high quality, aquamarines, especially those which are rich in color and less glassy, heliodor, and vorobyevite. The requirements for jewelry-grade beryl include uniform coloration, absence of cracks and inclusions, and transparency.

References: Betekhtin, A.G., Mineralogiya [Mineralogy], Moscow, 1950; Fersman, A.Ye., Drotsennyye i tsvetnyye kamni Rossii [Precious and Colored Stones of Russia], Vol. 1, Petrograd, 1920; Kryzhanovskiy, V.I., Akvamarin, v kn. [Aquamarine, in book]: Nemetallicheskiye iskopayemyye SSSR [Nonmetallic Minerals of the USSR], Vol. 1, Moscow-Leningrad, 1936; Grum-Grzhimaylo, S.V., and Pevneva, L.A., Krivyye spektral'nogo pogloshcheniya berillov i topazov razlichnykh okrasok [Spectral Absorption Curves of Beryls and Topazes of Various Colors], Tr. In-ta kristallogr. AN SSSR [Transactions of the Institute of Crystallography, Academy of Sciences USSR], 1956, No. 12; Narayana, Rao, Dielectric Constands of Crystals - III, "Proc. Indian Acad. Sci. A., 1949, Vol. 30, No. 2; Hummel, F.A., Observations on the Thermal Expansion of Crystalline and Glassy Substances, "J. Amer. Ceram. Soc., 1950, Vol. 33, No. 2.

Yu.L. Orlov

BERYLLIUM, Be – a chemical element of group II of Mendeleyev's periodic system, with an atomic number of 4 and an atomic weight of 9.013. It has one stable isotope, Be^9, and is included among the rare elements.

The beryllium content of the earth's crust amounts to $6 \cdot 10^{-4}$% by weight. The great difficulties involved in the metallurgy of beryllium made it impossible to produce it commercially until the end of the 1920's.

The outstanding properties of this metal, high strength in conjunction with a low specific gravity (1.84), a relatively high melting temperature (1283°), and good corrosion resistance have made it an irreplaceable structural material in some cases, principally in aeronautic and rocket technology and in the manufacture of instruments. The discovery of atomic energy brought into play still another important property of beryllium, its low effective thermal-neutron cross-section, which, in conjunction with its low atomic weight, makes beryllium one of the best materials for thermal-neutron moderators and reflectors and heat-evolving-element casings in atomic reactors. Beryllium is the only metal with these nuclear characteristics. The use of beryllium in neutron sources based on radium, polonium, actinium, plutonium, etc., is based on its ability to become a high-power neutron source when bombarded with α-particles. Beryllium is highly permeable to soft x-radiation (its permeability is 17 times that of Al) and disks of this metal are consequently employed as windows in x-ray tubes with high beam powers. Beryllium is also distinguished by high reflectivity for the ultraviolet portion of the spectrum, high thermal conductivity and heat capacity, a high sound-propagation rate, and chemical activity at high temperatures. It is a good reducing agent and is capable of causing dispersion hardening in a number of alloys, especially those based on copper (see *Beryllium bronze*). Beryllium is used as an additive to aluminum alloys and for applying hard diffusion layers to steel surfaces (see *Beryllization of steel*).

Many of the properties of beryllium cannot be fully utilized because of the low plasticity and high toxicity of dispersed beryllium and its compounds. The reason for the low plasticity of this metal has not been fully explained, but it has been established that there is a marked anisotropy of properties in crystals and products, especially those subjected to pressure working. The plasticity of beryllium depends on the manner in which the impurities are distributed and the purity, grain size, and texture of the metal. Combinations of different processing methods and regimes make it possible to obtain bars, various shapes, sheets, wire, tubing, etc., from beryllium.

The low beryllium content of the earth's crust, the complexity of the techniques used for processing the ore and obtaining the metal, and the toxicity of the latter, which requires that special protective measures be taken during production, make beryllium relatively expensive and limit its application.

Production of metal. Beryllium is usually produced commercially by metallothermic reduction and electrolysis of melts. The metal obtained by reduction of beryllium fluoride with magnesium is generally referred to as fluoride or magnesiothermic beryllium. Fluoride beryllium contains 0.1-0.3% Fe, 0.007-0.02% Mn, 0.01% Cr, 0.01-0.03% Ni, 0.03-0.05% Mg, 0.02-0.15% Al, $1 \cdot 10^{-4}$% B, and 0.04-0.2% C. Ingots of fluoride beryllium are used in the manufacture of finished products by powder-metallurgical methods or by casting. The only electrolytic method used commercially is electrolysis of molten beryllium chloride mixed with NaCl. The metal obtained in this manner is referred to as chloride, scale, flake, or electrolytic beryllium. Chloride beryllium is usually higher in quality than magnesiothermic beryllium. The approximate content of basic impurities in chloride beryllium is as follows: $2{\cdot}10^{-3}$-$1{\cdot}10^{-2}$% Mn, $2{\cdot}10^{-3}$-$2{\cdot}10^{-2}$% Cu, $5{\cdot}10^{-3}$-$2{\cdot}10^{-2}$% Fe, $3{\cdot}10^{-3}$% Al, $3{\cdot}10^{-3}$-$2{\cdot}10^{-2}$% Si, $3{\cdot}10^{-3}$-$5{\cdot}10^{-2}$% Ni, and $2{\cdot}10^{-3}$% Cl.

Data on the oxygen and carbon contents are insufficient; isolated reports indicate that these impurities reach several tenths of a percent.

In order to increase its purity and improve its plasticity metallic beryllium is refined by high-vacuum distillation and soluble-anode or zone-melting electrolysis. Beryllium is distilled at a residual pressure of 10^{-5}-10^{-6} mm Hg, heating the metal to 1320-1350°. It is condensed on a molybdenum base. The distillate takes the form of large crystals, which adhere to one another. The contents of certain impurities in distilled beryllium are as follows: $6{\cdot}10^{-3}$% Fe, $3{\cdot}10^{-3}$% Al, $5{\cdot}10^{-4}$% Cu, $3{\cdot}10^{-3}$% Ni, $5{\cdot}10^{-3}$% Cr, $2{\cdot}10^{-3}$% Mn, $1{\cdot}10^{-3}$% Pb, and $1{\cdot}10^{-3}$% N. Metal of still higher purity (up to 99.98%) can be obtained by redistillation.

Manufacture of finished products. Powder metallurgy is the principal method used to produce blanks for manufacture of finished products (see Beryllium block). Beryllium is not very often cast, since the cast metal has low mechanical characteristics and a coarse-grained structure, which hampers working. Several powder-metallurgical processes are employed for beryllium: "cold" pressing and subsequent sintering, "warm" pressing, "hot" pressing, and sintering without pressing. Beryllium powder with a grain size of no more than 70 μ is used as the initial material for production of cermets. Powder with a grain size of no more than 0.5 mm is employed in isolated cases. Cast beryllium in which the grains have been pulverized by thermomechanical or other treatment is equal in quality to metal produced by powder metallurgy. Heating of beryllium to temperatures above 600° is carried out in a vacuum or an inert medium, in order to prevent oxidation.

Physical Properties

γ at 25° (determined by x-ray diffraction analysis) – 1.8447 ± 0.0007 g/cm3

Atomic radius 1,123 kX

Lattice type – tightly-packed hexagonal

Lattice parameters (kX) at temperature of (°C):

Room temperature

	a	c	c a
комнатной	2,281	3,577	1,568
200°	2,287	3,584	1,567
600°	2,305	3,606	1,564
1000°	2,325	3,632	1,562

Interatomic distances

d_1 . . . . . . 2.221 kX

d_2 . . . . . . 2.281 kX

Allotropic-transformation temperature (°C):

on heating	1250
on cooling	1244

Lattice type of β_{Be} – body-centered cubic

Density of liquid beryllium at 1500° – 1.42 g/cm^3

Vapor pressure at temperature of:

900°	$10^{-[illegible]}$ атм
1235°	$10^{-[illegible]}$ атм
1950°	$10^{-[illegible]}$ атм
2970°	1 атм

Heat of fusion . . . . 2335 cal/mole

Heat of vaporization . . . . .53490 cal/mole

Heat of sublimation. . . . . .76560 cal/mole

Shrinkage on solidification. 3%

Surface tension at 1500° – 1100 ± 35 ergs/cm^2

For data on α see Fig. 1

λ (cal/cm•sec•°C) at temperature of:

undeformed	0.37	0.36	not determined
deformed	0.32	0.29	0.24

For data on ρ see Fig. 2

Superconductivity. . . . . .below 11°K

Electrochemical equivalent . . . 0.0467 mg/coulomb
Electrolytic dissolution
potential of Be/Be^{++} $E_0 = 1.9$ v
Reflective capacity { 52-55% (for white light)
55% (for ultraviolet light)
Radiation factor:
at wavelength of 6500 A. . .0.61 (to melting point)
" " 5500 A. . .0.61 (to melting point)
Sound-propagation speed 12,600 m/sec
For other physical properties of beryllium see Tables 1-3.

TABLE 1

Isotopes of Beryllium

Изотопы 1	Масса 2	Упаковочный множитель 3	Энергия связи (Мэв) 4	Вид и энергия излучения (Мэв) 5	Период полураспада 6
Be^6	6,0219	0,00365	4,41	неизвестен 7	0,4 сек 10
Be^7	7,01916	0,00274	5,33	γ 0,453—0,485	52 суток
Be^8	8,00785	0,00098	7,02	α 0,047	10^{-16}—10^{-15} сек 11
Be^9	9,01503	0,00167	6,42	устойчив 8	—
Be^{10}	10,01677	0,00168	6,45	β 0,557	2,7·10^6 лет
Be^{11}	11,0277	0,00252	5,69	излучения нет 9 неизвестен	—12

1) Isotope; 2) mass; 3) packing factor; 4) bonding energy (mev); 5) type and energy of radiation (mev); 6) half-life; 7) unknown; 8) stable; 9) no radiation; 10) sec; 11) days; 12) years.

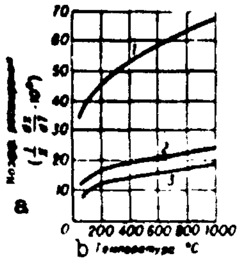

Fig. 1. Coefficient of thermal expansion of beryllium: 1) Volumetric; 2) linear, perpendicular to c axis; 3) linear, parallel to c axis. a) Coefficient of expansion; b) temperature, °C.

Figure 3 shows the effective neutron cross-section.

Chemical properties. Beryllium occupies a position intermediate between magnesium and aluminum with respect to chemical properties, which determines its position in the Mendeleyev Table. This element exhibits high reactivity (Tables 4 and 5).

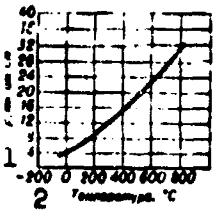

Fig. 2. Electrical resistance of beryllium. 1) ρ, μ ohms/cm; 2) temperature, °C.

The solubility of hydrogen in molten beryllium is substantially reduced on solidification and further cooling. There are no reliable reports of a noticeable interaction between solid beryllium and hydrogen. Reaction of beryllium with phosphorus vapor produces beryllium phosphide. Finely-dispersed beryllium powder burns in sulfur, selenium, or tellurium vapor. This metal reduces borates, phosphates, and silicates to the corresponding elements. Molten beryllium reacts with the majority of oxides, nitrides, sulfides, and carbides, including those of magnesium, calcium, aluminum, titanium, and zirconium.

The mechanical properties of products fabricated from beryllium vary within wide limits, depending on the purity of the metal, production technology, grain size, degree of anisotropy, and testing late. The test results are also influenced by the size of the specimens and the manner in which they are prepared, since beryllium is highly sensitive to notching. In order to eliminate notching cutting is carried out with a well-sharpened hard-alloy tool and heating of the specimen is avoided. Preparation of the specimens should terminate in removal of the surface layer (0.04-0.05 mm) by chemical etching and subsequent electropolishing.

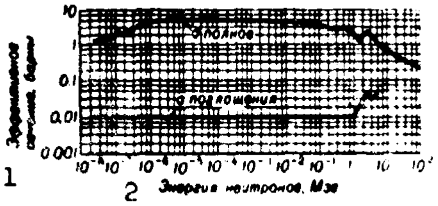

Fig. 3. Effective neutron cross-section of beryllium. 1) Effective cross-section, barns; 2) neutron energy, mev; 3) total; 4) absorption.

Fluoride beryllium powder is the material predominantly used in the manufacture of finished products and it is consequently the properties of this metal which are given (Table 6).

I-16b6

TABLE 2

Thermodynamic Properties

Темп-ра (°K) 1	c_p (кал/моль·°K) 2		Теплосодержание (кал/моль)	
	конденсированного 3	пара 4	конденсированного 5	пара
298.16	4.26	6.97	465	1481
400	4.56	—	880	—
600	5.14		1880	
800	5.72	—	3000	
1000	6.30	6.97	4210	4671
1200	6.88		5455	
1300	7.17	—	6080	—
1556 (твердого) 6	8.00	—	8080	
1556 (жидкий) 7	[illegible]		11615	—

1) Temperature (°K); 2) c_r (cal/mole•°K); 3) condensed; 4) vapor; 5) heat content (cal/mole); 6) solid; 7) liquid.

TABLE 3

Heat Capacity at Low Temperatures

Темп-ра (°K) 1	c_p (кал/моль·°K) 2	Темп-ра (°K) 3	c_p (кал/моль·°K) 4
10	0.00	100	0.41
25	0.01	150	1.26
50	0.05	200	2.38

1) Temperature (°K); 2) c_r (cal/ /mole•°K).

TABLE 4

Reaction of Beryllium with Certain Acids and Alkalies

Реактив		Концентрация	Темп-ра	Характер взаимодействия
5 Плавиковая кислота		любая 15	комнатная 19	бурно реагирует 21
6 Соляная	»	»	»	бурно »
7 Серная	»	концентрированная 16	»	слабо » 22
Серная	»	разбавленная 17	»	бурно »
8 Азотная	»	концентрированная	»	не реагирует. Заметная реакция лишь с тончайшим порошком 23
Азотная	»	разбавленная	»	слабо реагирует
Азотная	»	»	при нагреве 20	небольшое ускорение реакции 24
9 Щавелевая	»	разбавленная	»	слабо реагирует
10 Уксусная	»	ледяная 18	комнатная	не реагирует даже с высокодисперсным порошком 25
Уксусная	»	разбавленная	при нагреве	слабо реагирует
11 Винная	»	концентрированная	комнатная	реагирует с образованием на поверхности металла гидрата окиси, препятствующего дальнейшему взаимодействию 26
12 Лимонная	»	»	»	
13 Щелочь		концентрированная	комнатная	реагирует 27
»		разбавленная	при нагреве	»
14 Водный раствор аммиака		любая	комнатная	не реагирует 28

1) Reagent; 2) concentration; 3) temperature; 4) character of reaction;

5) hydrofluoric acid; 6) hydrochloric acid; 7) sulfuric acid; 8) nitric acid; 9) oxalic acid; 10) acetic acid; 11) tartaric acid; 12) citric acid; 13) alkali; 14) aqueous ammonia; 15) any; 16) concentrated; 17) dilute; 18) glacial; 19) room; 20) on heating; 21) reacts vigorously; 22) reacts weakly; 23) does not react; noticeable reaction only with finely dispersed powder; 24) slight acceleration of reaction; 25) does not react, even with finely dispersed powder; 26) reacts until a hydrated oxide is formed on the surface of the metal, preventing further interaction; 27) reacts; 28) does not react.

TABLE 5

Nature of Interaction of Beryllium with Certain Gases

Газ 1	Темп-ра 2	3 Характер взаимодействия
Фтор 4	комнатная 15	реагирует 18
Хлор 5	повышенная	»
Бром 6	17 » 16	»
Иод 7	»	»
Сероводород 8	»	»
Кислород 9	выше 600°	»
Азот 10	выше 650°	»
Аммиак 11	1000°	»
Циан 12	800°	» 19
Двуокись углерода (сухая) 13	500°	разрушение наступает после 8000 час
	600°	разрушение наступает после 400 час
Двуокись углерода (влажная) 14	550°	20 21 То же

1) Gas; 2) temperature; 3) type of reaction; 4) fluorine; 5) chlorine; 6) bromine; 7) iodine; 8) hydrogen sulfide; 9) oxygen; 10) nitrogen; 11) ammonia; 12) hydrogen cyanide; 13) carbon dioxide (dry); 14) carbon dioxide (moist); 15) room; 16) elevated; 17) above; 18) reacts; 19) attack begins after 8000 hours; 20) attack begins after 400 hours; 21) same.

TABLE 6

Basic Properties of Beryllium

Свойства 1	Горячепрессованный 2	Горячепрессованный выдавленный и отожженный 3	4 Горячепрессованный прокатанный
E (кг/мм²) 5	[illegible]	[illegible]—30300	—
$E_{сж}$ (кг/мм²)	[illegible]	[illegible]	[illegible]—31600
$E_{ср}$ (кг/мм²)	[illegible]	[illegible]	—
ν	[illegible]	[illegible]	—
σ_b (кг/мм²)	28—3[illegible]	[illegible]—63	30—45
δ (%)	[illegible]—3	2—16	1.5—3.5
RH	[illegible]	[illegible]—93	—

1) Property; 2) hot-pressed; 3) hot-pressed, extruded, and annealed; 4) hot-pressed and rolled; 5) kg/mm².

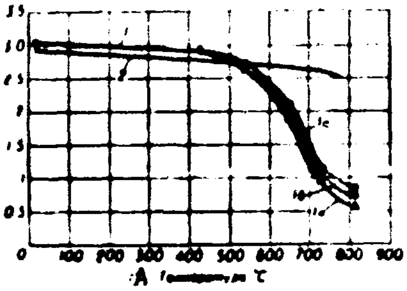

Fig. 4. Modulus of elasticity as a function of temperature during dynamic tensile testing: 1a) during extension at a rate of 0.005 mm/mm•min; 1b) during extension at a rate of 0.001 mm/mm•min; 1c) during extension at a rate of 0.0002 mm/mm•min. A) Temperature, °C.

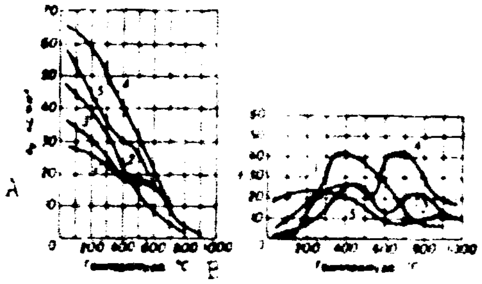

Fig. 5. Ultimate strength (a) and elongation (b) of beryllium produced by different methods as a function of temperature during extension: 1) extruded cast beryllium; 2) extruded electrolytic (chloride) beryllium; 3) hot-pressed; 4) hot-pressed and warm-extruded; 5) hot-pressed and hot-extruded. A) σ_b, kg/mm²; B) temperature, °C.

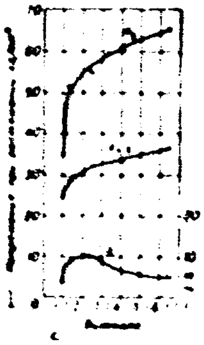

Fig. 6. Properties of hot-pressed, warm-extruded beryllium as a function of elongation during extension. 1) Tensile stress, kg/mm²; 2) elongation.

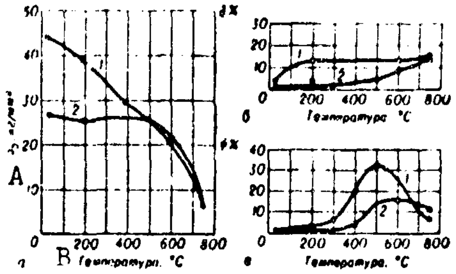

Fig. 7. Ultimate strength (a), elongation (b), and necking (c) of hot-pressed, warm-extruded beryllium as a function of temperature: 1) Along extrusion axis; 2) perpendicular to extrusion axis. A) σ_b, kg/mm^2; B) temperature, °C.

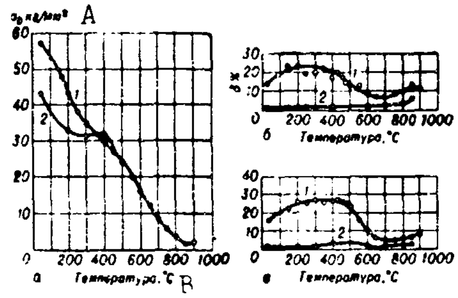

Fig. 8. Ultimate strength (a), elongation (b), and necking (c) of hot-pressed, hot-extruded beryllium as a function of temperature: 1) Along extrusion axis; 2) perpendicular to extrusion axis. A) σ_b, kg/mm^2; B) temperature, °C.

E varies only slightly as a function of deformation rate (Fig. 4). On compression accompanied by a rise in temperature E varies in the same manner as the modulus of elasticity on extension, but has a lower value.

Table 7 shows the change in the modulus of elasticity of beryllium under torsion. Table 8 shows the properties of fluoride and chloride beryllium under tension. Table 9 shows the change in the properties of hot-pressed beryllium blocks.

Figures 5 (a and b), 6, 7(a, b, and c), 8 (a, b, and c), and 9 (a, b, and c) show certain properties of beryllium as a function of temperature and elongation.

There is a large discrepancy in the properties of different batches of extruded beryllium (more than 10% in σ_b and 60% of the average value of δ), as well as within a single bar, where it amounts to approximately 1/2 of the discrepancy between batches (Table 9).

Figure 10 shows the properties of sheets obtained from extruded strips by transverse rolling at 980° with various elongations. Sheets with uniform properties ($\delta \sim 40\%$) are obtained at an elongation of 6-8.

Grain size is an important factor affecting the mechanical properties of beryllium. Figure 11 shows the properties of hot-pressed blocks produced from powders of varying coarseness. The favorable influence of fine grain size on the properties of hot-pressed and hot-extruded beryllium (at temperatures of up to 500°) is shown in Figs. 12 and 13. The properties of beryllium produced from fine-grained powders decrease at temperatures above 400-500°, where fracture becomes transcrystalline. Coarse-grained material usually has better characteristics than fine-grained metal at temperatures above this level.

The properties of beryllium under tension depend on the deformation rate. A rise in temperature from 430 to 540° has no material effect, but an increase to more than 650° causes a sharp decrease in properties (Table 10).

Figure 14 presents data on the long-term strength of hot-pressed beryllium, while Fig. 15 shows the influence of an increase in BeO content. Figure 16 and Table 11 show the change in yield strength under compression as a function of deformation rate at different temperatures.

The hardness of beryllium is not taken into account in evaluating its quality, since it depends to a considerable extent on the anisotropy of the material. The hardness of beryllium varies within the following limits: RB = 60-85 for hot-pressed beryllium and RB = 60-93 for beryllium extruded from the hot-pressed metal, depending on the direction and prior annealing. The highest hardness is observed parallel to

TABLE 7

Change in Modulus of Torsion of Hot-Vacuum-Pressed Beryllium

Темп-ра (°C) 1	Скорость деформации 2 при расчетной длине 101,6 мм (радиан мин)	3 Модуль (10^6 кг/см²)
Комнатная 4	0,01	1,57
650	0,01	0,91
Комнатная	0,02	1,40
650	0,02	1,16
650	0,06	0,84

1) Temperature (°C); 2) deformation rate at calculated length of 101.6 mm(radians/min); 3) modulus (10^6 kg/cm^2); 4) room temperature.

TABLE 8

Properties of Cast and Cermet Beryllium Under Tension

Состояние материала 1	Направление 2 испытания	3 σ_b (кг/мм²)	δ (%)
4 Фторидный литой в вакууме	—	14	0
5 Фторидный литой, выдавленный и отожженный	продольное	28	1.8
6 Хлоридный металлокерамический выдавленный и отожженный	то же	45	5.0
7 Фторидный металлокерамический выдавленный отожженный	»	42—57	2-16

1) Condition of material; 2) test direction; 3) kg/mm^2; 4) vacuum-cast fluoride beryllium; 5) extruded and annealed cast fluoride beryllium; 6) extruded and annealed chloride cermet beryllium; 7) extruded and annealed cermet fluoride beryllium; 8) longitudinal; 9) the same.

TABLE 9

Properties of Hot-Pressed Fluoride Beryllium Blocks as a Function of Processing

Состояние материала 1	2 σ_b (кг/мм²)	$\sigma_{0,2}$ (кг/мм²)	δ (%)
3 Исходный блок	32	23	2,3
4 Тепловыдавленный с вытяжкой 5	59—69	58—68	0—1
5 Тепловыдавленный с вытяжкой 5 и отожженный при 750°	42—63	32—39	2—7
6 Горячевыдавленный с вытяжкой 12	63	32	11,7
7 Горячевыдавленный с вытяжкой 12 и отожженный при 750°	57	28	15,8
8 Прокатанный (60%-ное обжатие при 850—900°)	45	29	3,5
9 Прокатанный с 60%-ным обжатием при 850—900° (в направлении, перпендикулярном оси)	31	25	1,8

1) Condition of material; 2) kg/mm^2; 3) initial block; 4) warm-extruded with an elongation of 5; 5) warm-extruded with an elongation of 5 and annealed at 750°; 6) hot-extruded with an elongation of 12; 7) hot extruded with an elonation of 12 and annealed at 750°; 8) rolled (60% re-

duction in area at 850-900°); 9) rolled with 60% reduction in area at 850-900° (in direction perpendicular to axis).

TABLE 10

Properties of Hot-pressed Beryllium Blocks as a Function of Temperature and Deformation Rate (initial grain size – 70 μ)

Темп-ра испытания (°С)	Скорость деформации (мм/мм·мин)	σ_b	$\sigma_{0,2}$	δ	ψ
		(кг/мм²)		(%)	
630	0.0002	15	11	19	38
	0.020	16	16	22	38
650	0.0002	7	8	4	3
	0.020	13	13	9	17
815	0.0002	1.3	1.3	0.1	0.5
	0.020	6.0	6.0	6.2	5.5

1) Test temperature (°C); 2) deformation rate (mm/mm•min); 3) kg/mm².

TABLE 11

Properties Under Compression

Состояние материала 1	$\sigma_{0,2}$ (кг/мм²) 2		σ_b (кг/мм²)	
	3 при 20°	при 400°	при 20°	при 400°
4 Литой выдавленный	50	41	152	107
5 Металлокерамический выдавленный	56	41	147	107

1) Condition of material; 2) kg/mm²; 3) at; 4) extruded cast beryllium; 5) extruded cermet beryllium.

TABLE 12

Properties Under Shear and Torsion

Состояние материала 1	Тип испытания 2	$\tau_{0,3}$	τ_b	Угол скручивания до разрушения (в градусах) 4
		3 (кг/мм²)		
5 Горячепрессованный	8 кручение двойной срез	12.9 —	27.3 25.9	— —
6 Горячепрессованный и тепловыдавленный (вытяжка 5)	9 кручение	21.8	33	163
7 Горячепрессованный, тепловыдавленный и отожженный при 750°	кручение	12.7	46.4	190

1) Condition of material; 2) type of test; 3) kg/mm²; 4) torsion angle to fracture (in degrees); 5) hot-pressed; 6) hot-pressed and warm-extruded (elongation – 5); 7) hot-pressed, warm-extruded, and annealed at 750°; 8) torsion, double shear 9) torsion.

TABLE 13

Properties During Impact Testing

Состояние материала 1	Вид образца 2	3 Работа ударного разрушения на изгиб в кгм (сечение 2,54 см²)	Работа ударного разрушения при растяжении в кгм (d=5,4 мм) 4
5 Горячепрессованный	без надреза	0,11	0,19
6 Теплопрессованный и горячевыдавленный (вытяжка 12)	—	0,56	0,02
7 Теплопрессованный и горячекатаный	без надреза	0,27—0,41	—
8 Горячепрессованный и горячевыдавленный	» »	0,14—0,33	—
9 то же	с надрезом	0,07—0,13	—
Литой горячевыдавленный 10	—	0,02	—

1) Condition of material; 2) type of specimen; 3) work of impact fracture on bending, in kg-m (cross-section – 2.54 cm²); 4) work of impact fracture on extension, in kg-m (d = 5.4 mm); 5) hot-pressed; 6) warm-pressed and hot-extruded (elongation – 12); 7) warm-pressed and hot-rolled; 8) hot-pressed and hot-extruded; 9) the same; 10) cast and hot-extruded; 11) without notch; 12) with notch.

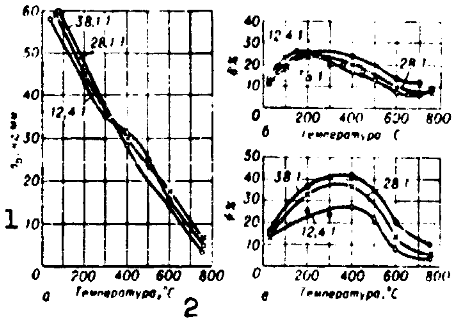

Fig. 9. Ultimate strength (a), elongation (b), and necking (c) of hot-pressed and hot-extruded beryllium as a function of temperature at different drawing depths. 1) σ_b, kg/mm²; 2) temperature, °C.

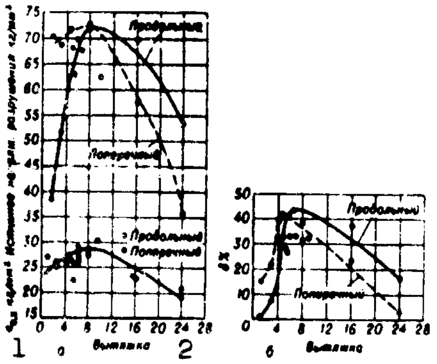

Fig. 10. Ultimate strength (a) and elongation (b) of beryllium sheets rolled from extruded strips perpendicular to axis as a function of drawing depth. 1) $\sigma_{0.2}$, kg/mm²; test fracture stress, kg/mm²; 2) drawing depth; 3) longitudinal; 4) transverse.

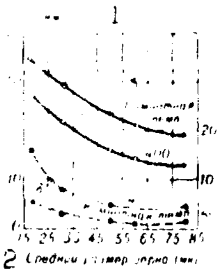

Fig. 11. Properties of hot-pressed beryllium as a function of average grain size under tension. 1) σ_b, kg/mm^2; 2) average grain size (μ); 3) room temperature.

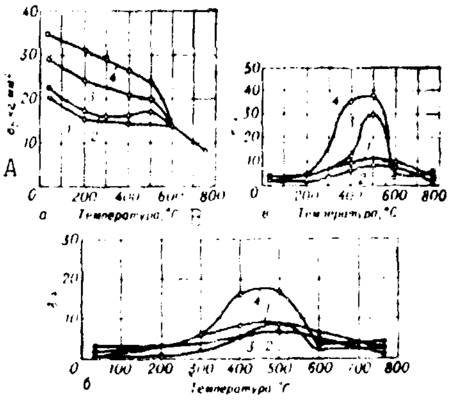

Fig. 12. Ultimate strength (a), elongation (b), and necking (c) of beryllium hot-pressed from powders of varying coarseness as a function of temperature under tension: 1) Average grain size – 0.061 mm; 2) average grain size – 0.051 mm; 3) average grain size – 0.031 mm; 4) average grain size – 0.017 mm. A) σ_b, kg/mm^2; B) temperature, °C.

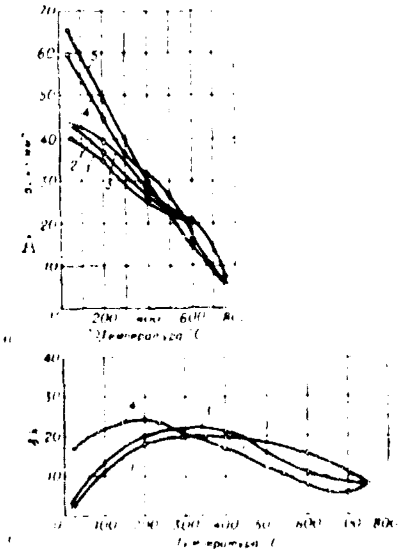

Fig. 13. Ultimate strength (a) and elongation (b) of beryllium hot-pressed from powders of varying coarseness and hot-extruded as a function of temperature: 1) Average grain size – 0.066 mm: 2) average

grain size – 0.049 mm; 3) average grain size – 0.037 mm; 4) average grain size – 0.020 mm; 5) average grain size – 0.013 mm. A) σ_b, kg/mm^2; B) temperature, °C.

the extrusion axis.

Table 12 shows the ultimate strength (under torsion and double shear) and yield strength (under torsion) of beryllium, as well as the maximum torsion for metal obtained by various methods.

The surface preparation of the specimen and the hammer speed have a strong influence on the results of impact tests on beryllium (Tables 13 and 14).

Tensile testing of notched hot-pressed beryllium specimens has shown that elongation decreases from 1.8 to 0% and ultimate strength from 35 to 34 kg/mm^2. Semicircular notching of hot-pressed beryllium containing 1 and 2% BeO yields decreases in ultimate strength from 28 to 17 kg/mm^2 and from 38 to 21 kg/mm^2 respectively. The theoretical stress-concentration factor is 1.8.

The fatigue strength of warm-extruded (with an elongation of 4) beryllium (which has the following properties under tension: σ_n = 40 kg/mm^2, $\sigma_{0.2}$ = 37 kg/mm^2. and [illegible] 17%) is 22 kg/mm^2.

When beryllium is subjected to thermal-shock testing in metallic sodium at 350-530° specimens obtained from cast beryllium by hot extrusion crack after 100 cycles, while those obtained from cold-pressed and hot-pressed metal crack after 100-200 cycles. Specimens of hot-pressed beryllium crack after 300-500 or more cycles.

Beryllium sheets withstand bending poorly; the minimum bending radius is approximately 40 times the sheet thickness (Table 15). However, the permissible bending radius is sharply reduced in bending narrow specimens. A specimen 1.65 mm thick and 2.16 mm wide can be bent around a core 3.17 mm in diameter. The degree of fracture becomes neg-

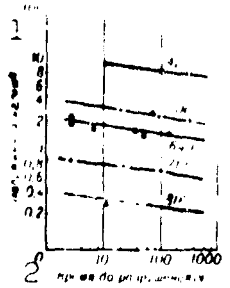

Fig. 14. Long-term strength of hot-pressed beryllium as a function of time. 1) Stress, kg/mm²; 2) time to fracture, hr.

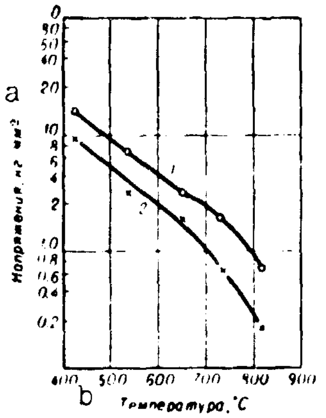

Fig. 15. Long-term strength (in 100-hr tests) of hot-pressed beryllium as a function of BeO content: 1) 3% (by weight); 2) 1% (by weight). a) Stress, kg/mm²; b) temperature, °C.

TABLE 14

Work of Impact Fracture of Beryllium on Bending (in kg-m) as a Function of Temperature (Unnotched Charpy Specimens)

Состояние материала 1	Температура (°C) 2								
	3 комнатная	100	200	300	400	500	600	700	800
4 Горячепрессованный	0.0165	0.0195	0.0250	0.0305	0.026[illegible]	0.0412	0.0265	0.[illegible]	0.0380
5 Горячепрессованный и выдавленный	0.0170	0.0184	0.0350	0.0353	0.1700	0.0310	0.1900	0.2800	0.2800

1) Condition of material; 2) temperature (°C); 3) room temperature; 4) hot-pressed; 5) hot-pressed and extruded.

TABLE 15

Properties of Hot-Pressed Beryllium Specimens During Bending

Направление прокатки 1	2 Направление испытания	3 Темп-ра испытания (°C)	4 Наименьший радиус изгиба без разрушения (мм)
5 В одном направлении	8 продольное	1p комнатная	51
6 то же	поперечное	то же	76
»	продольное	427	13
»	поперечное	427	38
7 В двух взаимно-перпендикулярных направлениях	9 продольное	10 комнатная	38
то же	поперечное	то же	44
»	продольное	427	13
»	поперечное	427	19

1) Rolling direction; 2) test direction; 3) test temperature (°C); 4) least bending radius without fracture (mm); 5) in one direction; 6) the same; 7) in two mutually perpendicular directions; 8) longitudinal; 9) transverse; 10) room temperature.

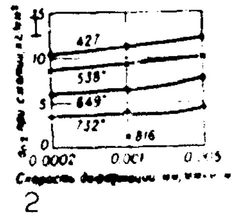

Fig. 16. Yield strength of hot-pressed beryllium as a function of temperature and test rate under compression. 1) $\sigma_{0.2}$ under compression, kg/mm^2; 2) deformation rate, mm/mm•min.

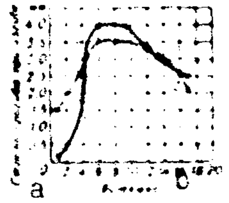

Fig. 17. Plasticity of beryllium sheet during bending test as a function of elongation of extruded strip during rolling (during 950°): 1) Along rolling axis; 2) perpendicular to rolling axis. a) Rise of fracture during bending; b) elongation.

TABLE 16

Influence of Irradiation on Hot-Pressed Beryllium

1 Поток нейтронов/см² (1 Мэв)	2 γ (г/см³)	RB	3 σ_b кг/мм²	δ (%)
0	1.847	71.5	25.5	1.4
$8.0 \cdot 10^{20}$	1.847	88.8	46.2	0.2
$2.4 \cdot 10^{21}$	1.847	97.4	35.3	0.2

1) Flux, neutrons/cm^2 (mev); 2) g/cm^3; 3) kg/mm^2.

ligible for strips more than 5 mm wide (Fig. 17).

When the surfaces and edges of beryllium sheets are carefully finished they can be bent through 375-540° with a minimum radius equal to 4 times their thickness and through more than 540° with a minimum radius equal to twice their thickness.

Effect of irradiation. No material changes in length, density, hardness, modulus of elasticity, electrical resistance, or thermal conductivity are observed after irradiation of beryllium with fast neutrons (energy – 0.5 mev) at a flux of $5 \cdot 10^{18}$ neutrons/cm^2 and a temperature of 30°. Raising the flux to $1.8 \cdot 10^{20}$ neutrons/cm^2 leads to a slight increase in hardness and a decrease in thermal conductivity; there is no difference in the behavior of metals produced by different methods. A pronounced rise in hardness is observed when the neutron flux is further increased (Table 16).

Beryllium irradiated at a flux of $7.6 \cdot 10^{21}$ fast neutrons/cm^3 contains 10 cm^3 of helium. Formation of gas bubbles is observed on heating, beginning at 600° and being especially pronounced along the grain boundaries; the bubbles reach 0.01 mm in diameter at 1100° and cause the volume of the beryllium to increase by up to 30%.

References: Berilliy [Beryllium], edited by D. White and J. Berk, translated from English, Moscow, 1960; Silina, G.F., Zarembo, Yu.I., Bertina, L.E., Berilliy. Khimicheskaya tekhnologiya i metallurgiya [Beryllium. Chemical Technology and Metallurgy], Moscow, 1960; Atomnaya energiya [Atomic Energy], 1958, Vol. 5, No. 6, pages 624-630; Darwin, G.E., Buddery, J.H., Beryllium, London, 1960; Williams, J., Metallurgical Reviews, 1958, Vol. 3, No. 9, pages 1-44; Reactor Handbook, Edited by C.R. Tipton, 2nd Edition, Vol. 1, Materials, London, 1960, pages 897-942; Conference on the Metallurgy of Beryllium, the Institute of Metals, London, 1961.

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BERYLLIUM ALLOYS – alloys based on beryllium or on more complex combinations containing considerable quantities of beryllium (no less than 10–20%), such as beryllium-aluminum alloys.

Beryllium-aluminum alloys. Be-Al alloys are of great interest as structural materials for aircraft equipment, since they have valuable

TABLE 1

Properties of Deformed Be-Al Alloys (data furnished by ALCOA, USA)

Содержание Be (%) 1	Полуфабрикат 2	Состояние 3	σ_b	$\sigma_{0,2}$	E	δ	ψ
			4 (кг/мм²)			(%)	
9.8	5 лист	50%-ное обжатие 11	25.0	23.8	—	2.8	—
9.8	то же 6	закалка при 562° 12	15.5	7.2	—	25.5	—
16	»	50%-ное обжатие	27.5	26.2	—	2.0	—
16	»	закалка при 562°	18.7	8.9	—	19.5	—
19.94	»	после прессования 13	14.6	7.7	11 400	17.0	15.5
19.94	»	испытание при 315°	4.7	2.9	8 600	25.0	33.4
22	кованый 7 пруток (d = 10,5 мм)	— 14	19.7	12.7	14 100	4.5	10.5
23	лист	50%-ное обжатие 15	26.7	24.6	—	4.0	—
23	то же	отжиг при 300° 16	18.6	11.9	—	12.5	—
23	»	закалка при 620°	21.2	13.1	—	12.5	—
23	»	закалка при 620°, старение 17	23.5	17.1	—	12.0	—
25	»	75%-ное обжатие 18	37.3	35.7	—	2.8	14.55
25	»	отжиг при 400° 19	27.5	15.8	9 700	14.3	—
25	»	закалка при 600° 20	27.3	14.2	11 900	18.7	—
25	»	отжиг при 600° 21	23.6	11.4	—	18.3	—
32.51	»	50%-ное обжатие	37.2	33.7	—	2.0	—
39	»	75%-ное обжатие	41.0	39.5	13 700	0.5	—
39	»	отжиг при 343° 22	26.7	23.4	—	1.7	—
39	»	отжиг при 410° 23	27.8	23.2	—	2.0	—
39	»	75%-ное обжатие	46.2	41.1	12 900	1.5	—
39	»	отжиг при 400°	32.2	23.6	10 400	7.3	—
39	»	закалка при 600°	31.4	19.6	11 200	9.7	—
39	»	отжиг при 600°	29.1	16.3	—	14.4	—
40	8 лист толщиной 0.2 мм	после прокатки 24	28.1	21.8	15 500	1.5	—
40	9 лист толщиной 4 мм	после отжига 25	15.5	9.5	—	5.0	—
67.5	10 отливка	отливка в землю 26	19.7	19.6	14 300	0.0	—
67.5	отливка	испытание при 260° 27	7.4	—	—	1.0	—
70	отливка	отливка при охлаждении 28	17.6	13.4	20 400	3.0	—

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*Sheets 1.6 mm thick are produced in addition to those mentioned.

1) Be content (%); 2) semifinished product; 3) condition; 4) kg/mm^2; 5) sheets; 6) the same; 7) forged bars (d = 10.5 mm); 8) sheets 0.2 mm thick; 9) sheets 4 mm thick; 10) castings; 11) 50% reduction in area; 12) quenching from 562°; 13) after pressing; 14) testing at 315°; 15) annealing at 300°; 16) quenching from 620°; 17) quenching from 620°, aging; 18) 75% reduction in area; 19) annealing at 400°; 20) quenching from 600°; 21) annealing at 600°; 22) annealing at 340°; 23) annealing at 410°; 24) after rolling; 25) after annealing; 26) loam casting; 27)

testing at 260°; 28) chill casting.

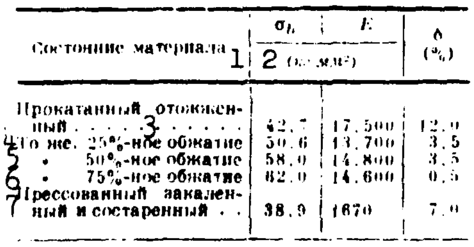
properties: lightness (the specific gravity Be is 1.84 and that of Al is 2.8), high rigidity (the modulus of elasticity of Be is ~30,000 kg/ /mm^2 and that of Al is 7000 kg/mm^2), a higher technological plasticity than Be, and the capacity to be pressed, forged, or rolled into thin sheets at Be contents of up to 50-60%. The phase diagram of the Be-Al system shows such alloys to be eutectic mixtures. The solubility of Be in Al is extremely limited, not exceeding 0.1% at room temperature and 0.3% at the melting temperature of the eutectic. Al and Be can be mixed in any proportions when molten. In the solid state the structure of alloys based on this system (at Be contents of no more than 1.1-1.4%) consists of a beryllium phase and a eutectic containing predominantly Al. According to the data of various researchers, the eutectic contains from 98% to 99.5% Al.

A characteristic of Be-Al alloys containing more than 1.1-1.4% Be is the fact that they are of the eutectic type and have a structure with a pronounced phase heterogeneity. The eutectic, which consists of virtually pure Al, provides a plastic base in alloys containing up to 50% Be and, despite the presence of hard, brittle Be, permits such alloys to flow and makes it possible to manufacture pressed and forged products from them.

At the same time, the pronounced heterogeneity of the structural constituents of Be-Al alloys give them a tendency to crack under the tensile forces which act during pressure working, so that they have a lower technological plasticity than commercial aluminum alloys. Be-Al alloys should be pressed and rolled at 600-650°. Cold rolling with frequent intermediate annealing at 600° is also possible. Manufacture of dense ingots entails considerable difficulties, since Be-Al alloys have a broad crystallization-temperature range and a tendency toward intensive absorption of gases when molten, which produces considerable porosity in castings. Moreover, molten beryllium has a high chemical activity, which makes it preferable to melt it in a vacuum or inert medium. It is in principle possible to obtain Be-Al casting alloys of any composition, as well as to produce Be-Al alloys with a more complex composition and higher mechanical characteristics than binary Be-Al alloys (Table 1). According to data obtained by the Aluminum Company of America, the strength of an annealed binary Be-Al alloy containing 25% Be can be increased by a factor of $1\frac{1}{2}$-2 by alloying with additives of other elements (Table 2).

TABLE 2

Properties of Be-Al Alloys Containing 25% Be and Additives (data furnished by ALCOA, USA)*



Состояние материала 1	σ_b	E	δ
	2 (кг/мм²)		(%)
Прокатанный отожженный . . . 3	42.7	17.500	12.0
4 То же. 25%-ное обжатие	50.6	13.700	3.5
5 » 50%-ное обжатие	58.0	14.800	3.5
6 » 75%-ное обжатие	82.0	14.600	0.5
7 Прессованный закаленный и состаренный . .	38.9	1670	7.0

*The additives and quantities employed are not indicated.

1) Condition of material; 2) kg/mm^2; 3) rolled and annealed; 4) the same, 25% reduction in area; 5) 50% reduction in area; 6) 75% reduction in area; 7) pressed, quenched, and aged.

Among the factors which limit the applicability of Be-Al alloys are the high toxicity of processes in which Be vapor and dust are liberated (melting, casting, welding, and cutting), which necessitates the construction of specially equipped production rooms, and the high cost of Be. For these reasons it is wise to use Be-Al alloys in aircraft

TABLE 3

Typical Properties of Beryllides

Соединение 1	Точка плавления (°C) 2	Твердость по Виккерсу при комнатной темп-ре (нагрузка 2,5 кг) 3	4 $\sigma_{изг}$ (кг/мм²)			7 Скорость окисления (мм за 100 час)		δ при комнатной темп-ре (%) 8
			при комнатной темп-ре 5	6 при 1370°	при 1510°	при 1370°	при 1480°	
Бериллиды ниобия: 9								
$NbBe_{12}$	1688	500	15	28	15	0,02	0,05	0,1
Nb_2Be_{17} . . .	1704	1000	22	44	25	0,01	0,03	0,1
Nb_2Be_{19} . . .	1704	1050	21	46	19	—	—	0,1
Бериллиды тантала: 10								
$TaBe_{12}$	1849	720	22	30	18	0,01	0,02	0,1
Ta_2Be_{17}	1988	1120	21	39	25	0,007	0,02	0,1
Бериллиды циркония: 11								
$ZrBe_{13}$	1927	1000	17	26	17	0,01	0,03	0,05
$ZrBe_{17}$	1982	1130	17	28	25	0,01	0,02	0,1

1) Compound; 2) melting point (°C); 3) Vickers hardness at room temperature (load – 2.5 kg); 4) kg/mm²); 5) at room temperature; 6) at; 7) oxidation rate (mm over 100 hr); 8) δ at room temperature (%); 9) niobium beryllides; 10) tantalum beryllides; 11) zirconium beryllides.

equipment only when rigidity is a definite structural factor.

Alloys based on beryllium. Alloys based on Be are of exceptional interest, since the melting temperature of Be is almost twice that of Al of Mg, it is as light as magnesium, its modulus of elasticity is more than 4 times that of Al, its heat capacity is more than twice that of Al, and it has a number of valuable properties from the standpoint of nuclear physics. It is theoretically possible to obtain alloys with higher properties than the initial base metal from Be (as well as from Al, Mg, Cu, and other metals). Addition of 0.5% Ni increases the long-term strength of Be at 900°. It is also possible to improve considerably the mechanical and even the technological properties of Be by using beryllium alloys based on complex systems containing 2-4% Si, 0.1-1% Ag, and 2-4% Al. The best casting properties are obtained with a Be alloy containing 0.5% Ti and 0.1% Ag.

Broad prospects have been opened up in the design of beryllium-based technological alloys by the use of the β modification of Be as the alloy base; this modification has a body-centered cubic lattice and exists over a very narrow temperature range near the melting point of Be (the hexagonal lattice of Be becomes cubic at approximately 1252°). The high-temperature β modification of Be has a higher plasticity than the α modification with its hexagonal crystal lattice. Addition of certain elements, such as Ni, Co, Cu, Ag, Si, etc., to the Be permits considerable expansion of the temperature range over which the β-phase, with its cubic lattice, exists. Despite the presence of the high-temperature β-phase in Be alloys containing a whole series of elements, attempts to obtain this phase at lower temperatures by quenching have been unsuccessful.

An important achievement in the creation of materials capable of functioning at exceptionally high temperatures has been the development of a group of intermetallic compounds of Be with Ta, Nb, Zr, and other high-melting elements, the beryllides. According to the data of the Brach Beryllium Company (USA), the tantalum beryllide Ta_2Be_{17} has a melting temperature of 1988°, while that of the zirconium beryllide Zr_2Be_{17} is 1982°. The specific gravity of beryllides varies from 2.72 to 5.05. The working temperatures of beryllides are 40-50% higher than those of Co, Ni, or niobium alloys; these compounds can function at 1650° for 10 hr. The ultimate bending strength of beryllides ranges from 58 to 70.0 kg/mm^2 at 1260°. Beryllides have an exceptionally high hardness and oxidation resistance (Table 3).

These compounds have a greater high-temperature strength and oxidation resistance than boron and silicon carbides, aluminum and beryllium oxides, tungsten, or molybdenum. The coefficient of linear expansion of α-beryllides is comparable to that of nickel.

According to the data of Brach Beryllium, beryllides are now employed in the manufacture of various small products and components, such as shapes, bars, tubes, cones, cylinders, blocks, strips, and disks. Beryllide components are fabricated by hot pressing of powders, cold pressing and sintering, and precision casting in lost-metal molds. The density of such products amounts to 98-100% of its theoretical value. Until 1963 beryllium alloys were used only for experimental purposes. The prospects for creation and expansion of applications for beryllium-based alloys depend primarily on advances in the development of methods for producing plastic Be and pure, finely dispersed powders, reduction of the cost of Be, and progress in research and development.

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K.P. Yatsenko and I.A. Akopov

BERYLLIUM BLOCK – compact metallic beryllium in the form of geometrically uncomplicated cylinders, bars, etc., produced by powder metallurgy. The Be powder used in the manufacture of such blocks is easily obtained in the following manner: remelted ingots of the reduced metal are converted to chips and the latter, or electrolytic scale, are pulverized in grinders. Chips obtained in the fabrication of products from blocks are usually added to the initial chips, first thoroughly removing all impurities. After pulverization the individual batches of powder are thoroughly mixed and tested.

Beryllium block is produced in various sizes. Small blocks are manufactured by pressing the powder into briquets (under a pressure of 4000-14,000 kg/cm^2) in steel pressforms at room temperature and then sintering them at 1170-1225°. Large beryllium blocks, such as cylinders up to 2.0 m in diameter and weighing up to 5 t, are produced by hot vacuum pressing: the powder is poured into steel shell molds and vibration-compacted. The powder-containing molds are loaded into steel, carbon, or graphite pressforms and placed in vacuum furnaces installed in hydraulic presses. Pressing is carried out at 1000-1100° and a pressure of 14-50 kg/cm^2 over a period of several days. Blocks 100 x 600 x 1300 mm are the standard product and are cut into smaller blocks. Beryllium blocks serve as blanks for fabrication of products by cutting and as semifinished products for pressure working (see Pressure working of beryllium).

Vacuum sintering of the powder without pressing permits production of blocks for subsequent extrusion. The equipment used in this process is simpler. The powder must satisfy high requirements with respect to chemical and granulometric composition.

Beryllium block is checked for chemical composition, density, uniform density both longitudinally and transversely, strength, and absence of cracks and internal defects.

The properties of beryllium block (electrical conductivity, strength, etc.) deteriorate as its density decreases. They also depend on the impurity content and the coarseness of the initial powder. Hot-vacuum-pressed beryllium blocks have a density approximating the theoretical value and completely isotropic properties. Blocks produced by this method from powders with a grain size of less than 0.071 mm have a fine-grained, randomly oriented structure (σ_b – approximately 28 kg/ /mm^2, δ – approximately 1.0%). Blocks obtained by cold pressing and subsequent sintering (cold or hot grooving when necessary) have considerably lower characteristics and a lower average density (less uniformly distributed) than hot-vacuum-pressed blocks. For such blocks σ_b ranges up to 22 kg/mm^2 and δ up to 0.1%.

Beryllium block is readily cut with hard-alloy tools (high-speed steel in some cases).

References: Atomnaya energiya [Atomic Energy], 1958, Vol. 5, No. 6, pages 624-630; Yadernyye reaktory [Nuclear Reactors], translated from English, Vol. 3, Moscow, 1956 (materialy Komis. po atomnoy energii SShA [Materials of the Atomic Energy Commission, USA]); Berilliy [Beryllium], edited by D. White and J. Berk, translated from English, Moscow, 1960; J. Metals, 1961, Vol. 13, No. 8,pages 15-22.

N.F. Mironov

BERYLLIUM BRONZE - an alloy of copper and beryllium. Small quantities of nickel, cobalt, and titanium are incorporated as alloying elements, but the properties of beryllium bronze are governed by its beryllium content. Presence of only about 2% Be in copper increases its strength by a factor of 5-6. The maximum solubility of beryllium in copper is 2.1% at a temperature of 864°; solubility drops with temperature, amounting to 0.2% at 300°. Beryllium bronzes are dispersion-hardening alloys. They have a high plasticity and are quite soft when quenched; annealing produces a high hardness, strength, and elastic limit and a sharply reduced elongation. The structure of beryllium bronze consists principally of crystals of an α-solid solid solution and a small quantity of a β-solid solution. The strengthening which occurs during annealing results from precipitation of finely dispersed solid crystals of a γ-phase from the supersaturated α-solid solution, which is usually not visible microscopically. The γ-phase becomes noticeable (as a dark border along the grain boundaries of the α-phase) only when annealing is improperly conducted (when overaging occurs). The mechanical properties of the alloy are reduced in this case. The number of β-phase crystals present in the structure depends on the beryllium content. Only a very small quantity of β-phase is found in alloys containing 1.9-2.1% Be; substantial amounts of β-phase are usually present at Be contents of 2.3% or more. It is necessary to avoid formation of large β-phase crystals, which often separate out in the form of scales, since this sharply reduces the mechanical properties of beryllium bronze and causes cracking and elastic fracture under operational conditions. Beryllium bronzes containing from 1.7 to 2.5% Be are of commercial importance (Table 1). A characteristic feature of beryllium bronze is the extreme rapidity with which phase transformations take place. Small quantities of nickel or cobalt retard these transformations, as well as recrystallization of the alloy. Nickel and cobalt also promote more uniform distribution of the β-phase. Addition of 0.1-0.25% Ti ensures high mechanical characteristics at low beryllium contents. Impurities of iron, silicon, phosphorus, and magnesium have a negative effect on the properties of beryllium bronze, while lead, bismuth, and antimony are very detrimental, since they cause brittleness and hamper pressure working. Beryllium bronze is distinguished by a rare combination of very high mechanical (Table 3), physical (Table 2), and anticorrosion properties. Thus, the corrosion rate of copper in salt water at 20° is 0.05 mm per year, while that of quenched and tempered BrB2 bronze is 0.01 mm per year; the corrosion rate of BrB2 bronze in 10% aqueous hydrochloric acid at 20° is 1.42 mm per year.

TABLE 1

Chemical Composition (according to GOST 493-54)

Сплав 1	2 Содержание элементов (%)								
	Be	Ni	Ti	Cu	Fe	Al	Si	Pb	3 Сумма примесей
					4 не более				
БрБ2,5 5	2.3—2.6	0.2—0.5	—	9 Остальное	0.15	0.15	0.15	0.005	0.5
БрБ2 6	1.9—2.2	0.2—0.5	—		0.15	0.15	0.15	0.005	0.5
БрБНТ1,9 7	1.85—2.10	0.2—0.4	0.10—0.25		0.15	0.15	0.15	0.005	0.5
БрБНТ1,7 8	1.60—1.85	0.2—0.4	0.10—0.25		0.15	0.15	0.15	0.005	0.5

1) Alloy; 2) content of elements (%); 3) total impurities; 4) no more than; 5) BrB2,5; 6) BrB2; 7) BrBNT1, 9; 8) BrBNT1, 7; 9) remainder.

Beryllium bronze is nonmagnetic and does not produce sparks on impact. All types of bronze quenched from high temperatures have a high plasticity and cold-workability (Fig. 1) and are strengthened both by

TABLE 2

Physical Properties of BrB2 Bronze

Критические точки (°C) 1		γ (г/см³) 4	α·10⁶ (20—300°) (1/°C)	λ при 20° (кал/см·сек·°C) 5	ρ при 20° (ом·мм²/м) 6	c при 20° (кал/г·°C) 7	Электропроводность в % от электропроводности меди 8	Величина гистерезиса (%) 9
верхняя 2	нижняя 3							
955	886	8.2	17.6	10 0.20 закаленная 0.25 отпущенная 11	0.1 закаленная 0.07 отпущенная	0.10	30	0.4—1.9

1) Critical points (°C); 2) upper; 3) lower; 4) g/cm^3; 5) λ at 20° (cal/cm•sec•°); 6) ρ at 20° (ohms•mm^2/m); 7) c at 20° (cal/g•°C); 8) electrical conductivity, in % of conductivity of copper; 9) hysteresis (%); 10) quenched; 11) tempered.

TABLE 3

Mechanical Properties

Сплав 1	Состояние материала 2	$\sigma_{пц}$	$\sigma_{0,2}$	σ_b	δ (%)	E	σ_{-1} на базе 10⁷ циклов 4	$a_н$ (кгм/см²) 5	HB (кг/мм²)
		(кг/мм²) 3				(кг/мм²)			
БрБ2,5 6	Закаленный 10	—	—	50	30	—	—	—	115
	Облагороженный 11	—	120	130	1.5	13 000	29	—	400
БрБ2 7	Закаленный	6	—	45	40	11 700	—	7	90
	Облагороженный	—	90	125	2	13 200	20	1.25	380
8 БрБНТ1,9	Закаленный	—	—	45	40	11 900	—	—	90
	Облагороженный	—	—	125	2	13 150	—	—	380
9 БрБНТ1,7	Закаленный	—	—	40	50	10 700	—	—	80
	Облагороженный	—	—	115	3	12 450	—	—	360

1) Alloy; 2) state of material; 3) kg/mm^2; 4) on basis of 10^7 cycles; 5) kg-m/cm^2; 6) BrB2, 5; 7) BrB2; 8) BrBNT1, 9; 9) BrBNT1, 7; 10) quenched; 11) dispersion-hardened.

immediate postquenching annealing and by postquenching plastic deformation (Fig. 2). Beryllium bronzes subjected to postquenching coldworking are strengthened more rapidly and effectively (Fig. 3) and undergo less distortion and oxidation during tempering. Thus, quenched and tempered BrB2 bronze has an ultimate strength of 125 kg/mm^2; when it is tempered after quenching and deformation by ~30% its σ_b = 140 kg/mm^2. The annealed material is not subject to dispersion hardening and has a high hardness and brittleness. It must be held in the furnace for a rather long time before quenching, in order to ensure complete dissolution of the phases precipitated during annealing. Strips, sheets, wire, and bars shipped to consumer plants must be quenched or quenched and deformed by 30-50%. Components fabricated by stamping, bending, etc., are tempered at elevated temperatures to permit dispersion hardening. The principal process during prequenching heating is dissolution of the precipitated γ-phase, which requires a sufficiently high temperature and prolonged holding. However, growth of the solid-solution grains may also occur under these conditions. A large grain size causes a decrease in the cyclic strength of beryllium bronze (Fig. 4). The optimum α-solid-solution grain size is 15-40 μ and it is consequently necessary to keep careful watch over prequenching heating, observing the optimum temperature regime (Table 4) and holding time.

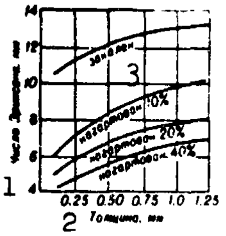

Fig. 1. Erikson extrusion depth of quenched and deformed sheets of BrB2 bronze. 1) Erikson number, mm; 2) thickness, mm; 3) quenched; 4) cold-worked.

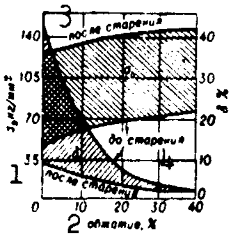

Fig. 2. Change in mechanical properties of quenched and tempered BrB2 bronze as a function of degree of deformation. 1) σ_b, kg/mm^2; 2) reduction in area, %; 3) after aging; 4) before aging.

Dispersion hardening at higher than optimum temperatures and longer than optimum holding times causes segregation of coarse particles of the γ-phase, which coagulates and thus reduce the elasticity of the material and often increase its brittleness. Too low a tempering tem-

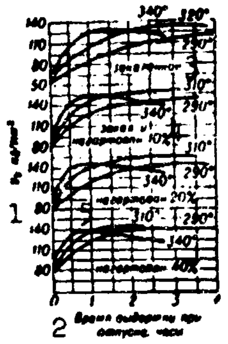

Fig. 3. Strength of BrB2 bronze as a function of tempering temperature and time. 1) σ_b, kg/mm^2; 2) tempering time, hr; 3) quenched; 4) quenched and cold-worked; 5) cold-worked.

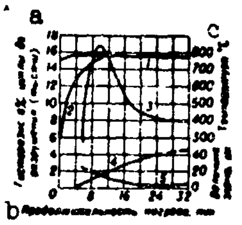

Fig. 4. Change in cyclic strength, hysteresis, and grain size of beryllium bronze membranes as a function of prequenching-heating time with tempering at 300° for 1.5 hr: 1) Furnace temperature; 2) metal temperature; 3) cyclic strength; 4) grain size; 5) hysteresis. a) Hysteresis, %; cycles to fracture (thousands); b) heating time, min; c) grain size, mm; d) temperature, °C.

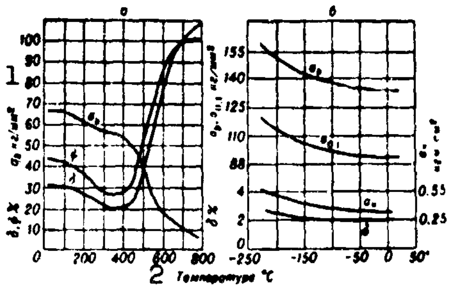

Fig. 5. Mechanical Properties of BrB2 bronze at high (a) and low (b) temperatures. 1) σ_b, kg/mm^2; 2) temperature, °C.

perature or too short a holding time makes it impossible to realize the very high mechanical characteristics inherent in beryllium bronze. This bronze is the best material for critical springs, spring-like components, and elastic elements of the membrane and sylphon type used in the construction of precision instruments. In addition to having high elas-

TABLE 4

Technological Properties and Processing Regimes

Сплав 1	Темп-ра литья (°C) 2	Темп-ра горячей прокатки (°C) 3	Темп-ра закалки (°C) 4	Темп-ра отпуска (°C) 5	Допускаемая деформация в холодном состоянии 6 (%)	Травитель 7
БрБ2,5 8	1030—1060	780—800	770—790	200—300	40—50	10%-ная серная кислота + 5%-ный раствор хромпика
БрБ2 9	1030—1060	780—800	765—785	310—320	40—50	
БрБНТ1,9 10	1030—1060	780—800	760—780	310—320	40—50	
БрБНТ1,7 11	1030—1060	780—800	755—775	320—330	40—50	

1) Alloy; 2) casting temperature (°C); 3) hot-rolling temperature (°C); 4) quenching temperature (°C); 5) tempering temperature (°C); 6) permissible cold deformation (%); 7) mordant; 8) BrB2, 5; 9) BrB2; 10) BrBNT1, 9; 11) BrBNT1, 7; 12) 10% sulfuric acid + 5% potassium dichromate.

ticity, strength, and hardness, the materials used for such components must be stable during prolonged exploitation (e.g., the membranes of critical instruments should have a hysteresis of no more than 0.5%). The combination of properties obtained is governed by the mechanical- and heat-treatment methods employed. Beryllium bronze retains sufficient strength at high temperatures, but its strength and plasticity are enhanced at low temperatures (Fig. 5).

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O.Ye. Kestner

BERYLLIUM CARBIDE, Be_2C – is the chemical compound or beryllium with carbon. Beryllium carbide has a cubic lattice of the fluorite (CaF_2) type with a lattice constant of 4.344 A. The color of the crystals depends on the quantity and the degree of dispersity of the free carbon and changes from a semitranslucent yellow to a metallic gray-b black one. This compound is well able to moderate neutrons and is characterized by a low capture cross section. It can be used as a moderator in high-temperature nuclear reactions. Beryllium carbide is obtained by the reaction of a mixture of finely powdered metallic beryllium with finely powdered graphite, or of powder of beryllium oxide with lamp black at 2100-2200°. Pieces from beryllium carbide are prepared by methods of powder metallurgy. Pieces with a density of 75-90% of the theoretical one are prepared by pressing, using 5.0-7.5% of a wax-like binder under a pressure of not less than 2.5 tons/cm^2 and a subsequent sintering at 1800-1900° in an inert gas atmosphere. Blocks with a density of 90-95% of the theoretical values are obtained by hot pressing in graphite molds at 1800-2050° under a pressure of 70-350 kg//cm^2 in argon or hydrogen atmosphere. The blocks can be machined by grinding with diamond discs using a water-free coolant (carbon tetrachloride or kerosene).

The properties of beryllium carbide change considerably depending on the method of preparation and the density of the specimens. The main physical and chemical properties of beryllium carbide are: the density (g/cm^3) determined by roentgenography is equal to 2.44, that of the hot-pressed one (maximum) 2.26, and that of the sintered one (maximum) 2.10.

I-12K1

Melting point (°C): when heated above 2200°, a partial melting with simultaneous dissociation is observed. The free energy of formation ΔF° (2127°) is 7.84 kcal/mole. c (98% Be_2C is equal to 0.334±0.013 cal/g·°C at a temperature within 30-100°.

TABLE

1 Давление пара (ат)	
2 при темп-ре 1627°	0,006
» » 1827°	0,04
» » 2127°	0,44
» » 2327°	1,5
3 Термический коэффициент линейного расширения $\alpha \cdot 10^6$ (1/°C)	
4 от 25 до 50°	5,6
от 25 до 200°	7,7
от 25 до 400°	9,5
от 25 до 600°	10,5
5 Коэффициент теплопроводности λ (кал/см·сек·°C)	
6 $0,3585 \cdot 10^{-5} t + 0,20793 \cdot 10^{-2}$ в интервале темп-р 300—950°; погрешность определения ±20%; при 30° λ=0,0215	

1) Vapor pressure (atm); 2) at a temperature of; 3) linear thermal expansion coefficient, $\alpha \cdot 10^6$ (1/°C)1 4) from ... to ...; 5) heat conduction coefficient λ (cal/cm·sec·°C); 6) $0.3585 \cdot 10^{-5}$ t + $0.20793 \cdot 10^{-2}$ in the temperature range of 300-950°; error of determination ±20%; λ is equal to 0.0215 at 30°.

The electrical resistance of sintered specimens from unpurified beryllium carbide is 0.063 ohm·cm at 30°, 0.047 ohm·cm at 425°; in hot pressed specimen 1.09 ohm·cm at 65°, and 0.047 ohm·cm at 975°. The values change with the change in the content of free carbon. The electrical resistance of pure beryllium carbide is evidently very high.

The data for the mechanical properties of beryllium carbide, depending on the technology of preparation, the chemical state and the density are not standardized. The properties of hot-pressed blocks, however, are usually considerably higher than the properties of sintered specimens. The Knoop microhardness of beryllium carbide crystals lies between 2400-2700, which is higher than the hardness of boron carbide. The compression strength is: 50 kg/mm^2 for pressed and sintered specimens, and 75 kg/mm^2 for hot-pressed. The bending strength at room temperature lies within 5.5 and 7.0 kg/mm^2 and changes insignificantly when heated to 1310-1370°. The normal modulus of elasticity changes, according to the data of diverse authors, within wide limits from 9100 kg/ /mm^2 to 21,000-28,000 kg/mm^2. The Poisson ratio is equal to 0.1. Beryllium carbide is insignificantly stable against thermal shocks. Plates of a spatial beryllium carbide – graphite composition breakdown within 1.5 hours when cooled from 1093° to room temperature. Beryllium carbide is not resistant to moist air at low temperatures. Beryllium carbide resists corrosion in moist air at temperatures of some hundred degrees owing to the formation of a protective beryllium oxide film. Beryllium carbide with a high density is well resistant to corrosion to 1260°.

Beryllium carbide reacts with nitrogen above 1000°, and with ammonia above 775°. The reaction of beryllium carbide with diverse reagents is listed in the Table.

TABLE

Reaction of Beryllium Carbide with Diverse Reagents

Реагент 1	Состояние 2	Темп-ра (°C) 3	Основные продукты реакции 4
F_2	газ 5	нагретый 6	$BeF_2 + C$
Cl_2	то же	то же	$BeCl_2 + C$
Br_2	» 7	» 7	$BeBr_2 + C$
J_2	»	800	не взаимодействует 8
O_2	»	нагретый 6	поверхностное 9 воздействие
S	пары 10	1000	BeS
HF	то же	450	$Be + F_2$
HCl	» 7	600	$BeCl_2 + C + H_2$
HJ	»	750	$BeJ + CH_4$
H_2O	—	—	$Be(OH)_2 + CH_4$ (чистый) 11 (реакция идет медленно) 12
KOH	раствор 13	—	$Be(OH)_2 + CH_4$ (реакция идет быстро) 13a
H_2SO_4	концентрированная 14	—	реакция замедляется (кислота восстанавливается до SO_2) 15
HNO_3	то же	—	кислота медленно восстанавливается 16
HCl	» 7	—	то же 7
HNO_3	разбавленная 17	—	заканчивается растворение в неск. час 18
HCl	разбавленная	—	то же 7
KOH	расплавленный 19	—	разлагает карбид, который раскаляется добела
$KMnO_4$	раствор 13	—	окисление карбида 20
PbO_2	расплав	—	то же 7
$KClO_3$	раствор 13	—	не реагирует 22
KNO_3	раствор	—	не реагирует
Na	расплав 21	500	+6.5 мг/см^2 в месяц. После испытаний образцы разбухают вследствие гидратации 23

1) Reagent; 2) state; 3) temperature; 4) main reaction products; 5) gas; 6) heated; 7) the same; 8) does not react; 9) surfacial effect; 10) vapor; 11) pure; 12) slow reaction; 13) solution; 13a) very rapid reaction; 14) concentrated; 15) reaction becomes retarded (the acid is reduced to SO_2); 16) the acid is slowly reduced; 17) diluted; 18) the dissolution is finished after some hours; 19) melted; 19a) the carbide is

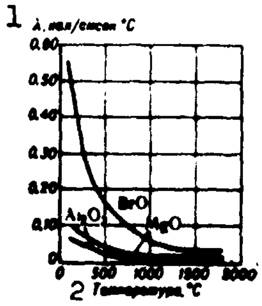
decomposed and becomes white hot; 20) exidation of the carbide; 21) smelt; 22) does not react; 23) the specimens swell after the test due to hydration.

Beryllium carbide is protected from atmospherical effects at high temperatures by means of special coatings. Platinum coatings and ceramic silicate glazes protect beryllium carbide efficiently from the reaction with air upt to a temperature of above 1370° by formation of a tightly adherent layer rich in beryllium oxide. The coating materials are applied by smearing with suspensions in organic fluids or by immersion, and must be fired at 1500° in air or in inert atmosphere. The toxicity of beryllium carbide is near to that of beryllium oxide, therefore, the working with it must be carried out under the same precautions. Working with beryllium carbide must be carried out in absence of water vapor. A storage of beryllium carbide in glass containers is not allowed owing to the danger of hydrolysis accompanied by increase in volume.

References: Reactor Handbook, edited by C.R. Tipton, 2nd ed., Vol. 1 - Materials, London, 1960; Yadernyye reaktory [Nuclear Reactors], translated from English, Vol. 3, Moscow, 1956 (Materials of the Atomic Energy Commission of U.S.).

N.F. Mironov

BERYLLIUM OXIDE – the higher compound of beryllium and oxygen (BeO). It crystallizes in the form of colorless hexagonal crystals with a wurtzite lattice. The polycrystalline mass is white in color. The lattice parameters of this compound at 18° are a = 2.693 A and c = = 4.397 A, its Moos hardness is 9, its crystallographic density is 3.025 g/cm^3, and H = 1520 kg/mm^2. It exhibits no polymorphic transformations.



Comparison of the λ of BeO with the λ of MgO and Al_2O_3. 1) Cal/cm·sec·°C; 2) temperature, °C.

Beryllium oxide is produced commercially by calcination of beryllium hydroxide or sulfate. The purest beryllium oxide is obtained by pyrolysis of basic beryllium acetate. It is used as a highly refractory material, as a thermal-neutron moderator and reflector in nuclear reactors, as the raw material for production of copper-beryllium ligatures, and in the manufacture of high-quality electrical insulators. It is distinguished from other oxides by its high thermal conductivity, which is comparable to that of metals, and thermostability. These characteristics are conjoined with chemical inertness. The properties of beryllium oxide depend on its nature and the conditions under which it is subjected to high-temperature treatment. The characteristics of beryllium-oxide products are closely related to their density.

Physical characteristics: t^{o}_{pl} = 2470 ± 20°, t^{o}_{kip} = 4120 ± 170°, latent heat of fusion – 17 ± 1.4 kcal/mole, latent heat of vaporization – 117 ± 10.5 kcal/mole, latent heat of sublimation (at 600-3000°) –

TABLE 1

Thermal Conductivity as a Function of Specific Gravity (at 800°)

γ (г/см³) 1	1,89	2	2,1	2,16	2,24	2,87
λ (кал/см·сек·°C) 2	0,03	0,035	0,041	0,043	0,05	0,075

1) g/cm³; 2) cal/cm·sec·°C.

TABLE 2

Mean Coefficient of Linear Expansion as a Function of Temperature

Темпера (°C) 1	25—100	25—600	25—1000	[illegible]
α·10⁶ (1/°C)	6,5÷7,1	9,6÷10,8	10,8÷11	9,[illegible]÷10,6

1) Temperature (°C).

152 ± 10 kcal/mole; molar heat capacity C_t at 298-1200°, in kcal/mole··°C:

$$C_p = 8,45 + 4\frac{T}{10^3} - 3,17\frac{10^5}{T^2}.$$

Beryllium oxide does not display any marked vaporization at temperatures of up to 2200° in a vacuum of 10^{-4} mm Hg.

The figure shows the variation in thermal conductivity of a material with an assumed porosity of zero.

The mechanical characteristics of beryllium oxide depend on its density, specific gravity, grain size, and sintering temperature. The

TABLE 3

Mechanical Characteristics*

Темпера (°C) 1	σ_{-b}	σ_{b}	$\sigma_{изг}$	E	[illegible]
	2 (кг/мм²)				
20	80—113	13—18	18,2	27000—36000	[illegible]
200	70—98	11—15	—	38000	-
400	61—86	8,9—12,5	—	27000—37500	[illegible]
600	52—71	7	12,4	36500	—
800	42—59	5,2—9,8	—	27000—36000	[illegible]
1000	33—35	3,3	12,6	26000—35000	[illegible]
1200	23—27	1,3	9,8	7000	—
1400	15	1,7	—	—	—
1600	5,6	—	—	—	—

* The minimum value corresponds to a material with γ = 2.7, while the others correspond to one with γ = = 2.9-3 g/cm³.

1) Temperature (°C); 2) kg/mm².

modulus of elasticity E is expressed as a function of density by the formula $E = 320\gamma - 595$, where $E = 1\cdot10^{10}$ dynes/cm^2 and γ is in g/cm^3. The shear modulus G is $1\cdot10^6$ kg/cm^2. Pronounced creep is detected from 950° onward. The elongation of specimens with a porosity of 30% loaded to 6.7 kg/cm^2 amounts to (% per hr):

at	1095°	0,00021
"	1150°	0,0007
"	1205°	0,00136
"	1260°	0,01

It is known that addition of Al_2O_3, CaO, or ZrO_2 reduces the creep of beryllium oxide.

TABLE 4

Thermostability of Certain Oxides in Heat-Exchange Tests* (Number of Cycles to Fracture)

1 Материал	1600°	1600°	1700°
Окись бериллия 2	12	5	4
3 Окись магния	0	—	0
Окись алюминия 4	6	2	1

* Heating to a predetermined temperature and cooling in a stream of air to room temperature over a period of 1 min.

1) Material; 2) beryllium oxide; 3) magnesium oxide; 4) aluminum oxide.

TABLE 5

Specific Electrical Resistance of Beryllium Oxide (Sintered at 2100°, Density – 2.25 g/cm^3)

Темп-ра (°C) 1	$\rho\cdot10^{-6}$ (ом·см) 2	Темп-ра (°C)	$\rho\cdot10^{-6}$ (ом·см)
0	7 000 000		
1000	80 000	1600	35
1100	16 000	1700	15
1200	4 000	1800	6.5
1300	800	1900	3.5
1400	250	2000	1.6
1500	80	2100	0.8

1) Temperature (°C); 2) ohm·cm.

The dielectric constant of beryllium oxide (at a density of 2.79 g/cm^3) amounts to 6.3.

The chemical composition of beryllium oxide depends on its grain size and calcination temperature. Oxide calcinated at 1200° is soluble in mineral acids, while that calcinated at 1800° is soluble only in hydrofluoric acid. This compound is soluble in molten alkalis, carbonates, and alkali-metal pyrosulfates. At 2000° it is reduced by carbon to form beryllium carbide. Sintered beryllium oxide is resistant to the

TABLE 6

Loss of Weight in BeO as a Result of Direct Evaporation and Reaction with Water Vapor

Темп-ра (°C) 1	2 Потеря веса за 2 часа (г/см²)	
	3 за счет испарения	4 за счет реакции с водяным паром *
1000	$7.4\cdot10^{-10}$	$2.01\cdot10^{-6}$
1200	$2.3\cdot10^{-8}$	$1.9\cdot10^{-3}$
1600	$1.1\cdot10^{-6}$	$3.65\cdot10^{-1}$
2000	$1.1\cdot10^{-4}$	2.32

* Saturated-vapor pressure at 20° = 175 mm Hg.

1) Temperature (°C); 2) loss of weight over 2 hr (g/cm²); 3) as a result of evaporation; 4) as a result of reaction with water vapor.

TABLE 7

Typical Chemical Composition (%) of Beryllium Oxide

Наименование 1	2 Окись, применяемая в металлургии	3 Окись для огнеупоров	4 Окись, полученная из ацетата бериллия
BeO	99.76	99.15	99.98
SiO_2	0.09	0.22	$3\cdot10^{-3}$
Al_2O_3	0.01	0.22	$4\cdot10^{-3}$
Fe_2O_3	0.1	0.07	$5\cdot10^{-3}$
MgO	0.02	0.12	$5\cdot10^{-3}$
CaO	0.02	0.02	$4\cdot10^{-3}$

1) Compound; 2) oxide used in metallurgy; 3) oxide for refractory materials; 4) oxide obtained from beryllium acetate.

action of hydrogen, carbon dioxide, hydrogen sulfide, sulfur, bromine, iodine, and ammonia and is not reduced by molten lithium, sodium, potassium, magnesium, calcium, or aluminum; however, it reacts weakly with niobium, silicon, titanium, and zirconium and strongly with fluorine and fluorides at 1800° and is chlorinated by chlorine in the presence of carbon at temperatures above 600° or by carbon tetrachloride. At temperatures above 1400° it reacts with Be in accordance with the reaction $Be + BeO = Be_2O$ to form the volatile compound beryllium suboxide, which is stable at normal temperatures. The corrosion rate of beryllium oxide in water vapor at 250° is approximately $0.3\cdot10^{-3}$ $mg/cm^2\cdot hr$ for specimens with a γ of 2.7-2.9 g/cm^3.

Beryllium oxide is the only refractory crucible material suitable for melting beryllium. This compound reacts with water vapor in accordance with the reaction:

$$BeO_{(s)} + H_2O_{(g)} = BeO\cdot H_2O_{(g)}$$

The resultant volatile product decomposes on cooling to form BeO.

II-9,0-5

The volatility of BeO is greatly increased by the presence of water vapor (Table 6).

In the manufacture of finished products the oxide is calcined and ground to a grain size of no more than 25 μ with a definite granulometric composition. Fabrication of high-density products from beryllium oxide presents considerable difficulties. Intensive grain growth is observed during calcination. Finished products are produced by dross casting, hot pressing, and pressing followed by annealing.

References: White, D. and Berk, J., Berilliy [Beryllium], translated from English, Moscow, 1960; Tresvyatskiy, S.G., Cherepanov, A.M., Vysokoogneupornyye materialy i izdeliya iz okislov [Highly Refractory Materials and Oxide Products], Moscow, 1957; Belyayev, R.A., Okis' berilliya [Beryllium Oxide], Moscow, 1962.

L.A. Izhvanov

BERYLLIUM TOXICITY. Soluble beryllium compounds (beryllium sulfate, fluoride, chloride, acetate) are the most toxic. However, unsoluble compounds and metallic beryllium can also have an adverse effect should then penetrate the organism in the form of high-disperse dust. The falling of beryllium compounds as well as of metallic beryllium into a skin wound, cut or lesion can result in the development of sores which heal with difficulty.

Compact beryllium and its alloys in the form of ingots, billets, stampings, she ts, bar stock, elements of designs, etc., are not dangerous to workers.

When beryllium is produced (extracted from ores) and in metallurgical processes it is possible that soluble beryllium compounds will affect the workers, and also that they will be affected by beryllium oxide dust, which is the most toxic from among unsoluble compounds.

Intensive, highly detrimental escape into the air of highly disperse dust of beryllium and its oxides is possible in the production of metal ceramics, in melting, welding and soldering of beryllium and its alloys. An exception is low-temperature soldering (up to 300°) which is not dangerous. All forms of machining of beryllium and its alloys are also dangerous. Pressureworking of pure beryllium and its compounds at t° of up to 1000° in airtight shells is not dangerous, since beryllium dust does not escape. An insignificant escape of dust is possible only if the integrity of the airtight shell has been disturbed.

Heat treatment not above 600-700° is also safe. Certain processes for processing alloys with a 20-30% beryllium are not dangerous even without airtight shell protection. These processes include hot rolling, stamping, pressing, upsetting, etc., heat treatment, cold rolling, cutting with shears, etc.

The production and processing of alloys with a low (1-2%) beryllium content, with the exception of welding, are not accompanied by air contamination.

All the production processes which result in air contemination should be performed in isolated premises; when these are equipped, provision should be made for the possibility of daily washing. Walls, protective hoods and the ceiling should be painted with oil paint, and the floor should be paved with large-size ceramic tile or marble chips. The communications should be concealed in the walls of the premises. All the equipment should be provided with protective hoods equipped with exhaust ventilation facilities. The air motion velocity in the working holes of the protective hoods should be at least 1.5 m/sec. A vacuum of at least 20 mm of water should be maintained in the isolated premises. The premises are equipped with total-air-replacement suction exhaust ventilation. All the air removed from these premises is subjected to two-stage purification before being exhausted to the atmosphere.

The production sections should be provided with toilet and comfort facilities modeled after a sanitary check point, with separate storage of personal and work clothing.

All the premises are checked for the beryllium and beryllium compound content in their atmosphere. The limiting permissible concentration of the above comprises 0.001 mg/m^3. Continuous automatic recording of the beryllium content by automatic recording devices is most rational. Workers employed in the isolated premises should use respirators, which protect the respiratory system from penetration by beryllium and its compounds. Hose or insulating gas masks are used for protection from beryllium compound vapor and gas penetration. When the dust concentration in the air is higher than 20-30 mg/m^3 the use of gas masks is not effective, since they are rapidly stopped up and highly interfere with breathing. The use of helmets or pressurized suits with a pure air supply is recommended in these cases.

Each enterprise which is involved in the processing and production of beryllium and its alloys should be provided with instructions on preventing the contamination of the air of the production premises and individual protection of workers.

All those who work with beryllium and its compounds should pass a medical examination at least once in 6 months.

If all the above preventive measures are taken the danger of occupational disease is eliminated.

D.M. Bobrishchev-Pushkin, K.P. Yatsenko

I-15b

BERYLLIZATION OF STEEL – superficial impregnation of steel with beryllium in order to increase its high-temperature oxidation resistance at 800-1100° or more. This process usually provides better oxidation resistance than lithium plating and is used for many alloys and metals other than steel. Beryllization is carried out with powdered mixtures consisting of 99% Be (or ferroberyllium) and 1% NH_4Cl or 75% Be (or ferroberyllium), 24% Al_2O_3, and 1% NH_4Cl. The process temperature is 950-1050° and the holding time 4-10 hr. Holding at 1050° for 4 hr produces a beryllized layer 0.2 mm thick with a hardness of from 1000 HV (St10) to 1200 HV (St45). Ferric beryllide, $FeBe_2$ (St10), or beryllium carbide, Be_2C (high-carbon steel), is formed in the outer zone of the beryllized layer. Methods have also been developed for beryllization of steel in a gaseous medium (HCl) and in vacuum furnaces. The applications of this process are limited, since beryllium is costly and also highly toxic.

A.N. Minkevich

BESHTAUNITE - see Natural acid-resistant materials.

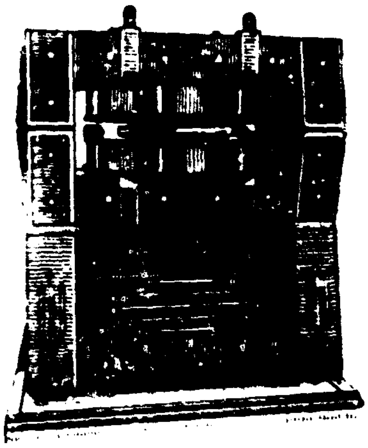
I-18b

BETA-BRASS – brass containing from 45 to 49% Zn and, when annealed, having the structure of a copper-zinc β-phase. This metal has low plasticity when cold and high plasticity when hot. Manganese, aluminum, and iron are added to beta-brass to improve its mechanical properties. Thus, for example, an alloy consisting of 52% Cu, 5% Mn, 2% Al, 1% Fe, and the remainder zinc has an ultimate strength of 65 kg/mm^2 and a relative elongation of 27%. Beta-brass has not been standardized.

Ye.S. Shpichinetskiy

BETA-TITANIUM - see Alpha-titanium.

BETATRON – a cyclic induction electron accelerator, whose action is based on use of a vortical electric field set up by an alternating magnetic flux. Structurally, the betatron takes the form of a "radial transformer," where the role of the secondary winding is played by a toroidal vacuum chamber in which the electrons are accelerated as they move along a circular orbit. Stable electron movement is ensured by magnetic focusing, which is accomplished by appropriate distribution of the magnetic field in the orbital region. The primary winding of the betatron is usually supplied with commercial-frequenty alternating current; acceleration takes place over 1/4 of each period. At the end of each acceleration cycle the beam of accelerated electrons can be withdrawn from the vacuum chamber through a window or directed at a metal target within the chamber. Deceleration of the electrons in the target produces x-radiation, which is used for transmissive defectoscopy of metal objects. For defectoscopic purposes the electrons are accelerated to energies of 20–30 mev, so that the penetrating power of betatron x-radiation, whose quanta have an energy of the same order of magnitude, is substantially higher than that of the radiation produced by ordinary x-ray tubes (whose quanta have an energy of the order of several hundred kev) or gamma-radioactive isotopes (whose quanta have an energy of less than 1.5 mev). The betatron can be used for defectos-


Betatron for irradiation of thick objects (steel up to 400–500 mm thick).

copy of very thick (up to 500-600 mm) steel and cast-iron objects, which cannot be done with industrial x-ray equipment. The technique of betatron defectoscopy is analogous to that of X-ray defectoscopy and Gamma-defectoscopy; fluorescent magnifying screens and lead foil 2-3 mm thick are used to reduce the exposure time and increase sensitivity. The relative sensitivity of the betatron in defectoscopy of objects 200-450 mm thick is 2-1.5% of the thickness of the object, so that defects with diameters of 4-7 mm can be detected. Devices known as "stereobetatrons," which have two radiation beams at an angle to one another, have been designed. Defectoscopy with an apparatus of this type permits both detection of defects and determination of their depth within the object. Wide commercial use of the betatron is prevented by its complexity and cost and the difficulty of providing biological radiation shielding.

L.K. Tatochenko

BICYCLE TIRE-THREAD FABRIC – see <u>Cord fabric</u>.

BIOLOGICAL RESISTANCE – the resistance of materials, objects, and assemblages to damage caused by various plants (principally fungi and bacteria) and animals (insects, mollusks, crustaceans, and mammals).

Detrimental fungi and bacteria are lower plants lacking the green pigment chlorophyll; in contrast to green plants, they do not assimilate carbon from the atmosphere and feed on ready-synthesized organic substances of vegetable or animal origin. Bacteria damage materials of both animal (e.g., albumin and casein glues) and vegetable (e.g., natural rubber) origin. Fungi destroy materials of animal and vegetable origin (paper, wood, textiles, and other materials); the products of their vital activity (principally certain organic acids) are damaging to some materials not containing organic compounds (metals, silicate glasses, etc.). Materials are protected against fungal damage (given mycological resistance) by preservation with antiseptics poisonous to fungi, such as fluorine, copper, mercury, tin, phenol, etc., compounds. Depending on operating conditions, the materials are treated with antiseptics by impregnation or by application of a superficial coating. Rubber, lacquers, and paints are protected by introducing antiseptics directly into the material itself.

Among animals great damage to various nonmetallic materials, especially wood and wood products, is caused by insects (various beetles, termites, ants, etc.). The best method for protecting wood against insect damage is treatment with antiseptics (insecticides); in some cases the insects are killed by injecting insecticides into the holes which they have made. Arsenic compounds, chlorinated phenols, DDT, etc., are used as antiseptics. Fumigation with poisonous gases is employed to kill insects in furniture. Wool, felt, and rubber are damaged by moths, prevention of which is basically a sanitary-prophylactic problem. Woolen materials can be made moth-resistant by application of naphthalene, formulas based on DDT, etc. Rodents, especially rats and mice, cause a great deal of damage to plant and animal materials; they are killed with poisoned bait. In some cases free-living animals are killed by fumigation of their burrows and tunnels with poison gases. Materials and products used in water, especially salt water, are also damaged by various organisms. In the oceans (principally in the south) these are the so-called marine borers (mollusks and shipworms) and organisms which cause overgrowth. Marine borers bore tunnels in wood, greatly weakening it and making it completely unusable. The rate at which the wood is weakened depends on the species of borer, the type of wood, the extent of the infestation, the temperature and salinity of the water, etc. The most radical method for protecting wood against borers is to impregnate it with insoluble antiseptics; substances such as creosote oil give good results. The organisms which cause overgrowth (these occur widely in both southern and northern seas) include a number of types of animals (crustaceans, sponges, mollusks, etc.) and plants (algae) that use metallic and nonmetallic surfaces as a substrate for attachment. Ships and hydroplanes are subject to the greatest damage. Considerable injury is caused by the crustacean known as the barnacle, which covers the surface of the material to which it attaches with dense calcereous formations difficult to remove. Overgrowth weighs down an object, disrupts normal gliding, damages lacquers and paints, and intensifies the corrosion of metals. The overgrowth rate depends on the hydrological conditions of the body of water: the temperature and salinity of the water and the species composition of its population. The principal preventive measure is to coat the material with an overgrowth-resistant paint (see Overgrowth-resistant paints). Techniques have been developed for preventing overgrowth with ultrashort waves. Biological resistance of materials and biological sterility of flight equipment is important in astronautics.

B.K. Flerov

BITUMINOUS MATERIALS – mixtures of natural and petroleum bitumens with various materials (asbestos-bitumen mixtures, rubber-bitumen mixtures, asphalt compositions, etc.). Bitumens vary in origin and in the methods by which plastic solids or viscous liquids are produced; they are complex mixtures of carbohydrates and their polymerization and oxidation products. Bitumens are divided into two categories: 1) natural (mineral) – asphaltites (the most pure), asphalts (with substantial mineral impurities), and asphaltic rocks (asphaltic sandstones and limestones containing 8-30% and 3-25% bitumen respectively); 2) artificial (petroleum) – heavy products of the distillation of petroleum and its products, or pitches. At low temperatures bitumens are brittle and lustrous and exhibit conchoidal fracture. They are highly soluble in benzene, toluol, chloroform, carbon tetrachloride, carbon bisulfide, etc., and insoluble in water and alcohol. They are sufficiently resistant to acids and alkalies. Bitumens are distinguished by high hydrophobicity, have a negligible hygroscopicity, and are impermeable to water in thick layers. Their resistance to oils is low; mineral oils liquefy them and reduce their solidification capacity, but improve their solubility. They are miscible with vegetable oils, partially or completely dissolving when heated. Bitumens are weakly polar substances with high dielectric characteristics, a dielectric-loss-angle tangent of 0.005, a specific electrical resistance of 10^{15}-10^{16} ohms·cm, and an electric strength of 100-300 kv/cm. They are easily ignited (their kindling temperature is no less than 180-200°) and burn with a smoky flame. Depending on the deposit and the method and degree of concentration, the softening temperature of natural and artificial bitumens lies between 15 and 150°. Natural bitumens are obtained by treating the rock with boiling water or by extraction with organic solvents (e.g., dichloroethane). Petroleum wastes from which no final product can be obtained are subjected to aeration at 260-280° in a special apparatus for several hours (oxidized bitumens). The residual bitumens have a lower thermal resistance than oxidized bitumens, but combine high viscosity with a higher plasticity.

Natural and artificial bitumens have a wide range of hardnesses. Bitumens are a constituent of various bituminous materials (lacquers, paints, electrical-insulating materials, etc.) fabricated from cloth, cardboard, paper, powders, etc. Bitumens are employed as binders, as insulating substances (to water, steam, gases, temperature, electric currents, sound, and shock), to impart chemical resistance to salts, alkalies, acids, and etching agents, and as stains or dyes. Addition of mineral fillers to bitumens increases their hardness, softening temperature, and resistance to atmospheric factors. Their low cost and valuable technological properties have resulted in the wide use of bituminous materials in many branches of industry. Bituminous Rubrax is used in the rubber industry, as a softener in the leather-substitutes industry, and as a lubricant for the hot necks of rolling-mill rollers in the metallurgical industry. A special petroleum bitumen is used as the sealing mastic for storage batteries. The housings of the cells of acid storage batteries used in radio receivers and as starter batteries are hot-pressed from asphalt-lac materials.

Ruberoid (GOST 2165-51) – a material based on glass or fiberglass cloth. As a result of its strong base, which does not rot and is not damaged by microorganisms, this material has high operational characteristics: a tearing resistance of from 20 to 100-150 kg/cm^2, a water absorption of no more than 0.3-5%, and a usable glass-cloth thickness of 0.06-1.4 mm. It is used to protect metal subterranean piping from water damage.

Gidroizol – a roll waterproofing material manufactured from asbestos board impregnated with bitumen. It is fireproof and more expensive than asphalt board; it is used for multilayer waterproofing.

Borulin – a roll waterproofing material manufactured by mixing asbestos fiber and heated bitumen on rollers and then rolling the mixture. It is a plastic waterproof material with a softening temperature of 150°, but has a low tensile strength. It is used for waterproofing heating pipes.

Ground unreclaimable automobile tires and bitumens are used in the manufacture of insulating materials, the mastic "Izol" and the roll material "Brizol." Brizol does not crack on repeated 180° bending. Thi material is intended for corrosion protection of subterranean metal piping. Oil-free bitumen blacks, which have considerable water resistance, are used for underwater paints. Addition of vegetable oils, natural and synthetic resins, and a filler (powdered aluminum) to bitumen lacs considerably improves the atmosphere- and light-resistance of those used for protection of metal components (of automobiles and agricultural machinery) from atmospheric corrosion. Bitumen lacs have been used as a basis for dark-colored printing inks and artists' colors. Hot molten bitumen is used for corrosion protection of gas-distribution pipes. Bituminous materials are used as sealers, compounding agents, cements, and electrically insulating impregnation lacquers in the electronics industry.

References: Kreytser, G.D., Asfal'ty, bitumy i peki [Asphalts, Bi-

tumens, and Pitches], 3rd Edition, Moscow, 1952.

E.G. Gashnikov

BLUE BRITTLENESS OF STEEL – a decrease in the plasticity of steel under static loading at temperatures which cause blue irridescence (approximately 300°). Under dynamic loading the embrittlement temperature shifts to 500-550°.

References: Pogodina-Alekseyeva, K.M., Pogodin-Alekseyev, G.I., ZL [Indl. Lab.], 1958, Vol. 24, No. 2.

Ya.M. Potak

BLUING OF STEEL (oxidizing, blackening, bluing) – obtaining on the surface of steels, predominantly carbon and low-alloy, a chemical coating consisting of oxides such as Fe_3O_4, etc.

Bluing of steel practically does not change the dimensions and the mechanical properties of components. It is used for decorative finishes and corrosion protection of components with small dimensional tolerances (instrument components, springs, tools, etc.); for increasing the corrosion resistance of a surface after bluing it is covered by a grease or lacquer.

The blued component is colored in various shades of black: lustrous on polished and matted on rough surfaces. The coating thickness is 1-5 microns. The coating structure is fine crystalline, microporous. The coating has a high elasticity, abrasion resistance and electric insulation properties.

Alkaline bluing is treatment of a component in alkaline solutions with oxidizers, for example, NaOH (750g/liter), $NaNO_3$ (150 g/liter), $NaNO_2$ (75 g/liter), NaCN (3 g/liter). The standard temperature is 137-142° and the process duration is 40-90 minutes. Bluing by oxidation is performed in a solution of $Ba(NO_3)_2$ (40-50 g/liter), H_3PO_4 (specific weight 1.55, 3.5 g/liter) at 98-100° for 20-30 minutes. Bluing can also be performed by using solutions containing oxidizing substances; in this case the solution is applied to the component's surface, is allowed to react with the metal, and then the excess of the reaction products ("rust") is removed; this process is repeated several times. Heat treatment methods of bluing consist in heating the components in muffles, retorts or inert media (coal, sand, chalk) with a limited air access at 250-350° for several minutes. It is also possible to perform this treatment without air access in a superheated steam atmosphere at 550° for 30-60 minutes; this method is used to protect cutting tools from corrosion and to increase their serviceability.

References: Korrozia i zashita metallov [Corrosion and Protection of Metals]. Part 4 – Layner, V.I. and Shvyryayev, G.K., Metallicheskiye pokrytiya, elektrokhimicheskaya i khimicheskaya obtabotka metallov [Metal Coatings, Electrochemical and Chemical Treatment of Metals]. Moscow, 1951; Badal'yan, G.M., Zashchita metallov fosfatnymi i okisnymi plenkami [Protecting Metals by Phosphate and Oxide Films]. [Leningrad], 1952; Spravochnik po zashchitno-dekorativenym pokrytiyam [Handbook of Protective and Decorative Coatings]. Moscow-Leningrad, 1951.

M.I. Gamov

BOILER STEEL is the steel for components of boiler installations which operate at elevated temperatures in contact with water and steam media. Boiler steel is required to satisfy the characteristics of heat resistance, including resistance to creep and stress-rupture; plasticity under conditions of long-term loading; stability to scale formation, water and steam corrosion.; stability of the properties at a given temperature (for fittings); stability under repeated loadings; low tendency to aging, graphitization and spheroidization. In the selection of the grade of boiler steel, account is usually taken of the conditions under which the corresponding components must operate: temperature, stress, service life and permissible deformation during this life.

Depending on the operating conditions, use is made of carbon steel, low-alloy steel, alloy steel of the perlitic and austenitic classes for boiler steel. For the application of sheet boiler steel for elements of steam boilers see GOST 5520-62, 380-60; for tubes in boiler construction see GOST 8731-58, 8738-58, ChMTU (Ferrous Metal Specs.) 2579-54, 2580-54, GOST 1753-53. For the characteristic of the sheet steels VSt2, VSt3, St2, St3 see Construction Steel.

Widest use is made of the carbon steels 15K and 20K, and recently the high-strength steels (low-alloy) 09G2S(M), 10G2S1(MK) and 16GS(ZN) which are less prone to hot brittleness and loss of strength after long-term heating; the chemical composition of the boiler steels of these grades is shown in Table 1 and the mechanical properties in Tables 2 and 3.

The low-carbon and low-alloy steels are melted in open hearth furnaces and delivered in the hot-rolled condition, heat treatment (normalization or normalization with tempering) is performed on request of the user.

TABLE 1

Chemical Composition of Carbon and Low-Alloy Boiler Steel

Сталь 1	2 Содержание элементов (%)				
	C	Si	Mn	S	P
				3 не более	
15К	0,12—0,2	0,15—0,3	0,35—0,65	0,045	0,04
20К	0,16—0,24	0,15—0,3	0,35—0,65	0,045	0,04
09Г2С(М)	≤ 0,12	0,5 —0,8	1,3 —1,7	0,04	0,04
10Г2С1(МК)	≤ 0,12	0,9 —1,2	1,3 —1,65	0,04	0,04
16ГС(3Н)	0,12—0,18	0,4 —0,7	0,9 —1,2	0,04	0,04

1) Steel; 2) content of elements (%); 3) not more than

TABLE 2

Mechanical Properties of Carbon Boiler Steel

Сталь 1	2 $\sigma_т$ (кг/мм², не менее) при толщине листа (мм)			$\sigma_в$ (кг/мм²) 3	δ_5	δ_{10}	4 a_H (кгм/см²) при толщине листа (мм)		
	4—20	21—40	41—60		(%)		4—20	21—40	41—60
15К	23	22	21	38—43	25—27	21—23	7—8	6,5—7,5	6—7
20К	25	24	23	41	23—26	19—22	6—7	5,5—6,5	5—6

1) Steel; 2) σ_T (kg/mm^2, no less than) with sheet thickness (mm); 3) ^{T}(kg/mm^2) with sheet thickeness (mm).

TABLE 3

Mechanical Properties of Low-Alloy Boiler Steel (not less than)

Сталь 1	Толщина листа (мм) 2	$\sigma_т$	$\sigma_в$	δ	δ_5	4 a_H (кгм/см²)		
		(кг/мм²) 3		(%)		+20°	−40°	−70°
09Г2С(М)	4—10	35	50	22	18	—	—	—
	11—18	33	48	22	18	6	3,5	3
	19—24	32	48	22	18	6	3,5	3
	25—30	31	47	22	18	6	3,5	3
	31—48	30	46	22	18	6	3,5	3
	50—80	28	45	22	18	6	3,5	3
	81—160	27	44	22	18	6	3,5	3
10Г2С1(МК)	4—7	38	52	22	18	—	—	—
	8—32	35	50	22	18	6	3	2,5
	34—60	34	48	22	18	6	3	2,5
	61—160	32	46	22	9	6	3	2,5
16ГС(3Н)	4—10	33	50	22	18	—	—	—
	11—16	32	50	22	18	6	3	2,5
	17—30	30	48	22	18	6	3	2,5
	32—60	29	47	22	18	6	3	2,5
	60—160	28	46	22	18	6	3	2,5

1) Steel; 2) sheet thickenss (mm); 3) kg/mm^2); 4) a_H (kgm/cm^2).

TABLE 4

Chemical Composition of Boiler Steel for Pipes

Сталь 1	2 Содержание элементов (%)				
	C	Mn	Si	Mo	Cr
20	0,17–0,25	0,35–0,65	0,17–0,37	—	0,3
16M	0,12–0,2	0,4–0,7	0,17–0,37	0,4–0,6	0,3
12MX	0,09–0,16	0,4–0,7	0,17–0,37	0,4–0,6	0,4–0,6
15XM	0,09–0,16	0,4–0,7	0,17–0,37	0,4–0,6	0,8–1,1
12XMФ	0,08–0,12	0,4–0,7	0,15–0,35	0,25–0,35	0,9–1,2

3 Продолжение

Сталь 1	2 Содержание элементов (%)				
	Ni	Cu	W	S	P
				4 не более	
20	≤0,35	≤0,25	—	0,045	0,04
16M	≤0,3	≤0,25	—	0,04	0,04
12MX	≤0,3	≤0,25	—	0,04	0,04
15XM	≤0,3	≤0,25	—	0,04	0,04
12XMФ	≤0,3	≤0,25	0,15–0,3	0,045	[illegible]

1) Steel; 2) content of elements (%); 3) continued; 4) not more than.

TABLE 5

Mechanical Properties of Boiler Steel for Pipes (ChMTU 2579-54)*

Механич. свойства 1	2 Сталь				
	20	16M	12MX	15XM	12XMФ
σ_b (кг/мм²) 3	≥40	40–55	42–57	44–60	45–[illegible]
$\sigma_{0,2}$ »	≥0,5 σ_b	—	—	—	≥0,5 σ_b
δ_{10} (%)	≥20	≥18	≥18	≥18	≥18
δ_5 »	≥24	≥21	≥21	≥21	≥21

* For pipes with outside diameter 10-108 mm and wall thickness of 2-18.5 mm

1) Mechanical properties; 2) steel; 3) (kg/mm^2)

TABLE 6

Mechanical Properties of Boiler Steel for Pipes (ChMTU 2580-54)[1]

Механич. свойства	Сталь				
	20	16M	12MX	15XM	12XMФ
σ_b (кг/мм²) 7	≥42	[illegible]	[illegible]	[illegible]	[illegible]
δ (%)	≥24/22	[illegible]	[illegible]	[illegible]	[illegible]
ψ »	≥45/40	[illegible]	[illegible]	[illegible]	[illegible]
a_k (кгм/см²) 8	≥5/[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1. For pipes with outside diameter 114-426 mm and wall thickness 7-60 mm. [2] $\sigma_{0.2}$ for steel of all grades is not less than 0.5 σ_b. [3] Values of σ_b for longitudinal and lateral specimens coincide; [4] Numerator is value for longitudinal and denominator is value for lateral specimens.

5) Mechanical properties[2]; 6) steel; 7) (kg/mm^2)[3]; 8) (kgm/cm^2)[4].

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The 15K and 20K steels are delivered in sheets of thickness from 4 to 60 mm, the low-alloy steel is delivered in sheets from 4 to 160 mm thick. On request of the user a determination is made of the yield strength at elevated temperatures (320°); the yield strength for sheets 60 mm and more thick from the 09G2S(M) steel must be no less than 18 kg/mm^2, and for the 10G2S1(MK) steel it must be no less than 23 kg/mm^2. Figure 1 shows the variation of the mechanical properties of the 15K and 20K steels as a function of temperature. The stress-rupture limit 1 (after 100,000 hours) and creep limit 2 (1% after 100,000 hours) for these same steels at various temperatures are shown in Fig. 2. Figure 3 shows the variation of the stress-rupture (after 100,000 hours) for various temperatures of the low-alloy steel 16GS(ZN) (curve 1) and for 09G2S(M) (curve 2). The chemical composition and mechanical properties of boiler steel for pipes used in boiler construction are shown in Tables 4, 5, 6. The variation of the stress-rupture and creep limit for certain grades of alloy boiler steels as a function of temperature are shown in Figures 4-7.

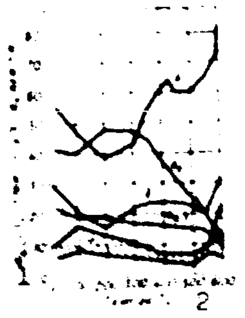

Fig. 1. 1) $\sigma_{0.2}$, σ_b kg/mm^2; $\delta \cdot \psi$%: σ_n kgm/cm^2; 2) temp. °C.

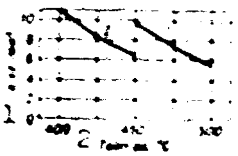

Fig. 2. 1) σ, kg/mm^2; 2) temp. °C.

Fig. 3. 1) σ, kg/mm^2 2) temp. °C.

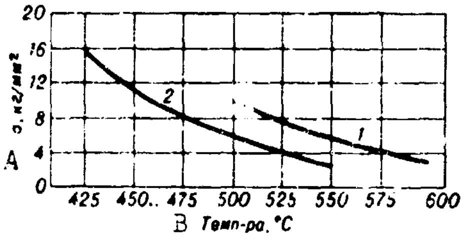

Fig. 4. Stress-rupture limit after 100,000 hours (1) and creep limit for 1% after 100,000 hours (2) for 16M steel. A) σ, kg/mm²; B) temp. °C.

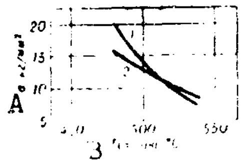

Fig. 5. Stress-rupture limit after 100,000 hours (1) and creep limit for 1% after 100,000 hours (2) for 12MKh steel. A) σ, kg/mm²; B) temp. °C.

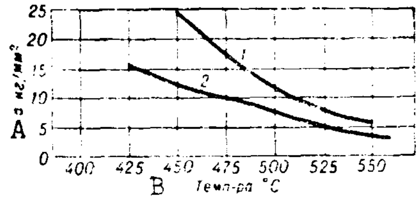

Fig. 6. Stress-rupture limit after 100,000 hours (1) and creep limit for 1% after 100,000 hours (2) for 5KhM steel. A) σ, kg/mm²; B) temp. °C.

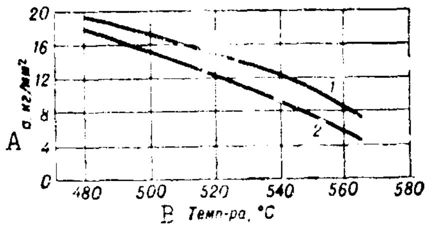

Fig. 7. Stress-rupture limit after 100,000 hours (1) and creep limit for 1% after 100,000 hours (2) for 12KhMF steel. A) σ, kg/mm²; B) temp. °C.

References: Liberman L.Ya., Peysikhis M.I., Spravochnik po svoystvam staley, primenyayemykh v kotloturbostroyenii [Handbook on Properties of Steels Used in Boiler and Turbine Construction], 2nd ed., M.-L., 1958; Spravochnik po kotlonadzoru [Handbook on Boiler Inspection], ed. by M.P. Morozov, 3rd ed., M.-L., 1961; Pridantsev M.V., Lanskaya K.A.,

II-16k5

Stali dlya kotlostroyeniya [Steels for Boiler Design], M., 1959; Larichev V.A., Kachestvennyye stali dlya sovremennykh kotel'nykh ustanovok [High-Quality Steels for Modern Boiler Installations], M.-L., 1951.

E. Sh. Volokhnyanskaya

BORIDES – compounds of boron and metals formed at high temperatures.

The borides of high-melting metals (titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten) are metalline phases. The bonds between the metal and boron atoms are metallic in character. This explains the fact that borides have approximately the same electrical resistance as metals and, just as metals, have a constant ratio of electrical conductivity to thermal conductivity. These compounds are distinguished by high melting points, high hardness, the ability of certain of them to become superconductive, etc.

Of the many boride phases based on high-melting transition metals and the rare earths, Tables 1 and 2 show the properties of the diborides of the aforementioned metals (MeB_2, and the hexaborides of the rare-earth metals (MeB_6). These boride phases are the most stable and the most widely used in engineering. Monoborides (MeB), tetraborides (MeB_4), etc., have a lower thermal resistance, are less strong, and are rarely used in engineering.

High-melting borides of the alkaline-earth metals (calcium, strontium, and barium) are also known. Zinc, cadmium, gold, silver, mercury, gallium, indium, thallium, lead, and tin do not form borides. Copper forms borides with difficulty.

The borides of high-melting metals are stable when heated to high temperatures (2000–2500°) in contact with graphite.

The borides of chromium, tungsten, and molybdenum are poorly wetted by molten pig iron, while those of zirconium remain completely unwetted by molten pig iron or steel. The borides of titanium, chromium, and zirconium are stable in contact with molten aluminum, while molten silicon does not react with the borides of zirconium. Many metalline borides are highly refractory, are poorly wetted by molten salts and alkalies, and are rather resistant to weakly acid and certain aggressive gaseous media.

All borides are distinguished by high stability in vacuo at high temperatures. The borides of high-melting metals (titanium, zirconium, etc.) have high electrical conductivities, sometimes exceeding those of the corresponding metals, and rather high thermoelectric characteristics; those of the rare-earth metals have high thermoemissive charcteristics.

TABLE 1

Properties of Borides of High-Melting Metals

1 Свойства	2 борид титана TiB_2	3 борид циркония ZrB_2	4 борид гафния HfB_2	5 борид ванадия VB_2	6 борид ниобия NbB_2	7 борид тантала TaB_2	8 борид хрома CrB_2	9 борид молибдена MoB_2	10 борид вольфрама W_2B_5
11 Молекулярный вес	69.54	112.86	200.14	72.13	114.55	202.59	73.65	117.59	421.82
12 Содержание бора:									
13 атомных %	66.67	66.67	66.67	66.67	66.67	66.67	66.67	66.67	71.43
14 весовых %	31.12	19.17	10.81	29.81	18.89	10.68	29.38	18.40	12.83
15 γ ($г/см^3$)	4.52	6.09	11.2	5.10	7.00	12.62	5.60	7.78	13.1
$t_{пл}$ (°C)	2980	3040	3250	2400	3000	3100	2200	2100	2300
16 Теплота образования при 298°K (ккал/моль)	70.0	78.0	—	—	36.0	52.0	30.0	23.0	25–45
17 Энтропия образования из элементов (кал/моль·°C)	7.8	10.7	14.2	7.9	10.4	13.9	9.4	12.21	28.3
18 c при 20° (кал/моль·°C)	10.57	12.00	—	—	—	—	12.24	—	—
19 λ (кал/см·сек·°C)	0.144	0.058	—	0.137	0.040	0.026	0.053	0.064	0.076
20 ρ (мком·см)	14.4	16.6	12.0	19.0	34.0	37.4	57.0	45.0	43.0
21 Термический коэффициент электросопротивления ($град^{-1}\cdot 10^3$)	+2.78 (300–2000°)	+1.76 (300–1800°)	+3.6 (20–2830°)	+3.16 (100–1100°)	+1.39 (100–1100°)	+1.48 (100–1100°)	−3.1	—	—
$\alpha\cdot 10^6$ (1/°C)	8.1	6.88	5.73	7.5	7.9–8.3	5.12	11.1	—	—
22 Термоэдс (мкв/град)	−6.6	−0.2	+1.2	+7.7	−2.8	−4.5	−3.7	+1.8	+1.8
23 Работа выхода (эв)	3.88	3.67	—	3.95	3.65	2.89	3.36	3.38	2.62
E ($кг/мм^2$)	54000	35000	—	27300	—	26200	21500	—	—
24 $\sigma_{изг}$ ($кг/мм^2$)	24.5	9.3	—	—	—	—	62	17–35	—
σ_{-b} ($кг/мм^2$)	135	159	—	—	—	—	128	—	—
RA ($кг/мм^2$)	86	84	—	83	—	—	84	90	—
H ($кг/мм^2$)	3370	2250	2900	2800	2600	2500	2100	1200	2660

1) Property; 2) titanium boride; 3) zirconium boride; 4) hafnium boride; 5) vanadium boride; 6) niobium boride; 7) tantalum boride; 8) chromium boride; 9) molybdenum boride; 10) tungsten boride; 11) molecular weight; 12) boron content; 13) atom-%; 14) % by weight; 15) γ (g/cm^3); 16) heat of formation at 298°K (kcal/mole); 17) entropy of formation from elements (cal/mole·°C); 18) c at 20° (cal/mole·°C); 19) λ (cal/cm·sec·°C); 20) ρ(μohms/cm); 21) Thermal coefficient of electrical resistance ($degrees^{-1}\cdot 10^3$); 22) thermal emf (μv/degrees); 23) work function (ev); 24) kg/mm^2.

The data on the strength characteristics of borides, especially at high temperatures, are extremely limited. By way of example, Table 3 shows the ultimate strength of certain borides on compression and bending.

Borides (MeB_2) have high chemical stability in various aggressive media and resist oxidation in air at high temperatures somewhat better than carbides or nitrides. The borides of titanium, zirconium, molybdenum, and tungsten are resistant to cold acids, while those of tantalum and niobium are more stable in cold or heated acids at any concentration.

The hexaborides of the rare earths are easily decomposed in oxidizing media (Table 4). Alkalies and mixtures of sodium hydroxide and perhydrol have no effect on hexaborides, even when heated, with the exception of cerium hexaboride.

Boride-based alloys can be subdivided into the following basic groups: pure boride alloys (TiB_2-CrB_2, NbB_2-TiB_2), boride-carbide alloys (TiB_2-TiC, ZrB_2-ZrC), boride-nitride alloys (TiB_2-TiN), boride-silicide alloys (TiB_2-$TiSi_2$), and boride-metal alloys, the so-called boroalloys (TiB_2-Fe, CrB_2-Mo). Pure boride, boride-metal, and boride-silicide alloys are now being used. Table 5 shows the approximate physical and mechanical properties of boride-based alloys with somewhat elevated strength, durability, and high-temperature oxidation resistance. An alloy of titanium boride and iron will serve as an example of a boride-metal alloy; this alloy has a high resistance to thermal shock, good cutting characteristics, and an elevated high-temperature oxidation resistance (Table 6). The production of completely compacted, nonporous products from borides presents great difficulties at the current level of technology. However, it is possible to obtain alloys with virtually no porosity by combining titanium boride and iron and sintering the resultant alloy in an argon atmosphere at 1700-2000°. The high strength of TiB_2-Fe alloys remains almost unchanged over the temperature range 20-1100° (Table 6), while their high hardness and durability make them quite promising for use as structural and tool materials. A titanium-boride-based alloy containing 15% iron has good cutting characteristics and is more stable than the standard alloy T15K6.

TABLE 2

Properties of Hexaborides of Rare-Earth Elements

Свойства	борид лантана LaB_6	борид церия CeB_6	борид празеодима PrB_6	борид неодима NdB_6	борид самария SmB_6	борид европия EuB_6	борид гадолиния GdB_6	борид тербия TbB_6	борид диспрозия DyB_6	борид гольмия HoB_6	борид эрбия ErB_6	борид тулия TmB_6	борид иттербия YbB_6	борид лютеция LuB_6
Молекулярный вес	203.84	205.05	205.8[illegible]	209.19	215.35	[illegible]	221.82	[illegible]5.12	227.38	228.42	232.12	[illegible]	[illegible]	[illegible]
Содержание бора (вес. %)	31.7	31.6	31.5	30.9	[illegible]	29.8	29.2	28.8	28.6	28.3	27.8	[illegible]	[illegible]	27.0
γ (г/см³)	4.73	4.81	4.84	4.94	[illegible]	4.95	5.27	5.36	[illegible]	5.52	5.53	[illegible]	[illegible]	[illegible]
$t_{пл}$ (°C)	2100	2190		2540	25[illegible]	~2150	2100	—	—	—	—	—	—	—
α·10⁶ (1/°C)	6.4	7.3	7.[illegible]	7.3	6.6	6.9	8.7	7.8	—	—	—	—	[illegible].85	—
λ (кал/см·сек·°C)	—	—	—	—	—	—	0.0466—0.0536	—	—	—	—	—	—	—
ρ (мком·см)	15.0	29.4	19.[illegible]	20.0	207.0	84.7	44.7	37.4	—	—	—	—	46.6	—
Термический коэффициент электросопротивления (град⁻¹·10³)	+2.68	+1.0	+1.92	+1.93	−0.42	+0.90	+1.40	+1.31	—	—	—	—	+2.34	—
Термо-э.д.с. (мкв/°C)	+0.4	+2.8	−0.6	+0.4	+7.6	−17.7	+0.1	−1.1	—	—	—	—	−25.5	—
Коэффициент Холла·10⁴ (см³/кулон)	−4.96	−4.18	−4.[illegible]	−4.39	+1.54	−50.2	−4.39	−4.57	—	—	—	—	−83.6	—
Эффективный магнитный момент магн. бора	0	2.91	3.57	3.82	2.52	—	7.63	—	—	—	—	—	4.58	—
Магнитная восприимчивость·10⁶	174	2715	5310	5600	1810	—	—		—	—	—	—	—	—
Работа выхода (эв)	2.68	2.93	3.46	3.97	4.4	4.9	2.05	2.29	3.53	3.42	3.37	[illegible]	[illegible]	3.[illegible]
Постоянная Ричардсона (а/см²·град²)	73.0	580	300	420	—	—	0.84	120	25.1	13.9	9.9	—	2.5	0.36
Коэффициент вторичной эмиссии (макс.)	0.95	0.68	—	—	—	—	0.8	—	0.8	0.7	—	—	—	0.8
Коэффициент излучения при λ=655 ммк	0.7	0.75	0.67	0.64	0.77	0.83	0.65	0.74	0.7	0.7	0.7	—	0.74	0.7
$σ_{изг}$ (кг/мм²)	—	—	—	—	—	—	21.1	—	—	—	—	—	—	—
H (кг/мм²)	2660	2470	2470	2470	2300	2660	2300	2300	—	—	—		2680	—
Цвет	пурпурно-фиолетовый	сине-фиолетовый	синий	синий	синий	черный	синий	синий	синий	синий	синий	синий	черный	синий

1) Property; 2) lanthanum boride; 3) cerium boride; 4) praseodymium boride; 5) neodymium boride; 6) samarium boride; 7) europium boride; 8) gadolinium boride; 9) terbium boride; 10) dysprosium boride; 11) holmium boride; 12) erbium boride; 13) thulium boride; 14) ytterbium boride; 15) lutetium boride; 16) molecular weight; 17) boron content (% by weight); 18) γ (g/cm³); 19) λ (cal/cm·sec·°C): 20) ρ (μ ohms·cm); 21) thermal coefficient of electrical resistance (degrees $^{-1}$·10^3); 22) thermal emf (μv/°C); 23) Hall's coefficient x 10^4 (cm³/coulomb); 24) effective moment of magnetic boron; 25) magnetic permeability x effective magnetic moment of magnetic boron; 25) magnetic permeability x 10^6; 26) work function (ev); 27) Richards' constant (amps/cm^2·degrees^2); 28) coefficient of secondary emission (maximum); 29) radiation factor at λ = 655 mμ; 30) $σ_{izg}$ (kg/mm^2); 31) H(kg/mm^2); 32) color; 33) purplish-violet; 34) blue-violet; 35) blue; 36) black.

TABLE 3

Ultimate Strengths (kg/mm^2) of Borides on Compression and Bending* at Various Temperatures

Борид 1	2 Температура (°C)									
	20°		1000°		1200°		1400°		1600°	
	σ_{-b}	$\sigma_{изг}$	σ_{-b}	$\sigma_{изг}$	σ_{-b}	$\sigma_{изг}$	σ_{-b}	$\sigma_{изг}$	σ_{-b}	$\sigma_{изг}$
TiB_2	135,0	—	22,7	—	25,8	—	18,3	—	11,0	—
ZrB_2	158,7	9,3	30,6	6,6	24,1	2,1	24,4	—	—	1,0
CrB_2	127,9	—	86,8	—	40,2	—	58,1	—	41,2	—

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*The bending values are for specimens with a porosity of 22-24%.

1) Boride; 2) temperature (°C).

TABLE 4

Solubility of Borides of Rare-Earth Metals in Acids

Борид	HCl (1:1)*	H_2SO_4 (1:1)*	HNO_3 (1:1)	Царская водка	H_2SO_4 (1:1) (с добавкой HNO_3)
	нерастворимый осадок (%)				
VB_6	77—78	71—72	Полное растворение при слабом нагревании в течение 5 ч.	Полное растворение на холоде в течение 5 мин.	Полное растворение при слабом нагревании в течение 5 мин.
LaB_6	93—94	89—92			
CeB_6	84—86	83—84			
PrB_6	90—94	27—30			
NdB_6	87—88	78			
SmB_6	79—80	77			
GdB_6	91—93	87			

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*On gentle heating for 2 hr.

1) Boride; 2) aqua regia; 3) H_2SO_4 (1:1, with HNO_3 added); 4) insoluble precipitate (%); 5) complete dissolution on gentle heating for 5 hr; 6) complete dissolution in cold acid within 5 min; 7) complete dissolution on gentle heating for 5 min.

TABLE 5

Properties of Boride Alloy Based on Solid Solution of Permium Boride in Titanium Boride (Ti, Cr) B_2n

γ (г/см^3)	$t_{пл}$ (°C)	α (1/°C)	λ (кал/см·сек °C)	$\sigma_{изг}$	E	RA
				кг/мм^2		
4,3—4,7	2500	$8,5\cdot10^{-6}$	0,056	33—50	32 800	85

1) γ (g/cm^3); 2) λ (cal/cm•sec•°C);
3) kg/mm^2.

Borides are obtained chiefly by reduction of metal oxides with a mixture of boron carbide and carbon (Table 7), in accordance with the reaction

A

by reduction of a mixture of metal oxides and boron anhydride with carbon,

B

or by direct combination of metals with boron.

Products are manufactured from borides and their alloys by powder metallurgy (pressing of blanks and subsequent sintering or hot pressing). Nonporous products cannot be obtained by pressing and sintering, but hot pressing makes it possible to produce articles with a porosity of 1-3%.

Because of their high hardness, articles fabricated from borides and their alloys cannot be dimensioned by the usual mechanical-machining methods. Anodomechanical, electric-discharge, and ultrasonic machining or treatment with abrasives are used for this purpose. The ultrasonic method has come into especially wide use. Certain data on the machinability of borides are given in Table 8.

TABLE 6

Influence of Composition and Temperature on the Strength of Alloys of Titanium Boride and Iron

Содержание железа в сплаве (вес. %)	Температура (°C)			
	20°	400°	800°	1100°
	$\sigma_{изг}$ (кг/мм²)			
8.22	45	53	57	47
14.90	52	55	59	46
18.93	64	66	76	54
29.89	40	43	50	47
38.42	51	66	65	49
48.00	55	—	55	40

1) Iron content of alloy (% by weight); 2) temperature (°C); 3) σ_{izg} (kg/mm^2).

TABLE 7

Technological Regimes for Production of Certain Borides by the Carbide-Boron Method

Борид	В вакуумных печах		В графито-трубчатых печах	
	Темп-ра (°C)	Длительность процесса (мин.)	Темп-ра (°C)	Длительность процесса (мин.)
TiB_2 . . .	1650—1750	80—90	1800—1900	40—50
ZrB_2 . . .	1700—1800	50—60	1800	60—70
CrB_2 . . .	1600—1700	60—90	1700—1750	60—90
(Ti, Cr) B_2	1650	50—60	—	—

1) Boride; 2) in vacuum furnaces; 3) temperature (°C); 4) process time (min); 5) in tubular graphite furnaces.

TABLE 8

Ultrasonic Machinability of Certain Borides (frequency – 18 kc)

Борид	Относительная плотность материала (%)	Глубина резания (мм)	Коэффициент обрабатываемости (отношение износа материала к износу инструмента)
TiB_2 . . .	91	12.5	23
ZrB_2 . . .	92	5.9	23
NbB_2 . . .	96	10.0	39
CrB_2 . . .	98	12.0	45
Mo_2B_5 . . .	92	5.0	15
W_2B_5 . . .	91	5.0	38
(Ti, Cr) B_2	88	12.5	28

1) Boride; 2) relative compactness of material (%), 3) cutting depth (mm); 4) coefficient of machinability (ratio of material wear to tool wear).

The borides of high-melting transition metals are used principally for the electrodes of high-temperature thermocouples, piping for transfer of molten metals, and crucibles for precision metallurgy, in high-hot-strength and refractory alloys, etc. Hexaborides are used in the cathodes of electronic devices and ionic current sources, in nuclear engineering and electronics, in devices for the conversion of thermal [illegible] to electrical energy, etc.

References: Samsonov, G.V., Portnoy, K.I., Splavy na osnove tugoplavkikh soyedineniy [Alloys Based on High-Melting Compounds], Moscow,

1961; Samsonov, G.V., Tugoplavkiye soyedineniya. Spravochnik po svoystvam i primeneniyu [High-Melting Compounds. Handbook of Properties and Applications], Moscow, 1963; Samsonov, G.V., Paderno, Yu.B., Boridy redkozemel'nykh metallov [Borides of the Rare Earths], Kiev, 1961; Funke, V.F., Yudkovskiy, S.I., and Samsonov, G.V., ZhPKh [J. Appl. Chem.], 1961, Vol. 34, No. 5; Samsonov, G.V., et al., Bor, yego soyedineniya i splavy [Boron and Its Compounds and Alloys], Kiev, 1960.

K.I. Portnoy

BORIZATION OF STEEL – superficial saturation of steel with boron in order to increase its hardness (up to 1400 HV), thermostability, durability (particularly with respect to abrasion), and corrosion resistance. Structural and austenitic steels and various metals and alloys can be subjected to borization. The brittleness of the borization layer prevents wide use of this process. Electrolysis in molten borax is used for borization of steel (the component serves as the cathode and graphite as the anode). A current density of 0.1-0.2 amp/cm^2 is employed. The working temperature is 950° and the process time 6-8 hr. The resultant borization layer is 0.15-0.25 mm thick (the external zone consists of the boride FeB and the internal zone of the boride Fe_2B). It is recommended that the workpiece be surface-quenched to provide a strengthened cushion under the thin hard layer (the hardness of the latter is unaffected in this case). Methods have also been developed for borization of steel in molten borax containing boron carbide, in gaseous media ($H_2B_6 + H_2$, $BCl_3 + H_2$), in vacuum furnaces, and in powdered mixtures. Borization is employed in the manufacture of casing and bushings for mud pumps, components of wire mills, bushings for caterpillar tracks, etc.

A.N. Minkevich

I-29b

BORIZATION OF TITANIUM ALLOYS – superficial saturation of titanium-alloy components with boron. This process can be carried out by electrolysis in molten borax. At a current density of 2.5–3.0 amp/cm^2 and a temperature of 1050° or more a layer of titanium boride with a hardness of ~2500 HV and a thickness of several microns is formed on the surface of the workpiece; this is underlain by a solid solution of oxygen in α-titanium. Only a thin oxygen-saturated layer is obtained at lower current densities or temperatures. Borization of titanium alloys can also be conducted in powdered boron at temperatures above 1000° in vacuo. No matter what borization method is used, the hardened layer is very brittle and bonds poorly to the base metal.

References: Minkevich, A.N., Shul'ga, Yu.N., Metallovedeniye i obrabotka metallov [Phys. Metallurgy and Metalworking], 1957, No. 12.

I.S. Anitov

BORULIN - see Bituminous materials.

II-39k

BRAKE STRIP is elastic friction material used to provide the required friction forces in band and disc brake devices for tractors, various types of highway-construction, hoisting and transporting (excavators, bulldozers, cranes and hoists) and other machinery. Industry produces both woven and rolled brake stripping. The woven brake stripping (GOST 1198-55) is fabricated from woven, multilayer asbestos fabric strips containing in the fibers brass wire of cross section 0.16-0.19 mm. The woven brake stripping is produced in type "A" impregnated with bitumen and type "B" impregnated with oil in rolls of width 13-270 mm and thickness 4-12 mm. The rolled brake strip (TU MKhP 3027-51) is made by rolling on a special machine of an asbestos-rubber mass with subsequent vulcanization; it is produced in the form of rolls of straight strip of length up to 20 meters or as individual brake discs in accordance with drawings agreed on by the suppliers and consumers. The width of the strips and discs linings is 20-160 mm, thickness 4-10 mm. The tensile strength of the woven brake strip is 500-600 kg/cm^2, that of the rolled strip is 100-140 kg/cm^2. The woven and rolled brake stripping provide for operation of the brake unit up to 270°, after which their frictional resistance is sharply reduced because of the decomposition of the binder. The physical and mechanical properties of the brake strippings are shown in the Table.

II-89k1

Physical and Mechanical Properties of Woven and Rolled Strip

Показатели 1	Тканая лента типа «А» 2	Тканая лента типа «Б» 3	Вальцованная лента шифра 6КВ-10 4
5 Коэфф. трения по чугуну при темп-ре 100—120°, скорости 7,5 м/сек и уд. давлении 2,7 кг/см² не менее . .	0,35	0,45	0,37
6 Износ по толщине за 2 час (мм, не более)	0,20	0,15	0,20
7 Увеличение веса после погружения в воду (%, не более):			
8 при толщине до 6 мм	10,0	6,0	1,5
9 то же 6—8 мм . .	13,0	7,0	
» » 9 мм и более 10	13,0	9,0	
11 Увеличение веса после погружения в минеральное масло (%, не более):			
12 при толщине до 6 мм	15,0	6,0	2,0
то же 6—8 мм . . .	18,0	7,0	
» » 9 мм и более	18,0	9,0	

1) Characteristics; 2) type "A" woven strip; 3) type "B" woven strip; 4) type 6KV-10 rolled strip; 5) friction coefficient on iron at a temperature of 100-120°, velocity 7.5 m/sec and specific pressure 2.7 kg/ /cm², no less than; 6) wear in thickness after 2 hours (mm, no more than); 7) weight increase after water immersion (%, no more than); 8) with thickness to 6 mm; 9) same 6-8 mm; 10) same 9 mm and more; 11) weight increase after immersion in mineral oil (%, no more than); 12) with thickness to 6 mm.

Ye.S. Popova

BRASS is a binary or multi-component alloy based on copper in which the primary alloying element is zinc. The binary copper-zinc alloys are termed simple brasses while the multi-component alloys are termed special brasses (see Special Brasses). With regard to technological principle, these alloys are divided into the wrought brasses and the cast brasses. The brasses containing 88-97% Cu are termed tombac, those with 79-86% Cu are termed semi-tombac.

The brasses have comparatively high mechanical properties and good corrosion resistance in atmospheric conditions, while the special brasses have these properties in sea water as well. Being the cheapest of the copper alloys, the brasses are widely used in various branches of the national economy. The simple brasses are used for all sorts of products fabricated by stamping and other forms of plastic deformation, for heat exchange equipment, furniture, signs, bellows, flexible hoses, sieves for paper finishing machines, cartridges and other specialized products. The special brasses, having higher corrosion resistance and strength, are used for details of sea-going vessels and aircraft, instruments and chemical apparatus. From the brasses containing lead and which are therefore easily machined, we make watch parts and parts for other precision mechanisms, and also antifriction parts. Cast products are made from the casting brasses. Sheets, strips, plates, tubes, rods and wire, forgings are made from the brasses which can be pressured worked.

Copper forms six phases with zinc: α, β, γ, δ, ε and η (the copper-zinc state diagram is shown in Fig. 1). Of these only the α- and β-

phases belong to the region occupied by the brasses. The copper-rich α-phase has a face-centered cubic lattice with period a = 3.608-3.693Å. The limiting solubility of zinc in copper at a temperature of 453° is 38-39% and diminishes with further increase of the temperature. The α-phase alloys (see Alpha-Brass) are very plastic in the cold condition. The β-phase is a solid solution based on the chemical compound CuZn with a body-centered cubic lattice with period a = 2.94Å. At the solidus temperature the β-phase occupies the region from 37 to 57% Zn, narrowing at room temperature to 45-49% Zn. With reduction of the temperature the alloys lying in the left portion of the β-phase region decompose with the release of α-phase crystals. Structural alteration of the β-phase takes place at a temperature of 450-470°, above these temperatures the alloys are plastic, and below they are brittle, therefore the β-brasses containing 45-47% Zn are pressure worked in the hot condition (see Beta-Brass). Consequently, depending on the zinc content the brasses may consist of α–, α + β–, and β-crystals (Figs. 2-4).

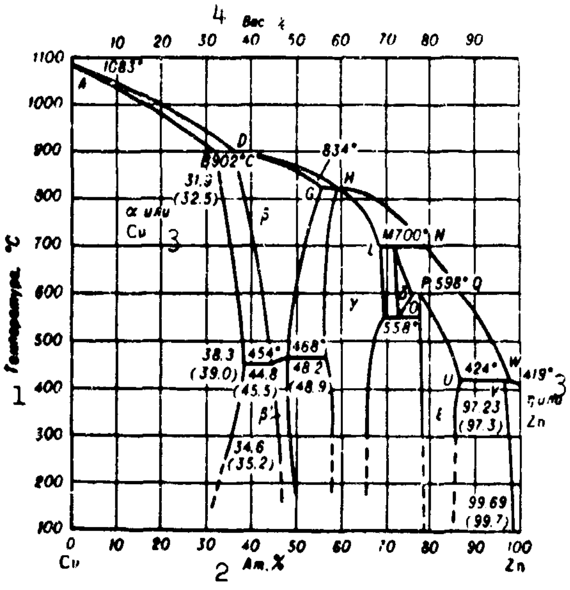


Fig. 1. State diagram of the copper-zinc system. 1) Temperature, °C; 2) at. %; 3) or; 4) weight.

The properties of the brasses depend on the zinc content and their structure. Figure 5 shows the variation of the ultimate strength and the relative elongation of the brasses as a function of the zinc content. The grain size and the mechanical properties of the brasses are determined by the temperature and duration of the anneal, and also by the degree of deformation. The most frequently encountered harmful impurities in the brasses are bismuth, lead, antimony, arsenic and phosphorus, which have an influence on their properties and structure (see Table).

Fig. 2. Typical microstructure of wrought annealed α-brass. Magnified 75 times.

In all the grades other than L70 and L68, up to 0.5% Ni (with relation to the copper) is permitted. In the antimagnetic brasses there must be no more than 0.03% Fe. Oxygen may be present in the form of zinc oxide which easily comes to the surface of the molten brass and is usually not present in the ingots if the casting temperature is sufficiently high. Lead impurity in the amount of more than 0.03% leads to cracking of ingots during hot rolling of the α-brasses; the presence of the β-phase facilitates hot working of the brasses containing lead. Bismuth reduces the plasticity of the brasses in the cold condition. Antimony reduces the capability of the brasses for cold deformation since it concentrates along the grain boundaries in the form of a brittle phase. The solubility of this phase in the copper solid solution is significantly reduced with an increase of the zinc content and a temperature reduction, therefore to facilitate cold working of the antimony brasses it is advisable to make use of quenching. Up to 0.1% arsenic is soluble in brass in the solid state. With increase of the arsenic the plasticity of the brasses

Fig. 3. Microstructure of wrought α + β-brass (62% Cu). Enlarged 100 times.

Fig. 4. Microstructure of wrought annealed β-brass (47% Zn, remainder copper). Enlarged 100 times.

diminishes as a result of the formation of intercrystalline lamina of the brittle compound Cu_3As. Arsenic improves the resistance of the

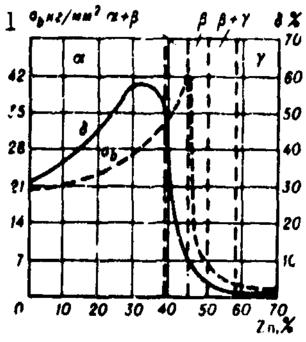


Fig. 5. Variation of mechanical properties of cast copper-zinc alloys with zinc content. 1) kg/mm^2.

Maximal Permissible Impurity Content in Brasses (from GOST 1019-47)

Сплав 1	Примеси (%) 2						
	Pb	Fe	Sb	Bi	P	3 Др. примеси	4 Сумма примесей
Л96 . . 5	0,03	0,10	0,005	0,002	0,01	—	0,2
Л90	0,03	0,10	0,005	0,002	0,01	—	0,2
Л85	0,03	0,10	0,005	0,002	0,01	—	0,3
Л80	0,03	0,10	0,005	0,002	0,01	—	0,3
Л70	0,03	0,07	0,002	0,002	0,005	0,005 As 0,005 Sn 0,002 S	0,2
Л68	0,03	0,10	0,005	0,002	0,01	—	0,3
Л68*	0,03	0,07	0,002	0,002	0,005	0,005 As 0,002 S	0,2
Л62	0,08	0,15	0,005	0,002	0,01	—	0,5

* For details in critical applications.

1) Alloy; 2) impurity; 3) other impurities; 4) total impurities; 5) L.

brasses to dezincification. The solubility of phosphorus in the solid state in the brasses is slight, therefore, it may separate out along the grain boundaries in the form of the brittle copper phosphide Cu_3P and thereby reduce the plasticity of the brasses. Iron restrains the recrystallization of the brasses and refines the grain. Sulfur diminishes the plasticity of the brasses. The presence of tin is not harmful. Impurity purification is accomplished by refining the brasses. The alloying components – aluminum, silicon, manganese, tin and iron – improve the corrosion resistance, strength, hardness and other properties of the brasses.

References: Smiryagin A.P., Promyshlennyye tsvetnyye metalli i splavy [Industrial Nonferrous Metals and Alloys], 2nd ed., M., 1956; Hansen M, Anderko K., Structures of the Binary Alloys, transl. from Eng, 2nd ed., Vols. 1-2, M., 1962.

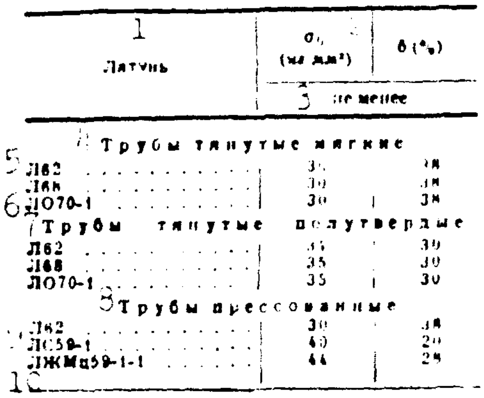
A.V. Bobylev, Ye.S. Shpichinetskiy

BRASS BARS – round, square, and hexagonal semifinished products (GOST 2060-60). They are manufactured from various types of brass, including L62, LS59-1, LS63-3, LO62-1, LZhS58-1-1, LMts58-2, LZhMts59-1-1, and LAZh60-1-1. Brass bars can be pressed or drawn. Drawn bars are fabricated in diameters of 5.0-40 mm to precision classes 3a, 4, and 5, while pressed bars are produced in diameters of 10-160 mm. Bar length is not standardized and ranges from 0.8 to 4 m, depending on bar bar diameter. Brass bars of other sizes are produced in accordance with special TU. Drawn bars are supplied in the hard and semihard states.

Ye.S. Shpitsinetskiy

BRASS PIPES – are made from various brass brands. The assortment and properties of round drawn tubes for heat exchangers from L68 brass for potable water operation and from L070-1 brass for sea water operation as well as of general purpose drawn pipes from L62 brass and extruded pipes from L62, L59-1 and LZhMts 59-1-1 brass are proscribed by GOST 494-52. Heat exchanger tubes are made with an external diameter from 10 to 38 mm and with a wall thickness of 0.75-1, 1.5, 2.0 and 3.0 mm. Drawn pipes from L62 brass are with diameters from 3 to 100 mm and wall thickness of 0.5, 0.75, 1.0, 1.5, 2.0, 2.5 and 3.0 mm. Extruded pipes from L62, LS59-1 and LZhMts59-1-1 brass are supplied with diameters from 21 to 195 mm and wall thickness from 1.5 to 42.5 mm. All-drawn round capillary tubes from L96 brass with an inside diameter from 0.35 to 0.50 mm and an outside diameter from 1.20 to 2.[illegible] mm are sup-

Mechanical Properties of
Brass Pipes (GOST 494-52)



1 Латунь	σ_в (кг/мм²) 2	δ (%)
	3 не менее	
4 Трубы тянутые мягкие		
5 Л62	30	38
Л68	30	38
6 ЛО70-1	30	38
7 Трубы тянутые полутвердые		
Л62	35	30
Л68	35	30
ЛО70-1	35	30
8 Трубы прессованные		
Л62	30	38
9 ЛС59-1	40	20
ЛЖМц59-1-1	44	28
10		

1) Brass; 2) (kg/mm^2); 3) not less than; 4) soft drawn pipes; 5) L; 6) L070-1; 7) semihard drawn pipes; 8) extruded pipes. 9) LS59-1; 10) LZh-Mts9-1-1.

plied according to GOST 2624-44.

Round and shaped tubes for radiator of different sizes are made from L96 brass according to GOST 529-41 and GOST 2644-44 with an ultimate strength of 35-60 kg/mm^2. Tubes for bellows from L80 brass are supplied according to GOST 5685-51. Pipes with other dimensions are supplied in accordance with special technical specifications. The mechanical properties of brass pipes are given in the table.

Ye.S. Shpichinetskiy

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508	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = All-Union State Standard

11-69K

BRASS PLATING OF THE TITANIUM ALLOYS is the creation of a brass layer on the surface of details. Brass plating of the titanium alloys can be accomplished after preliminary copper plating by deposition of the brass from a galvanic bath or as a result of diffusion annealing of copper plated details without air access in a mixture of powders of composition: 30% zinc, 60% chamotte, 8% ferrosilicon, and 2% ammonium chloride. With a copper layer thickness of 1.0 mm the annealing temperature is 730-740°, duration 6-7 hours. After this processing, on the surface of the detail there is formed two-phase brass and under this layer there is a layer of single-phase brass. Brass plating is one of the methods for improving the antifriction properties of titanium and its alloys.

References: Anitov I.S., Maksimova A.G., ZhPkh, 1960, Vol. 33, No. 12.

I.S. Anitov

BRASS SHEET AND STRIP are produced by cold and hot rolling. The dimensions of the hot- and cold-rolled sheet and strip which are most widely used are established by specifications. The hot-rolled sheet made from the L62, L062-1 and LS59-1 brasses and the cold-rolled sheet and strip from the L68, L62, LMts58-2, L062-1 and LS59-1 brasses are delivered in accordance with GOST 931-52. The hot-rolled sheets are produced in thickness from 5 to 22 mm, width and length 600x1500, 710x x1410 and 1000 x 2000 mm. The cold-rolled sheets are produced in thickness from 0.4 to 10 mm and the same widths and lengths as the hot-rolled sheet. The cold-rolled strip is delivered in thickness from 0.4 to 10 mm, width from 40 to 500 mm and length from 500 to 2000 mm. Sheet and strip of other dimensions are produced in accordance with special Specifications.

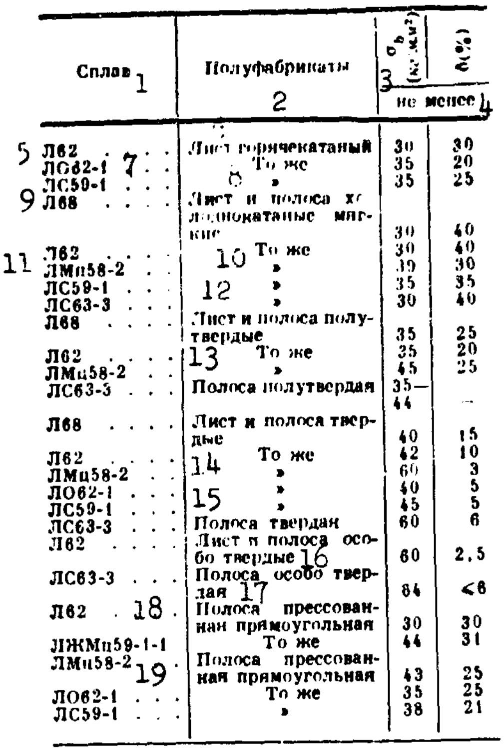
The cold-rolled sheet and strip in the soft (M) condition are produced from the L68, L62, LMts58-2 and LS59-1 brasses; the half-hard (PT) sheet and strip are made from the L68, L62 and LMts58-2 brasses; the hard (T) are made from the L68, L62, LMts58-2, L062-1 and LS59-1 brasses; and the extra hard are made from the L62 brass. Cold-rolled strip made from the LS63-3 watchmaker's brass is delivered in accordance with GOST 4442-48 in the soft, half-hard and extra hard conditions.

Rectangular strips from the L62, LZhMts59-1-1, LMts58-2, L062-1 a and LS59-1 brasses in the pressed form of thickness from 5 to 25 mm and width from 10 to 60 mm, and drawn strip of thickness from 3 to 10 mm and width from 6 to 30 mm are produced in accordance with GOST 6688-53. Soft tombac strips for cladding of thickness 1.1 to 1.6 mm, width 247-

390 mm and length 415-1030 mm are produced in accordance with GOST 2205-53. The mechanical properties of the brass sheet and strip are shown in Table 1 and the Erichsen penetration depth for the L62 and L68 brasses are presented in Table 2.

TABLE 1

Mechanical Properties of Brass Sheet and Strip (GOST 931-52 and GOST 4442-48)



Сплав 1	Полуфабрикаты 2	σ_b (кг/мм²) 3	δ(%)
		не менее 4	
5 Л62	Лист горячекатаный	30	30
ЛО62-1 7	То же	35	20
ЛС50-1	8 »	35	25
9 Л68	Лист и полоса холоднокатаные мягкие	30	40
Л62	10 То же	30	40
11 ЛМц58-2	»	39	30
ЛС59-1	12 »	35	35
ЛС63-3	»	30	40
Л68	Лист и полоса полутвердые	35	25
Л62	13 То же	35	20
ЛМц58-2	»	45	25
ЛС63-3	Полоса полутвердая	35—44	—
Л68	Лист и полоса твердые	40	15
Л62	14 То же	42	10
ЛМц58-2	»	60	3
ЛО62-1	15 »	40	5
ЛС59-1	»	45	5
ЛС63-3	Полоса твердая	60	6
Л62	Лист и полоса особо твердые 16	60	2.5
ЛС63-3	Полоса особо твердая 17	84	<6
Л62 18	Полоса прессованная прямоугольная	30	30
ЛЖМц59-1-1	То же	44	31
ЛМц58-2 19	Полоса прессованная прямоугольная	43	25
ЛО62-1	То же	35	25
ЛС59-1	»	38	21

1) Alloy; 2) semimanufacture; 3) (kg/mm²); 4) not less than; 5) L; 6) hot-rolled sheet; 7) LO; 8) same; 9) LS; 10) cold-rolled soft sheet and strip; 11) LMts; 12) half-hard sheet and strip; 13) half-hard strip; 14) hard sheet and strip; 15) hard strip; 16) extra-hard sheet and strip; 17) extra-hard strip; 18) pressed rectangular strip; 19) LZhMts.

II-98k2

TABLE 2

Erichsen Penetration Depth (in mm) of Brass Sheet and Strip*

Сплав 1	2 Полуфабрикаты	3 Толщина (мм)			
		0,4—0,45	0,5	0,6—1	1,2—1,5
4 Л68 Л62	5 Лист и полоса холоднокатаные мягкие (не менее)	10 9,5	11 9,5	11,5 10	12 10,5
Л68 Л62	Лист и полоса полутвердые 6	8—10 7—9	9—11 7—9	9,5—11,5 7,5—9,5	11—13 8—10
Л68 Л62	Лист и полоса твердые 7	7—9 5—7	7—9 5—7	7,5—9,5 5,7—7,5	— -

* Punch diameter 10 mm.

1) Alloy; 2) semimanufacture; 3) thickness (mm); 4) L; 5) cold-rolled soft strip and sheet (not less than); 6) half-hard sheet and strip; 7) hard sheet and strip.

Ye.S. Shpichinetskiy

BRASS STRIP is produced from the brass types L68, L62, LS59-1 and LMts58-2 with thickness from 0.05 to 2 mm and width from 300 to 600 mm.

The brass strips are delivered in accordance with GOST 2208-49 in the soft, half-hard and hard conditions. Strips of other dimensions are produced in accordance with special technical specifications. The brass strip is used for various details and products in machine construction and other branches of industry. Tombac strip intended for elements of special cartridges are produced in accordance with GOST 8036-56. The L90 tombac is used to made soft strip of dimensions 0.56 × 82 and 1.08 × 138 mm. Strip made from watchmaker's leaded brass is delivered in accordance with GOST 4442-48 in the soft, half-hard and extra hard conditions. The mechanical properties of the brass strip are presented in Tables 1 and 2.

TABLE 1

Mechanical Properties of Brass Strip (GOST 2208-49, 8036-56 and 4442-48)

Сплав 1	Состояние материала 2	σ_b (кг/мм²) 3	δ(%)
		4 не менее	
Л68 5	Мягкое 8	30	40
Л62	То же	30	35
ЛМц58-2 6	» 9	39	30
ЛС59-1	»	35	25
Л90 7	»	26	38
ЛС63-3	»	30	40
Л68	Полутвердое	35	25
Л62	То же	38	20
ЛМц58-2	» 10	45	25
ЛС63-3	»	35—44	—
Л68	Твердое	40	15
Л62	То же	42	10
ЛС59-1	» 11	45	5
ЛМц58-2	»	60	3
ЛС63-3	»	44—56	6
Л68	Особо твердое	56	13 4
Л62	То же	60	2.5
ЛС63-3	» 12	64	Не более 5

1) Alloy; 2) material condition;

3) (kg/mm^2); 4) no less than; 5) L; 6) LMts; 7) LS; 8) soft; 9) same; 10) half-hard; 11) hard; 12) extra hard; 13) no less than.

TABLE 2

Erichsen Penetration Depth (GOST 2208-49, 8036-56 and 4442-48)

Сплав 1	Состояние материала 2	3 Толщина ленты (мм)				
		4 до 0,25	0,3—0,55	0,6—1,1	1,2—1,6	1,7—2
		5 Глубина продавливания (мм) пуансоном диаметром 10 мм, не менее				
Л68 6	Мягкое 7 8	9	11	11,5	12	12,5
Л62	То же	7,5	9,5	10	10,5	11
Л68	Полутвердое 9	7—9	9—11	9,5—11,5	10—12	10,5—12,5
Л62	То же	5,5—7,5	7,5—9,5	8—10	8,5—10,5	9—11
Л68	Твердое 10	5—7	7—9	7,5—9,5	—	—
Л62	То же	3—5	5,5—7,5	6—8	—	

1) Alloy; 2) material condition; 3) strip thickness (mm); 4) up to; 5) penetration depth (mm) of 10 mm diameter punch, no less than; 6) L; 7) soft; 8) same; 9) half-hard; 10) hard.

Ye.S. Shpichinetskiy

III-98p

BRASS WIRE – manufactured from brass of various types, including L68, L62, and LS59-1 (GOST 1066-58). This wire can be round (from 0.1 to 12 mm in diameter), square, or hexagonal (with an inscribed-circle diameter of from 3 to 12 mm). Brass wire of other sizes is produced in accordance with special TU. Wire of this type is produced in soft, semihard, and hard varieties. It is used in instrument building and in light industry, for the manufacture of furniture, nails, etc.

Ye.S. Shpichinetskiy

BREAKDOWN – a process preceding fracture under stress and terminating in disruption of the structure of the material and formation of nuclei (foci) from which cracks propagate when the load (or its action time) is increased. Breakdown is also referred to as degradation. It is difficult to distinguish breakdown from prior (elastic, highly elastic, and plastic deformation) and subsequent true fracture) processes, since they all take place simultaneously. In order elucidate this phenomenon it is necessary to study the structure of the material under high magnification (by electron microscopy and x-ray- and electron-defraction techniques) and the changes in its physical and chemical properties (magnetic, electrical, electrochemical) and certain of its mechanical characteristics (damping, etc.).

Ya.B. Fridman

BRIDGE STEEL is open-hearth, carbon, hot-rolled steel for welded and riveted bridge structures. Bridge steel is produced in accordance with GOST 6713-53 in the form of rods, profiels, sheets and wide strip. It issued without heat treatment. Welding of all forms is used in fabrication of the welded structures.

TABLE 1

Chemical Composition and Application of Bridge Steel

Сталь 1	Назначение 2	3 Содержание элементов (в %)				
		C	Mn	Si	S	P
					4 не более	
5 М16С	6 Сварные мостовые конструкции	0,12–0,2	0,4–0,7	0,12–0,25	0,045	0,04
Ст. 3 мост 7	8 Клепаные мостовые конструкции	0,14–0,22	0,4–0,65	0,15–0,3	0,05	0,045

1) Steel; 2) application; 3) content of elements (in %); 4) not more than; 5) M16S; 6) welded bridge structures; 7) bridge steel 3; 8) riveted bridge structures.

TABLE 2

Mechanical Properties of Bridge steel (No Less Than)

1 Сталь	$\sigma_т$	$\sigma_в$	δ (%)				5 ψ (факультативно) (%)
	2 кг/мм²		3 для длинного образца		4 для короткого образца		
			6 [illegible]	7 [illegible]	[illegible]	[illegible]	
8 М16С	23	38	24	22	28	26	50
9 Ст. 3 мост	24	38	26	22	28	26	50

1) Steel; 2) kg/mm^2; 3) for long specimen; 4) for short specimen; 5) ψ (optional) (%); 6) rods, profiles; 7) sheet, strip; 8) M16S 9) bridge steel 3.

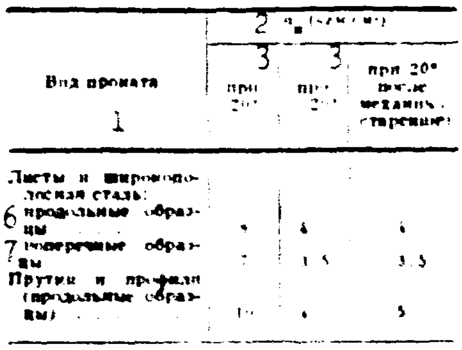
The M16S steel is deoxidized by additional introduction of aluminum into the ladle. With the agreement of the user, bridge steel 3 may also be delivered in rimming form. Standards for relative elongation are applicable to sheet and strip of thickness 8-20 mm, and profiles of thickness 8-40 mm.

The bridge steels are tested in the cold condition for 180-degree bending until the edges touch for thicknesses to 25 mm, with greater thickness they are bent around a mandrel with diameter equal to the sheet or strip thickness.

For the M16S steel the impact strength is determined after aging in accordance with the method for testing the sensitivity to mechanical aging following GOST 7268-54 (10% strain hardening and aging at 250° for 1 hour).

TABLE 3

Impact Strength of Bridge Steel
(No Less Than)



Вид проката 1	2 $a_н$ (кгм/см²)		
	3 при 20°	3 при [illegible]	при 20° после механич. старения
5 Листы и широкополосная сталь:			
6 продольные образцы	[illegible]	4	4
7 поперечные образцы	[illegible]	3.5	3.5
8 Прутки и профили (продольные образцы)	10	4	5

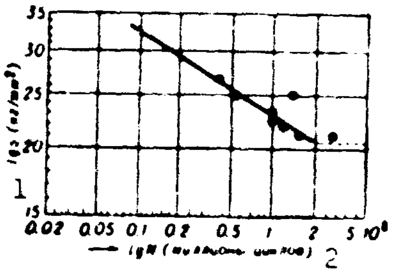
1) Form of rolled stock; 2) a_n (kgm/cm^2); 3) at 20°; 4) at 20° after mechanical aging; 5) sheet and wide strip steel; 6) longitudinal specimens; 7) transverse specimens; 8) rods and profiles (longitudinal specimens).

TABLE 4

Average Statistical Indices of Mechanical Properties of M16S

Толщина (мм) 1	Количество испытаний 2	σ_T	σ_B	δ	ψ	$a_н$ (кгм/см²) 3			
		(кг/мм²) 6		(%)		в состоянии поставки 20° 4		после наклепа и старения 20° 5	
						вдоль прокатки 7	поперек прокатки	вдоль прокатки	поперек прокатки 8
				Листы 9					
8–20	560	40	55.[illegible]	26	55.8	11.[illegible]	7.5	9	5.5
21–40	850	26.7	[illegible]	27.2	[illegible]	10	[illegible]	[illegible]	5
41–60	270	40	[illegible]	26.9	52.[illegible]	[illegible]	[illegible]	—	5
		Широкополосная сталь 10							
8–20	1170	30.7	57	26.2	55	9	—	[illegible]	—
21–32	470	27.8	45.7	22.6	60.1	[illegible]		[illegible]	—
33 и более 11	300	28.4	45.3	21.5	[illegible]	[illegible]		7.5	[illegible]

1) Thickness (mm); 2) number of tests; 3) a_n (kgm/cm^2); 4) as delivered, 20°; 5) after strain hardening and aging, 20°; 6) (kg/mm^2); 7) in rolling direction; 8) across rolling direction; 9) sheets; 10) wide strip steel; 11) 33 and more.



Fatigue strenght of M16S steel. 1) lg σ (kg/mm^2); 2) lg N (million cycles).

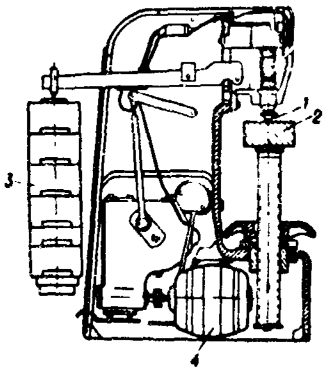
Table 4 presents the average values of the mechanical properties of the M16S steel obtained by statistical processing of the results of acceptance tests of sheets at the Magnitogorsk Metallurgical Combine (1959) and tests of wide strips at the Dzerzhinsk Metallurgical Plant (1959).

The figure shows the fatigue strength of M16S steel determined with asymmetric loading cycle on flat specimens 660-m long, 2-mm thick and 80-mm wide in the working section. The 15KhSND low-alloy high-strength steel is used in bridge structures with long spans to reduce the weight (0.6-0.9% Cr: 0.3-0.6% Ni; 0.2-0.4% Cu. It is recommended that this steel be substituted by the cheaper 10G2SD (MK) steel defined in GOST 5058-57 which contains less of the scarce alloying elements. The tensile strength of the 15KhSND steel is no less than 52 kg/mm^2, the yield strength is 35 kg/mm^2; the corresponding figures for the 10G2SD (MK) steel are respectivlely no less than 50 kg/mm^2 and 35 kg/mm^2.

References: Paton Ye.O., Shevernitskiy V.V., Stal'dlya svarnykh mostov (Steel for Welded Bridges), in book: Trudy po avtomaticheskoy svarke pod flyusom (Papers on Automatic Welding Under Flux), collection No. 6, Kiev, 1949; Kasatkin B.S., O stali dlya svarnykh mostov (On steel for Welded Bridges), ibid, collection No. 2-3, Kiev, 1948; Shevernitskiy V.V., et al., Staticheskaya prochnost' svarnykh soyedineniy iz malouglerodistoy stali (Static Strength of Weld Joints Made From Low Carbon Steel), Kiev, 1951, Bol'shakov K.P., et al., Vibratsionnaya prochnost' svarnykh mostov (Vibrational Strength of Welded Bridges), M., 1952; Navrotskiy D.I., Prochnost' svarnykh soyedineniy (Strength of Weld Joints), M.-L., 1961; Tsel'nosvarnyye proletnyye stroyeniya zheleznodorozhnykh mostov (All-Welded Spans of Railway Bridges), M., 1955 (Trudy NII mostov, v. 4) (Transactions of the Scientific Research Institute for Bridges, Vol. 4); Povysheniye mekhanicheskikh svoystv mostovoy stali (Improving the mechanical properties of bridge steel), Stal' (Steel), 1955, No. 10.

E.Sh. Volokhvyanskaya

BRINELL METHOD – a method of determining the hardness of materials by pressing a quenched steel sphere (indentor) against the surface of the specimen or article. The Brinell hardness (HB) is the mean specific pressure exerted on the surface of the indentation (kg/mm^2). The dia-



TSh hardness gauge: 1) Spherical tip; 2) test specimen: 3) interchangeable weights; 4) electric motor.

Conditions for Brinell Tests

Материал	*HB* (кг мм^2)	Толщина изделия или образца (мм)	Диаметр шарика (мм)	Нагрузка (кг)	Выдержка под нагрузкой (сек.)
Черные металлы	140—450	от 6 до 3 от 4 до 2 менее 2	10.0 5.0 2.5	3000 750 187.5	10
То же	менее 140	более 6 от 6 до 3 менее 3	10.0 5.0 2.5	1000 250 62.5	10
Цветные металлы	более 130	от 6 до 3 от 4 до 2 менее 2	10.0 5.0 2.5	3000 750 187.5	30
Цветные металлы (медь, латунь, бронза, сплавы магния)	35—130	от 9 до 3 от 6 до 3 менее 3	10.0 5.0 2.5	1000 250 62.5	30
Цветные металлы и сплавы (алюминий, баббиты)	8—35	более 6 от 6 до 3 менее 3	10.0 5.0 2.5	250 62.6 15.6	60

1) Material; 2) HB (kg/mm^2); 3) thickness of article or specimen (mm); 4) sphere diameter (mm); 5) load (kg); 6) loading time (sec); 7) ferrous metals; 8) the same; 9) nonferrous metals; 10) nonferrous metals (copper, brass, bronze, magnesium alloys); 11) nonferrous metals and alloys (aluminum, babbit); 12) less than; 13) more than; 14) from; 15) to.

meter of the indentation is measured with a magnifying glass (to within 0.05 mm) or gauges after the load has been removed and the radius of curvature is assumed to be equal to the radius of the sphere. In practice, the diameter of the indentation is often used for evaluating hardness by the Brinell method. The conditions for Brinell hardness tests have been established by GOST 9012-59. Devices known as hardness gauges can be used to make indentations under standard conditions. The figure shows the setup of the TSh semiautomatic hardness gauge. The spherical tip is pressed into the test specimen under the action of the force set up by the interchangeable weights when the electric motor is switched on. Observance of a predetermined loading time is ensured by a device which reverses the motor (in order to remove the load) and switches it off after the loading system has returned to its initial position. This method was proposed in 1900 by the Swedish engineer I.A. Brinell.

References: Shaposhnikov, N.A., Mekhanicheskiye ispytaniya metallov [Mechanical Testing of Metals], 2nd Edition, Moscow-Leningrad, 1954; O'Neill, G., Tverdost' metallov i yeye izmereniye [Hardness of Metals and Its Measurement], translated from English, Moscow-Leningrad, 1940.

I.V. Kudryavtsev and D.M. Shur

BRINELL HARDNESS - standard physicomechanical characteristic of a material, which determines its ability to resist local plastic deformation which is produced by statically forcing into the product or specimen surface a hardened steel ball 2.5, 5 or 10 mm in diameter. The methods for determining the Brinell hardness are presented in GOST 9012-59.

The Brinell hardness (or hardness number) HB is determined as the ratio of the lead P when making the impression to the area f of the surface of the spherical indentation, whose diameter d is measured after the load is removed;

$$HB = \frac{P}{f} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}.$$

By its physical meaning the hardness number (kg/mm^2) is the mean specific pressure at the surface of contact between the ball and the product when the indentation is made. The Brinell hardness depends on the relationship between the load and the ball diameter. Hence the Brinell hardness numbers for the same material obtained when impressing balls of different diameters (D_1 and D_2) are found to be equal only upon satisfying the similarity condition, consisting in the equality of impression angles. Here the loads are selected by the ratio

$$\frac{P_1}{D_1^2} = \frac{P_2}{D_2^2}.$$

Brinell hardness is determined on special hardness testers. The Brinell hardness of many materials is satisfactorily related to other major mechanical properties, in particular to the ultimate strength; $\sigma_b = k \cdot HB$.

For carbon steel, for example, k = 0.36 (see Hardness).

References: Shaposhnikov, N.A., Mekhanicheskiye ispytaniya metallov [Mechanical Testing of Metals], 2nd edition, Moscow-Leningrad, 1954.

I.V. Kudryatsev and D.M. Shur

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523	ГОСТ = GOST = Gosudarstvennyy obshesoyuznyy standart = All-Union State Standard

BRITTLENESS OF BERYLLIUM. The insufficient plasticity of beryllium limits its application.

There exists two points of view concerning the nature of the brittleness of beryllium. According to the one, the brittleness is an intrinsic property of beryllium, and, therefore, the solution of the problem of plasticity by establishing a preferable orientation (by working under pressure, for example) may result in a sufficient plasticity in two directions, but, probably at the expense of an almost total loss of the plasticity in the third direction. According to the other opinion, the brittleness of beryllium is caused by impurities which distort the crystal lattice; therefore, the problem of plasticity must be solved by an improved refining of the metal.

Sliding occurs in beryllium only along the basis plane (0001) and the prism plane $(10\bar{1}0)$, the twinning, however, on the pyramide plane $(10\bar{1}2)$ and, in a lower degree along the planes $(10\bar{1}1)$ and $(10\bar{1}3)$. Sliding along the basis plane predominates in polycrystalline beryllium because the cleaving stress along the basis plane amounts to one-fourth of the stress along the prism plane. Sliding along the basis causes a curvature which results in the destruction along the basis plane or the plane of the prism of second type $(11\bar{2}0)$. The formation of the curvature and the destruction along the $(11\bar{2}0)$ plane is caused also by twinning. A considerable sliding without destruction is only possible along the prism planes $(10\bar{1}0)$. A rise in the temperature to 500° involves a considerable decrease of the cleaving stress along the prism planes and an insignificant increase of the sliding stress along the basis. The high increase in plasticity is connected with the decrease of the tendency to slide along the basis, a favored sliding along the prism plane, and an inhibited twinning. Sliding along the planes $(10\bar{1}X)$ of the pyramide occurs at high temperatures also.

An intense distortion of the lattice and, therefore, brittleness caused by the presence of dissolved oxygen, nitrogen, hydrogen or carbon must occur due to the small size of the beryllium atom (2.22 A).

Sliding deformation proceeds most readily along the planes with the highest atom density and the greatest interplanar spacings. The ratio c/a of the crystal axes of beryllium is equal to 1.568, i.e., it is considerably lower than that of an ideal crystal (1.663). Compression along the <u>c</u> axis reduces the interplanar spacing and the packing density on the basis planes, which, therefore, must not be sliding planes. Interstitial atoms especially oxygen atoms, are concentrated close to the prism plane and oppose the sliding along this plane. Sliding along the prism plane $(10\bar{1}0)$, therefore, only becomes prevalent when the purity of the system is increased. An increased purity of beryllium reduces the cleaving stress for sliding along a prism plane to a value lower than that needed for sliding along a basis, resulting in an increased plasticity of the beryllium.

Due to the fact that only a limited number of deformation mechanisms are possible in beryllium, any prevalent orientation will strongly effect the mechanical properties. The methods to increase the plasticity of beryllium by forming a texture are based on this fact. Because of the fact that the sliding occurs predominantly along the basis plane, it is necessary that the latter is situated parallel to the direction of the dilation when a highly plastic material is desired. A high plasticity is realizable also in the case when the $(10\bar{1}0)$ planes are perpendicular to the axis of the force because a double shift takes place. If, however, the $(11\bar{2}0)$ planes are perpendicular to the axis of the force, only the $(10\bar{1}0)$ planes will take part in the sliding mechanism, and a poorer plasticity occurs.

Reducing the grain size is one of the methods used to increase the plasticity of beryllium. The use of a finer ground powder is almost the only method of obtaining a fine grain; an increase in the content of oxide occurs in this case, which limits the application of this method.

Attempts to improve the plasticity of beryllium by alloying in order to realize a deoxidation, to stabilize the β phase, to reduce the grain size in the ingot, to obtain solid solutions, and to increase the interplanar spacing have not been successful.

A certain amount of success in increasing the plasticity of beryllium was attained in special cases. One method succeeded, for example, in attaining an elongation up to 140% (under a certain slope of the basis plane to the axis of dilation) by refining a beryllium singly-crystal by zone melting; the total sliding deformation was 220% in this case.

Long annealing of beryllium (at 600-850°) has a favorable effect on the plasticity of beryllium at higher temperatures, especially on that of the extruded cast metal. A peak of plasticity is not observable in this case, and an elongation of about 70% is attainable instead of the normal 10-12%.

For information on the plasticity of commercial beryllium produced by various technological methods see Beryllium.

References: Berilliy [Beryllium], edited by D. White and J. Berk, translated from English, Moscow, 1960, pages 326-446; Darwin, G.E., Buddery, J.H., Beryllium, London, 1960; Conference on the Metallurgy of Beryllium, London, 1961.

S.B. Kostogarov

BRITTLENESS OF STEEL on wetting by low-melting metals – is a strong reduction of the plasticity and, in many cases, also of the strength at the moment when the surface of a stressed steel is wet with molten low-melting metals. The contact of the steel with a molten metal coating may cause the strength to drop below the value of the external and internal stresses (taking into account the stress concentration) and result in a brittle failure; this effect is observable not only with steel but also with many other metals. It was found that this type of brittleness occurs in those cases where the basic and the surface metal are either mutually insoluble or possess only a very small region of solubility. Metals forming a solid solution with the basic metal do not cause brittleness. The physical nature of the brittleness of steel is explained by an adsorptional penetration of the molten metal coating into the zone of a pre-existing defect, by a lowering of the surface energy, and by a decrease of the tensile strength (see Rebinder's effect). Brittleness of steel at relatively low temperatures occurs in practice most frequently when molten low-melting solders and also when tin or cadmium come into contact with the steel. The low-melting metals usually penetrate into the cracks which are formed on the surface as the steel object is injured by wetting. This characteristic may be utilized to distinguish this type of destruction from other types. When the molten coating fills only a part of the crack, the other part not being protected by the coating, acquires the temper color which corresponds to the given temperature. The oxidized section of the crack (or the failure) is very often mistaken for an internal flaw of the part and for the cause of the fracture.

A contact between steel and a solid or solidified metal coating is almost harmless (when ignoring the hydrogenation during electroplating); therefore, if no cracking or failure occurs during soldering or other cases of contact of stressed steel with molten coatings, a brittleness will not take after the solidification of the coating. The effect of molten coatings or the strength of steel becomes more significant at higher temperatures, and the effect of the molten coating also becomes more significant when the tensile strength of the steel is increased. The presence of notches, changes in the cross section with a small radius, and other stress concentrators strongly affect the tendency of steel to yield to this type of brittle failure. Thus, for example, the destructive bending load of a specimen of 30KhGSA steel (σ_b = 120 kg/mm^2) with a diameter of 19 mm and a 2 mm deep circular notch with an angle of 90° and an apex radius of 0.1 mm was equal to 12,000 kg at 300°, but only 1500 kg when coated with tin.

The thickness of the molten coating does not affect the brittleness of the steel, therefore, the brittleness appears in practice in the case of electroplatings frequently with a thickness of only a few μ when the steel part works at a temperature which is higher than the melting point of the coating; a brittle failure of bolts and other threaded parts electroplated with cadmium occurs after heating them above 321° (the melting point of cadmium). These failures occur under the action of both the working stress and stresses generated by the previous tightening of the bolts during the assembly. Internal stresses generated by dressing the parts after the heat treatment, or by making local hollows, nicks and marks are frequently sufficient to cause the destruction of steel parts by molten coatings. Application of an electroplated underlayer with a higher melting point, of copper, for example, may somewhat decrease the brittleness of steel.

Although the brittle fracture caused by a molten metal coating occurs along the grain boundaries, a diffusion of the low-melting coatings into the steel does not, as a rule, take place. The brittleness is caused in some cases by the diffusion of the surface metal along the grain boundaries. This type of brittleness occurs at relatively high temperatures in contrast to the brittleness connected with the "Rebinder effect," and it does not disappear after the solidification of the coating. This type of brittleness appears in practice when using molten zinc, either as the result of the hardening heating of zinc-plated parts (frequently after the second heating) or of the hardening heating of parts of stainless steel stamped in dies made from a zinc-containing alloy.

References: Potak, Ya.M., Khrupkiye razrusheniya stali i stal'nykh detaley [Brittle Failures of Steel and of Steel Parts], Moscow, 1955.

Ya.M. Potak

III-28kh

BRITTLE TEMPERATURE – is the temperature below which the material undergoes a brittle failure while not displaying any appreciable residual deformation. Cold-short metals survive a plastic deformation, the plastics, however, a forced-elastic deformation above the brittle temperature. This may be explained by the fact that the yield stress (of metals) or the limit of the forced elasticity (of polymers) decreases at rising temperature and becomes smaller above the brittle temperature than the tensile strength. The brittle temperature is a conditional term because it depends on the test conditions: on the strain conditions, on the type of the stressed state, on the size of the specimen, and on other factors. A comparison of different materials, therefore, must be carried out under similar test conditions. The brittle temperature depends not only on the type of the material but also on its structure, especially in the case of metal alloys and solid polymers. The brittle temperature of polymers lowers when the orientation of the molecules is increased.

References: Kargin, V.A., Slonimskiy, G.L., Kratkiye ocherki po fiziko-khimii polimerov [Short Essays on the Physical Chemistry of Polymers], Moscow, 1960.

G.M. Bartenev

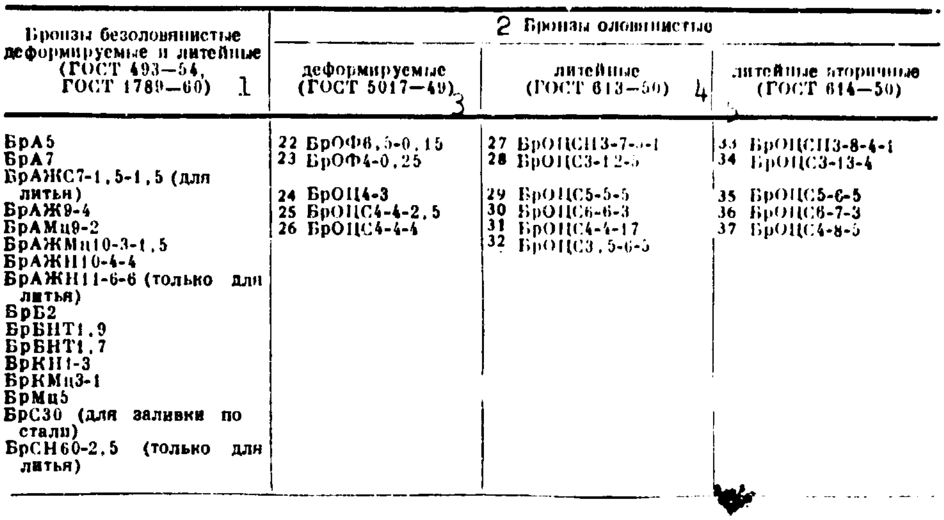
BRIZOL - see Bituminous materials.

BRONZE – an alloy based on copper alloyed with various elements; copper-zinc alloys are called brasses. Other exceptions are copper-manganese alloys containing ~85% Cu, which are called manganins, and copper-nickel alloys containing ~80% Cu, which are called cupronickels. Bronze readily undergoes pressure working and many types are produced in strips, sheets, bars, and wire. It is also an excellent casting material and is used in engineering and the fine arts. Bronze is corrosion-resistant under atmospheric conditions, in aqueous solutions of salts and organic compounds, in salt water, and in superheated steam. Beryllium bronzes and Aluminum bronzes have an especially high corrosion resistance. The properties of bronze exhibit little change at temperatures of up to 300° and special bronzes are suitable for working at 500-600°. Aluminum and tin bronzes are the most widely used in practice.

Aluminum bronzes are distinguished by high strength and plasticity and are consequently used for structural components in machine building (fasteners, brackets, flanges, etc.). They have good casting properties, permit pressure working (especially when hot), and are readily cut. The properties of aluminum bronzes include: $\sigma_b = 40\text{–}65$ kg/mm^2; $\sigma_{0.2} = 20\text{–}35$ kg/mm^2; $E = 10{,}000\text{–}12{,}000$ kg/mm$_2$; $\delta = 5\text{–}15\%$; $\sigma_{-1} = 20\text{–}30$ kg/mm^2; HB = = 140-220 kg/mm^2.

Tin bronzes have a rather high strength and good antifriction characteristics and durability. They are very useful technologically and are produced as bars, tubes, strips, bands 0.1 mm thick, sheets, and wire. They are used for critical components which must function under friction, wear-resistant screening, etc. Special casting tin bronzes are used in the manufacture of bearings. The properties of tin bronzes include: $\sigma_b = 30\text{–}45$ kg/mm^2; $\sigma_{0.2} = 15\text{–}25$ kg/mm^2; E = 10,000–11,000 kg/mm^2; $\delta = 10\text{–}20\%$; $\sigma_{-1} = 18\text{–}22$ kg/mm^2; HB = 80–150 kg/mm^2.

Principal Types of Bronze, According to GOST



Бронзы безоловянистые деформируемые и литейные (ГОСТ 493—54, ГОСТ 1789—60) 1	2 Бронзы оловянистые		
	деформируемые (ГОСТ 5017—49) 3	литейные (ГОСТ 613—50) 4	литейные вторичные (ГОСТ 614—50)
6 БрА5 7 БрА7 8 БрАЖС7-1,5-1,5 (для литья) 9 БрАЖ9-4 10 БрАМц9-2 11 БрАЖМц10-3-1,5 12 БрАЖН10-4-4 13 БрАЖН11-6-6 (только для литья) 14 БрБ2 15 БрБНТ1,9 16 БрБНТ1,7 17 БрКН1-3 18 БрКМц3-1 19 БрМц5 20 БрС30 (для заливки по стали) 21 БрСН60-2,5 (только для литья)	22 БрОФ6,5-0,15 23 БрОФ4-0,25 24 БрОЦ4-3 25 БрОЦС4-4-2,5 26 БрОЦС4-4-4	27 БрОЦСН3-7-5-1 28 БрОЦС3-12-5 29 БрОЦС5-5-5 30 БрОЦС6-6-3 31 БрОЦС4-4-17 32 БрОЦС3,5-6-5	33 БрОЦСН3-8-4-1 34 БрОЦС3-13-4 35 БрОЦС5-6-5 36 БрОЦС6-7-3 37 БрОЦС4-8-5

1) Tin-free shaping and casting bronzes (GOST 493-54 and 1789-60); 2) tin bronzes; 3) shaping (GOST 5017-49); 4) casting (GOST 613-50); 5) secondary casting (GOST 614-50);6) BrA5; 7) BrA7; 8) BrAZhS7-1.5-1.5 (for casting); 9) BrAZh9-4; 10) BrAMts9-2; 11) BrAZhMts10-3-1.5; 12) BrAZhN10-4-4; 13) BrAZhN11-6-6 (for casting only); 14) BrB2; 15) BrBNT1.9; 16) BrBNT1.7; 17) BrKN1-3; 18) BrKMts3-1; 19) BrMts5; 20) BrS30 (for plating steel); 21) BrSN60-2.5 (for casting only); 22) BrOF6.5-0.15; 23) BrOF4-0.25; 24) BrOTs4-3; 25) BrOTsS4-4-2.5; 26) BrOTsS4-4-4; 27) BrOTsSN3-7-5-1; 28) BrOTsS3-12-5; 29)BrOTsS5-5-5; 30) BrOTsS6-6-3; 31) BrOTsS4-4-17; 32) BrOTsS3.5-6-5; 33) BrOTsSN3-8-4-1; 34) BrOTsS3-13-4; 35) BrOTsS5-6-5; 36) BrOTsS6-7-3; 37) BrOTsS4-8-5.

The new technology has found applications for high-elasticity beryllium bronzes, thermally- and electrically-conductive chromium bronzes, etc. The ultimate strength of heat-treated beryllium bronzes reaches 130-140 kg/mm^2, while their yield strength reaches 110-120 kg/mm^2. These bronzes are distinguished by high plasticity when quenched, which means that they are easily formed during the manufacture of stampings from thin sheets. Tempering gives such components strength and elasticity. Beryllium bronzes are employed for elastic elements in the manufacture of precision instruments (flat and helical springs, membranes, silfons, spring contacts, etc.); their thermal and electrical conductivity is quite low ($\lambda = 0.25$ cal/cm•sec•°C, $\rho = 0.08$ ohm•mm^2/ /m).

Bronzes with a high thermal and electrical conductivity contain no less than 98.5% Cu and small quantities of alloying elements with a low solubility in solid copper. Such alloys as the chloride bronze BrKh0.5 and cadmium-copper have a $\lambda = 0.8$ cal/cm•sec•°C at 600° and a $\rho = 0.02$ ohm•mm^2/m at 20°. Special high-hot-strength thermally conductive bronzes ($\lambda = 0.5$–0.6 cal/cm•sec•°C) have high strength at elevated temperatures. On loading for 30 min at 600° the hardness of cadmium-copper is 8 kg/mm^2, that of BrKh0.5 is 20 kg/mm^2, that of VBr1 is 40 kg/mm^2, and that of MTs3 is 45 kg/mm^2.

Lead bronzes and Antimony bronzes, which have high antifriction characteristics, are excellent bearing materials for friction units. They can withstand high specific pressures and sliding speeds without grabbing and are suitable for operation in low-viscosity media and at elevated temperatures (200-300°).

These metals can be divided into Shaping bronzes and Casting bronzes. Casting bronzes also include tin Secondary bronzes, which are manufactured from remelted worn-out components and other scrap.

The trademark of every bronze begins with the letters Br, followed by the initial letters of the alloying elements and figures corresponding to their percentage content in the alloy. The letters and figures are usually arranged in order of descending alloying-element content. For example, the aluminum-iron-manganese bronze containing 10% Al, 3% Fe, and 1.5% Mn has the trademark BrAZhMts10-3-1.5, while the tin-phosphorus bronze containing 6.5% Sn and 0.15% P has the trademark BrOF6.5-0.15. The table shows the principal types of bronze established by the GOST.

During the production of bronzes they may be contaminated with various impurities from the charge and the atmosphere: these are both metallic, principally from the scrap and casting wastes, and organic, from production wastes (the various lubricants employed in pressure working and cutting). The most detrimental impurities are those which promote formation of gas bubbles in castings or make the alloy brittle and give it a tendency to crack during pressure working. Prime among these are bismuth, lead, antimony, arsenic, oxygen, iron, and silicon. Oxygen, which is found in copper as cupric oxide, causes formation of oxides of readily oxidized metals, such as aluminum and zinc. The presence of these metals in bronze reduces its quality. The oxygen content of copper is consequently strictly regulated (GOST 859-41); moreover, in making the melt the copper must be reduced before the remainder of the charge is added. Impurities of low-melting bismuth and lead, which are insoluble in solid copper, take the form of independent inclusions, often lying along the grain boundaries. These inclusions melt when the ingot is heated before pressure working and make the bronze hot-short. Impurities of antimony, arsenic, and sulfur, which form intermetallic compounds, lead to brittleness during pressure working.

Chemical Composition of Secondary Tin Bronzes (GOST 614-50)

Сплав и маркировка 1	Основные элементы (%) 2				Примеси (%, не более) 3					5 Применение
	Sn	Zn	Pb	Cu	Sb	Fe	Al	Si	4 Сумма примесей	
6 БрОЦСН3-8-4-1 * (полоса черного цвета)	2.5—4.5	7—10	3—6 0.5—1.5 Ni	Остальное 11	0.5	0.4	0.02	0.02	1.1	Шихтовой материал для бронзы БрОЦСН3-7-5-1 12
7 БрОЦС3-13-4 * (полоса зеленого цвета)	2—4	10—16	3—6		0.5	0.4	0.02	0.02	1.1	Шихтовой материал для бронзы БрОЦС-3-12-5 13
8 БрОЦС5-6-5 (полоса красного цвета)	4—6	4.5—7.0	4—6		0.5	0.4	0.05	0.05	1.1	Шихтовой материал для бронз БрОЦС5-5-5 и БрОЦС4-4-17 14
9 БрОЦС6-7-3 (полоса белого цвета)	5—7	6—9	2—4		0.5	0.4	0.05	0.05	1.1	Шихтовой материал для бронзы БрОЦС6-6-3 15
10 БрОЦС4-8-5 (полоса синего цвета)	3.5—5.0	6—10	4—6		0.5	0.4	0.05	0.05	1.1	Шихтовой материал для бронзы БрОЦС3.5-6-5 16

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*The total Si and Al should not exceed 0.02%. A Ni content of 1.5% (with respect to the copper content) is permissible in all bronzes.

1) Alloy and marking; 2) principal elements (%); 3) impurities (%, no more than); 4) total impurities; 5) application; 6) BrOTsSN3-8-4-1 (black band); 7) BrOTsS3-13-4 (green band); 8) BrOTsS5-6-5 (red band); 9) BrOTsS6-7-3 (white band); 10) BrOTsS4-8-5 (blue band); 11) remainder; 12) charge material for BrOTsSN3-7-5-1 bronze; 13) charge material for BrOTsS-3-12-5 bronze; 14) charge material for BrOTsS5-5-5 and BrOTsS4-4-17 bronzes; 15) charge material for BrOTsS6-6-3 bronze; 16) charge material for BrOTsS3.5-6-5 bronze.

Chemical Composition of Tin Bronzes for Artistic Casting (GOST 4116-48)

Сплав 1	2 Основные элементы (%)				3 Примеси (%, не более)				5 Применение
	Sn	Zn	Pb	Cu	Sb	Fe	Al	4 Сумма примесей	
6 БХ1	4—7	5—8	1—4	7 Остальное	1.0	1.0	0.1	3.0	Отливка скульптуры 8
БХ2	1—5	8—13	1—6		1.0	1.0	0.1	3.0	Крупное декоративное литье 9
БХ3	0.5—3.0	25—35	1—3		0.5	1.0	0.5	3.0	Мелкое декоративное литье 10

1) Alloy; 2) principal elements (%); 3) impurities (%, no more than); 4) total impurities; 5) application; 6) BKh; 7) remainder; 8) statuary casting; 9) large decorative castings; 10) small decorative castings.

Impurities of iron exceeding 0.02-0.05% are detrimental to pressure-worked tin bronzes, since they reduce their technological characteristics and corrosion resistance. The presence of more than 0.3% iron in silicon bronzes reduces their corrosion resistance. Iron is a component of aluminum bronzes. Other detrimental impurities in tin bronzes include aluminum,magnesium, and silicon, which are vigorously oxidized to form oxide films that often lie along the grain boundaries and reduce the density and sometimes the strength of castings. Strict restrictions have been established on the contents of a number of impurities for tin and tin-free bronzes. The total impurity content for casting bronzes is substantially higher (see Structural shaping bronze).

References: Smiryagin, A.P., Promyshlennyye tsvetnyye metally i splavy [Commercial Nonferrous Metals and Alloys], 2nd Edition, Moscow, 1956; Gorshkov, I.Ye., Lit'ye slitkov tsvetnykh metallov i splavov

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[Casting of Nonferrous Metals and Alloys], 2nd Edition, Moscow, 1952.

O.Ye. Kestner

BRONZE BARS — semifinished products manufactured from various types of bronze (tin, tin-free, aluminum, silicon, cadmium, chromium-zinc and beryllium bronzes). Such bars can be classified according to cross-section (as round, rectangular, or hexagonal) and according to production method (as drawn, pressed, or rolled). Bronze bars are produced to the following machining-precision classes: round drawn bars — 3a (OST NKM 1027), 4 (OST1024) and 5 (OST1025); round pressed bars — 7, 8, 9 (OST 1010), and precision group 10; round rolled bars — 9 (OST 1010) and precision group 10; square and hexagonal drawn bars — 4 (OST 1024) and 5 (OST 1025); pressed bars — 7 and 8 (OST 1010).

Round pressed bars with diameters of from 16 to 160 mm are fabricated from tin-free bronzes of type BrAMts 9-2, BrAZh9-4, BrAZhMts10-3-1.5, BrAZhN10-4-4, BrKMts3-1, BrKN1-3 in accordance with GOST 1628-60 (to precision classes 8 and 9); pressed square bars no less than 500 mm long are produced from BrAZh9-4 (160 ± 3 mm on each side) in accordance with TTsM01319-54; round drawn bars ranging from 5 to 40 mm in diameter are fabricated from BrAMts9-2 and BrKMts3-1 bronzes (to precision classes 4 and 5); square and hexagonal drawn bars with nominal inscribed-circle diameters of from 5 to 36 mm are produced from BrKMts3-1 bronze (to precision classes 4 and 5). Bars are manufactured from BrNA13-3 nickel-aluminum bronze in accordance with TsMTU 3443-53 and are intended for components with increased strength and heat-resistance to be employed in various areas of machine building. Round, square, and hexagonal drawn bars ranging from 6 to 32 mm in diameter and from 1 to 4 mm in length are produced from BrB2 beryllium bronze in accordance with TsMTU 274-41; round drawn bars with diameters of from 5 to 40 mm (precision classes 4 and 5) and pressed bars with diameters of from 20 to 120 mm are fabricated from tin-zinc bronze in accordance with GOST 6511-60. Bars of chromium-zinc and cadmium bronzes are used in the manufacture of welder electrodes.

O.Ye. Kestner

BRONZE PIPES. Extruded thin-walled bronze pipes are made from the BrAZhMts 10-3-1.5 and BrAZhN10-4-4 aluminum bronzes (GOST 1208-54). The

TABLE 1

Dimensions of Special Purpose Extruded Bronze Pipes

Сплав 1	ТУ 2	Наружный диаметр 3 (мм)	Толщина стенки 4 (мм)
5 БрАЖМц 10-3-1,5	6 ТУ ЦМО 1592-55	60–250	12.5–30.0
7 БрАЖН 10-4-4	ТУ ЦМО 1573-55	200–240	20–15
5 БрАЖМц 10-3-1,5	ТУ ЦМО 1527-56	408	Диаметр внутренний 8 250
9 Бронза с 5% Ni (МН 95-5)	ТУ ЦМО 1563-56	27	2.1

1) Alloy; 2) TU; 3) outside diameter (mm); 4) wall thickness (mm); 5) BrAZhMts 10-3-1.5; 6) TU TsMO; 7) BrAZhN10-4-4; 8) inside diameter; 9) bronze with 5% Ni (MN 95-5).

TABLE 2

Mechanical Properties of Bronze Pipes

Сплав 1	2 Трубы	3 ГОСТ или ТУ	Диаметр или толщина (мм) 4	5 σ_b (кг/мм²)	δ (%)	5 НВ (кг/мм²)
БрОФ4-0,25 6	Холоднотянутые: 8 Жесткие плоско-овальные	9 ГОСТ 2622—44	10 7,5×5,0; толщина стенки 0,40—1,20	50	2	—
	Овальные	11 То же	10×2,5; толщина стенки 0,55	50	2	—
	12 Мягкие овальные	»	10×2,5, толщина стенки 0,55	33	40	—
	13 Твердые круглые	ЦМТУ 315-41	6,34×7,05, толщина стенки 0,15—0,70	60	1,5	—
	Мягкие круглые	ЦМТУ 302-41	7×7, 13, толщина стенки 0,6; 0,53	33	40	—
	15 Твердые 16	ЦМТУ 325-41	6,0, толщина стенки 0,2	60	1,5	—
	17 Твердые овальные манометрические	ТУ ЦМО 1507-53 18	15×6, толщина стенки 0,20—0,50	50	3	—
	19 Твердые овальные	ЦМТУ 3326-53 14	7,5×5,0, толщина стенки 1,0	60	3	—
БрАЖМц 10-3-1,5 20	Прессованные 21	ТУ ЦМО 1527-56	22 Диаметр наружный 408, внутренний 250	—	—	—
		ГОСТ 1208—54	23 Диаметр наружный 50—200, толщина стенки 5—50	60	12	129—171
		ТУ ЦМО 1592-55	24 Диаметр наружный 60—250, толщина стенки 12,5—30	—	—	—
БрАЖН 10-4-4 25	Прессованные	ГОСТ 1208—54	26 Диаметр наружный 50—220, толщина стенки 5—30	65	5	170—220
		ТУ ЦМО 1573-55	27 Диаметр наружный 200—240, толщина стенки 20—15	—	—	—

1) Alloy; 2) pipes; 3) GOST or TU; 4) diameter or thickness; 5) (kg/

/mm^2); 6) BrOF4-0.25; 7) cold-drawn; 8) rigid flat oval; 9) GOST; 10) wall thickness; same as above; 12) soft oval; 13) hard round; 14) TsMTU; 15) soft round; 16) hard; 17) hard oval manometer; 18) TU TsMO 1507-41; 19) hard oval; 20) BrAZhMts 10-3-1.5; 21) pressed; 22) diameter: outside 408, inside 250; 23) outside diameter 50-200, wall thickness 5-50; 24) outside diameter 60-250, wall thickness 12.5-30; 25) BrAZhN 10-4-4; 26) outside diameter 50-220, wall thickness 5-50; 27) outside diameter 200-240, wall thickness 20-15.

dimensions of special purpose extruded pipes are given in Table 1. Thin-walled drawn tubes are made from the BrOF4-0.25 tin-phosphorus bronze with round and oval cross sections (Table 2). Bronze pipes of other dimensions are made on the basis of special technical specifications (see Instrument Shaping Bronze, Beryllium Bronze).

O.E. Kestner

Manuscript Page No.	[Transliterated Symbols]
541	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = All-Union State Standard
541	ТУ = TU = tekhnicheskiye usloviya = technical specifications
541	ЦМТУ = TsMTU = tsvetnykh metallov tekhnicheskiye usloviya = = technical specifications for nonferrous metals

BRONZE SHEET AND STRIP are produced by cold and hot rolling. Sheet is made from all grades of bronze, strip is made from tin bronze, aluminum bronze, beryllium bronze and silicon-manganese bronze. The dimensions of the cold-rolled and hot-rolled sheets, and also the permissible deviations in thickness as a function of the width are established by GOST 4124-48. The minimal thickness of the cold-rolled sheets is 0.5 mm (with permissible deviations of 0.07 mm for sheet width to 500 mm, and 0.09 mm for sheet width to 710 mm). The greatest thickness of the sheet is 10 mm, the greatest width is 1000 mm, length varies from 1400 to 2000 mm. The hot-rolled sheets have thickness from 2 to 25 mm and width from 600 to 3000 mm (with thickness from 8 mm). The sheet length varies from 1000 to 6000 mm.

Strip made from the tin, aluminum and silicon-manganese bronzes are produced in the soft (annealed) condition, and those from beryllium bronze are produced in the solution treated, hard (strain hardened) and extra-hard (with greatest percentage of strain hardening) conditions. The strip differs from the sheet primarily in thickness, its uses are the same as for the sheet (see Bronze Strip). The GOST and specifications used in the production of the strip, and the dimensions as well, are shown in the Table. For the mechanical properties of the strips see article, Wrought Spring Bronze.

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Dimensions of Bronze Strip (limits)

Сплав 1	ГОСТ или Технич. условия 2	3 Толщина	4 Ширина	5 Длина
		(мм)		
Алюминиевая бронза БРАМц 9-2 . . . . 6 . . .	7 ГОСТ 1595 47	1—12,5	50—300	8 Не менее 1000
Бериллиевые бронзы: БрВ2; БрБ2,5; БрБНТ 1,9; БрБНТ 1,7 . . . . . 9 . .	ГОСТ 1789—60	0,15—6	40—300	200—1500
Кремнемарганцовистая бронза БрКМц3-1	ГОСТ 4748—49	1,8—10	40—500	400—2000
10 Оловянноцинковая и оловянно-фосфористая бронза . 11 . .	ГОСТ 1761—50	1—10	100—300	400—2000
Оловянносвинцовоцинковая бронза БрОЦС4-4-2,5 12 .	13 ЦМТУ 3444-53	0,9—1,95	33—50	Не менее 1000

1) Alloy; 2) GOST or specification; 3) thickness; 4) width; 5) length; 6) aluminum bronze, BRAMts9-2; 7) GOST; 8) not less than; 9) beryllium bronzes: BrB2, BrB2.5, BrBNT1.9, BrBNT1.7; 10) tin-zinc and tin-phosphorus bronze; 12) tin-lead-zinc bronze BrOTsS4-4-2.5; 13) TsMTU

O.Ye. Kestner

BRONZE STRIP is produced from aluminum, beryllium, tin-phosphor, tin-zinc, silicon, and manganese bronzes. It is delivered in the soft, hard and half-hard conditions. Bronze strip is used for springs, flexible contacts of the sensitive elements of instruments and apparatus, and also for details which must have corrosion resistance and wear resistance which are intended for precision instrument construction and machine construction, electrotechnical and other branches of industry.

Thickness of Bronze Strip (limits)

Сплав 1	ГОСТ или ТУ 2	Толщина (мм) 3
Бериллиевые бронзы: 4		
БрБ2; БрБНТ 0,9; БрБНТ 1,7 5	ГОСТ 1789–60	0.05–1.5
Кремнемарганцовистая бронза БрКМц 3-1 6	13 ГОСТ 4748–49	0.05–2
7 Оловяннофосфористые и оловянноцинковые бронзы:	13	
БрОФ 6,5-0,15	ГОСТ 1761–50	0,1–2
8 БрОФ 4-0,25	МПТУ 4213-53	0,1–2
9 БрОФ 6,5-0,4	14 ЦМТУ 3383-53	0.1–2
БрОЦС 10 4-4-2,5	15 ЦМТУ 512-41	0,5–2
Алюминиевые бронзы: 11		
БрА5, БрА7	ГОСТ 1048–49	0,1–1,2
БрАМц9-2 12	ГОСТ 1595–47	0,4–1

1) Alloy; 2) GOST or TU; 3) thickness (mm); 4) beryllium bronzes; 5) BrB2, BrBNT0.9, BrBNT1.7; 6) silicon-manganese bronze BrKMts3-1; 7) tin-phosphorus and tin-zinc bronzes: BrOF6.5-0.15; 8) BrOF4-0.25; 9) BrOF6.5-0.4; 10) BrOTsS4-4-2.5; 11) aluminum bronzes: BrA5, BrA7; 12) BrAMts9-12; 13) GOST; 14) MTsTY; 15) TsMTU.

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Bronze strips are produced with width from 10 to 600 mm, the strip of thickness from 0.05 to 0.09 mm having a width up to 175 mm and the strip of thickness 0.5 mm and more having widths starting at 20 mm. Most of the strip has a length of no less than 2000 mm. The government standards and the technical specifications under which the bronze strip is produced and the limiting thicknesses are presented in the Table.

O.Ye. Kestner

BRONZE STRIPS — manufactured from tin, aluminum, and silicon-manganese bronze in the soft (annealed) condition, and from beryllium bronzes in the tempered (hard, cold-worked), and in the particularly hard state (with maximum percent of cold working). Bronze strip differs from bronze ribbon in dimensions, chiefly the thickness, although strip is designed for roughly the same purpose as ribbon (see Bronze ribbon). The GOST and TU governing bronze strip, as well as the dimensions, are given in the article Bronze sheet and strip. The mechanical properties of bronze strip are given in the article Deformable spring bronze.

O.Ye. Kestner

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BRONZE WIRE. This wire is produced from various types of bronze and with round, rectangular, and square cross-sections. Round bronze wire is manufactured from beryllium bronze and is used for springs, electrical components, and metallic screening; wire produced from BrKMts3-1 silicon-manganese bronze is used for springs and elastic components with high corrosion resistance (GOST 5222-50); wire produced from BrOF6.5-0.4, BrOF6.5-0.15, and BrOTs4-3 tin bronzes are employed for springs and coverings for flexible hose. Rectangular and square wire for special springs is manufactured from these bronzes in accordance with GOST 5221-50, MPTU 2632-50, TU GTsMO 325-46 and 330-46. Beryllium-bronze wire is produced in accordance with TsMTU 673-41. For the mechanical characteristics of bronze wire see the articles entitled Spring shaping bronze and Beryllium bronze.

O.Ye. Kestner

BRONZOGRAPHITE – a porous cermet consisting of bronze and graphite particles uniformly distributed between the metallic crystals; the pores of the material are oil-filled. It is produced in the form of bushings, which are used as sliding bearings. In many cases the presence of oil in the pores of the material permits the use of bearings without forced lubrication. The unusual structure of bronzographite (the presence of graphite and oil-filled pores) ensures a very low coefficient of friction, high durability, and the ability to function at high sliding speeds. The chemical composition of bronzographite is as follows: copper – base, tin – 8.5-9.0%, and graphite – 1.5-3.0%. The porosity of this material ranges from 20 to 25%, while its oil absorption varies from 2 to 3%. The table shows the properties of the bronzographite produced in the USSR.

Свойства 1	2 Единица измерения	3 Показатель свойств
4 Плотность	10 г/см^3	6.0—6.2
HB	11 кг/мм^2	18—20
$\sigma_{изг}$	То же	28—32
σ_b	12 »	18—25
σ_{-b}	»	60—70
$a_н$	кгм/см^2	0.65—0.70
5 Относит. осадка при сжатии . .	13 %	45—50
6 λ в интервале 100—600° . . .	кал/см·сек·°С	0.08—0.07
7 α·10^6 в интервале 20—800°	14 1/°С	12.2—17.2
8 Коэфф. трения по стали без принудит. смазки	—	0.04—0.06
9 Коэфф. трения по стали с применением принудит. смазки . .	—	0.004—0.006

1) Property; 2) unit of measurement; 3) index; 4) density; 5) relative shrinkage on compresion; 6) λ over the range 100-600°; 7) α•10^6 over the range 20-800°; 8) coefficient of friction over steel without forced lubrication; 9) coefficient of friction over steel with forced lubrication; 10) g/cm^3; 11) kg/mm^2; 12) the same; 13) kg-m/cm^2; 14) cal/cm••sec•°C.

The working temperature of bronzographite is 75-80°, while the maximum permissible stress is 60-80 kg/cm^2 at a sliding speed of 20 m/sec. This material is used in the friction units of machine tools, automobiles, tractors, aircraft, instruments, etc. See Antifriction cermets.

References: Bal'shin, M.Yu., Poroshkovaya metallurgiya [Powder Metallurgy], Moscow, 1948; Rakovskiy, V.S. and Saklinskiy, V.V., Metallokeramika v mashinostroyenii [Cermets in Machine Building], Moscow, 1956.

V.S. Rakovskiy

BRUCITE – a mineral, the natural hydroxide of magnesium ($Mg[OH]_2$); it is white, brown, greenish, or colorless and has a specific gravity of 2.3-2.4, a Mohs hardness of 2.5, a heat capacity (at 35°) of 0.311 cal/g, and a coefficient of thermal expansion which varies in different crystallographic directions: $4.47 \pm 0.02 \times 10^5 \perp \{0001\}$ and $1.10 \pm$ $\pm\ 0.15 \times 10^5 \perp \{1\overline{01}0\}$. Brucite becomes lighter in color when heated; when cooled after heating it has piezoelectric properties, the ends of the crystals lying in the $\{0001\}$ direction being charged negatively and the sides of the crystals positively. There are two polymorphous varieties of brucite, laminar and fibrous (namalite). Nemalite can be polarized by electric waves. Brucite is found naturally in monomineral deposits or in brucite marbles in conjunction with <u>Calcite</u> ($CaCO_3$) and dolomite ($CaMg\ [CO_3]_2$). It is used in the production of magnesia compounds and metallic Mg. In Canada brucite marbles are used in the manufacture of slate lime and granulated magnesia in both the chemically active and dead-burned forms. Chemically active magnesia is used in the production of magnesia cements, in the extraction of uranium, and in the electrolytic production of metallic Mg. Dead-burned granulated magnesia is used as a metallurgical powder for chemically stable hearth-lining mixtures, especially for electric furnaces, as a substitute for molten periclase, as insulation for the electric-arc furnaces used for firing ceramics in reducing atmospheres, as firebrick in especially critical areas (the crowns of reverberatory furnaces, converters, etc.), and in the manufacture of special types of paper. In addition, brucite magnesia can be used in place of Mg oxide (<u>Magnesite</u>) and as a substitute for talc. Laboratory experiments have established that it is possible to produce autoclaved structural components from brucite marble mixed with active alumosilicates.

References: Smolin, P.P., Brusitovyye mramory – novoye magnezial'noye syr'ye [Brucite Marbles – A New Magnesia Raw Material], Ogneupory [Refractory Materials], 1957, No. 5; Goudge, M.F., Phillips, J.G., Canadian Brucite as a Material for the Production of Basic Refractories, Amer. Ceram. Soc. Bull., 1946, Vol. 25, No. 3, Goudge, M.F., Brucite magnesia, J. Amer. Ceram. Soc., 1944, Vol. 27, No. 1.

P.P. Smolin

BURNING OF STEEL - oxidation of the grain boundaries of steel as a result of heating to high temperatures; this is an uncorrectible defect.

Ya.M. Potak

BUTYLACRYLATE RUBBER - is the product of the polymerization of a copolymer from butylacrylate and acrylonitrile in emulsion; it is characterized by heat resistance up to 180-200° in air and in oils, resistance to oxidation, to the action of ozone and sunlight, a good resistance to cracking, and gas tightness. Disadvantages of the butylacrylate rubber are: plasticity (high residual deformation after compression), insufficient waterproofness, and a relatively low frostproofness (up to -30°). The specific gravity is 1.2-1.3, the vitrification point is -35°. In the U.S., it has the commercial name Lactoprene BN. The copolymer of ethylacrylate and chlorovinyl acrylate is also delivered, it is termed Lactroprene EV. The vulcanization of the butylacrylate rubber is carried out by polyamines, sulfur, or benzoyl peroxide; oxides and hydroxides of certain bivalent metals are also used. The combination of sulfur and polyamines gives vulcanizates with the highest heat resistance. The vulcanization proceeds somewhat slower than that of the most synthetic rubbers, 30-60 min at 150°. The vulcanization process depends strongly on the pH of the compound, a fact which must be taken into account when making the formula for rubber stocks. It is not recommended to use clays, acid plasticizers or other ingredients which adsorb bases or react with them. The use of neutral or weakly alkaline fillers is the best. Plasticizers are applied to increase the frostproofness. The properties of the vulcanized butylacrylate rubber compounds (with 50 parts by weight of chimney soot) are: tensile strength 90-120 kg/cm^2; relative elongation 250-350%; residual elongation 10-16%; swelling in gasoline (24 hrs) 20%; point of brittleness -35°; hardness according

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to TM-255 70; resilience 10% at 20°, and 35% at 100°. The aging coefficient after 5 days aging in air at 175° is: with regard to the strength 0.65-1.0; with regard to the relative elongation 0.2-0.3; after 10 days aging, the aging coefficient is equal to 0.7-0.8 for the strength, and 0.2-0.25 for the relative elongation. No cracks occur after ozonization for 13 hrs in an ozone concentration of 0.0015%. Butylacrylate rubber may be used for making packing rings, gaskets, membranes, packings, valve seats, connecting pieces, hoses, belts, and other technical rubber products for working in oils or in air at high temperatures (up to 150-180°). The combination of the heat resistance and resistance to ozone with high dielectric properties permits the application of the butylacrylate rubber for the insulation of wires for special purposes, and of feeder cables for distributing transformers. Printing rollers, coating rollers for high-melting materials, protective coatings of fabrics (glass or asbestos fabrics), protective coatings of rubber products, stable to sunlgiht and nonfading, are made from butylacrylate rubber. Butylacrylate rubber is used in combination with a number of synthetic resins for the preparation of oil- and heat-resistant rubber cements and pastes.

I.V. Borodina

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BUTYL RUBBER – a copolymer of isobutylene and isoprene (0.6-3%). It is produced in the USSR, as well as in the USA under the trade name Enjay butyl, in Canada as polysarbutyl, and in France as Socabutyl. The principal chemical peculiarity of butyl rubber is its low unsaturation, 0.6-2.5 mol-%. The individual types of butyl rubber are distinguished by their degree of unsaturation and molecular weight. In appearance this material is a clear elastic mass, white or light-brown in color, with no taste or odor. It has a specific gravity of 0.91 and a vitrification temperature of from –67 to –69°. In contrast to natural rubber, butyl rubber is highly distensable and dissolves more readily in aliphatic than aromatic hydrocarbons; like natural rubber, it is insoluble in alcohols, acetone, ketones, ethers, and glycols. This type of rubber does not require rolling. Mixtures based on butyl rubber are prepared at higher temperatures than is the case for natural rubber and other types of synthetic rubber (120-150°). Because of its low unsaturation, vulcanization of this material requires more active accelerators and higher temperatures than are needed for natural rubber or other types of synthetic rubber. The rate at which butyl rubber is vulcanized increases with its unsaturation. The quantity of sulfur used amounts to 1-2.5 parts by weight. Thiuram disulfides (tetron A, etc.) and dithiocarbamates (selenak, tellurak, etc.) are good accelerators. Benzothiazoles, guanidines, sulfonamides, aldehydamines, etc., are used as secondary accelerators. Butyl rubber can be vulcanized without sulfur, using alkyl phenol-formaldehyde resins (amberol ST, resin 101). The best fillers are flue and chimney soot, which raise the tearing resistance, modulus of elasticity, and durability of butyl-based rubbers. Saturated compounds with low polarity (oils, waxes, and aliphatic and aromatic esters) are used as softeners. Unsaturated softeners are not employed, since they do not combine with butyl rubber. Plasticizers (dioctylphthalate, dioctylsebacinate, etc.) are used to increase the frost resistance of this material. Rubbers containing plasticizers retain their elasticity down to -60°, while those without plasticizers lose it at a temperature of from -45 to -50°. Butyl rubber does not combine with unsaturated rubbers (natural, butadienestyrol, butadiene-nitrile), but does combine in small quantities with chloroprene rubber. The peculiarities of the chemical and molecular structure of butyl rubber explain a number of the valuable technical properties of rubber mixtures based on it: low gas-permeability and exceptional resistance to oxygen, ozone, and atmospheric factors. The gas-permeability of butyl rubber is less than that of natural rubber by a factor of 20 for air, 3.5 for helium, 7 for hydrogen, and 60 for carbon dioxide. Butyl rubbers also have a very high resistance to acids, alkalies, salt solutions, acetone, alcohols, ethers, animal and vegetable oils, nitrogen-containing organic compounds, and water. Just as other crystallized rubbers, butyl rubber is characterized by high tensile strength in unadultrated mixtures. These rubbers also have a high resistance to tearing, thermal aging, and repeated bending, as well as good dielectric properties. The drawbacks of butyl rubbers include high residual deformation after compression, poor resistance to petroleum oils and fuels, low resistance to light, and low elasticity at normal temperatures. Their elasticity increases rapidly as the temperature rises; at 70° or more the elasticity of butyl rubbers is virtually the same as that of natural rubber.

Tables 1, 2, and 3 show the principal mechanical and electrical properties of butyl rubbers and present data on their chemical stability.

TABLE 1

Principal Mechanical Properties of Butyl Rubbers

Показатели 1	Ненаполненная резина 2	Резина с 50 вес. ч. канальной сажи 3
4 Предел прочности на разрыв (кг/см²)	180—220	160—200
5 Модуль при удлинении 500% (кг/см²)	12—15	100—120
6 Относит. удлинение (%)	850—950	650—800
7 Остаточное удлинение (%)	6—9	25—35
8 Сопротивление раздиру (кг/см)	10—15	70—95
9 Твердость по ТМ-2 . . .	32—34	50—60
10 Эластичность по отскоку при 20° (%)	11—14	8—12
11 Сопротивление многократному изгибу (количество циклов до разрушения)	—	$(6-9)\cdot 10^5$

1) Characteristic; 2) unadultrated rubber; 3) rubber containing 50 parts by weight chimney soot; 4) ultimate tensile strength (kg/cm²); 5) modulus of elasticity after elongation by 500% (kg/cm²); 6) relative elongation (%); 7) residual elongation (%); 8) tearing resistance (kg//cm); 9) hardness, determined with TM-2 apparatus; 10) recoil elasticity at 20° (%); 11) resistance to repeated bending (number of cycles to breakage).

TABLE 2

Dielectric Properties of Unadultrated Butyl Rubbers

Показатели 1	Нормы 2
3 Пробивное напряжение (в/мм)	24
4 Диэлектрич. постоянная (10 в, 1000 циклов)	
5 сухого бутилкаучука	2.11
6 после 88 час. в воде	2.10
7 Тангенс угла диэлектрич. потерь tg δ (10 в, 1000 циклов)	
сухого бутилкаучука	0.04
после 88 часов в воде	0.05
8 Уд. объемное сопротивление (ом·см) .	10^{16}

1) Characteristic; 2) normal; 3) breakdown voltage (v/mm); 4) dielectric constant (10 v, 1000 cycles); 5) dry butyl rubber; 6) after 88 hr in water; 7) tangent of dielectric-loss angle, tgδ (10 v, 1000 cycles); 8) specific deep resistance (ohm•cm).

It is possible to improve the valuable technical properties of butyl rubber and to alter them to conform to the assumed operational conditions by proper formulation of the rubber mixtures and correct selection of the type of butyl rubber to be used. For example, produc-

TABLE 3

Chemical Resistance of Butyl Rubbers

Среда и темп-ра испытаний 1	Свойства резин после выдерживания в течение 14 суток 2	
	Прочность на разрыв $(кг/см^2)$ 3	4 Относительное удлинение (%)
) Исходные показатели .	175	880
70% H_2SO_4 при 38° . . .	134	920
70% H_2SO_4 при 60° . . .	137	940
37% HCl при 26°	200	850
70% HNO_3 при 26° . . .	117	910
85% H_3PO_4 при 26° . . .	173	850
30% NaOH при 26° . . .	221	850

1) Medium and test temperature; 2) properties of rubber after soaking for 14 days; 3) tensile strength (kg/cm^2); 4) relative elongation (%); 5) initial values; 6) at.

tion of ultrathermostable rubbers (which will function for prolonged periods at 150° or even 170° and have a reduced residual deformation after compression) requires butyl rubber with a high unsaturation, which is vulcanized without sulfur, using phenol-formaldehyde resins. Sulfur-vulcanized butyl rubber with low unsaturation must be used in producing mixtures with high chemical stability. The mechanical properties of butyl rubber can be substantially improved by heat treatment of soot-containing mixtures. The best results are obtained by treatment of mixtures containing flue soot at 200° (or more) in a rubber mixer. Addition of activators (n-quinone dioxime, N-methyl-$N_1$4-dinitrosoaniline, etc.) makes it possible to use other types of soot and to reduce the processing temperature to 170° or less. Heat treatment produces an increase in modulus of elasticity, tensile strength, durability, dielectric characteristics, and chemical stability. Modified butyl rubber, which contains 3.5% bromine by weight, is characterized by a higher vulcanization rate, the ability to combine with natural and synthetic rubbers, and good adhesion to other polymers and metals. Most of the properties of brominated butyl rubber are similar to those of pure butyl rubber, although the former has a somewhat lower water resistance, tensile strength, and relative elongation. Chlorinated butyl rubber has the advantages of brominated butyl rubber, as well as a better resistance to thermal aging. As a result of its valuable properties, butyl rubber is widely used in the manufacture of water-, acid-, and alkali-resistant fabrics, acid-resistant gloves, the linings of chemical apparatus, all types of gaskets, and flexible tubing for transferring various chemical products. It is also employed in the production of packing and sealing components, intended to function at elevated temperatures. Other important uses of this material are in inner tubes, brewing chambers, tires, and diaphragms for vulcanizing-forming machines. Butyl-rubber tires are seamless, exhibit less slippage, and have good resistance to puncturing and sidewall cracking. As a result of its good dielectric properties, moisture resistance, and ozone resistance, this rubber is one of the principal insulating rubbers. It is also used in the manufacture of clear and colored rubber products.

References: Sinteticheskiy kauchuk [Synthetic Rubber], edited by G.S. Whitby, translated from English, Leningrad, 1957; Novyye kauchuki. Svoystva i primeneniye [New Rubbers. Properties and Uses], collection of translations, Moscow, 1958; Borodina, I.V., Nikitin, A.K., Tekhnicheskiye svoystva sovetskikh sinteticheskikh kauchukov [Technical Characteristics of Soviet Synthetic Rubbers], Leningrad-Moscow, 1952; Rubber Age, 1956, Vol. 79, No. 4; Rubber World, 1959, Vol. 140, No. 3.

I.V. Borodina

CABLE PAPER – paper manufactured from sulfated wood cellulose (GOST 645-59). It has high electrical-insulation characteristics and mechanical strength and is used for insulating power cables; it is produced in types K (low-voltage, up to 35 kv), KV (high-voltage), and KVU (heavy high-voltage).

TABLE 1

Technical Characteristics
of Low-Voltage Cable Paper

Показатели 1	К-080	К-120	К-170
Толщина (*мм*) 2	0,080	0,120	0,170
Разрывное усилие (*кг*, не менее) 3			
4 в продольном направлении	8,5	13,0	17,5
5 в поперечном направлении	4,0	6,0	8,5
6 Сопротивление излому (число двойных перегибов в среднем по двум направлениям, не менее)	2000	2400	2500
7 Сопротивление раздиранию в поперечном направлении (*г*, не менее)	70	120	200

1) Characteristic; 2) thickness (mm); 3) tearing force (kg, no less than); 4) longitudinal; 5) transverse; 6) breaking resistance (average number of double bends in two directions, no less than); 7) tearing resistance in transverse direction (g, no less than).

The technical characteristics of cable paper are shown in Tables 1, 2, and 3.

Type K cable paper has the following general properties: bulk weight – 0.76 ± 0.06 g/cm^3; elongation – 22% longitudinally and 6.5% transversely; air-permeability – 25 ml/min; ash content – no more than 1%; specific electrical conductivity of aqueous extract at 25° – no more than $6.5 \cdot 10^{-5}$ ohm$^{-1}\cdot$cm^{-1}; pH of aqueous extract – 7.0-9.5.

The bulk weights of types KV and KVU cable paper are 0.85 and

TABLE 2

Technical Characteristics of High-Voltage Cable Paper

Показатели 1	2 КВ-030	3 КВ-045	4 КВ-080	5 КВ-120	6 КВ-170	7 КВ-240
8 Толщина (мм)	0,030± ±0,003	0,045± ±0,004	0,080± ±0,005	0,120± ±0,007	0,170± ±0,010	0,240± ±0,015
9 Разрывное усилие (кг, не менее)						
в продольном направлении 10	3,4	5,3	9,0	14,0	18,5	22,0
11 в поперечном направлении	1,5	2,3	4,2	6,5	9,0	10,0
12 Удлинение (%, не менее)						
в продольном направлении	2,2	2,3	2,3	2,3	2,3	2,3
в поперечном направлении	5,0	7,0	7,0	7,0	7,0	7,0
13 Сопротивление излому (число двойных перегибов в среднем по двум направлениям, не менее)	1500	2000	2000	3000	3000	3000
14 Сопротивление раздиранию в поперечном направлении (г, не менее)	10	20	60	150	240	300
15 Содержание железа в пересчете на Fe (%, не более)	0,0070	0,0065	0,0050	0,0050	0,0050	0,0050
16 Воздухопроницаемость (мл/мин, не более)	15	25	25	20	20	25

1) Characteristic; 2) KV-030; 3) KV-045; 4) KV-080; 5) KV-120; 6) KV-170; 7) KV-240; 8) thickness (mm); 9) tearing force (kg, no less than); 10) longitudinal; 11) transverse; 12) elongation (%, no less than); 13) breaking resistance (average number of double bends in two directions, no less than); 14) tearing resistance in transverse direction (g, no less than); 15) iron content, calculated for Fe (%, no more than); 16) air-permeability (ml/min, no more than).

TABLE 3

Technical Characteristics of Heavy High-Voltage Cable Paper

Показатели 1	2 КВУ-015	3 КВУ-020	4 КВУ-030	5 КВУ-045	6 КВУ-080	7 КВУ-120
8 Толщина (мм)	0.015± ±0.0015	0.020± ±0.002	0.030± ±0.003	0.045± ±0.004	0.080± ±0.005	0.120± ±0.007
9 Разрывное усилие (кг, не менее)						
10 в продольном направлении	2.1	2.8	4.5	6.8	12.0	17.5
в поперечном направлении 11	0.9	1.2	2.0	3.0	5,3	8.5
12 Удлинение (%, не менее)						
в продольном направлении	2.2	2.2	2.3	2.3	2.3	2.3
в поперечном направлении	5.0	5.0	7.0	7.0	7.0	7.0
13 Сопротивление излому (число двойных перегибов в среднем по двум направлениям, не менее)	1500	1500	2000	2000	2200	3000
14 Сопротивление раздиранию в поперечном направлении (г, не менее)	5	7	15	30	70	160
15 Воздухопроницаемость (мл/мин)	5	5	5	5	10	10

1) Characteristic; 2) KVU-015; 3) KVU-020; 4) KVU-030; 5) KVU-045; 6) KVU-080; 7) KVU-120; 8) thickness (mm); 9) tearing force (kg, no less than); 10) longitudinal; 11) transverse; 12) elongation (%, no less than); 13) breaking resistance (average number of double bends in two directions, no less than); 14) tearing resistance in transverse direction (g, no less than); 15) air-permeability (ml/min).

1.09-1.1 g/cm^3 respectively; they have better electrical-insulation characteristics than type K. For dry paper the tangent of the dielectric-loss angle at 100° is 0.0025 (KV) and 0.0027 (KVU), while for oil-impregnated paper it is 0.0037. The specific electrical conductivity of an aqueous extract of KV or KVU is $2.5 \cdot 10^{-5}$ $\text{ohm}^{-1} \cdot \text{cm}^{-1}$. The ash content of these papers does not exceed 0.3%, while the pH of aqueous extracts of both types is 6.5-8.0.

Z.I. Gruzdeva

CABLE POLYETHYLENE — see Polyethylene.

I-5K

CABLE STEEL – is a hot-rolled, round shaped carbon steel, melted in Martin or electric furnaces. It is destined for the production of cable wire. The classes KK (fine) and VK (high-grade) (GOST 1457-60) are produced, depending on the purpose. It is delivered either cooled in air (group I) or sorbitized (group II). The diameters of cable steel are from 5 to 10 mm. The grades are: steel 35, 40, 45, 50, 55, 60, 65, and 70 (according to GOST 1050-52 with a manganese content of 0.3-0.6%), and steel 75, 80, and 85 (according to GOST 1052-53 with a manganese content of 0.5-0.8%). Cable steel of the KK class contains: not more than 0.03% sulfur and phosphorus each, not more than 0.12% chromium and nickel each, and not more than 0.15% copper. Cable steel of the VK class contains not more than 0.03% sulfur, not more than 0.025% phosphorus (the sum of the sulfur and phosphorus content must not exceed 0.05%), not more than 0.1% chromium, not more than 0.12% nickel and copper. The ovality of the cable steel rods must not exceed 0.5-0.6 mm. The standards of the mechanical properties are given in the Table.

TABLE

1 Сталь	2 Группа I (охлаждение на воздухе после проката)			3 Группа II (сорбитизация)		
	σ_b 4 (кг/мм²)	δ (%)	ψ (%)	σ_b 4 (кг/мм²)	δ (%)	ψ (%)
35	70	15	50	75	14	45
40	75	15	45	80	14	45
45	80	14	42	90	13	40
50	80	14	40	95	12	40
55	85	13	38	95	12	35
60	90	12	35	100	11	35
65	100	11	32	105	10	35
70	105	10	30	104	9	30
75	110	9	28	110	8	30
80	115	8	25	110	7	30
85	120	7	20	115	7	30

1) Steel; 2) group I (cooled in air after rolling); 3) group II (sorbitization); 4) kg/mm².

I-5K1

Cable steel is delivered in bundles (of a single piece) with a weight of 60-180 kg.

M. L. Bernshteyn

CALCITE (calc spar), $CaCO_3$ – is a mineral. Iceland spar is a variation of calcite. The specific gravity of the chemically pure crystals is 2.72. The mineral is brittle, completely cleavable; the Mohs hardness is 3; calcite is optically monoaxial, negative with a very high birefringence. It crystallizes in the trigonal system. It occurs in the form of crystals with various shapes (some hundred). The various form of the crystals is explained by the various conditions of crystallization, and, especially, by the different crystallization temperature. Crystalline calcite formations of hydrothermal origin are widespread. Calcite is observable in cracks and holes of the oxidation zones of mineral deposits and rocks as a result of weathering processes. Calcite is the relatively low resistant but main rock-forming material of the carbonate rocks. An immence quantity of $CaCO_3$ is formed by precipitation (chalk, limestone, marble). Calcite contains Mg, Fe, Mn (up to 8% and also Zn, Co, Sr, Be as impurities. It is colored dark-green, yellow, rose, brown, and other colors by the impurities. Yellow, lemon-yellow, rose, or violet colored calcite crystals become to a certain degree colorless under the action of ultraviolet rays or when heated slowly up to 350-400°. Deposits of transparent calcite crystals are known in the USSR on the Nizhnyaya Tunguska River, in Central Asia, etc. Chalk in the form of rocks is mined for the chemical and cement industry near the town Belgorod; marble as facing plates and for creation of statuaries is mined in Ural, Transbaikalia, Crimea, etc.

Calcite crystals are used in the optical industry for the design of diverse polarization instruments (microscopes, polarimeters, colorimeters). More than 200 devices are known in which calcite crystals are used. The minimum dimensions of a conditioned crystal are 20 × 20 × 14 (mm).

References: Betekhtin A.G., Kurs mineralogii [Course of Mineralogy] 3rd edition, Moscow, 1961; Suderkin A.I., Nifontov R.V., Chernova V.N., Opredeleniye kachestva p'yezoopticheskogo syr'ya pri oprobovanii mestorozhdeniy [Determination of the Quality of Piezooptical Raw Material in the Sampling of Deposits], Moscow, 1957.

V.P. Butuzov

CALENDAR PAPER – a paper manufactured from cotton (no more than 65%) and silk (no less than 35%) fiber. It is used for lining the calendar rolls of supercalendars. Depending on the purpose for which the paper is intended, the cotton fiber can be replaced by other plant (unbleached cellulose), artificial, or mineral (asbestos) fibers. The weight of 1 m^2 is 80, 100, 120, or 140 g. Calendar paper has a bulk weight of no less than 0.38 g/cm^3, an average tearing length in two directions of no less than 1100 m, a 10-min moisture absorption of no less than 50 ml, and a moisture content of no more than 8%. This paper is uniformly laid and should have no folds, wrinkles, tears, or holes. The principal drawback of calendar paper is the presence of poorly processed fiber bundbles. This material is produced in sheets of various formats. The properties of the calendar paper and the lining regime are of great importance in determining the quality of calendar rolls, whose hardness should reach 35-50 units on the Shore scleroscopic scale. Increasing the silk content of the paper reduces the hardness of the calendar roll and increases its elasticity. The paper used for calendaring technical grades of paper consists of up to 75% asbestos and 25% pulped linen rags or unbleached sulfated cellulose.

References: Ivanov, S.N., Tekhnologiya bumagi [Paper Technology], Moscow-Leningrad, 1960; Eydlin, I.Ya., Bumagodelatel'nyye i otdelochnyye mashiny [Paper-Making and Finishing Machines], Moscow-Leningrad, 1955; Sbornik tekhnicheskikh usloviy na produktsiyu, vyrabatyvayemuyu predpriyatiyami tsellyulozno-bumazhnoy promyshlennosti [Handbook of

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Technical Specifications for Products Manufactured by the Cellulose-Paper Industry], Leningrad, 1956.

Z.I. Gruzdeva

CALMALLOY – see Thermomagnetic Alloys.

CANEBIAN - is a synthetic fiber produced in Japan, see Polyvinyl Alcohol Fibers.

Z.A. Zozulina

CANTAL – is an alloy with a high specific electric resistance ($\rho = 1.2-1.45$ ohm·mm^2/m), used for the production of heating elements of electric furnaces. The chemical composition of the A1 alloy is: 30% chromium, 5% aluminum, 3% cobalt, the rest is iron. The alloys of the cantal type may be used: A1 up to 1350°, A up to 1300°, B up to 1150°. The properties of the above-mentioned alloys are similar to those of the Soviet iron-chromium-aluminum alloys OKh23Yu5 and OKh25Yu5A (GOST 9232-59) (see Alloys for Heating Elements). The durability of cantal (up to the burning out of the wire) as a function of the heating temperature is compared with that of the Soviet alloys in the Fig.

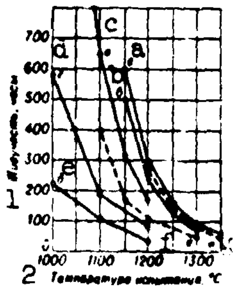


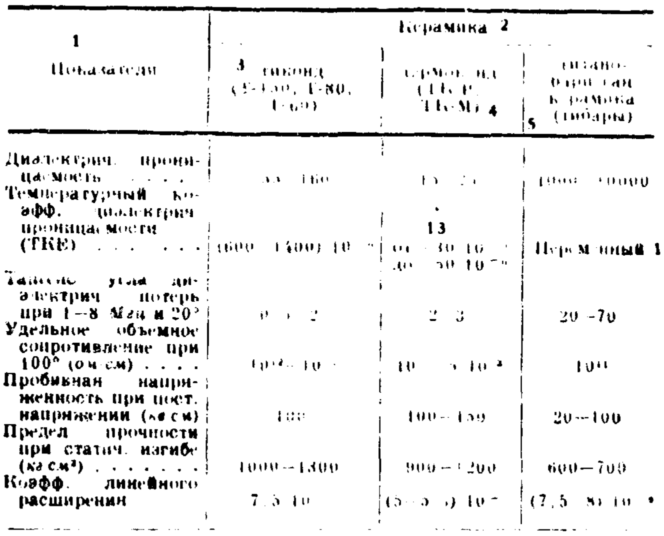
Fig. Effect of the temperature on the durability of the alloys: a), b), and c) Cantal A1, cantal A, and cantal B, respectively (according to the data of the catalog of the firm "Cantal"); d) alloy with 80% Ni and 20% Cr; e) alloy with 65% Ni, 20% Fe, and 15% Cr; f) alloy EI595; g) alloy EI626. 1) Durability, hours; 2) test temperature.

References: Kornilov, I.I., Splavy zhelezo-khrom-alyuminiy [Iron-Chromium-Aluminum Alloys], Moscow-Leningrad, 1945 (Zheleznyye splavy [Iron Alloys], Vol. 1); Khimushin F.F., Nerzhaveyushchiye, kislotoupornyye i zharoupornyye stali [Stainless, Acidproof, and Heatproof Steels], 2nd edition, Moscow, 1945; Semenova N.V., Zhukov L.L., "Stal'" [Steel], 1959, No. 7.

F.F. Khimushin

CAPACITOR CERAMICS – are ceramic materials characterized by a high dielectric constant (ε). The basic material for the production of capacitor ceramics is titania, TiO_2 with additions of BaO, MgO, ZrO_2, clay, etc. The basic properties of capacitor ceramics are listed in the Table.

TABLE



1 Показатели	Керамика 2		
	3 тиконд (Т-150, Т-80, Т-60)	термоконд (ТК-Р, ТК-М) 4	5 титано-бариевая керамика (тибары)
6 Диэлектрич. проницаемость	[illegible]—160	15—25	1000—10000
7 Температурный коэфф. диэлектрич. проницаемости (ТКЕ)	(600—1400)·10 [illegible]	13 от +30·10 [illegible] до −50·10 [illegible]	Переменный 14
8 Тангенс угла диэлектрич. потерь при 1—8 Мгц и 20°	[illegible] 2	2—3	20—70
9 Удельное объемное сопротивление при 100° (ом·см)	[illegible]	10 [illegible] 5·10 [illegible]	[illegible]
10 Пробивная напряженность при пост. напряжении (кв/см)	[illegible]	100—150	20—100
11 Предел прочности при статич. изгибе (кг/см²)	1000—1300	900—1200	600—700
12 Коэфф. линейного расширения	7,5·10 [illegible]	(5—5,5)·10 [illegible]	(7,5—8)·10 [illegible]

1) Characteristics; 2) ceramics; 3) Tikond (T-150, T-80, T-60); 4) Termokond (TK-R, TK-M); 5) titania barium oxide ceramics (Tibars); 6) dielectric constant; 7) temperature coefficient of the dielectric constant (TKYe); 8) tangent of the loss angle at 1-8 Mcps and 20°; 9) specific volume resistance at 100° (ohm·cm); 10) breakdown dc-voltage (kv/cm); 11) ultimate static bending strength (kg/cm²); 12) coefficient of line expansion; 13) from ... to ...; 14) variable.

For details of the classification and properties of capacitor ceramics see Ceramic Materials for Radio Engineering.

V.I. Balkevich

CAPACITOR PAPER – a paper manufactured from unbleached sulfated cellulose, without sizing or filler (GOST 1908-57). It has an ash content of no more than 0.45% (of the weight of completely dry paper) and a total iron and copper content of no more than 0.02%; the alkalinity of an aqueous extract of this paper (calculated in terms of NaOH) is no more than 0.01% and no acidity is present. The specific electrical conductivity of an aqueous extract at 25° is no more than $4 \cdot 10^{-5}$ $\text{ohm}^{-1} \cdot \text{cm}^{-1}$. Capacitor paper has a high electrical strength and is quite resistant to aging. It is used in the manufacture of capacitors. Two types, KON-I and KON-II, are produced, differing in purpose and proper-

TABLE 1

Technical Characteristics of KON-I Paper

Показатели 1	2 Разновидности КОН-I						
	КОН-I-1 3	КОН-I-2 4	КОН-I-3 5	КОН-I-4 6	КОН-I-5 7	КОН-I-6 8	КОН-I-7 9
10 Толщина (мк)	$7^{+0.5}_{-0.4}$	$8^{+0.8}_{-0.4}$	$10^{+0.9}_{-0.5}$	12±1	15±1	22±1.5	30±2
11 Объемный вес (г/см³)	1.0±0.03	1.0±0.03	1.0+0.03	1.0±0.03	1.0±0.03	1.0±0.03	1.0±0.3
12 Разрывная длина в продольном направлении (м, не менее)	7000	7000	7000	7000	7000	7000	7000
13 Воздухопроницаемость по аппарату ВП-2 (мл/мин, не более)	7	7	7	5	5	3	3
14 Пробивное напряжение на перем. токе при частоте 50 гц (в, не менее)	275	275	300	325	350	425	475
15 Количество токопроводящих включений на 1 м² (не более)	1000	600	300	200	200	30	15
16 Тангенс угла диэлектрич. потерь tgδ при 60° (не более)	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
17 Влажность (%)	8±1	8±1	8±1	8±1	8±1	9±1	8±1

1) Characteristic; 2) varieties of KON-I; 3) KON-I-1; 4) KON-I-2; 5) KON-I-3; 6) KON-I-4; 7) KON-I-5; 8) KON-I-o; 9) KON-I-7; 10) thickness (μ); 11) bulk weight (g/cm³); 12) tearing length in longitudinal direction (m, no less than); 13) air-permeability in VP-2 apparatus (ml/min, no more than); 14) breakdown voltage for 50 cps alternating current (v, no less than); 15) number of current-carrying inclusions per m² (no more than); 16) tangent of angle of dielectric loss, tgδ, at 60° (no more than); 17) moisture content (%).

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TABLE 2

Technical Characteristics of KON-II Paper

Показатели 1	КОН-II-1 2	КОН-II-2 3	КОН-II-3 4	КОН-II-4 5	КОН-II-5 6	КОН-II-6 7	КОН-II-7 8	КОН-II-8 9	КОН-II-9 10
11 Толщина (мк)	$5^{+0,4}_{-0,4}$	[illegible]	[illegible]	$8^{+0,4}_{-0,4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12 Объемный вес (г/см³)	$1,16^{+0,07}_{-0,02}$	$1,16^{+0,07}_{-0,02}$	$1,17^{+0,07}_{-0,03}$	$1,17^{+0,07}_{-0,03}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13 Разрывная длина в продольном направлении (м, не менее)	8500	8500	8500	8000	7500	[illegible]	[illegible]	[illegible]	[illegible]
14 Воздухопроницаемость по аппарату ВП-2 (мл/мин, не более)	30	15	3	[illegible]			[illegible]		[illegible]
15 Пробивное напряжение на переменном токе при частоте 50 гц (в, не менее)	250	270	280	310	350	[illegible]	[illegible]	[illegible]	[illegible]
16 Количество токопроводящих включений на 1 м² (не более)	2000	1500	1300	800	500	[illegible]	[illegible]	[illegible]	[illegible]
17 Тангенс угла диэлектрич. потерь tgδ при 60° (не более)	0,002	0,002	0,002	0,002	0,002	[illegible]		[illegible]	0,002
18 Влажность (%)	8^{+2}_{-1}	8^{+2}_{-1}	8^{+2}_{-1}	8^{+2}_{-1}	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1) Characteristic; 2) KON-II-1; 3) KON-II-2; 4) KON-II-3; 5) KON-II-4; 6) KON-II-5; 7) KON-II-6; 8) KON-II-7; 9) KON-II-8; 10) KON-II-9; 11) thickness (μ); 12) bulk weight (g/cm³); 13) tearing length in longitudinal direction (m, no less than); 14) air-permeability in VP-2 apparatus (ml/min, no more than); 15) breakdown voltage for 50 cps alternating current (v, no less than); 16) number of current-carrying inclusions per m² (no more than); 17) tangent of angle of dielectric loss, tgδ, at 60° (no more than); 18) moisture content (%).

ties. Using thickness as a basis we can distinguish 7 varieties of KON-I and 9 varieties of KON-II. The technical characteristics of these papers are shown in Tables 1 and 2.

Measuring electrodes with a diameter of [illegible] and no guard rings are used to determine tgδ. Capacitor paper is uniformly laid and has no fiber bundles, spots, foreign inclusions, tears, folds, wrinkles, punctures, or holes. It is produced in spools 12-750 mm wide; the variation in width should not exceed ± 0.2 mm for spools less than 50 mm wide, ±0.3 mm for spools 50-100 mm wide, ± 0.5 mm for spools 100-500 mm wide, and ±1.0 mm for spools more than 500 mm wide. Capacitor paper with a low bulk weight (1 g/cm³) is used in the manufacture of power capacitors, which are employed to improve the power factor [illegible], in [illegible] regulators, and for [illegible].

References: [illegible] Kitaeva, [illegible] eskikh poter' tsellyulozy dlya kondensatornoy i vysokovol'tnoy kabel'noy bumagi [Reducing the Dielectric Losses of Cellulose for Capacitor and High-Voltage Cable Paper], Bumazhnaya promyshlennost' [Paper Industry], 1959, No. 5.

Z.I. Gruzdeva

CAPILLARY FLAW DETECTION. It is based on filling the hollows of the flaws by means of capillary forces with compositions contrasting in light or color and following development of the flaws by substances with high absorbability. The kerosene-chalk, luminescence, dye and soap methods are the principal methods of the capillary flaw detection. In the kerosene-chalk, luminescence, and dye methods of the capillary flaw detection, the preliminarily cleaned surface of the object is covered with a fluid having a great penetrability. Thereupon, the excess of the fluid is removed, and a layer of the developing dye, a suspension of white hygroscopic powder is laid on. These substances absorb the fluid flowing out from the hollows of the flaw and make visible the contours of surface defects. In the soap test, a small quantity of soap solution is placed on the surface sections to be checked, the solution penetrates into the hollow of the crack. The defect becomes visible by a line of soap bubbles. In the luminescence method, the penetration fluid contains a substance which luminesces when irradiated by ultraviolet rays. In the dye method, the penetrating fluid is colored bright-red by aniline dyestuffs soluble in oil or alcohol. The cracks of diverse origin are visible as luminescent or red lines, the pores of pitting corrosion as isolated points or spots. The intercrystallite corrosion becomes visible in most of the cases as an intergranular fine network (in material with coarse-grained structure) or as diffuse bands (in material with fine-grained structure). The intergranular cracking of heat-proof alloys appears as a fine net. In Fig. 1, a rational scheme for controlling pieces by capillary methods is shown. The "insurance operations" consist in heating, electrolytic polishing, ultrasonic cleaning, etc., in order to increase the sensibility of the capillar methods. In the luminescence method, the examination of the pieces is carried out by irradiation with ultraviolet light sources, such as the ultraviolet lamps LYuM-1 of the Geologorazvedka Plant; LA-1 of the Plant for Commercial Equipment (Leningrad); UI-1, KP-1ML, KP-1N of the Physicomechanical Technical School (Leningrad) are used. Principal compositions of penetrating fluids and developing paints and powders used in the luminescence and dye methods are: Shubekol or one of the following compositions are used in the luminescence method: 65% kerosene + 25% Noriol + 10% gasoline; 84.5% kerosene + 15% aviation oil + 0.5% emulsifier OP-10, or OP-7; 55% kerosene + 25% aviation oil + 25% gasoline + 24.97 light mineral oil (transformer or vaseline oil) + 0.3% gold-yellow defectol. Magnesia (pure for analysis), silica gel MSM (fine-grained fine porous silica gel), or talcum are used as developing powders. The powder must be dried at 100-150° and screened through a sieve with 300-1000 meshs per 1 cm^2 before being used. Kerosene (80%) + benzene (20%) + oil-soluble dark-red aniline dyestuff (sudan IV) (10 g per liter); benzene (95%) + transformer oil (5%) + oil-soluble dark-red aniline dyestuff (10 g per 1 liter); kerosene (80%) + turpentine (20%) + oil-soluble dark-red aniline dyestuff (10 g per 1 liter); kerosene (40%) + benzene (40%) + turpentine (20%) + oil soluble aniline dyestuff (10 g per 1 liter) are used as penetrating fluids in the dye method.

The developing paints and suspensions are: 70% collodion on the basis of ether-alcohol (commercial) 10% RDV diluent + 20% benzene + 50 g per 1 liter zinc white pigment paste; 60% collodion on the basis of RDV solution of 4 g linters colloxylin VV in 100 ml RDV diluent) + 40% benzene + 50 g per 1 liter zinc white pigment paste; 50% water + 50% ethanol + 300 g chalk per 1 liter; 100% water + 300-400 g chalk per 1 liter. The duration of the checking of objects by luminescence and dye methods depends mainly on the time the defects are filled with the penetrating fluids and on the time of the development of the defects. The duration of the penetration depends on the viscosity of the fluid, on the temperature, on the material of the object, and on the origin of the flaw, and lies within 3 to 50 minutes. The time of the development of flaws depends on the quality of the developing composition and on the temperature of the object, and lies within 5 to 60 min. The sensibility of the capillary flaw detection methods is determined by the dimensions of the flaws to be detected, and depends in main on the correctly selected pair of penetrating fluid and developing composition. The evaluation of the sensibility is carried out on objects with surface defects whose sizes are known. The standards (Fig. 2, a, b, c) are usually prepared from U10 and U12 grades of carbon steel.

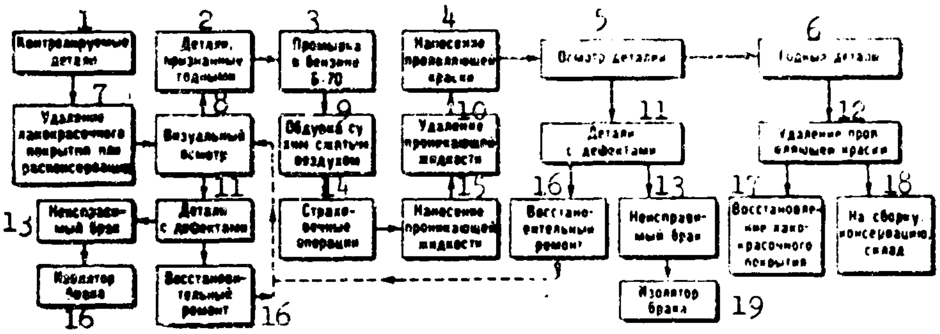

Fig. 1. Scheme of the control process of capillary flaw detection methods. 1) Pieces to be checked; 2) pieces recognized as suitable; 3) washing in B-70 gasoil; 4) application of the developing paint; 5) examination of the pieces; 6) suitable pieces; 7) removal of the varnish and paint coating or dispreservation; 8) visual examination; 9) blowing with dry compressed air; 10) removal of the penetrating fluid; 11) pieces with defects; 12) removal of the developing paint; 13) irreparable flaws; 14) insuring operations; 15) application of the penetrating fluid; 16) repair; 17) restoring of the varnish and paint coating, 18) to assembling, preservation and storage; 19) collector for rejected pieces.

Cylindrical specimens with a diameter of 25-26 mm and a length of 200-220 mm are hardened and then ground to a diameter of 22-23 mm. A 0.3-0.4 mm thick layer of hard porous chromium is applied on the sur-

Fig. 2. Complex of standards to check sensitivity of capillary flaw-detection methods: a) Specimen with grinding cracks; b) specimen with cracking of chrome coating; c) films with fixed flaws (magnification 1.3×.

face of the specimens. The specimens are ground at diverse conditions which permits one to obtain cracks with a gap width from 0.0005 mm and a depth from 0.01 mm upward. The finished specimens are cut longitudinally. Small pieces are cut off from the specimens for the metallographic analysis to determine the depth and gap width of the cracks obtained on the standard specimens. The results of the metallographic analysis are compared with the results of the check of the same specimens by capillary methods. The design of the cracks developed by capillary methods is photographed or fixed (when the dye method is used) on the film with a developing white dye. The further control of the sensibility of the applied penetrating fluids and developing dyes and powders results in the comparison of the designs of the cracks, fixed on the photograph or the dye film, with the designs of cracks developed on the standard specimens. The luminescence powder method permits one to make apparent defects with a minimum gap width of 0.01 mm and a depth 0.02-0.04 mm; the luminescence-vacuum and ultrasonic variations, 0.0C mm and 0.02-0.04 mm, respectively; the kerosene-chalk method with use of white developing suspensions 0.01 and 0.03-0.04 mm, respectively; the dye method with use of white developing nitro-dyestuffs 0.004-0.0006 mm and 0.01 mm, respectively. The methods of capillary flaw detection permit to make apparent cracks of any origin (fatigue, grinding, hardening, straightening, welding cracks, and others), the porosity loose structure and forging flaws reaching to the surface of the piece, intercrystalline and pickling corrosion (by the dye method only), and leakings of diverse kind in joints. Graduation lines do not appear because the ratio of the depth of the crack to the gap width, which must be always greater than unit, is one of the conditions for making the defects appear. The ratio of the depth of a graduation line to the width, which must be always greater than unit, is one of the conditions for making the defects appear. The ratio of the depth of a graduation line to the width, however, is usually smaller than unit, and the penetrating fluid is removed too easily from the hollow owing to this fact. The rules of the accident prevention must be kept when the methods of capillary detection of flaws are used, the operation must be carried cut in a room with good ventilation by local exhaustion or in the open, because the compositions of some penetrating fluids and developing paints contain toxics.

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S.I. Kalashnikov

CAPRON - is a synthetical heterochained polycaprolactam fiber, widely used for technical and general purposes. It is delivered in the USSR in the form of common and high-proof filament, staple fiber, monofilament, and bristles; fibers of the capron type are known in other countries under diverse terms: Nylon-6 (U.S.), Silon (Czechoslovakia), Perlon (GDR and FRG), Stilon (Poland), Encalon (Netherland). Capron is produced in the form of a lustrous mat, and diverse fiber. The physicomechanical properties of capron are: specific gravity 1.14; moisture absorption at standard conditions 3.5-3.9%; at 20° and 95% relative humidity 7-8%; swelling degree 13%; t°_{pl} = 225°; softening point = 170°; zero-strength temperature = 193-195°; temperature of the beginning of plastic flow = 160°; resistance to frost up to -70°; optimum temperature of fixation: 190° in dry steam, 127° in saturated steam, 105° in water; maximum ironing temperature 150°; permissible temperature for washing the fiber stabilized in hot air or saturated steam 72°; heat conductivity $5.4\text{-}8.7 \cdot 10^{-4}$ cal/cm·sec·degree; specific heat 0.4-0.5 cal/ /g·degree; linear expansion coefficient (per 1°C) $11\text{-}14 \cdot 10^{-5}$; 10-11% shrinkage in boiling water; capron does not burn in a flame, it melts, however; the thermal stability is insufficiently high: it loses 30-40% of the initial strength at 130-150°; it is inferior to nylon-66 and enanth in heat resistance and stability to thermal aging (loss of 36.3% of strength after heating 1 min. at 140°, change of the elongation by 29.7%). Copper or chromium salts, certain organic admixtures, phenyl-beta-naphthylamine, di-beta-naphthyl-p-phenylenediamine, for example, are added to the fiber in order to increase the stability to heat effects. Addition of manganese salts (especially of manganese chloride) increase the ligh-proofness which is lower in the mat fiber than in the lustrous one. Capron is considerably destroyed when irradiated with ultraviolet rays; the dielectric constant is 3-4 (at 1000 cps). The specific volume resistance is 4.5-10^{13} ohm·cm; the breakdown strength (in short-time test) is 16.8 kv/mm. Capron is stable to concentrated alkaline solutions, it is insoluble in carbon tetrachloride, dichloroethane, acetone and other organic solvents; it dissolves in concentrated hydrochloric, sulfuric, formic and acetic acids, and in m-cresol: it is decomposed in concentrated nitric and phosphoric acids, it is damaged by hypochlorite and peroxides, and is bleached by sodium chlorite. It is not attacked by microorganisms and insects and does not show a physiological affect on human skin. It is well colorable by certain direct and vat dyestuffs. The breaking length of the thread is: 41-50 km for the common, and 60-76 for the strengthened thread, 32-46 for the staple fiber. (The following figures in parentheses refer to filament – common and strengthened – and to staple fiber, respectively.) Temporary breaking strength 47-57 kg/mm^2 (69-86; 36-53). Loss in strength: in wet state 12.0-16.0% (11.0-15.0, 3.7-15), in a loop 2.9-6.0% (8.0-12.5; 12.0-13.0). Breaking elongation at standard conditions 20-32% (15-16; 45-60), in wet state 24-33% (17-18; 50-65). Modulus of elasticity 210-270 kg/mm^2 (320-260); initial modulus of elasticity (at elongation by 1%) 2-3 kg/mm^2, modulus of shear in torsion 4500-4800 kg/cm^2 6400-6800, –); elasticity at stretching by 4%-100% (100, –), by 10% 97.2 (100, –); elasticity of the fibrous body (degree of restoration after the compressing load is removed) after 1 min: –, (–, 88.1%), after 30 min: –, (–, 94.8%) stability to ultraviolet irradiation (loss of strength after 20 hrs irradiation) 24.4-42.1% (25.5-31.2); the stability to repeated bending is 2 times higher (for the common filament) than that of Nylon-

66. and Anid, but the heat resistance and resistance to wear are lower. Capron has a smooth surface and a round cross section. The assortment of produced capron filament is: N_m and N_{el} 64, 150, 200, 300 (common thread); 300, 450, 600 (single fiber); 34.5, 10.4 (strengthened thread); 1500-3000 (staple fiber).

Technical purposes are: filament for tire cord, driving belts, filter fabrics (not for acids), cables, strings, parachute yarn, lining fabrics for sails and shoes, working and protective clothes, lining fabrics for railway cars, aircraft, automobiles, insulating materials, etc.; monofilament: for fishing tackle and nets, mats, brushes, paint brushes, mill sieves, etc.; staple fiber for filter materials and for the production of diverse technical fabrics with a high wearing resistance. For general purposes are used: filament for hosiery, underwear for men and women, etc.; monofilament for hosiery, gloves, gripsacks, brushes, etc.; staple fiber for the manufacture of dresses for men and women, linen, rugs, etc. Staple fiber is added to yarns from wool, cotton and viscose staple fiber in order to improve the physicomechanical properties. Elastic thread for haberdashery is manufactured from caprone filament thread.

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E.M. Ayzenshtayn

CARBAMIDE ADHESIVE — is the resin-like product of the condensation of urea with formaldehyde, which becomes cured by addition of acid substances (change of the pH of the medium) at room temperature or by heating. Fillers (wood powder, starch, dextrin, mineral substances) and plasticizers are added during the production of carbamide adhesives in order to avoid a shrinking and cracking of the hardened adhesive layer. The low stability of the carbamide adhesive against water, especially hot water, may be partially reduced by addition of melamine-formaldehyde resins to the compoun d. The carbamine adhesives are used for the bonding of wood (the adhesive grades K-17, and MKh-4), of plywood (adhesives of the grades M-1, NIIF-M-3, MFS-1, and M-60) and for the production of woodpulp-resin plates (adhesive grade M-48). Foamed carbamide resins obtained by mechanical mixing of the liquid resin with air are also used for bonding wood. The amount of the adhesive used is reduced by 3-4 times in this case owing to the increased volume of the foamed resins. Foaming agents (surface-active substances) are added to improve the stability of the foamed carbamide resins. Powdered resins obtained by spraying the liquid resin (by means of centrifugal, mechanical or pneumatic devices) and subsequently drying the fine particles in hot air, superheated steam or in a gas at a fixed temperature are also used for the production of adhesives instead of the liquid carbamide resins. The use of powdered carbamide resins facilitates the transport of the basic raw material and simplifies the production of adhesives. Higher water- and heat-resistant adhesives obtained by condensation of melamine and formaldehyde, curing in a neutral medium at 140°, are used

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as well as carbamide adhesives; the curing temperature drops when acid substances are introduced into the compound. In addition to the liquid melamine adhesives, powdered adhesives are also used. The composition and the properties of certain carbamide adhesives are quoted in the Tables 1 and 2 on page 390.

TABLE 1

Composition and Properties of Certain Carbamide Adhesives

Название клея 1	Назначение 2	3 Карбамидная смола			Срок хранения (мес) 6	7 Отвердитель		8 Наполнитель		Жизнеспособность (часы) 10	Примечание 11
		концентрация (%) 4	pH	вязкость по Форду-Энглеру 5		(количество вес. ч. на 100 вес. ч. смолы) 9					
К-17 12	Склеивание древесины 13	70–7[illegible]	6.8–8.0	20–120	[illegible]	Щавелевая кислота 14	7.5–22	Древесная мука 15	8–10	[illegible]	16 Смола МФ-17
М-1 17	Склеивание фанеры 18	—	—	—	—	Хлористый аммоний 19	[illegible]	То же 20	1 21	[illegible] 21	—
22 НИИФ-М-3	То же 20	60–6[illegible]			—	То же 20	[illegible]			[illegible]	—
МХ-4 23	Склеивание и фанерование древесины 24	58–62	5.5–6.0	8–25*	[illegible]	•	[illegible]				25 [illegible] М-4
МФС-1 26	Склеивание фанеры 18	55–60	—	—	[illegible]	•	[illegible]		—	[illegible]	—
М-48 27	Произ-во древесно-стружечных плит и др. 28	45–51	6.0–7.0	11 секунд по ВЗ-4 29	[illegible]	•			—	—	—
М-60 30	Склеивание фанеры 18	57–61	6.5–7.0	1.5–3.0	2–3	•		—			[illegible]

1) Adheisive grade; 2) purpose; 3) carbamide resin; 4) concentration (%); 5) Ford-Engler viscosity; 6) shelf life (months); 7) hardener; 8) filler; 9) quantity in parts by weight per 100 parts by weight of the resin; 10) working life (in hrs); 11) note; 12) K-17; 13) bonding of wood; 14) oxalic acid; 15) wood powder; 16) resin MF-17; 17) M-1; 18) bonding of plywood; 19) ammonium chloride; 20) the same; 21) up to; 22) NIIF-M-3; 23) MKh-4; 24) bonding and veneering of wood; 25) resin M-4; 26) MFS-1; 27) M-48; 28) production of woodpulp-resin plates; 29) seconds according to V3-4; 30) M-60; 31) 5-10% lactic acid is used when bonding is performed without heating.

TABLE 2

Bonding Conditions for Certain Carbamide Adhesives (in Veneering of Wood

1 Параметры режима	2 Клей К-17		3 МФС-1	4 Клей М-60	
	холодное склеивание	горячее склеивание		5 холодное склеивание	6 горячее склеивание
7 Температура помещения (°С)	20—25	14—25	15—20	16—25	20—25
8 Температура древесины (°С)	20—25	14—25	10—15	15—25	20—25
9 Вязкость клеевого раствора (град. по Форду — Энглеру)	40—90	20—60	20—70	20—70	20—70
10 Расход клея (г/м²)	250—400	200—300	120—150	200—250	100—110
11 Продолжительность от момента нанесения клея до прессования (мин)	12 Не более 20	—	Не более 20	—	—
13 Удельное давление (кг/см²)	3—5	5—8	3—8	4—6	12—14
14 Температура плит пресса (°С)	—	90—100	105—125	20—25	115—120
15 Выдержка под давлением (мин)	180—360	10—12	3—4	240—300	5—6
16 Выдержка после распрессовки (часы)	12—24	До полного остывания	До полного остывания	10—25	3—4

1) Operating conditions; 2) adhesive K-17; 3) MFS-1; 4) Adhesive M-60; 5) cold bonding; 6) hot bonding; 7) room temperature (°C); 8) temperature of the wood; 9) viscosity of the adhesive solution (Ford-Engler degrees); 10) amount of adhesive used (g/m^2); 11) time interval between the application of the adhesive and the pressing (in min); 12) not more than; 13) specific pressure (kg/cm^2); 14) temperature of the press plates (°C); 15) holding under pressure (min); 16) holding after the pressure is removed; 17) up to complete cooling.

D.A. Kerdashev

CARBIDE – is a carbon compound of a metal (metal-like carbides) or of a metalloid (nonmetallic carbides), which is formed at a high temperature. The metal-like carbides are divided into two groups according to their structure. Carbides with simple structure, forming a lattice of metal atoms and hollows in which the carbon atoms are placed (titanium, circonium, hafnium carbides, etc.) belong to the first group. Carbides with a complex structure (chromium. manganese, tungsten carbides) belong to the second group. The principal physicochemical and mechanical properties of metal-like and nonmetallic carbides are given in Table 1.

TABLE 1

Properties of the Carbides of High-Melting Metals

Свойства 1	Карбид титана TiC 2	Карбид циркония ZrC 3	Карбид гафния HfC 4	Карбид ванадия VC 5	Карбид ниобия NbC 6	7 Карбид тантала TaC	8 Карбид хрома Cr₃C₂	9 Карбид молибдена Mo₂C	10 Карбид вольфрама WC	11 Карбид урана UC	12 Карбид бора B₄C	13 Карбид кремния SiC
14 Молекулярный вес	59.91	103.2[illegible]	190.51	62.96	104.92	[illegible]	180.0[illegible]	203.[illegible]	195.87	250.08	55.29	40.10
15 Содержание углерода:												
16 атомных %	50.0	50.0	50.0	50.0	50.0	50.0	[illegible]	33.33	50.0	50.0	20.0	50.0
17 весовых %	20.05	11.64	6.31	19.08	11.5[illegible]	6.2[illegible]	13.33	5.89	6.13	4.80	21.72	29.9[illegible]
18 γ (г/см³)	4.93	6.66	12.67	5.48	7.82	14.[illegible]	6.74	9.17	15.77	13.63	2.52	3.22
19 $t_{пл}$ °C	3150	3530	3890	2810	3500	3880	1890	2410	2720	2370	2350	2600
20 Теплота образования при 298°K (ккал/моль)	43.85	47.7	[illegible]	31.2	33.6	38.5	21.01	4.2	9.1	40.0	13.8	16.0
21 Энтропия [illegible]	5.8	8.[illegible]		6.77	8.9	1[illegible]	20.[illegible]	19.6	8.5	13.9	6.47	3.9[illegible]
22 c при 20° [illegible]	4.[illegible]	16.[illegible]	—	7.37	8.52	8.[illegible]	23.18		8.5[illegible]	23 0.046 при 125°C	12.55	6.44
24 λ (кал/см сек °C)	0.097	0.049	0.070	0.059	0.0[illegible]	0.0[illegible]	0.046	0.016	0.07	0.05–0.06	0.06	0.02
25 ρ (мком·см)	52.5	50.[illegible]	[illegible]	65.0	[illegible]	42.1	[illegible]	[illegible]	19.2	100	1.10	[illegible]
26 Термич. коэфф. линейного расширения (град⁻¹·10⁶)	[illegible] (300–2000°)	6.65 (100–2300°)	[illegible] (400–2000°)	—	0.8[illegible] ([illegible]–2[illegible])	[illegible]	[illegible]	7.78	[illegible]95 ([illegible]–1500°)	—	0.012 (1000–2000°)	[illegible]
(α·10⁶)(1/°C)	7.74 (12–2707°)	6.73 (20–1100°)	6.[illegible] (25–[illegible])	7.[illegible] (17[illegible])	6.5 ([illegible]–1000°)	8.2[illegible]	7 (20–1100°)	7.[illegible]	3.84 ([illegible]–1000°)	10.6 ([illegible]–1000°)	4.5	4.68 (100–2500°)
27 Термоэдс (мкв/°C)	−11.2	−[illegible]1.3	−[illegible]	[illegible]7	[illegible]	[illegible]	6.7	[illegible]	[illegible]		[illegible]60	[illegible]
28 Работа выхода (эв)	2.35	3.8	2.04		[illegible]	3.14				[illegible]7		
29 E (кг/мм²)	46000	35[illegible]	35000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71000			[illegible]
30 $σ_{изг}$ (кг/мм²)	25–40	30	—	5	[illegible]	[illegible]		31 [illegible]	[illegible]		[illegible]	16.9
32 $σ_{сж}$ (кг/мм²)	138	84	—	64			[illegible]		[illegible]	[illegible]	180	150
HRA	93	87	86	—	[illegible]1	92	8[illegible]	79	91			—
H (кг/мм²)	3000	2600	2800	2100	1[illegible]00	16[illegible]	1300	1[illegible]	1740	[illegible]	5000	3350

1) Properties; 2) titanium carbide; 3) zirconium carbide; 4) hafnium carbide; 5) vanadium carbide; 6) niobium carbide; 7) tantalum carbide; 8) chromium carbide; 9) molybdenum carbide; 10) tungsten carbide; 11) uranium carbide; 12) boron carbide; 13) silicon carbide; 14) molecular weight; 15) carbon content; 16) atomic %; 17) % by weight; 18) γ (roent-

gen); 19) melting point; 20) heat of formation at 298°K (kcal/mole); 21) entropy of the formation from the elements (cal/mole·°C); 22) c at 20° (cal/mole·°C); 23) at; 24) λ (cal/cm·sec·°C; 25) ρ (micro-ohm·cm); 26) thermal coefficient of the electric resistance (degree$^{-1}\cdot 10^3$); 27) thermo-emf (microvolt/degree); 28) work function (ev); 29) E (kg/mm^2); 30) bending strength (kg/mm^2); 31) porosity; 32) (kg/mm^2).

Carbides belong to the highest melting compounds. Hafnium carbide, for example, has a t°_{pl} of 3890°, and the alloy from 80 mole-% TaC and 20 mole-% HfC a melting point of about 4000°. The microhardness of carbides is high, it is equal to 3300-5000 kg/mm^2 for nonmetallic carbides.

Metal-like carbides have a high electric and thermal conductivity, near to the analogous properties of metals. They are metallic conductors with a positive temperature coefficient of the electric resistance. Some carbides (HfC, ThC_2) and alloys of uranium and zirconium carbides are characterized by high thermoemission properties under both normal and conversion conditions. Carbides of tantalum, niobium and molybdenum pass at relatively high temperatures into a superconducting state. The thermal expansion of the metal-like carbides is equal to 60-70% of that of the corresponding metals. Their moduli of elasticity have high values. The metal-like carbides are brittle and become plastic at high temperatures only (1400-1900°).

Nonmetallic carbides (B_4C, SiC) have a high specific electric resistance at normal temperature and are semiconductors with great values for the width of the forbidden zone. They possess a high hardness, brittleness and wear resistance. Their melting point is lower than that of metal-like carbides, moreover, they melt under decomposition or decompose before the melting point is reached. The specific heat of boron and silicon carbide increases with rising temperature, the values of the specific heat at 250° and 1350° being 0.13 and 0.40 cal/g·°C for B_4C, and 0.30 and 0.66 cal/g °C for SiC, respectively.

Carbides prove a high chemical stability to cold and heated acids and their mixtures. Thus, titanium carbide is stable in cold and hot hydrochloric, sulfuric, phosphoric, and oxalic acid, in cold perchloric acid, and also in mixtures of certain acids. Chromium carbide is characterized by a particularly high chemical stability: is stable to almost all acids and their mixtures. The nonmetallic carbides of boron and silicon prove a still higher chemical stability. Concentrated and diluted acids and their mixtures do not affect boron carbide for a long time both in cold and at the boiling point, excluded mixtures of sulfuric and nitric, and also hydrofluoric and nitric acids. Boron carbide is also resistant to the action of diluted and concentrated alkalis (Table 2).

TABLE 2

Acidproofness of Carbides

Темп-ра кислоты (°C) 1	Время обработки (часы) 2	3 Кислота (концентр.)	TiC	ZrC	HfC	NbC	TaC	Cr_3C_2	Mo_2C	WC
			4 количество нерастворимого остатка (%) после обработки*							
20	24	HCl (1,19)	99	—	100	100	100	—	80	97
5 Кипящая	2	»	6 100	—	100 (120°)	96 (115°)	98 (120°)	П. р.	89	48
20	24	HNO_3 (1,43)	П. р.	—	60	100	100	—6	П. р.	63
Кипящая	2	»	7 Р.б.ч.	—	6 П. р. (112°)	9 Ч. р. (120°)	99 (114°)		П. р.	1
20	24	H_2SO_4 (1,84)	8 Н. р.	97	100	8 Н. р.	100	—	89	91
Кипящая	2	»	88	6 П. р.	П. р. (280°)	6 П. р. (275°)	0 (260°)	П. р. (280°)	П. р.	1
20	24	H_3PO_4 (1,21)	99	98	97	100	98	100	93	91
Кипящая	2	»	98	7 Р б. ч.	П. р. (115°)	Н. р. (120°)	Р. б. ч.	--	76	93

* P.r. = total dissolution; P.b.ch. = dissolution of the greater part of the carbide; N.r. = insoluble; Ch.r. = partially soluble.

1) Temperature of the acid; 2) treatment time (hours); 3) acid (concentration); 4) quantity of the insoluble residue (in %) after treatment; 5) boiling; 6) P.r.; 7) R.b.ch.; 8) N.r.; 9) Ch.r.

Many of the carbides possess high refractory properties. Crucibles from titanium carbide or an alloy from titanium and chromium carbides, for example, do not become wet and do not react during 10 hours with molten tin, bismuth, lead, cadmium and zinc. Molten copper at 1100°-1300°, and silver at 980° in vacuum, aluminum at 700° in argon atmosphere do not wet titanium carbide. An alloy of 80% TiC, 5% WC, or TaC, and 15% Co is for more than 150 hrs stable to the action of molten sodium and bismuth at 900-1000°. The carbides of zirconium, chromium, molybdenum, tantalum, tungsten, and titanium do not react in contact with the analogous metals when heated to 1800-2000°.

Carbides are prepared by reduction of metal oxides with carbon according to the schematical reaction $MeO + C \rightarrow MeC + CO$ or by direct combination of metals with carbon. The preparation of pure carbides is carried out by reduction of metal oxides with carbon in vacuum, and continuous exhaustion of the carbon monoxide generated during the reaction. The production of carbides with commercial qualities is usually carried out in electric resistance furnaces with graphite tube.

Objects were produced from carbides by the methods of powder metallurgy: molding of powder-blanks in metallic dies with following heat treatment (sintering) at high temperatures (2000-2500°) in protecting gas media or in vacuum; by hot pressing of the powder in graphite molds, the processes of pressing and sintering occur simultaneously in this case.

Interalloys of carbides which have a face-centered cubic lattice i.e., of monocarbides of the IV and V group of the Periodic System: titanium, zirconium, hafnium, vanadium, niobium and tantalum, form continuous series of solid solutions. These alloys are characterized by resistance to wear and a minimum of mechanical strength. The highest absolute values of microhardness have been found in the systems TiC - ZrC (3100 kg/mm^2 at 75 mole-% TiC) and TiC – TaC (3000 kg/mm^2 at 75 mole-% TiC).

Viscous metals (nickel, iron, cobalt, etc.) are frequently added to carbides in order to accelerate and facilitate the process of production of compact carbide products, which otherwide proceeds with difficulty owing to the high brittleness of carbides; at the same time, additions raise the structural stability of these materials termed cermets. A series of technical alloys was developed on the basis of the carbides of titanium and chromium with metallic binders, having a density from 5 to 8 g/cm^3, and relatively high strength properties (Table 3). The loss in strength at high temperatures is in these alloys very much smaller than in metallic alloys.

TABLE 3

Properties of Alloys on Basis of Titanium and Chromium Carbides with Nickel and Cobalt

1 Содержание карбида (%)		2 Содержание металла (%)		3 γ (г/см^3)	RA	4 $\sigma_{изг}$ (кг/мм^2)
TiC	Cr_3C_2	Ni	Co			
76.0	4.0	20.0	—	5.8	89.0	70.3
63.0	7.0	30.0	—	5.9	85.0	91.4
48.0	12.0	40.0	—	6.2	84.0	126.5
47.5	2.5	50.0	—	6.4	81.5	161.7
32.0	8.0	60.0	—	6.8	77.5	154.6
80.0	—	—	20	5.4	89.0	87.8
63.0	7.0	—	30	5.9	87.5	80.8
48.0	12.0	—	40	6.3	87.0	98.4
45.0	5.0	—	50	6.4	84.0	161.7
32.0	8.0	—	60	6.9	81.0	161.7

1) Carbide content (%); 2) metal content (%); 3) g/cm^3; 4) σ_{izg} (kg/mm^2).

The strength of carbide-metal alloys is maintained up to higher temperatures than is observed in heatproof alloys on metallic basis (Table 4).

TABLE 4

Dependence of the Strength of Carbides on the Temperature

1 Карбид	2 Пористость (%)	3 Темп-ра (°C)								
		20	800	1000	1300	1500	1800	2000	2200	2450
		4 $\sigma_{изг}$ (кг/мм^2)								
TiC	21—25	3.3	2.5	—	1.4 (1400°)	—	4.0	5.7	3.6	1.3
Mo_2C	2[illegible]—28	3.6	4.3	3.1	9.8	9.0	10.0	1.6	—	—
WC	14—16	3.0	—	6.3	—	—	6.9	13.5	—	—

1) Carbide; 2) porosity (%); 3) temperature (°C); 4) σ_{izg} (kg/mm^2).

The usual methods of machining are unsuitable for products from carbides. Ultrasonic treatment providing a roughness of the machined surface of the 8-9 class is applied in this case. The working conditions of the ultrasonic treatment of certain carbides are given in Table 5. Electrolytic polishing of carbide products is also possible.

TABLE 5
Relative Workability of Carbides (Frequency 18,000 cps)

1 Карбид	2 Относительная плотность материала (%)	3 Глубина резания (мм)	Коэфф. обрабатываемости (отношение износа материала к износу инструмента) 4
TiC	96	5.0	11
ZrC	92	7.5	30
NbC	81	12.5	90
Mo_2C	89	2.1	84
B_4C	96	1.0	4

1) Carbide; 2) relative density of the material (%); 3) depth of cutting; 4) workability coefficient (ratio between the wear of the material and that of the tool).

Carbides of high-melting metals have found a wide utilization in cermet alloys for cutting tools, for example; in special refractories, and for protection tubes of thermocouples for the measurement in furnaces with reducing and inert gaseous media and in vacuum up to 2500°; in nuclear technology; as a composite of welding hard alloys and of acidproof materials.

References: Samsonov G.V., Portnoy K.I., Splavy na osnove tugoplavkikh soyedineniy [Alloys on Basis of High-melting Compounds], Moscow, 1961; Umanskiy Ya.S., Karbidy tverdykh splavov [Carbides of Hard Alloys]. Moscow, 1947; Samsonov G.V., Tugoplavkiye soyedineniya [High-Melting Compounds], a handbook on their properties and application, Moscow, 1963; Kharchenko V.K., and Struk L.I., "Poroshkovaya metallurgiya" [Powder Metallurgy], 1962, No. 2; Tekhnika vysokikh temperatur [High Temperature Engineering], edited by I.E. Campbell, translated from English, Moscow, 1959; Kratkiy spravochnik inzhenerafizika [Short Handbook for Physics and Engineers], Moscow, 1961.

K.I. Portnoy

CARBINOL ADHESIVE – is a compound containing stabilized "carbinol cyrup" (100 parts by weight), benzoyl peroxide (3 parts by weight), Portland cement grade 400 (50 parts by weight) and pure commercial acetone (15 parts by weight). The initial product (the "carbinol syrup") is obtained by heating dimethyl vinyl ethinyl carbinol in a vacuum at 60-65%. Carbinol adhesive is used to bond ceramics, plastics, metals and other materials which have working temperatures of up to 60° in an atmosphere of low humidity. Other proportions of the components and other hardeners, fillers and solvents are also possible. The syrup without hardener can be stored for 6 months.

The 1st method of the preparation of carbinol adhesive is: the carbinol syrup, previously dissolved in acetone, is mixed with benzoyl peroxide. The mixture is heated at 50-53° for 2.5-3 hours until a viscosity of 3000-5000 centipoises is attained. Thereupon, the mixture is cooled to 20-25°. The working life of carbinol adhesives is 2-2.5 hrs when stored in a cool and dark place. 2nd method: the carbinol syrup and the benzoyl peroxide (with or without cement) are mixed at 18-25° for 30-40 minutes and then stored for 3-4 hours. The bonding with carbamide adhesive is carried out at 15-30° with a holding time of 24-30 hours, and, when heated up to 60-70°, in 6-8 hours. The pressure during the bonding must be not lower than 0.5 kg/cm^2. The shearing strength of Duralumin joints bonded with carbamide adhesive is (in kg/cm^2): 50 at –60°; 120 at 20°, and 130 at 60°; it is equal to 80 at 20°, a humidity of 98%, and 30 days after the bonding was carried out. The adhesive consumption is 100-200 g/m^2. Joints bonded by carbamide adhesive are only limitedly shakeproof and limitedly resistant to the effects of fungi, fuel and oils.

D. A. Kardashev

CARBOLIT - see Molded Phenoplast.

I-58v

CARBON CHAIN FIBER – synthetic fibers from polymers whose macromolecules contain only carbon atoms in the base of the chain. Properties of the polymers (and of fibers made from them) can be varied by changing the character of functional groups in the macromolecule or the regularity of the polymer's structure. The carbon chain fibers are produced on an extensive raw materials base (ethylene and acetylene) and are obtained by spinning from softened polymer (almost all the carbon chain polymers or thermoplastic) by extrustion through spinnerets, from the melt or solution of the polymer (Teflon is spun from the dispersion of the polymer). The melting temperature of almost all the carbon chain polymers is higher than their decomposition temperature. The majority of carbon-chain polymers is highly resistant to acids and alkalis. To increase the strength, carbon-chain fibers are stretched by a factor of 10-20; to reduce shrinkage they are heat treated at 140-180°. They are produced in the form of filament thread, staple- or monofiber of the following types: fibers from acrylonitrile polymers and copolymers (Orlon, nitron, Acrilan, Vinyon N, Verel, etc); fibers from the copolymer of vinylidenecyanide and vinyl acetate (Darvan): fibers from polymers and copolymers of vinyl chloride (Rhovyl, Pe-Ce, chlorin, Saran, Vinyon HH, etc.); fibers from polyvinyl alcohol (Vinylon, Kuralon, Mewlon), etc.; fibers from polystyrene (Styroflex, Shalon); fibers from polyolefins, that is, from polyethylene (Polythene, Reevon), from polypropylene (prolen, Moplen, etc.); fibers from fluoride-containing polymers (Teflon, polifen, ftorlon, etc.).

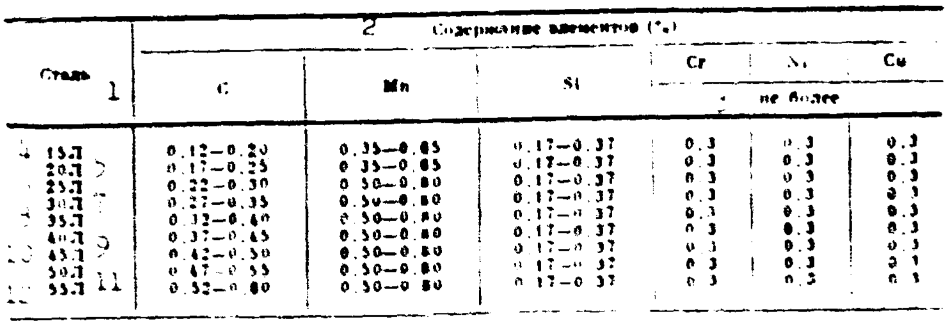
References: Rogovin, Z.A. Osnovy khimii i tekhnologii proizvodstva khimicheskikh volokon [Fundamentals of the Chemistry and Technology of Chemical Fibers Production]. 2nd edition, Moscow, 1957; Koch, P.A., "Z. ges. Textilind." [Textile Industry Journal], Vol. 60, No. 1, page 17, 1958; Vol. 61, No. 3, page 87, 1959; Vol. 62, No. 1, page 3, 1960.

Z.A. Zazulina

CARBON STRUCTURAL CASTING STEEL – ordinary unalloyed steel for cast machine components. Carbon casting steels differ from shaping steels of similar composition in their lower plasticity in impact strength; these two types of steel differ only slightly in physical, chemical, and technical characteristics (specific gravity, thermal conductivity, corrosion resistance, weldability, etc.). According to GOST 977-58, carbon structural casting steels are used for three groups of shaped castings (ordinary-quality, high-quality, and especially high quality), which differ in the requirements imposed on their chemical composition and mechanical characteristics. Tables 1 and 2 show the chemical composition of steels of this type.

TABLE 1

Chemical Composition of Carbon Structural Casting Steels (GOST 977-58)



Сталь 1	2 Содержание элементов (%)			Cr	Ni	Cu
	C	Mn	Si	не более		
4 15Л	0.12—0.20	0.35—0.65	0.17—0.37	0.3	0.3	0.3
20Л 5	0.17—0.25	0.35—0.65	0.17—0.37	0.3	0.3	0.3
25Л	0.22—0.30	0.50—0.80	0.17—0.37	0.3	0.3	0.3
30Л 7	0.27—0.35	0.50—0.80	0.17—0.37	0.3	0.3	0.3
35Л	0.32—0.40	0.50—0.80	0.17—0.37	0.3	0.3	0.3
40Л 9	0.37—0.45	0.50—0.80	0.17—0.37	0.3	0.3	0.3
10 45Л	0.42—0.50	0.50—0.80	0.17—0.37	0.3	0.3	0.3
50Л	0.47—0.55	0.50—0.80	0.17—0.37	0.3	0.3	0.3
12 55Л 11	0.52—0.60	0.50—0.80	0.17—0.37	0.3	0.3	0.3

1) Steel; 2) content of elements (%); 3) no more than; 4) 15L; 5) 20L; 6) 25L; 7) 30L; 8) 35L; 9) 40L; 10) 45L; 11) 50L; 12) 55L.

Table 3 shows the mechanical characteristics of annealed or normalized carbon structural casting steel, according to GOST 977-58. The annealing or normalization temperature is assumed to be 30-50° above the upper critical point Ac_3. It is not necessary to check the mechani-

TABLE 2

Permissible Sulfur and Phosphorous Contents of Carbon Structural Casting Steels

1 Группа отливок	2 Содержание элементов (%), не более					
	3 сера			4 фосфор		
	5 при способе выплавки стали					
	6 основной	7 кислой	8 конвертерной	основной	кислой	конвертерной
9 I группа	0,05	0,08	0,07	0,05	0,06	0,09
10 II группа	0,045	0,08	0,06	0,04	0,06	0,08
11 III группа	0,045	0,05	—	0,04	0,05	—

1) Group of castings; 2) content of elements (%), no more than; 3) sulfur; 4) phosphorous; 5) method of smelting steel; 6) basic ; 7) acidic; 8) Converter; 9) group I; 10) group II; 11) group III.

TABLE 3

Minimum Mechanical Characteristics of Carbon Structural Casting Steel in annealed or normalized state.

1 Сталь	$\sigma_{0,2}$	σ_b	δ	ψ	3 a_n (кгм/см²)
	2 (кг/мм²)		(%)		
4 15Л	20	40	24	35	5,0
5 20Л	22	42	22	35	5,0
6 25Л	24	45	19	30	4,0
7 30Л	26	48	17	30	3,5
8 35Л	28	50	15	25	3,5
9 40Л	30	53	14	25	3,0
10 45Л	32	55	12	20	[illegible]
11 50Л	34	58	11	20	2,5
12 55Л	35	60	10	18	2,5

1) Steel; 2) kg/mm^2; 3) kg-m/cm^2; 4) 15L; 5) 20L; 6) 25L; 7) 30L; 8) 35L 9) 40L; 10) 45L; 11) 50L; 12) 55L;

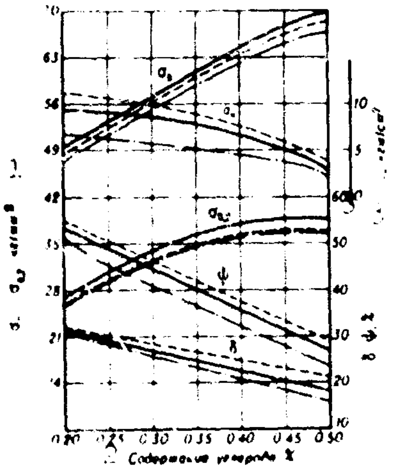


Fig. 1. Mechanical characteristics of castings as a function of carbon content and type of heat treatment: -·- · - · - annealing; ———— normalization; ------Normalization and Tempering at 650°. 1) kg/mm^2; 2)

carbon content, %: 3) kg-m/cm^2.

cal characteristics of group I castings, the yield strength and relative elongation of group II castings must be checked, while the yield strength, relative elongation, and impact strength of group III castings must be checked.

The mechanical characteristics of castings of types 25L-55L steel with walls up to 15 mm thick can be increased quenching and tempering. The quenching temperature is selected so as to be 20-30° above the upper critical point Ac_3, while the tempering temperature is selected in accordance with the mechanical characteristics required. Figure 1 shows the mechanical characteristics of carbon structural casting steel as a function of carbon content and type of heat treatment. The influence of tempering temperature on the mechanical characteristics of ater-quenched 30L steel is shown in Fig. 2. Quenching of sections of 45L steel (0.44% C, 0.37% Si, and 0.8% Mn) up to 15 mm thick from 850° in oil makes it possible to obtain an ultimate strength of more than 80 kg/mm^2 and satisfactory plasticity and impact strength ($\delta_n > 10\%$, $\psi > 30$kg, and 30 and $\alpha_n \geq 3$ kg-m/cm^2) after tempering at 600°. Increasing the casting thickness reduces all the mechanical characteristics and the density of the raw and annealed steel.

Figures 3 and 4 show the influence of elevated and low temperatures on the mechanical characteristics of carbon structural casting steels. The creep strength of 30L steel has a function of temperature and loading time is shown in Fig. 5.

The physical characteristics of these steels include: a specific gravity that depends on carbon content and the state of the steel (annealed, quenched), ranging from 7.86 to 7.82 for the types mentioned

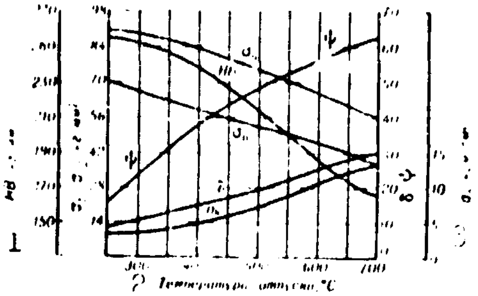


Fig. 2. Mechanical characteristics of 30L steel (0.30% C, 0.35% Si, 0.75% Mn, 0.03% P, and 0.026% S) as a function of tempering temperature after quenching in water from 900°. 1) kg/mm²; 2) tempering temperature °C; 3) kg-m/cm².

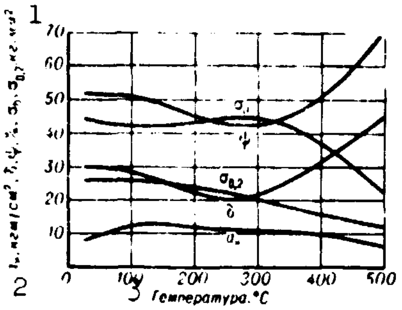


Fig. 3. Mechanical characteristics of 20L steel (0.18% C, 0.19% Si, 0.77% Mn, 0.064% P, and 0.043% S) at elevated temperatures. 1) kg/mm²; 2) kg-m/cm²; 3) temperature, °C.

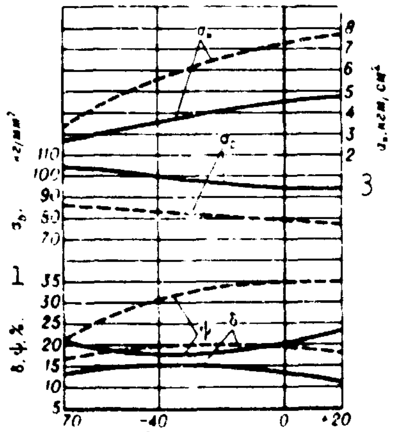


Fig. 4. Mechanical characteristics of 45L steel at low temperatures: ——— tempering at 550°; -------tempering at 650°. 1) kg/mm²; 2) temperature, °C; 3) kg-m/cm².

above: $\alpha \cdot 10^6$ (1/°C) = 11.1 (20-100°), 12.1 (20-200°), 12.8 (20-300°), 13.4 (20-400°), 13.9 (20-500°), 14.5 (20-600°), λ = 0.185-0.162 (100°), 0.159-0.132 (200°), 0.113-0.085 (400°), and 0.098-0.075 (500°) cal/

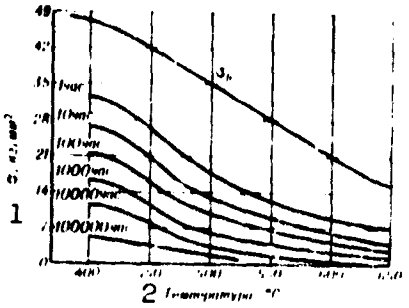


Fig. 5. Creep strength of 30L steel as a function of temperature and loading time. 1) kg/mm^2; 2) temperature, °C; 3) hr.

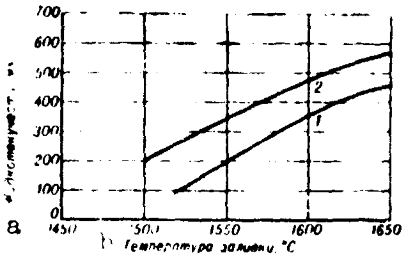


Fig. 6. Flowability of 15L and 35L steels as a function of quenching temperature: 1) 15L steel; 2) 35L steel. a) flowability, mm; b) quenching temperature, °C.

/·cm·sec°C, and c = 0.113 (0–100°), 0.115 (0–200°), 0.124 (0–400°), and 0.136 (0–600°) cal/g·°C.

The critical points of 15L steel are Ac_1 = 735°, Ac_3 = 860°, Ar_3 = = 840°, and Ar_1 = 685°, while those of 55L steel are Ac_1 = 727°, Ac_3 = = 774°, Ar_3 = 755°, and Ar_1 = 690°.

As for the technical characteristics of these steels, their flowability increases with quenching temperature, as shown in Fig. 6. When the quenching temperature is kept constant flowability increases with carbon content. The linear shrinkage of carbon structural casting steels ranges from 1.8 to 2.2% for free shrinkage and from 1.4 to 1.8% for impeded shrinkage. The cracking resistance of steels of this type depends on their carbon content and the quenching temperature. Cracking resistance is determined in a special apparatus, using a cast specimen. It is characterized by the force in kg required to cause cracking of the solidifying, cooling metal during shrinkage. Steel with a carbon content of 0.2% has the highest cracking resistance during impeded shrinkage (1.2-1.3%). Type 15L steel has a high weldability, while types 45L-55L have a low weldability. Figure 7 shows the hardenability of carbon structural casting steels. The machinability of these steels is satisfactory.

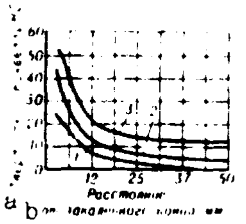


Fig. 7. Hardenability of carbon structural casting steel as a function of carbon content: 1) 0.2% C; 2) 0.3% C; 3) 0.4% C (determined by end quenching). a) Rockwell hardness, RC; b) distance from quenched end, mm.

Carbon structural casting steels are employed for various cast machine components in shipbuilding, locomotive building, boiler and pipe fabrication, the production of road-building machinery, the petroleum, metallurgical, automobile, and tractor industries, etc. These steels can be used to cast components weighing from several g to 200 t or more. Types 15L and 20L are used principally for components subjected to impact loads, sharp changes in temperature, or operation at temperatures of up to 400°, as well as for components to be cemented. Types 25L, 30L, and 35L steel are intended for ordinary components of assemblies and machinery. Types 45L, 50L, and 55L steel are used for components subject to wear and for thin-walled and heat-treatable components.

References: Metallovedeniye i termicheskaya obrabotka stali i chuguna [Metalworking and Heat Treatment of Steel and Pig Iron], Handbook, Moscow, 1956; Spravochnik po stalyam i metodam ikh ispytaniy [Handbook of Steels and Steel-Testing Methods], translated from German, Moscow, 1958; Liberman, L.Ya. and Peysikhis, M.I., Spravochnik po svoystvam staley, primenyayemykh v kotlotrubostroyenii [Handbook of Characteristics of Steels Used in Boiler and Pipe Fabrication], 2nd Edition, Moscow-Leningrad, 1958; Akimov, G.V. and Akomova, K.I., Yedinaya spetsifikatsiya metallicheskikh materialov mashinostroyeniya Soyuza SSR [Composite Specifications for Metallic Machine-Building Materials in the USSR], Pts. 1-2, Moscow-Leningrad, 1945, Pt. 3, Moscow, 1948; Steel Castings Handbook, 1950, Cleveland, 1950; Nekhendzi, Yu.A., Stal'noye lit'ye [Steel Casting], Moscow, 1943; Trubitsyn, N.A., Pribor dlya opredeleniya lineynoy usadki i treshinoustoychivosti splava [An Instrument for Determining the Linear Shrinkage and Cracking Resistance of Alloys], Moscow, 1957 (Peredovoy nauchn.-tekhn. i proizv. opyt [Advanced Scientific, Technical, and Production Experience], Report 32, No. P-57-90-10).

N.M. Tukevich

III-105s

CARBON STRUCTURAL SHAPING STEEL – unalloyed steel used in the manufacture of machine components. The element responsible for all the properties of such steel is carbon. Steels of this type usually contain impurities of Si, Mn, and detrimental elements (S and P); alloying elements (Cr, Ni, Mo and Cu) are sometimes present, passing into the metal from the scrap or melt. The various types of carbon structural shaping steel are distinguished by their C and S-P contents.

TABLE 1

Carbon Content of Carbon Structural Shaping Steel (GOST 380-60)

Сталь 1	C(%)	Сталь	C(%)
2 Мартеновская сталь		Бессемеровская сталь	
3 МСт.1 кп	≤0,23	14 БСт.0	<0,14
МСт.1 кп 4	0,06–0,12	БСт.3кп	<0,12
5 МСт.2 кп	0,09–0,15	БСт 3	<0,12
МСт.3 кп 6	0,14–0,22	БСт 4кп	0,12–0,20
7 МСт.3	0,14–0,22	БСт.4	0,12–0,20
МСт.4 кп 8	0,18–0,27	БСт.5	0,17–0,30
9 МСт.4	0,18–0,27	20 БСт.6	0,26–0,40
МСт.5 10	0,28–0,37		
11 МСт.6	0,38–0,49		
МСт.7 12	0,50–0,62		

1) Steel; 2) open-hearth steel; 3) MSt.1 kp; 4) MSt.1 kp; 5) MSt.2 kp; 6) MSt.3 kp; 7) MSt.3; 8) MSt.4 kp; 9) MSt.4; 10) MSt.5; 11) MSt.6; 12) MSt.7; 13) Bessemer steel; 14) Bst.0; 15) Bst.3kp; 16) Bst.3; 17) BSt.4 kp; 18) BSt.4; 19) BSt.5; 20) BSt.6.

TABLE 2

Mechanical Characteristics of Carbon Structural Shaping Steels (GOST 380-60)

Сталь 1	σ_b 2 (кг/мм²)	$\sigma_{0.2}$* (кг/мм²)	δ,* (%)
Ст 0	≤32	–	≤22
Ст.1 Ст.1кп	32–40	–	33
Ст.2 Ст.2кп	34–42	19–22	≤31
Ст.3кп	38–47	21–24	27–25
Ст 3	38–47	22–24	[illegible]
Ст.4 Ст.4кп	42–52	24–26	25–23
Ст 5	50–62	26–28	21–19
10 Ст 6	60–72	30–31	16–14
Ст.7	70–75 и более		11–1[illegible]

---

*The values of $\sigma_{0.2}$ are given as a function of the thickness and shape of the semifinished product; δ is given as a function of σ_b.

1) Steel; 2) kg/mm^2; 3) St.0; 4) St.1, St.1 kp; 5) St.2, St.2 kp; 6) St.3 kp; 7) St.3; 8) St.4, St.4 kp; 9) St.5; 10) St.6; 11) St.7; 12) or more.

TABLE 3

Carbon Content of High-Quality Carbon Structural Shaping Steels (GOST 1050-60)

Сталь 1	C (%)	Сталь	C (%)
05кп 2	≤ 0,06	35	0,32—0,40
3 08кп	0,05—0,11	40	0,37—0,45
08	0,05—0,12	45	0,42—0,50
10кп 4	0,07—0,14	50	0,47—0,55
10	0,07—0,14	55	0,52—0,60
5 15кп	0,12—0,19	60	0,57—0,65
15	0,12—0,19	65	0,62—0,70
6 20кп	0,17—0,24	70	0,67—0,75
20	0,17—0,24	75	0,72—0,80
25	0,22—0,30	80	0,77—0,85
30	0,27—0,35	85	0,82—0,90

1) Steel; 2) 05kp; 3) 08kp; 4) 10kp; 5) 15kp; 6) 20kp.

TABLE 4

Mechanical Characteristics of High-Quality Carbon Structural Shaping Steels in the Normalized State* According to GOST 1050-60) (no less than)

Сталь 1	σ_b	$\sigma_{0,2}$	δ_5	ψ	3 a_n (кгм/см²)
	2 (кг/мм²)		(%)		
4 08кп	30	18	35	60	—
08	33	20	33	60	—
5 10кп	32	19	33	55	—
10	34	21	31	55	—
6 15кп	36	21	29	55	—
15	38	23	27	55	—
7 20кп	38	23	27	55	—
20	42	25	25	55	—
25	46	28	23	50	9
30	50	30	21	50	8
35	54	32	20	45	7
40	58	34	19	45	6
45	61	36	16	40	5
50	64	38	14	40	4
55	66	39	13	35	—
60	69	41	12	35	—
65	71	42	10	30	—
70	73	43	9	30	—
75	110	90	7	30	—
80	110	95	6	30	—
85	115	100	6	30	—

*The characteristics of types 75, 80, and 85 steel are determined after quenching from 820° in oil and tempering at 480°; a_n is determined on specimens quenched in water and tempered at 600°.

1) Steel; 2) kg/mm^2; 3) kg-m/ /cm^2; 4) 08 kp; 5) 10 kp; 6) 15 kp; 7) 20 kp.

Ordinary-quality carbon structural shaping steels, whose characteristics are basically set by GOST 380-60, can be divided into two groups (A, B) and one subgroup (C), depending on the requirements imposed on them. Group A must satisfy requirements for mechanical characteristics, group B must satisfy requirements for chemical composition, and subgroup C must satisfy requirements for mechanical characteristics and also for chemical composition. The C content of ordinary-quality steels of this type is shown in Tables 1 and 3.

Tables 2 and 4 show the mechanical characteristics of ordinary-quality steels of group A and subgroup C.

Quenching and subsequent tempering materially improve the mechanical characteristics of carbon structural shaping steels. In some cased it is expedient to utilize the high plasticity of low-carbon steel for manufacturing components by deep drawing, upsetting, etc., giving them the requisite mechanical characteristics by subsequent quenching and tempering. It is recommended that 08 and 10 steels be quenched in an aqueous alkali solution (which is best cooled to 0°). Quenching and tempering give low-carbon steel good viscosity and plasticity in addition to high strength; in its combination of characteristics in this state such steel is equivalent to certain heat-treatable alloy steels. Low-carbon steel has a low hardenability, so that only components with a small cross-sectional area are subjected to quenching. Types 08, 10, and 20 low-carbon steel are often employed in the manufacture of cemented or cyanided components, which are hardened by quenching in water and low tempering; in this case it is principally the cemented surface layer that is quenched. Components of medium-carbon steel are sometimes cyanided.

Components with a C content of 0.30% or more are often heat-treated to harden their entire cross-section. Figures 1 and 2 show the mechanical characteristics of certain types of steel after quenching and tempering at various temperatures. In order to obtain the necessary viscosity on through hardening the steel is subjected to postquenching tempering to a σ_b of no more than 110-120 kg/mm^2.

TABLE 5

Mechanical Characteristics of Carbon Structural Shaping Steel after Quenching in Water and Tempering as a Function of Cross-Sectional Area of Component or Blank

1	2	Сталь 3	σ_b 4	σ_s	δ (%)	a_k 5	Сталь	σ_b	σ_s	δ (%)	a_k
400	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45	[illegible]	[illegible]	[illegible]	[illegible]
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
500	20		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
600	20		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
400	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50	[illegible]	[illegible]	[illegible]	[illegible]
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
500	20		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
600	20		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
400	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55	[illegible]	[illegible]	[illegible]	[illegible]
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
500	20		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
600	20		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	40		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	60		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

1) Tempering temperature (°C); 2) thickness of component or blank (mm); 3) steel; 4) kg/mm^2; 5) kg-m/ /cm^2.

The cross-sectional area of the quenched component or blank has a material influence on the strength of heat-treatable steel. The strength of a component decreases substantially as its thickness increases, even on quenching in water; its impact strength may also drop at the same time. Table 5 shows the mechanical characteristics of the principal types of carbon structural shaping steel as a function of component

TABLE 6

Ultimate Strength and Yield Strength (kg/mm^2) of Carbon Structural Shaping Steel at Elevated Temperature

1	2 20		100		200		300		400		500		[illegible]		[illegible]	
	σ_B	σ	σ_B	σ	σ_B	σ	σ_B	σ	σ_B	σ	σ_B	σ	σ_B	σ	σ_B	σ
10	[illegible]	[illegible]	[illegible]	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17	[illegible]	16	19	15	11	9
20	[illegible]	27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17	[illegible]	12	[illegible]	7

1) Steel; 2) temperature (°C).

TABLE 7

Creep Strength (kg/mm^2) of Carbon Structural Shaping Steel at Elevated Temperatures

1	2 400		450		[illegible]		[illegible]		5[illegible]		[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	11	7.7–8.5		6.[illegible]	7	4.[illegible]–4.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	11.8	9.[illegible]	1[illegible]	7	8	6.8	[illegible]	[illegible]	[illegible]	[illegible]	–
20	[illegible]	10	–	7.[illegible]	–	5	[illegible]	–	[illegible]	–	–
25	[illegible]	[illegible]	10	8	8.[illegible]	[illegible]	[illegible]	4.6	[illegible]	–	–
30		[illegible]	–	8.[illegible]	–	[illegible]	[illegible]	–	[illegible]		[illegible]
35	–	[illegible]	–	8.5	–	[illegible]	[illegible]	–	–	[illegible]	–

1) Steel; 2) temperature (°C).

thickness after quenching and tempering at 400-600°. These data can be used as a basis for selecting steels of this type for components of varying thickness. It is necessary to take into account the fact that the susceptibility to quenching of a flat component (of the plate or sheet type) or tube will be equivalent to that of a cylindrical component with twice its diameter in the case of bilateral cooling or with 4 times its diameter in the case of unilateral cooling (e.g., in quenching a tank with external cooling).

Tables 6 and 7 show the mechanical characteristics of normalized carbon structural shaping steel at elevated temperatures.

The characteristics of these steels at low temperatures depend to

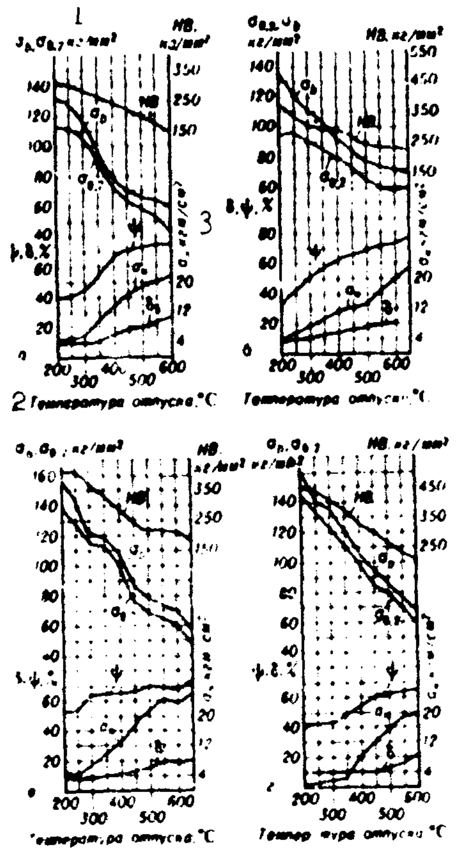


Fig. 1. Mechanical characteristics of quenched carbon structural shaping steel as a function of tempering temperature (quenching in water, specimens with d = 10 mm): a) type 20; b) type 25; c) type 30; d) type 35. 1) kg/mm^2; 2) tempering temperature, °C; 3) kg-m/cm^2.

a substantial extent on the grain size and the method by which the steel is smelted; as the grain size increases the cold-shortness temperature is materially raised and the danger of brittle fracture during operation at low temperatures is increased.

Durability depends principally on ultimate strength, as well as on the stressed state during testing. Figure 3 shows the durability of carbon structural shaping steels (bend testing of rotating specimens) with different ultimate strengths and in different surface conditions.

The physical characteristics of these steels include: critical point $Ac_1 = 725°$ for 15, 25, 35, 45, and 50 steels, critical point $Ac_3 = 860$, 840, 800, 780, and 765° respectively for these same steels, $\alpha = 11.5\cdot10^{6}$ (20°) 1/°C, and $\lambda = 0.136$, 0.121, and 0.109 cal/cm·sec·°C

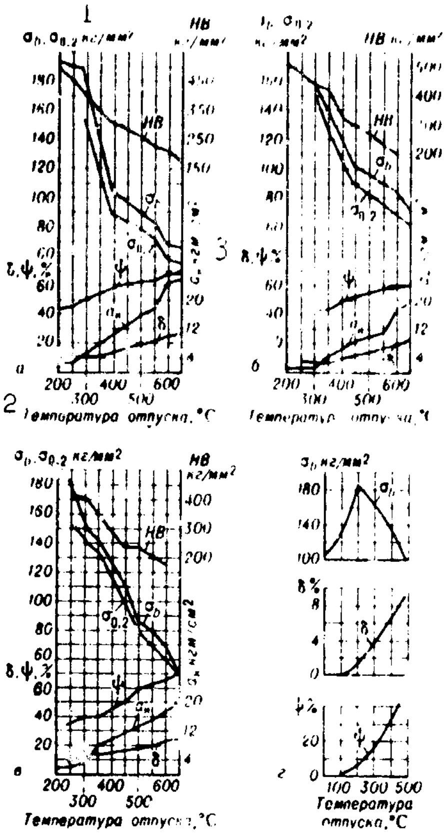


Fig. 2. Mechanical characteristics of quenched carbon structural shaping steel as a function of tempering temperature (quenching wa water, specimens with d (10 mm): a) type 40; b) type 45; c) type 50; d) type 65.1) kg/mm^2; 2) tempering a temperature, °C; 3) kg-m/cm^2.

for 15, 25, and 50 steels respectively.

Table 8 shows certain of the technical characteristics of these steels; for purposes of comparison, the cuttability of low-carbon coold-worked free-cutting steel is taken as 100%.

Carbon structural shaping steels are generally used after quenching or normalization and less frequently after quenching and tempering. Water serves as the quenching medium for low-carbon steel, including components intended for cementation or cyaniding, and for medium-carbon steel. Quenching cracks often develop during the quenching of medium-carbon and high- carbon steels especially when dealing with components having complex shapes or sharp notches; this is the chief drawback of carbon structural shaping steels. These steels have a re-

TABLE 8

Technical Carbon structural Shaping steel

1 Сталь	2 Темп-ра ковки (°C)		5 Обрабатываемость резанием	6 Свариваемость
	3 начало	4 конец		
10	1250	800	80% (в холоднотянутом состоянии) 7	Отличная 12
20	1270	800	65% (при НВ=137–174 кг/мм²) 8	Хорошая 13
40	1260	800	65% (после отжига)	Низкая
45	1250	800	60% (после отжига на НВ=179–230° кг/мм²) 10 9	Низкая 14
50	1250	800	50% (после отжига) 11	Низкая

1) Stee; 9) forging temperature (°C); 3) initial; 4) final; 5) cuttability; 6) weldability; 7) 80% (in cold-drawn state); 8) 65% (at HB = 137-174 kg/mm^2); 9) 65% (after annealing); 10) 60% (after annealing to HB = 179-230 kg/mm^2; 11) 50% (after annealing); 12) excellent; 13) good; 14) low.

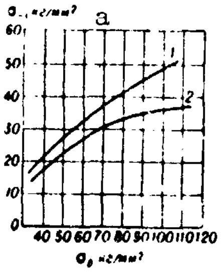


Fig. 3. Variation in the durability of carbon structural shaping steel as a function of ultimate strength and of specimen: 1) polshed specimens; 2) rough-turned specimens. a) kg/mm^2.

duced hardness on quenching in oil and in many cases are not susceptible to quenching. Quenching cracks may appear some time after quenching but before tempering; cracking can be prevented by quenching in water and subsequent transfer to oil, quenching and incomplete cooling intended to produce self-tempering, or slow tempering immediately after quenching. It is also necessary to limit stress concentrators, which may serve as foci of crack formation. The danger of quenching cracking is substantially reduced by surface quenching with high-frequency electric heating. Thin-walled components of medium-carbon and high-carbon steel, particularly those with complex shapes, are occasionally quenched

TABLE 9

Heat Treatment of Various Machine Components Fabricated From Different Types of Carbon Structural Shaping Steel

Сталь 1	Режим обработки 2	HRC	[illegible] 3
08; 08кп 4	Цианирование при 5 850—900° с толщиной твердого слоя 0,2—0,4 мм, закалка в воде, отпуск при 180—6 200°	58—62	-
15; 20	Цементация при 920—950°, закалка с 790—7 810° в воде, отпуск при 180—200°	58—62	
45	Закалка с 820—840° в воде, отпуск при 500—600° (для деталей 8 с толщиной сечения до 60 мм)	—	[illegible]
	То же, для деталей с 9 толщиной сечения до 20 мм	—	[illegible]
10	Закалка с 830—850° в масле, отпуск при 500—550° (для мелких деталей)	4,3—4,0 (HB, $d_{отп}$)	[illegible]
11	Поверхностная закалка с нагревом токами высокой частоты, отпуск при 180—200°	54—60	—
	То же, отпуск при 200—240°	48—52	—

1) Steel; 2) heat-treatment regime; 3) kg/mm^2; 4) 08kp, 5) cyaniding at 850-900° with hardened layer 0.3-0.40 mmthick, quenching in water, tempering at 180-200°; 6) cementation at 20-950°, quenching from 790 810° in water, tempering at 180-200°; 7) quenching from 820-840° in water, tempering at 500 -600° (for componet up to 60 mm thick); 8) the same, for components up to 20 ml thick; 9) quenching from 830-850° in oil, tempering at 500-550° (for small components); 10) surface quenching with high-frequency electric heating, tempering at 180-200°; 11) the same, tempering at 200-240°.

in oil. Carbon structural shaping steels have a low hardenability, which increases with their carbon content. Cemented, cyanided, and surface-quenched components and many components of high-carbon steel are subjected to low tempering at 160-180° or 180-200°, depending on the hardness required. The high surface hardness obtained by low tempering promotes high wear resistance. In this case the mechanical strength of the component on bending, extension, or torsion is reduced, especially in the presence of stress concentrators. When the tempering temperature is raised to 250-300° the strength of quenched high-carbon-steel components or cemented components increases and their hardness decreases. It is necessary to take this decrease in hardness into account in selecting a low-tempering temperature or high-carbon steel. In order to improve the plasticity and viscosity of components of carbon structural shaping steel they are tempered at temperatures of no less than 450-500° after quenching. Table 9 presents examples of the heat treatment of machine components fabricated from steels of this type.

Carbon structural shaping steels are widely used in machine building for comparatively low-stress components, as well as when it is inexpedient to harden a component by heat treatment. It is also wise to use non-heat-treated steel when a component must have a definite rigidity; in this case the decrease in rigidity may make the use of stronger alloy steel in order to reduce the cross section of the component unjustified. Carbon structural shaping steels are more easily cut in the annealed state than alloy steels. Low-carbon steel is used for welded components, as well as for components fabricated by cold deformation (upsetting, beating, deep stamping, etc.). Medium-carbon steel is employed chiefly for components to be machined. In connection with the need to produce the weight of machine components, carbon structural shaping steels are in many cases being used as substitutes for alloy steels.

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CARBOTHERMIC NIOBIUM is niobium which is obtained by reduction from a mixture of the pentoxide and carbide according to the reaction: $nNb_2O_5 + 5NbC_n = (5 + 2n)Nb + 5nCO$, where $n < 1$ (direct reduction is also possible: $Nb_2O_5 + 5C = Nb + 5CO$). The reduction process is accomplished by heating bars or briquets which have been pressed from the forementioned mixture in a vacuum ($0.1-1\cdot10^{-4}$ mm Hg) at a temperature of 1600-1900°. The reduced metal compact retains the original form; the bars, for example, may have dimensions of $\sim(16-25) \times (16-50) \times (450-850)$ mm^3. After reduction and partial sintering at 1800-1900°, carbothermic niobium contains (weight %): 99.5-99.8 Nb (including Ta), and 0.02-0.150 O_2, N_2, C, 0.01 Fe, $<1\cdot10^{-3}$ Si. For additional purification this metal is remelted in electron beam furnaces, vacuum sintered directly or after hydrogenation, grinding, dehydrogenation, charging the metal powder with niobium oxide or carbide to the stoichiometric quantity for forming CO, and pressing. Plastic carbothermic niobium, sintered at 2300-2350°, contains up to 99.99 Nb (including Ta), $(3-10)\cdot10^{-3}$ C, $(2.5-10)\cdot10^{-3}$ O_2, $\leq1\cdot10^{-2}$ N_2, less than $(1-3)\cdot10^{-3}$ Ti, Fe, Si, S, P, As, Cu, Ca, Mg, less than $1\cdot10^{-4}$ H_2, Pb, Sn, Sb, Bi, Cd. After forging without preheating with a thickness reduction of 50% and brief resintering, the bars may be rolled without annealing into strip and foil of 20-micron thickness and less or may be subjected to other forms of pressure working.

The carbothermic method is one of the primary methods for industrial production of niobium (see Sintered Niobium, Niobium).

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O.P. Kolchin

CARBOXYLATE LATICES are latices of rubber-like polymers containing the carboxyl groups. The amount of dry material in the various carboxylate latices varies from 20 to 45 weight %. These latices. These latices are resistant to mechanical effects but coagulate with freezing. Those synthesized with the use of anionic emulsifiers, including the salts of the sulfo acids, can be used in the ion deposition and gelatinization processes (see Latices) with the formation of a strong gel. Among the other technological properties of the carboxylate latices, of great importance is their high impregnation capability with respect to the fibrous materials. The stiffness, strength and oil-resistance of products made from these latices improve with increase of the amount of polar carboxyl groups in the polymer. The presence of these groups, even in very small quantities (of the order of hundredths of parts gram-equivalent per 100 grams of rubber) sharply increases the adhesion of the polymers to the polar surfaces, particularly metallic ones. The physical properties of unvulcanized films made from these latices containing less than 0.1 g-eqv of carboxyl groups per 100 grams of polymer are almost analogous with the properties of films made from the corresponding latices which do not contain these groups. The primary characteristic of the carboxylate latices is that the carboxyl groups of the polymer easily enter into reaction with the ions of the polyvalent metals, which leads to unique vulcanization of the rubber as a result of the formation of salt bonds between its molecules. The vulcanizates thus obtained have very good physico-chemical properties, even in the absence of fortifying fillers.

The vulcanized products made from these latices are very wear resistant. The SKD-1 divinyl-carboxylate latex is used in combination with resorcin-formaldehyde resin for the impregnation of cord used in the production of tires based on divinyl-styrene oil-filled, natural and other rubbers. The divinyl-styrene and divinyl-nitrile carboxylate latices can be used for the production of industrial gloves, etc. Films made from the divinyl-nitrile carboxylate latices have particularly high strength (up to 300-500 kg/cm^2 with a relative elongation of 400-800%); both the vulcanized and unvulcanized films made from the carboxylate latices with a high content of acrylonitrile in the polymer have limited (to 15-20%) swelling in fuel containing up to 30% aromatic compounds, retaining adequate strength in this case. The high impregnation capability of the divinyl-nitrile carboxylate latices and the good properties of coatings made on their base are utilized in the paper industry in the preparation of high-strength, water- and oil-resistant grades of paper and cardboard. In mixtures with the melamino-formaldehyde and other thermoreactive resins, the divinyl-nitrile carboxylate latices are used for the production of gas- and oil-resistant nonwoven materials. Mixtures based on these latices are used, moreover, as bonding agents, sizings, binders for pigments, for the dressing of leathers and their substitutes, etc.

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A.I. Yezriyelev, A.V. Lebedev

CARBOXYLATE RUBBER – is the product of the polymerization of divinyl or isoprene, and also of divinyl with styrene or acrylonitrile, in emulsion, with addition of small quantities (1-3%) of methacrylic acid. Carboxylate rubbers containing 1-3% methacrylic acid show the highest values in the complex of their properties. Experimental lots of carboxylate rubbers with a content of 1-3% methacrylic acid are produced in the USSR: divinyl rubbers (SKD-1), isoprene rubbers (SKI-3-1); divinyl styrene rubbers with a proportion of 10 and 30% styrene (SKS-10-1 and SKS-30-1), and divinylnitrile rubbers SKN-1. The divinyl nitrile carboxylate rubber Hycar 1072 is produced abroad. Carboxylate rubbers contain Neozone D or a non-staining antioxidant. The workability and the physical properties of carboxylate rubbers with a proportion of 1-3% methacrylic acid do not significantly differ from those of the corresponding rubbers which do not contain carboxylic group. The addition of a greater quantity of carboxylic groups increases the stiffness of the carboxylic rubbers, decreases the resistance to water and deteriorates the workability. Hard or modified carboxylic rubbers, which do not require a mastication, are deliverable. The vulcanization of carboxylic rubbers is carried out by metal oxides (MgO, CaO, etc.). The usual sulfur vulcanization is possible owing to the presence of double bonds in the molecular chains. Carboxylate rubbers, nonfilled and filled with a low quantity of carbon black (30 parts by weight), obtained with metal oxides, are characterized by high mechanical and elastic properties.

Carboxylate rubbers vulcanized with metal oxides are viscous at temperatures of 100° and higher, especially under alternating deformations. This disadvantage may be removed by addition of sulfur, thiuram or other accelerants of the vulcanization to the metal oxides which results in the formation of a small quantity of bonds resistant to the effect of raised temperatures. The mechanical properties are decreased in this way, but they remain sufficiently high. Carboxylate rubbers vulcanized by means of metal oxides, sulfur or accelerants surpass the corresponding rubbers, which do not contain carboxylic groups, with regard to the tensile strength, elasticity, resistance to thermal aging and to the growth of cuts (see Tables 1-2).

TABLE 1

Properties of Nonfilled Carboxylate Rubbers Containing 3% Methacrylic Acid

1 Показатели	2 Полимеры					
	3 изопреновые		4 диметилстирольные		5 дивинилнитрильные	
	6 СКИ-3	6 СКИ-3-1	7 СКС-30А	7 СКС-30А-1	8 СКН-26	8 СКН-26-1
9 Прочность на разрыв (кг/см²)	20	275	66	250—300	40—60	300—400
10 Модуль при 300%-ном удлинении (кг/см²)	9	50—55	13	30—45	14	50—70

1) Characteristics; 2) polymers; 3) isoprene; 4) dimethyl styrene; 5) divinyl nitrile; 6) SKI; 7) SKS-30A; 8) SKN: 9) tensile strength (kg/cm^2); 10) modulus at 300% elongation (kg/cm^2).

TABLE 2

Properties of SKS-30A and SKS-30A-1 Rubbers With 30 Parts by Weight of Channel Carbon Black, Obtained Using Metal Oxides and Thiuram

1 Показатели	2 СКС-30А	3 СКС-30А-1
4 Прочность на разрыв (кг/см²)	до 260	до 300
5 Модуль при 300%-ном удлинении (кг/см²)	35	90
6 Сопротивление раздиру (кг/см)	44	81
7 Эластичность по отскоку (%)	51	50
8 Прочность на разрыв (кг/см²) после теплового старения:		
9 при 100° в течение 240 час.	-	363
10 при 100° в течение 144 час (при тиурамном режиме)	292	—
Сопротивление разрастанию 11 порезов (циклы)	131 тыс. 12	300 тыс. 12

1) Characteristics; 2) SKS-30A; 3) SKS-30A-1; 4) tensile strength (kg/cm^2); 5) modulus at 300% elongation (kg/cm^2); 6) tear resistance (kg/cm); 7) resilience (%); 8) tensile

strength (kg/cm²) after thermal
aging; 9) at 100° for 240 hrs;
10) at 100° for 144 hrs (for
thiuram rubbers); 11) resistance
to the growth of cuts (cycles);
12) thousands.

The main disadvantage of all carboxylate rubber compounds is the increased tendency to scorching. This disadvantage may be reduced, but not completely removed, by addition of antiscorchings (Phthalic anhydride and other substances), and also by removing the surplus of moisture from the stock. The higher adhesion to metals, leather and textiles is an advantage of the carboxylic rubbers. The possible fields of application are: tire treads, conveyor belts, and technical rubber products.

References: Novyye kauchuki. Svoystva i primeneniye [New Rubbers, Properties and Application. A Collection of Translations, Moscow, 1958, page 248; "Khimiya i tekhnologiya polimerov," 19[illegible], No. [illegible], page 15; "Kauchuk i rezina," 1957, No. 3, page 11; ibid. No. [illegible], page 1.

[illegible].Ya. Davirts

CARBURIZING OF STEEL - is the saturation of the surface of low-carbon steel (including alloy steel) by carbon in order to increase the hardness, the abrasion resistance, and the fatigue strength. The optimum carbon content in the carburized zone is 0.8-0.9 %.

After heat treatment, the carburized zone has a hardness of >58RC and has either the structure of martensite or of martensite with carbides and a small quantity of residual austenite; the core of the steel retains a sufficient ductility. Figure 1 shows the distribution of the carbon and of the hardness along the depth of the carburized zone, and Fig. 2 shows the effect of the thickness of the carburized zone on the endurance limit of the steel. The carburizing of steel is carried out at 900-970° usually up to a depth of 0.5-2.0 mm. Steel carburizing is used in the manufacture of pinions, piston pins, camshafts and crankshafts, bolts, nuts, and many other parts.

Fig. 1. Distribution of carbon and hardness (after hardening and tempering at 200°) in the carburized zone of steel grade 20, carburized in a solid carburizing agent at 930° for 12 hours. 1) Content of C, %; 2) depth of the zone, mm.

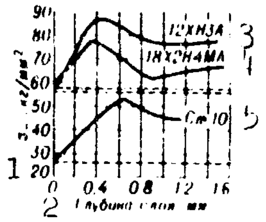


Fig. 2. Effect of the thickness of the carburized zone on the endurance limit at alternating bending of the steel grades St 10, 12KhN3A, and 18Kh2N4MA, hardened, and tempered at 200°. 1) σ_{-1}, kg/mm²; 2) thickness of the zone, mm.

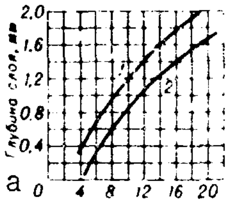


Fig. 3. The thickness of the carburized zone as a function of the hardening time at 930°: 1) Gas carburizing of large objects in continuous furnaces; 2) solid carburizing in large containers. a) Thickness of the zone, mm; b) duration of the process, hours.

When carburizing is carried out in a solid carburizing agent in containers, the fresh mixture is composed of 15-25% $BaCO_3$ or Na_2CO_3, 3-5% $CaCO_3$, 2-4% black oil, the rest being wood charcoal or semicoke. The working agent consists of 25% of the fresh and 75% of a waste mixture. The formation of the carburized zone is carried out at 930-950°, within 5-10 hours, and at a rate of about 0.10-0.12 mm/hr (Fig. 3). After the carburizing has been completed the containers with the parts are cooled in air, and then the parts are hardened and tempered at a low temperature (180-200°). Carburizing in a solid agent is always superseded by the gas carburizing which allows the process to be more easily controlled, the duration of the latter being reduced by 15-20%; a total mechanization and automation is possible. Natural, commercial, generator or petroleum gas, propane, butane, and also synthol, kerosene, benzene, spindle oil, etc., are used as carburizing agents. It is recommended that rich gases be previously burned in endothermic devices in order to obtain a gas having approximately the following composition: 40% CO, 40% H_2, 0.1-1% CH_4, the rest is N. This gas is used as a diluting agent or, with a higher CH_4 and CO content, directly for carburizing. The quality of the parts improves significantly when the carbon content in the carburized zone reaches the optimum and is controlled automatically. The composition and activity of the carburizing gas is tested either by means of the dew point or by means of the electrical resistance of an iron wire placed in the furnace. The supply of the gas (or the liquid) into the furnace and the working conditions of the endothermic arrangement are controlled on the basis of the results of this continuous and automatic test. After gas carburizing, the parts are cooled to 820-850°, and then hardened and tempered at low temperatures. Parts from high-alloy steel are sometimes annealed at high temperatures, at 650-760° before hardening (in order to improve the cuttability, and to increase the hardness after tempering), and, after hardening, they are submitted to a cold treatment at –60 to –80° (in order to increase the hardness by decreasing the residual austenite content in the carburized zone).

Areas which are not to be carburized are insulated by electrocoppering (thickness of the layer 0.01-0.05 mm) or coating with pastes.

Coarse-grained steel or a carbon supersaturation of the zone (fractures, splitting-off of the zone), a high content in residual austenite in the zone (a reduced endurance limit, formation of pittings), or a low hardness (reduced abrasion resistance) are, in the most cases, the causes for an untimely failure of cemented parts.

References: Metallovedeniye i termicheskaya obrabotka stali [Metal Science and Heat Treatment of Steel], a handbook, 2nd Edition, Vol. 2, Moscow, 1962.

A.N. Minkevich

CARBURIZING OF TITANIUM ALLOYS — is carried out in a solid carburizing agent, in air, or argon by forming a very brittle, up to 20 microns thick carbide-oxide crust (TiC, TiO_2) and a 0.15-0.18 mm thick layer of a solid solution of oxygen in α titanium having a hardness of about HV 1000 on the metal surface. A brittle TiC layer with a thickness of some microns, poorly adherent to the basic metal, is formed when carburizing of the titanium alloy is carried out in a vacuum furnace and in coal or graphite at temperatures of 950° and more. Highly hardened layers of $TiC_{0.5}$ with a thickness of up to 8 microns sufficiently adherent to the metal and with a good resistance to abrasion are obtainable by gas carburizing of titanium alloys in argon with an addition of 0.5-5% CO. A considerable (10 fold) increase of the hydrogen content in the alloy occurs in this case. None of the methods for carburizing titanium alloys has attained a practical significance owing to the considerable brittleness of the formed surface layers and their poor adhesion to the metal.

References: Smirnov, A.V. and Nachinkov, A.D., "Metallovedeniye i termicheskaya obrabotka metallov" [Metal Science and Heat Treatment of Metals], 1960, No. 3, pages 22-29.

I.S. Anitov and Ye.N. Novikova

CAST BRASS is brass intended for the fabrication of semimanufactures and shaped parts by the casting method. The casting brass contains 50-81% Cu. As the alloying elements use is made of aluminum, manganese, iron, silicon, tin and lead. These brasses have excellent casting properties and corrosion-resistance. The majority have good antifriction properties and in many cases are fully adequate replacements for the tin bronzes. 10 grades of the casting brasses are produced in accordance with GOST 1019-47 (Table 1). Pigs meeting GOST 1020-60 of the chemical composition shown in Table 2 are used for the production of brass castings. The basic physical properties of the casting brasses are presented in Table 3.

TABLE 1

Chemical Composition and Mechanical Properties of the Cast Brasses (GOST 1019-47)

Сплав 1	2 Содержание основных элементов (%)				Механич. свойства 3	
	Cu	Mn	другие элементы 4	Zn	5 σ_b (кг/мм², не менее)	δ (%)
6 ЛА67-2,5	66—68	—	2—3 Al	Остальное	40* 30**	15* 12**
7 ЛАЖМц66-6-3-2	64—68	1,5—2,5	6—7 Al 2—4 Fe	» 16	65* 60** 70***	7* 7** 7***
8 ЛАЖ60-1-1Л	58—61	0,1—0,6	0,75—1,5 Al 0,75—1,5 Fe 0,2—0,7 Sn	»	42* 38**	18* 20**
9 ЛК80-3Л	79—81	—	2,5—4,5 Si	»	30* 25**	15* 10**
10 ЛКС80-3-3	79—81	—	2,5—4,5 Si 2—4 Pb	»	30* 25**	15* 7**
11 ЛМцС58-2-2	57—60	1,5—2,5	1,5—2,5 Pb	»	35* 25**	8* 10**
ЛМцОС58-2-2-2 12	56—60	1,5—2,5	1,5—2,5 Sn 0,5—2,5 Pb	»	30* 30**	4* 6**
ЛМцЖ55-3-1 13	52—58	3—4	0,5—1,5 Fe	»	50* 45**	10* 15**
ЛМцЖ52-4-1 14	50—55	4—5	0,5—1,5 Fe	»	50*	15*
ЛС59-1Л 15	57—61	—	0,8—1,9 Sn	»	20***	20***

* Chill casting. ** Sand casting. *** Centrifugal casting.

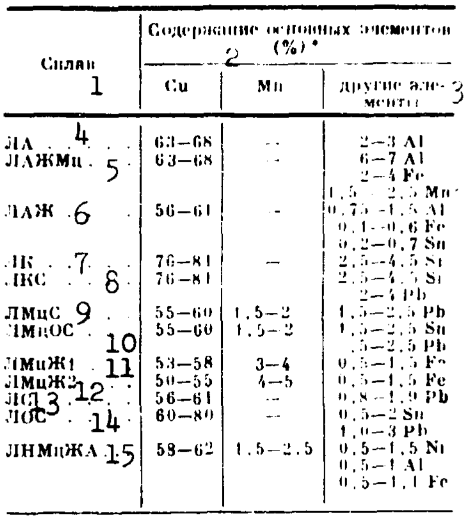
1) Alloy; 2) content of basic elements (%); 3) mechanical properties; 4) other elements; 5) σ_b (kg/mm², no less than); 6) LA67-2.5; 7) LAZhMts66-6-3-2; 8) LAZh60-1-1L; 9) LK80-3L; 10) LKS80-3-3; 11) LMtsS58-2-2; 12) LMtsOS58-

2-2-2; 13) LMtsZh55-3-1; 14) LMtsZh52-4-1; 15) LS59-1L; 16) remainder.

The cast brasses are used for the production of corrosion-resistant cast details for ocean vessels (propellers, blades, fittings, etc.), aircraft, various machines and equipment, all sorts of bolts and screws, gears, bearings and other antifriction details operating under severe conditions.

TABLE 2

Chemical Composition of Casting Brasses in Pigs (GOST 1020-60)



Сплав 1	Содержание основных элементов (%)* 2		
	Cu	Mn	другие элементы 3
ЛА 4	63—68	—	2—3 Al
ЛАЖМц 5	63—68	—	6—7 Al 2—4 Fe 1,5—2,5 Mn
ЛАЖ 6	56—61	—	0,75—1,5 Al 0,1—0,6 Fe 0,2—0,7 Sn
ЛК 7	76—81	—	2,5—4,5 Si
ЛКС 8	76—81		2,5—4,5 Si 2—4 Pb
ЛМцС 9	55—60	1,5—2	1,5—2,5 Pb
ЛМцОС 10	55—60	1,5—2	1,5—2,5 Sn 1,5—2,5 Pb
ЛМцЖ1 11	53—58	3—4	0,5—1,5 Fe
ЛМцЖ2 12	50—55	4—5	0,5—1,5 Fe
ЛС 13	56—61	—	0,8—1,9 Pb
ЛОС 14	60—80	—	0,5—2 Sn 1,0—3 Pb
ЛНМцЖА 15	58—62	1,5—2,5	0,5—1,5 Ni 0,5—1 Al 0,5—1,1 Fe

* Remainder zinc.

1) Alloy; 2) content of basic elements (%)*; 3) other elements; 4) LA; 5) LAZhMts; 6) LAZh; 7) LK; 8) LKS; 9) LMtsS; 10) LMtsOS; 11) LMtsZh1; 12) LMtsZh2; 13) LS; 14) LOS; 15) LNMtsZhA

TABLE 3

Physical Properties of Casting Brasses (of average chemical composition)

1 Свойства	2 ЛА67-2,5	3 ЛАЖМц66-6-3-2	4 ЛАЖ60-1-1Л	5 ЛК80-3Л	6 ЛКС80-3-3	7 ЛМцС58-2-2	8 ЛМцОС58-2-2-2	9 ЛМцЖ52-4-1	10 ЛМцЖ55-3-1	11 ЛС59-1Л
12 γ (г/см³)	8,5	8,5	8,5	8,3	8,6	8,5	8,5	8,3	8,5	8,5
13 Темп-ра ликвидуса (°С)	995	899	904	900	900	890	890	870	880	885
$\alpha \cdot 10^6$ (1/°С)	—	19,8	21,6	17	17	21	—	—	22	20,1
14 λ (кал/см·сек·°С)	0,27	—	0,27	—	—	0,26	0,26	—	0,24	0,26
15 σ_b (кг/мм²) при:										
20°	35	65	40	50	35	36	35	50	50	35
200°	—	—	—	40	—	40	—	50	—	37
300°	—	—	—	40	—	33	—	44	—	26
400°	—	—	—	30	—	24	—	42	—	23
16 δ(%) при:										
20°	15	7	20	20	20	20	6	20	10	40
200°	—	—	—	22	—	20	—	—	—	43
300°	—	—	—	17	—	22	—	24	—	—
400°	—	—	—	17	—	24	—	28	—	28
17 $\sigma_{0,2}$ (кг/мм²)	—	—	25	16	14	24	—	30	—	15
$a_н$ (кгм/см²)	—	—	—	12	4	7	—	—	—	2,6
HB (кг/мм²)	90	—	90	105	95	80	95	120	105	85
18 Линейная усадка (%)	—	—	—	1,7	1,7	1,8	—	1,7	1,6	2-2,3
19 Коэфф. трения в паре с осевой сталью:										
20 со смазкой	—	—	—	0,01	0,009	0,16	—	—	—	0,013
21 без смазки	—	—	—	0,19	0,15	0,24	—	—	—	0,17
22 Потеря веса (г/м²·ч.) при контакте:										
23 с морской водой	—	—	—	0,068	—	0,05	—	0,055	0,047	0,059
24 с паром	—	—	—	0,312	—	—	—	—	—	0,02

1) Properties; 2) LA67-2.5; 3) LAZhMts66-6-3-2; 4) LAZh60-1-1L; 5) LK80-3L; 6) LKS80-3-3; 7) LMtsS58-2-2; 8) LMtsOS58-2-2-2; 9) LMtsZh52-4-1; 10) LMtsZh55-3-1; 11) LS59-1L; 12) (g/cm²); 13) liquidus temperature; 14) (cal/cm-sec-°C); 15) σ_b(kg/mm²) at: 16) at; 17) (kg/mm²); 18) linear shrinkage (%); 19) coefficient of friction in pair with axle steel; 20) with lubrication; 21) without lubrication; 22) weight loss (g/m²-hr) in contact with; 23) sea water; 24) steam.

References: Metals Handbook 1948 edition, Cleveland, [1952]; Smiryagin A.P., Promyshlennyye tsvetnyye metally i splavy [Industrial Nonferrous Metals and Alloys], 2nd ed., M., 1956; Spravochnik po mashinostroitel'nym materialam [Handbook on Machine Construction Materials], Vol. 2, M., 1959.

Ye.S. Shpichinetskiy

CAST ELECTRIC INSULATION (or monolithic insulation) – see Electric insulation compounds.

II-54n

CAST HIGH-TEMPERATURE NICKEL ALLOYS are nickel-base alloys which have special advantages in comparison with the alloys based on the other elements of group VIII of the Mendeleyev Periodic System – absence of polymorphism, relatively high acid resistance and heat resistance, and also the formation of compounds of the $Ni_3(Al, Ti)$ type with a crystal structure which is similar to the solid solution structure.

TABLE 1

Chemical Composition of Cast High-Temperature Nickel Alloys with Carbide Strengthening

Сплав 1	2 Содержание элементов (%)							3
	C	Si	Mn	Fe	Cr	Mo	W	Другие элементы
4 Нимокаст 75	0,07 0,15	0,2 0,4	0,2 0,7	— ≤5	18 22	—	—	Al 0,1—[illegible] Ti 0,3—[illegible]
5 Хастелой B	≤0,12	≤1	≤1	4—7	—	26—30	0,25—0,[illegible]	—
Хастелой C	≤0,15	≤1	1	4—7	13—16	15—19	3,5—5,5	—
ВЛ7-45У 6	0,1	≤0,55	≤0,7	23—26	19,5—20,5	—	7,5—8,5	B [illegible]
ВХН1 7	0,5—1,2	1,5—2,5	≤0,5	≤5	35—40	—	—	—

1) Alloy; 2) element content (%); 3) other elements; 4) Nimocast 75; 5) Hastelloy; 6) VL7-45U; 7) VKhN1.

The cast alloys have higher stress-rupture strength than the same alloys in the wrought condition. This is associated with the dendritic structure of the cast alloys and the possibility of forming carbide and boride phases during the crystallization process along the grain boundaries in the form of pseudoeutectics which inhibit the development of cracks along these boundaries. The retardation of the small plastic deformation, corresponding to the creep limit of the cast high-temperature alloys, is practically the same or somewhat higher than for the wrought alloys. The casting alloys have good alloying capabilities, while in the wrought alloys this capability is limited by the need for the use of hot plastic deformation, which is very difficult with marked alloying. In this connection, the temperature level of the high-temperature strength of the cast alloys is 50-100° higher than for the wrought alloys.

TABLE 2

Mechanical Properties of Cast High-Temperature Nickel Alloys with Carbide Hardening

Сплав 1	2 Термич. обработка	Темп-ра 3 (°C)	σ_b (кг/мм²) 4	δ (%)	ψ (%)	σ [illegible] 4 (кг/мм²)	σ [illegible] (кг/мм²)	σ [illegible] (кг/мм²)
Хастелой B 5	—	20	[illegible]	6	10	—	—	—
		650	[illegible]	[illegible]		[illegible]	[illegible]	
		760	—		—	[illegible]	[illegible]	
		815	40	20	—	—	—	—
		870	—	—	—	12–13	[illegible]	
Хастелой C 5	—	20	[illegible]	10–15	11–16		—	
		650	43	15		[illegible]	[illegible]	-
		815	40	18	—			
		870	—	-	-	[illegible]	[illegible]	-
ВЛ7-45У 6	7 Нагрев до 950°, выдержка 5 час., охлаждение на воздухе	20	50	7	10	—	—	26
		700	40	5,5	9	[illegible]	—	—
		800	30	10	12	[illegible]	—	16
		900	—	—	—	9	—	—

1) Alloy; 2) heat treatment; 3) temperature (°C); 4) (kg/mm²); 5) Hastelloy; 6) VL7-45U; 7) heat to 950°, hold 5 hours, air cool.

TABLE 3

Chemical Composition and Heat Treatment of Some Soviet Cast High-Temperature Nickel Alloys with Intermetallide Strengthening*

Сплав	2 Содержание элементов (%)								3 Термич. обработка
	Cr	Al	Ti	W	Mo	C	B	Fe	
ЖС3 4	14–18	1,6–2,2	1,6–2,3	4,5–6,5	3–4,5	0,11–0,16	0,02	8	Нагрев до 1150°, выдержка 7 час., охлаждение на воздухе 5
АНВ-300 6	14–17	4,5–5,5	1,4–2	7–10	—	≤0,1	0,1	—	Нагрев до 1120°, выдержка 10 час., охлаждение на воздухе 7
ВЖ36-Л2 8	19–22	3,5–[illegible]	2,3–2,7	—	—	≤0,06	≤0,05	[illegible]	Нагрев до 1150°, выдержка 4 час., охлаждение на воздухе. Нагрев до 1080°, выдержка 4 час., охлаждение на воздухе 9
10 ЖС6	11,5–13,5	4,7–5,2	2,2–2,8	6–8	4–[illegible]	0,11–0,18	0,02	2	Нагрев до 1200°, выдержка 4 часа, охлаждение на воздухе 11
12 ЖС6-К	10,5–12,5	5–6	2,5–3	4,5–5,5	3,5–4,5	0,11–0,2	0,02	2	Нагрев до 1200±20°, выдержка 4 часа, охлаждение на воздухе 13
14 ВЖЛ8	[illegible]–17	2,5–3,5	1,8–2,5	—	4,5–[illegible]	0,1–0,2	0,06	8–12	Нагрев до [illegible], выдержка 4 часа, охлаждение на воздухе. Нагрев до [illegible], выдержка 4 часа, охлаждение на воздухе 15

*About 0.01% Ce and about 0.1% Zr is introduced into the alloys.

1) Alloy; 2) element content (%); 3) heat treatment; 4) ZhS3; 5) heat to 1150°, hold 7 hours, air cool; 6) ANV-300; 7) heat to 1120°, hold 10 hours, air cool; 8) VZh36-L2; 9) heat to 1150°, hold 4 hours, air cool. Heat to 1080°, hold 4 hours, air cool; 10) ZhS6; 11) heat to 1200°, hold 4 hours, air cool; 12) ZhS6-K; 13) heat to 1200 ± 20°, hold 4

hours, air cool; 14) VZhL8; 15) heat to 1150°, hold 4 hours, air cool. Heat to 1080°, hold 4 hours, air cool.

TABLE 4

Mechanical Characteristics of Some Soviet Cast High-Temperature Nickel Alloys with Intermetallide Strengthening

Сплав 1	Темп-ра (°С) 2	σ_b 3 (кг/мм²)	δ_{10} (%)	ψ (%)	σ_{100} 4 (кг/мм²) 3	σ_{-1} на базе $2\cdot10^7$ циклов (кг/мм²)
5 ЖС3	20	75	8,5	14	—	—
	800	56	3	17	29—30	30
	900	40	5	7	10	—
6 ЖС3-ДК	20	105	6—10	10—15	—	—
	850	85	7	8	38	—
	900	75	8—12	8—16	29—30	—
7 ЖС6	20	104	1	2	—	27
	800	85	0,5	1,5	50	27
	900	78	2,5	3	28	26
	1000	45	6	11	14	22
8 ЖС6-К	20	100	2,5	6,5	—	28
	800	92	2	5	52	28
	900	78	2	3	32	29
	1000	53	4,5	6,5	15—16	22
9 ВЖ36-Л2	20	86	3	5	—	—
	800	80	4	4,5	28	28
	900	51	10	11	13	17
10 ЭИ857	20	85	2	2	—	—
	800	80	2	2,5	51	26
	900	73	0,7	2,5	32	25
	1000	47	4	6	15	22
11 АНВ-300	20	85	1,4	2	—	—
	850	70	0,5	2,5	24	30
	950	50	1,7	3,5	14	25
12 ЭП23	20	125	2,2	11	—	—
	900	95	6,2	13	—	—
	1000	72	12,7	22	15	—
	1100	45	15	22	6	—

1) Alloy; 2) temperature (°C); 3) (kg/mm²); 4) on basis of $2\cdot10^7$ cycles; 5) ZhS3; 6) ZhS3-DK; 7) ZhS6; 8) ZhS6-K; 9) VZh36-L2; 10) EI857; 11) ANV-300; 12) EP23.

In comparison with the wrought alloys, the cast high-temperature nickel alloys have greater fabricability, particularly in the production of parts of complex shape. Among the deficiencies of the existing cast alloys is their lower impact strength in comparison with the wrought alloys.

With regard to the method of structural strengthening, the cast high-temperature nickel alloys may be divided into the alloys with carbide hardening (Tables 1, 2) and the alloys with intermetallide hardening (Tables 3, 4). The first type of alloys is small in number and not promising with relation to improvement of the high-temperature strength characteristics. The second is at present the basic type of cast nickel alloys.

The Nimocast 75 alloy does not have good high-temperature strength, it is used to fabricate heat-resistant parts. The Hastelloy B and C alloys have high corrosion resistance in acids. Hastelloy C has higher strength at high temperature than Hastelloy B and is used for

TABLE 5

Coefficient of Thermal Conductivity of Some Cast High-Temperature Nickel Alloys

1 [illegible]	2 λ [illegible] при температурах [illegible]									
	20	100	200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ЖС3 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ЖС6 4	[illegible]	0,027	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ЖС6-К 5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6 ЖС3-ДК	0,019	0,021	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ВЖ36-Л2 7	0,027	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8 АНВ-300	0,022	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1) Alloy; 2) λ (cal/cm-sec-°C) at temperatures (°C); 3) ZhS3; 4) ZhS6; 5) ZhS6-K; 6) ZhS3-DK; 7) VZh36-L2; 8) ANV-300.

TABLE 6

Coefficient of Linear Expansion ($\alpha \cdot 10^6$) of Some Cast High-Temperature Alloys

1 [illegible]	2 [illegible]						
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3 ЖС3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ЖС6 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ЖС6-К 5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ЖС3-ДК 6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7 ЭИ857	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ВЖ36-Л2 8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
АНВ-300 9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1) Alloy; 2) $\alpha \cdot 10^6$ in the temperature range (°C); 3) ZhS3; 4) ZhS6; 5) ZhS6-K; 6) ZhS3-DK; 7) EI857; 8) VZh36-L2; 9) ANV-300.

TABLE 7

Chemical Composition of Wear-Resistant and High-Temperature Nickel Casting Alloys

1	2 [illegible]							
	[illegible]	[illegible]	[illegible]	W	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1) Alloy; 2) element content (%); 3) V-56; 4) VZhL-1.

TABLE 8

Stress-Rupture Strength Limits of the ZhS6-K Alloy

Temperature (°C) 1	σ [illegible]	σ [illegible]	σ [illegible]	σ [illegible]
	2 (kg/mm²)			
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	—	[illegible]	[illegible]	[illegible]

1) Temperature (°C); 2) (kg/mm^2)

TABLE 9

Mechanical Properties of the ZhS6-KP Alloy

Alloy 1	Temperature (°C) 2	t	σ_b	δ	ψ	σ [illegible]	σ [illegible]
		(kg/mm²) 3		(%)		(kg/mm²) 3	
ZhS6-KP cast 4	20	[illegible]	[illegible]	[illegible]	[illegible]	—	—
	800	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	900	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1000	—	[illegible]	[illegible]	[illegible]	[illegible]	—
ZhS6-KP wrought 5	20	20000	[illegible]	12–13	[illegible]	—	—
	800	[illegible]	[illegible]	12–15	15–20	[illegible]	[illegible]
	900	[illegible]	[illegible]	[illegible]	[illegible]	27	[illegible]
	1000	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1) Alloy; 2) temperature (°C); 3) (kg/mm^2); 4) ZhS6-KP cast; 5) ZhS6-KP wrought.

the fabrication of heat-resistant parts (jet engine nozzle blades, etc.). The VL7-45U alloy is used for fabricating nozzle vanes. The VKhN1 alloy is used for aircraft engine exhaust valve facings.

The primary strengthening phase in the Nimocast 75 and VL7-45U alloys is the $Me_{23}C_6$ carbide type, in the VKhN1 alloy it is the Me_7C_3 carbide type, in the Hastelloy B and C alloys it is the double carbide $Ni_3(Mo, Cr)_3C$.

Excellent high-temperature strength characteristics of both the cast and wrought nickel alloys are obtained primarily by creating in them the a' phase strengthening (often designated as the γ' phase) of the type $Ni_3(Al, Ti)$, by its quantity, degree of dispersion, distribution, and form of precipitation. The strengthened and thermally stable solid solution in these alloys is created by alloying them with the elements Co, Cr, W, Mo, Ni which inhibit the diffusional processes in the solid solution, and also by the processes of diffusional exchange between these elements and the precipitation phases.

Depending on the alloying, the parameters of the elementary cell of the type $Ni_3(Al, Ti)$ phase may differ from the solid solution, which is a source for the formation of dislocations in the boundary regions between them. The best binding between the $Ni_3(Al, Ti)$ phase and the solid solution, and also the highest thermal stability of the alloys are achieved with identical or slightly differing parameters of the crystal lattices. There are nickel alloys with strengthening by other intermetallide phases. In the low-carbon nickel alloys containing niobium, at 650-800° the strengthening metastable Ni_3Nb phase is formed with a structure similar to the solid solution, and also the $Ni_3(Al, Ti)$ phase. At higher temperatures the stable Ni_3Nb phase with orthorhombic structure is formed. There are several cast alloys of this type EPE10, GPMJ, etc.) containing up to 0.05% C, 20% Cr, 5-6% W and Mo and 6.5% Nb. These alloys have good casting properties when cast in air. Their 100-hour stress-rupture strength at 870° is equal to 11-12 kg//mm^2. Several low-carbon cast high-temperature nickel alloys containing iron are strengthened by phases of the AB_2 type (Laves phases), where B is primarily iron and A-W, Mo. Nb, Ti. There are cast high-temperature nickel alloys with combined strengthening by the Ni_3Me phases and the Fe_2Me phases (VZhL9 alloy and others).

The amount of the α' phase is determined not only by the content of the mutually equivalent titanium and aluminum, but also by the content of the elements which enter into the solid solution and affect the solubility of aluminum and titanium in the alloy. Cobalt partially replaces nickel in the α' phase (with the presence of a sufficient amount of aluminum, molybdenum, and tungsten in the alloy). Cobalt does not enter into the α' phase in the alloys of the Ni-Co-Cr-Ti-Al system. In the existing cast high-temperature nickel alloys the amount of the α' phase varies in the range of 6-55% depending on the alloying. The high-temperature-strength temperature level increases from 700 to 1100° with increase of the amount of the α' phase. Many cast high-temperature nickel alloys are additionally strengthened by the carbide phases, for which carbon ($\leq$ 0.25%) is introduced. The carbon also contributes to the refining in the melting process thanks to its strong reducing action. The titanium carbides which are formed in these alloys in the crystallization process between the dendrite axes facilitate the disintegration of the grains, which is of great importance in increasing the resistance to temperature stresses and repeated loading. Among the smaller additives, a favorable influence is shown by cerium, which significantly reduces the sulfur content and has a favorable effect on the condition of the grain boundaries, and also boron (0.01-0.03%) and about 1% Zr, which strengthen the grain boundaries. Depending on the chromium, tungsten, and molybdenum content, carbides of the type $Me_{23}C_6$, $Me^1_3Me^2_3C$, where Me^1 = Ni, Fe, Co, Si, and Me^2 = Cr, W, Mo, Nb, are formed in the alloys. These carbides are preferentially precipitated along the grain boundaries. The temperature range for stability of $Me_{23}C_6$ is up to ~1050°, for the double carbides it is 1000-1300°. Strengthening of the grain boundaries is also achieved by microalloying, particularly by allowing with boron, which has low solubility in nickel and its alloys. The introduction of boron and carbon also aids in improving the casting properties of the alloys.

In connection with the reduction of the melting point of nickel by many of the alloying elements which enter into the cast alloys, their melting point is in the 1270-1380° range. The interaxial portions of the alloys are enriched with the elements which reduce the melting point of nickel – carbon, aluminum, titanium, chromium, molybdenum. The dendrite axes are enriched with tungsten, which increases the melting point of the nicke.

On the surface of the liquid nickel alloys containing aluminum and titanium, a hard elastic film is formed in air above the liquidus temperature and up to 1650° which then shows up in the part being cast in the form of blisters which cause a reduction of the mechanical characteristics. The oxide film is completely eliminated when the parts are vacuum cast. The oxide film which forms on the surface of the molten oxidized alloy is reduced in the vacuum, particularly as a result of interaction with carbon, forming carbon monoxide.

The quality of the cast alloy depends on the primary dendritic structure: 1) the grain size (macrograins) and their distribution; 2) the size and distribution of the dendrite offshoots (micrograins); 3) the intradendritic liquation; 4) the distribution and form of the microstructural components; 5) the defects of the crystalline structure (vacancies, dislocations, and packing defects) which are formed in the casting process and during heat treatment.

The formation of the cast structure depends basically on the pouring temperature and the rate of crystallization, which is to a considerable degree determined by the mold temperature. Large macro- and micrograins are formed when casting parts from high temperatures and also with low crystallization rates. The liquational phenomena are very strongly developed. The primary microstructural components are coarsely dispersed. The titanium carbides, normally having a polyhedral form, are precipitated out between the dendrite axes in the form of elongated particles and may even form a closed or semiclosed rigid network. Alloys with such a structure have reduced mechanical characteristics.

Casting parts with the metal temperature somewhat higher than the solidus temperature and also casting with a high crystallization rate provide for the formation of more highly dispersed and uniformly distributed structural components (micro- and macrograins and primary precipitation phases). In this case the liquation phenomena are not strongly developed; the alloy has high density and higher properties. Pouring of alloys from low temperatures (60-150° above the liquidus temperature) is performed using vacuum melting. The cast high-temperature nickel alloys have a quite wide crystallization range, which facilitates the formation of intercrystalline porosity during pouring of parts without adequate feed and with slow crystallization. Relatively rapid dendritic crystallization provides for dense structure of the casting without intercrystalline porosity.

Heat treatment of the cast high-temperature nickel alloys may be used to redistribute the alloying elements in the solid solution of the dendrites and between the phases, and also to create new structural components.

With increase of the aluminum content in the alloys, the solution temperature of the basic strengthening phase is increased and is equal to ~1000° with a content of 1% Al; 1100° with 2% Al; 1150° with 4-4.5% Al; 1200° and above with $\geq$ 5% Al.

The addition of titanium to the alloys somewhat increases the quenching temperature. A characteristic feature of the cast high-temperature nickel alloys containing more than 4% Al is the impossibility of performing a solid solution quency even with high cooling rates. There will inevitably be precipitation of the α' phase in the cooling process; the amount, degree of dispersion and distribution of the α' phase after quenching such alloys depend on the cooling rate. Therefore certain of the highly alloyed casting alloys are subjected to only a single heat treatment: air cooling above the solution temperature of the α' phase. When using this heat treatment the aging process takes place during the air cooling. Certain cast nickel alloys are subjected to double or triple heat treatment (quench from two temperatures, isothermal quency, or quench with subsequent aging at a temperature equal to or higher than the operational temperature of the alloy). In alloys containing carbon there is a redistribution of the carbon between the carbide phases during the heat treatment process. In the titanium-bearing alloys of the Ni-Cr-Al-Ti-W-Mo system there is partial solution of the metastable titanium carbide and binding of the dissolved carbon in other carbides during heating for quench and during aging: up to 1000°, binding takes place in carbides of the $Me_{23}C_6$ type (with possible formation of the Me_7C_3 carbides also); above 1000° there is binding primarily in carbides of the $Me_{\frac{1}{3}}Me_{\frac{2}{3}}C$ type which are more stable at these temperatures than chromium carbide. In alloys which do not contain tungsten and molybdenum, the carbides of the $Me_{23}C_6$ and Me_7C_3 type are stable to ~1250°.

Coagulation of the α' phase takes place during the process of long-term operation of the alloys at high temperatures; plastic deformation (creep) of the highly alloyed alloys at high temperatures causes, along with the coagulation of the α' phase, consolidation of its particles. The higher the level of stresses acting, the greater the creep and diffusional mobility of the atoms, and consequently the higher the rate of the process of coagulation of the strengthening phases, intermetallides and carbides. Series of cast high-temperature nickel alloys with intermetallide strengthening with varying ratio of the alloying elements are used in various countries. The presence of carbon is characteristic for most of the alloys. The Nimocast 80 and 90 casting alloys, which are analogous in chemical composition to the Nimonic 80 and 90 wrought alloys, also contain carbon. Aluminum and titanium [illegible] present in all the alloys with the exception of the Haynes [illegible] alloy which contains aluminum but no titanium. Strengthening of the solid solution is created primarily by molybdenum and less often by tungsten.

The majority of the alloys contain a considerable amount of cobalt. Iron is represented in the form of an impurity, since it reduces the high-temperature strength. As we noted above, the grain boundaries are strengthened by small amounts of boron or boron together with zirconium, which affect the retardation of the diffusional processes along the grain boundaries.

The harmful impurities, particularly impurities of the low-melting metals (Bi, Pb, Sb and others) which have low solubility in nickel, form a low-melting phase along the grain boundaries which leads to their premature failure. Bismuth and lead markedly reduce the high-temperature strength even with their presence in the alloys in thousandths of a percent by weight. A limiting lead content of no more than 0.005% is permitted for alloys of the Nimocast type. The bismuth content in the cast high-temperature nickel alloys must not exceed 0.001%.

The characteristics of certain Soviet cast high-temperature nickel alloys are shown in Tables 5, 6.

The high-temperature alloys which have high resistance to wear at high temperatures (Table 7) constitute a special class of cast high-temperature nickel alloys. These alloys must have not only high stress-rupture strength but also high resistance to wear, which is increased with creation in the alloys of boride and carbide phases, and also other hard phases included in the alloy base which is strong at high temperature.

The wear resistance of the V-56 alloy is increased by formation of borides, while that of the VZhL-1 alloy is achieved by the presence of borides and carbides. The high wear resistance of these alloys is retained to 600°.

The high-strength high-temperature alloys of the ZhS6 type with additional alloying with boron and silicon, which form hard particles of borides and double carbides in the alloy, are used for fabricating dies for hot pressing of the high-temperature alloys.

Mechanical working causes surface strain hardening of the high-temperature alloys and the formation of residual stresses, which may lead to premature failure of parts at high temperatures during operation. Relief of the residual stresses in the casting alloys of the ZhS type is performed by annealing in a neutral atmosphere at 950° for 2 hours.

The cast high-temperature nickel alloys are not notch sensitive in static short-term and stress-rupture tensile testing at 800° and above. Good weldability is characteristic for the VZhL8 alloy (analog of the GRM235 alloy) which is recommended for welded nozzle vanes. With respect to strength at high temperature, the VZhL8 alloy surpasses the cobalt casging alloys of the LK4 type.

Interacting with an oxidizing medium, the surfaces of the cast and wrought alloys are oxidized and depleted of the alloying elements to a definite depth. As a result, the surface layer of the alloy loses its strength. A marked depletion of the alloying elements from the surface of vanes made from the ZhS6-K alloys after operation for 200-600 hours takes place to a depth of 50-100 microns. A similar phenomenon takes place to a depth of 0.15-0.35 mm during heat treatment of the ZhS6-K alloy. This layer must be removed in order to avoid reduction of the resistance of the part during operation under conditions of high temperature. Various methods of thermochemical surface treatment have been developed to improve the heat resistance of the alloys. Most promising in this regard are the following methods for protecting the surface of the alloys against depletion of the alloying elements: aluminum plating, ceramic coating, etc.

In the high-temperature high-strength casting alloys operating in oxidizing media without surface protection, full utilization is not obtained of the service life capability which has been created by the alloying, casting, and heat treatment.

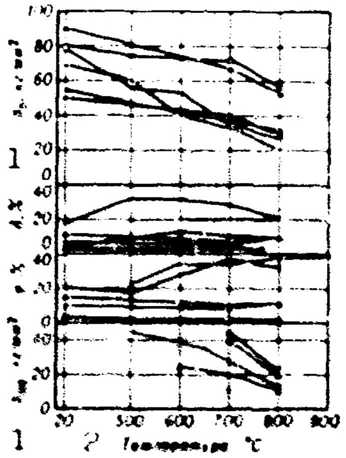
As a result of accelerated development of methods of obtaining high quality ingots of the high-temperature high-strength alloys and the use of advanced methods of hot mechanical working, the discrepancy between the possible temperature levels of operational use of the alloys in the cast and wrought conditions has been reduced from 100° to 30-50°. Characteristic in this respect is the ZhS6-KP alloy which is used in both the cast and wrought conditions (Table 9).

The operational service life of the high-temperature alloys depends significantly on the stress state and the temperature. Increase of the stress reduces the service life of the alloy more strongly at high than at low temperatures. This shows up particularly strongly when vibratory stresses are superimposed on the static stresses.

Under the influence of neutron irradiation the cast high-temperature nickel alloys undergo reversible changes characteristic for the low-alloyed alloys, which can be eliminated by annealing, and also undergo irreversible changes characteristic for the highly-alloyed multiphase alloys.

S.T. Kishkin, N.G. Lashko

CAST HIGH-TEMPERATURE STAINLESS STEEL is complex-alloyed austenitic chrome-nickel steel with carbide and intermetallide strengthening. The chemical composition of the cast high-temperature stainless steel is shown in Table 1, and the mechanical properties and heat treatment regimes are shown in Table 2 (the mechanical properties were determined on specimens cut from bars and cloverleaf castings pouring into sand forms). The physical properties of the cast high-temperature stainless steels are shown in Table 3. The figure shows the variation of the mechanical properties of the cast high-temperature stainless steels with temperature increase. The VZh36-L3 and VZh-L10 steels with intermetallide strengthening cast by the vacuum method have the highest strength properties at high temperatures. The 22-11-3W, VL7-20 and VL7-45U steels are melted in open induction and electric-arc furnaces.



Variation of mechanical properties of cast high-temperature stainless steels with temperature increase: x — 22-11-3W; o — EI451V; Δ — VL7-20; ● — VL7-45U; □ — VZh36-L3; ▲ — VZh-L10. 1) σ_b, kg/mm²; 2) temperature, °C.

TABLE 1

Chemical Composition of Cast High-Temperature [illegible]

1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	[illegible]	[illegible]	–
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	[illegible]	[illegible]	–
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	–	–	–	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	[illegible]	–	–	–	[illegible]	[illegible]	[illegible]
10	0.13–0.18	0.6	0.6	10–12	22–[illegible]	[illegible]	[illegible]	–	–	[illegible]	[illegible]	[illegible]	[illegible]
11	≤0.08	≤0.5	≤0.5	15–18	3–[illegible]	–	4.5–[illegible]	–	–	2.6–3.2	≤0.01	≤0.01	1.7–2.1 Al [illegible]0.05 B [illegible]0.1 Ce

1) Steel; 2) element content, %; 3) other elements; 4) EI481V; 5) EI481L; 6) 22-11-3W; 7) VL7-20; 8) to; 9) VL7-45U; 10) VZh-L10; 11) VZh36-L3.

The 22-11-3W steel is used to fabricate by the centrifugal casting method ring-shaped structural parts and nozzle cases for gas turbine engines. The steel is temperature resistant in air up to 950-1000°. Casting temperature is 1520-1550°, linear shrinkage is 2-2.5%. Weldability is good, weld repair of defects may be accomplished using weld wire of the same steel.

The VL7-20 steel is used for turbine blades which are welded to a disc made from the EI395 steel. It is a scale resistant to 1000°.

The EI481V steel is used to fabricate structural ring parts, gas turbine cases, compressor guide vanes operating at 400-650°. The steel welds wellby resistance welding using EI4[illegible] filler wire. It is temperature resistant to750-800°. Casting temperature is 1590-1610°.

The EI481I steel is used to fabricate various high-strength and high-temperature detail parts and has properties close to those of the wrought steel EI481, but has somewhat less plasticity.

The VL7-45U steel belongs to the austenitic class and is used to fabricate nozzle guide vanes as a replacement for the cobalt alloy LK-4. This steel has good processing properties, casts well using the

TABLE 2

Mechanical Properties of Cast High-Temperature Stainless Steel

Сталь 1	Термич. обработка 2	ТУ 3	Темп-ра (°С) 4	σ_b (кг/мм², не менее) 5	$\sigma_{0,2}$	δ (%, не менее) 6	ψ	$a_н$ (кгм/см²) 7	НВ (d отпечатка, мм) 8
ЭИ481В* 9	10 Гомогенизированные при 1100° в течение 5 час., закаленные и состаренные по режиму: нагрев под закалку 1150° в течение 3 час.; 1-е старение при 680° в течение 16 час.; 2-е старение при 820° в течение 10 час.	—	20	68	—	10	15	—	3,7–4
ЭИ481Л* 11	12 Закаленные с 1140 ± 10° в воде или на воздухе, старение в течение 10–14 час при 780–820°; охлаждение на воздухе	—	20	85	55	8	8		3,5–3,8
	13 Отливки в кокиль и в песчаные формы, нормализованные при 1050–1100°	—	20	50	—	12	14	—	4,3–5
	14 Отливки по выплавляемым моделям, нормализованные при 1050–1100°	15 АМТУ 433-58	20	50	—	10	10	—	4,3–5
22-11-3W	16 Отливки в кокиль и в песчаные формы, нормализованные и состаренные при 800–850°	—	20	48	—	12	14	—	4,3–5
	17 Отливки по выплавляемым моделям, нормализованные и состаренные при 800–850°	—	20	48	—	10	10	—	4,3–5
ВЛ7-20** 18	19 Состаренные при 800° в течение 12 час., охлаждение на воздухе	15 АМТУ 450-59	20 800	50 30	— —	5 5	— —	— —	— — 22
ВЛ7-45У** 20	21 Состаренные при 900° в течение 5 час., с последующим охлаждением на воздухе	АМТУ 316-52	20 800	45 30	— —	5–10 6–12	6 7	— —	150–180 кг/мм² 100 кг/мм²
ВЖ-Л10** 23	24 Закаленные с 1120° в масле, двойное старение: 1-е при 740° в течение 16 час. с охлаждением на воздухе, 2-е при 630° в течение 16 час. с охлаждением на воздухе	—	20 600 800	85–95 80 50	60–67 60 43	10–14 5 5	12–18 10 10	2–5 — —	— — —
ВЖ36-Л3** 25	26 Закаленные и состаренные по режиму: нагрев под закалку 1150°, выдержка 3 часа, охлаждение на воздухе; старение при 750°, выдержка 32 часа, охлаждение на воздухе	—	27 по согласованию						

*Castings in chill mold and sand forms.
**Lost wax casting.

1) Steel; 2) heat treatment; 3) TU; 4) temperature (°C); 5) (kg/mm², no less than); 6) (%, no less than); 7) a_n, kgm/cm²; 8) HB (d_{otp}, mm); 9) EI481V*; 10) homogenization at 1100° for 5 hours, quenched and aged as follows: heating for quench at 1150° for 3 hours; first aging at 680° for 16 hours; second aging at 820° for 10 hours; 11) EI481L*; 12) quenched from 1140° ± 10° in water or air, aging for 10-14 hours at 780-820°; air cool; 13) castings into chill molds and sand forms, normalized at 1050-1100°; 14) castings using lost wax method, normalized at 1050-1100°; 15) AMTU; 16) castings into chill molds and sand forms, normalized and aged at 800-850°; 17) castings using lost wax process, normalized and aged at 800-850°; 18) VL7-20**; 19) aged at 800° for 12

hours, air cool; 20) VL7-45U**; 21) aged at 900° for 5 hours with subsequent air cool; 22) kg/mm^2; 23) VZh-L10**; 24) quenched from 1120° in oil, double aging: first at 740° for 16 hours with air cool, second at 630° for 16 hours with air cool; 25) VZh36-L3**; 26) quenched and aged as follows: heating for quench at 1150°, hold for 3 hours, air cool; aging at 750° for 32 hours, air cool; 27) by agreement.

precision casting method at 1600-1620, and has linear shrinkage of the order of 2-2.5%. This steel has low tendency to aging as a result of the formation of chromium carbides and tungsten carbides, which affects the increase of the stress rupture strength: after aging for 15 hours the time to failure at 800° and a stress of 15 kg/mm^2 increases by 10-20 hours for an over-all test duration of 150-200 hours. To stabilize dimensions, castings are subjected to aging for 5 hours at 900° and subsequent air cooling.

The VZh36-L3 steel is used to fabricate gas turbine nozzle vanes operating up to 800-850°. In cast form this steel has comparatively high strength properties up to 800°, casts well using precision casting methods, has a linear shrinkage of about 1.5%, and volumetric shrinkage of about 5.5%.

With respect to high-temperature strength properties, the VZh-L10 steel surpasses most of the cast steels in use at the present time; it is a chrome-nickel steel of the austenitic class, alloyed with tungsten, molybdenum, titanium, aluminum, with additions of boron and cerium.

Melting and pouring of the steel are performed in vacuum induction furnaces at a pressure from $1 \cdot 10^{-2}$ to $5 \cdot 10^{-2}$ mm Hg. The steel is strengthened by heat treatment consisting of oil quench from 1120° and double aging at 740 and 630° with soak at each aging temperature for 16 hours (air cool); the time at the prequench temperature is 3 hours. With respect to mechanical properties up to 800°, this steel surpasses in many cases even the nickel- and cobalt-base high strength cast alloys and at the same time is considerably more economical than the latter, since it contains much less nickel and no cobalt at all.

Various defects of the castings are satisfactorily repaired by manual electric-arc welding using electrodes made from the VZh98 alloy with a NZh-4 coating or using IMET-4P electrodes (rod made from the EI1435 alloy). This steel has good resistance to gaseous corrosion. At 800° after 100 hours the weight increase in 0.053 g/m^2-hr, and at 900° after 100 hours it is 0.389 g/m^2-hr.

TABLE 3

Physical Properties of Cast High-Temperature Stainless Steel

Сталь 1	2 Свойства	3 Показатели свойств при различных темп-рах
4 ЭИ481В ($\gamma=7{,}85$ г/см³)	$\alpha\cdot10^6$ (1/°C) λ (кал/см·сек·°C) 5	18,3 (100—200°); 21,6 (400—500°); 22,9 (700—800°) 0,036 (25°); 0,045 (300°), 0,057 (600°), 0,068 (900°)
22-11-3W ($\gamma=7{,}95$ г/см³) 6	$\alpha\cdot10^6$ (1/°C) λ (кал/см·сек·°C) ϱ (ом·мм²/м) 7	14,49 (100—200°); 19,56(400—500°); 20,01 (700—800°) 0,052 (100°), 0,0555 (300°); 0,065 (600°); 0,082 (900°); 0,85 (20°); 1,13 (500°); 1,24 (900°)
ВЛ7-20 ($\gamma=8$ г/см³) 8	$\alpha\cdot10^6$(1/°C) λ (кал/см·сек·°C) ϱ (ом·мм²/м) 7	12,52 (20—100°); 15,1 (20—500°); 16,77 (20—800°); 17,1 (20—900°) 0,027 (20—100°) 0,9 (20—100°)
ВЛ7-45У ($\gamma=8{,}3$ г/см³) 9	$\alpha\cdot10^6$ (1/°C) λ (кал/см·сек·°C) 5	13,19 (20—100°) 16,82(400—500°); 18,56(700—800°); 19,08(800—900°) 0,026 (20°), 0,048 (500°); 0,068 (900°)
ВЖ-Л10 ($\gamma=8{,}08$ г/см³) 10	$\alpha\cdot10^6$ (1/°C) λ (кал/см·сек·°C) c (кал/г·°C) 11	13,8 (20—100°); 16,2 (20—500°); 18,2 (20—800°); 13,8 (20—100°); 18,5 (400—500°), 24,2 (700—800°) 0,031 (25°); 0,046 (500°); 0,056 (900°) 0,105 (100°); 0,125 (500°); 0,15 (900°)
ВЖ36-Л3 ($\gamma=8{,}04$ г/см³) 12	$\alpha\cdot10^6$ (1/°C) λ (кал/см·сек·°C) 5	14,8 (20—100°); 18,4 (400—500°); 28,4 (700—800°); 38,4 (800—900°); 15,3 (20—200°); 16,6 (20—500°); 18,7 (20—800°); 20,9 (20—900°) 0,022 (25°); 0,043 (500°); 0,062 (900°)

1) Steel; 2) properties; 3) property indices at various temperatures; 4) EI481V (γ = 7.85 g/cm^3); 5) λ(cal/cm-sec-°C); 6) γ_3= 7.95 g/cm^3); 7) λ(cal/cm-sec-°C) ρ(ohm-mm^2); 8) VL7-20 (γ = 8 g/cm^3); 9) VL7-45U (γ = 8.3 g/cm^3); 10) VZh-L10 (γ = 8.08 g/cm^3); 11) λ(cal/cm-sec-°C), c(cal/g-°C); 12) VZh36-L3 (γ = 8.04 g/cm^3).

The VZh-L10 steel is intended for fabricating extremely varied cast parts operating up to 800°, including parts of very complex form. At several plants this steel is being tested as a material for fabricating integrally cast rotors for gas turbines (discs cast together with the blades), which will accelerate and reduce the costs of the entire production cycle many fold.

F.F. Khimushin

CASTING BRONZE – a bronze intended for casting shaped components, blocks, and tube blanks. The castings are produced in sand molds and chill molds, by both the centrifugal and lost-metal methods. Aluminum bronzes, Tin bronzes, and a number of the new alloys used as substitutes for tin bronzes have good casting properties (flowability, mold-filling ability) and are widely employed in casting. Aluminum casting bronzes, which are high-melting alloys with a small crystallization range, are distinguished by high shrinkage (2.2%) and consequently require large lost heads in casting; however, they are virtually free from liquation

TABLE 1

Mechanical Properties of Tin-Bronze Castings

Сплав 1	Состояние контрольных образцов 2	3 Способ литья	4 σ_b (кг/мм²)	δ (%)	HB (кг/мм²)
БрОЦСН3-7-5-1 5	18 Без термич. обработки	В землю, 21	18	8	60
		в кокиль 22	21	5	60
БрОЦС3-12-5 6	То же 19	В землю,	18	8	60
		в кокиль	21	5	60
БрОЦС5-5-5 7	»	В землю,	15	6	60
		в кокиль	18	4	60
БрОЦС6-6-3 8	»	В землю,	15	6	60
		в кокиль	18	4	60
БрОЦС4-4-17 9	»	В землю	15	5	60
БрОЦС3,5-6-5 10	»	В землю,	15	6	60
		в кокиль	18	4	60
БрОФ10-1 11	»	В землю,	22	3	80
		в кокиль	25	3	90
БрОЦ10-2 12	»	В землю,	22	8	75
		в кокиль	23	5	75
БрОС10-10 13	»	В кокиль	20	5	65
БрОС5-25 14	»	В землю,	12	4	40
		в кокиль	14	6	50
БрОС8-12 15	» 20	В землю,	15	3	
		в кокиль 23	15	3	—
БрОС16-5 16	Отожженные при 450° — 2 часа	В кокиль,	25	0,5	150
		центробежный	-	—	100
БрО19 17	Без термич. обработки	В кокиль,	30	0,5	160
	Отожженные при 450 — 2 часа	центробежный	—	—	163–198

1) Alloy; 2) conditions of control specimens; 3) casting method; 4) kg/mm²; 5) BrOTsSN3-7-5-1; 6) BrOTsS3-12-5; 7) BrOTsS5-5-5; 8) BrOTsS6-6-3; 9) BrOTsS4-4-17; 10) BrOTsS3.5-6-5; 11) BrOF10-1; 12) BrOTs10-2; 13) BrOS10-10; 14) BrOS5-25; 15) BrOS8-12; 16) BrOS16-5; 17) BrO19; 18) without heat treatment; 19) the same; 20) annealed at 450° for 2 hr; 21) in loam mold; 22) in chill mold; 23) in centrifugal chill mold.

I-43b1

TABLE 2

Mechanical Properties of Tin-Free Bronze Castings

Сплав 1	2 Состояние контрольных образцов	3 Способ литья	4 σ_b (кг/мм²)	δ (%)	HB (кг/мм²)
БрАЖ9-4Л 5	Без термич. обработки 15	В землю, 18	40	10	100
		в кокиль	50	12	100
БрАЖМц10-3-1,5 6	То же 16	В кокиль 19	55	10	110
БрАМц9-2 7	»	В кокиль	49	20	100
БрАЖН10-4-4 8	» 17	В кокиль	60	5	170
	Закалка с 900° 2 часа, отпуск при 650° 2 часа	В кокиль	70	6	200–240
БрАЖН11-6-6 9	Без термич. обработки	В землю,	60	2	250
		в кокиль	60	2	250
БрАЖС7-1,5-1,5 10	То же	В землю 20	30	18	—
11 БрСуН6-2	»	В кокиль, центробежные	26	6	82
12 БрСуФ6-1	»	В кокиль, центробежный	22	5	80
13 БрСуСФ6-12-0,3	»	В кокиль, центробежный	15	2	60
14 БрСуНЦСФ3,5-3,5-3,5-20-0,2	»	В кокиль, центробежный	17	2	65

1) Alloy; 2) condition of control specimens; 3) casting method; 4) kg/ /mm²; 5) BrAZh9-4L; 6) BrAZhMts10-3-1.5; 7) BrAMts9-2; 8) BrAZhN10-4-4; 9) BrAZhN11-6-6; 10) BrAZhS7-1.5-1.5; 11) BrSuN6-2; 12) BrSuF6-1; 13) BrSuSF6-12-0.3; 14) BrSuNTsSF3.5-3.5-3.5-20-0.2; 15) without heat treatment; 16) the same; 17) quenching from 900° over 2 hr, annealing at 650° for 2 hr; 18) in loam mold; 19) in chill mold; 20) in centrifugal chill mold.

TABLE 3

Physical and Technological Properties of Tin Casting Bronzes

Сплав 1	2 γ (г/см³)	$\alpha \cdot 10^6$ (1/°C)	3 λ (кал/см·сек·°C)	4 ρ (ом·мм²/м)	5 E (кг/мм²)	Темп-ра плавления (°C) 6	7 Темп-ра отжига (°C)	8 Жидкотекучесть (см)	9 Линейная усадка (%)	10 Темп-ра литья (°C)
11 БрОЦСН3-7-5-1	8,7	—	—	0,085	8 500	1022	—	50	—	1170
12 БрОЦС3-12-5	8,7	—	—	0,075	8 400	998	—	60	—	1160
13 БрОЦС5-5-5	8,8	18,1	—	0,08	9 450	970	—	40	—	1150
14 БрОЦС6-6-3	8,8	17,1	0,22	0,09	9 000	967	—	40	1,6	1150
15 БрОЦС4-4-17	—	—	—	—	—	—	—	—	—	1150
16 БрОЦС3,5-6-5	—	—	—	—	—	—	—	—	—	1160
17 БрОФ10-1	8,7	17,3	0,117	—	10 300	934	—	—	1,4	1150
18 БрОЦ10-2	8,5	17,3	0,132	0,155	9 800	1015	—	21	1,5	1120—11[illegible]
19 БрОС10-10	9,0	19,2	0,108	—	—	—	—	—	1,4	11[illegible]
20 БрОС5-25	9,2	18,0	0,14	—	7 000	940	— 24	—	1,5	11[illegible]—11[illegible]
21 БрОС8-12	9,0	17,1	—	—	7 500	940	—	[illegible]	1,4	1150
22 БрОС16-5	8,8	19,2	—	—	—	—	450 — 2 часа*		—	—
23 БрО19	8,6	18,8	—	—	9 800	—	450 — 2 часа	—	—	1120—1140

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*In order to fix the joints of oil packing rings.

1) Alloy; 2) g/cm³; 3) cal/cm·sec·°C; 4) ohm·mm²/m; 5) kg/mm²; 6) melting point (°C); 7) annealing temperature (°C); 8) flowability (cm); 9) linear shrinkage (%); 10) casting temperature (°C); 11) BrOTsSN3-7-5-1; 12) BrOTsS3-12-5; 13) BrOTsS5-5-5; 14) BrOTsS6-6-3; 15) BrOTsS4-4-17; 16) BrOTsS3.5-6-5; 17) BrOF10-1; 18) BrOTs10-2; 19) BrOS10-10; 20) BrOS5-25; 21) BrOS8-12; 22) BrOS16-5; 23) BrO19; 24) hr.

I-43b2

TABLE 4

Physical and Technological Properties of Tin-Free Casting Bronzes

Сплав 1	γ (г/см³) 2	α·10⁶ (1/°C)	λ (кал/см·сек·°C) 3	ρ (ом·мм²/м) 4	E (кг/мм²) 5	Темп-ра плавления (°C) 6	Темп-ра отжига (°C) 7	Жидкотекучесть (см) 8	Линейная усадка (%) 9	Темп-ра литья (°C) 10
11 БрАЖ9-4Л	7.5	18.1	0,14	0,124	10 500	1040	700—750	85	2.5	1100—1140
12 БрАЖМц10-3-1,5	7.5	16.1	0,14	0,19	10 000	1045	—	70	2.4	1120—1150
13 БрАЖН10-4-4	7.5	17.1	0,18	0,193	11 500	1084	700—750	65	-	1120—1180
14 БрАМц9-2	7.6	17.0	0.17	0,110	10 000	1060	650—750	48	—	1120—1150
15 БрАЖН11-6-6	7.6	—	—	—	—	1085	700—750	—	—	1120—1200
16 БрАЖС7-1,5-1,5	7.5	—	—	—	—	1040	700—750	—		1120—1140
17 БрСуН6-2	8.7	17.9	0.15	—	9 500	950	—	—	—	1150—1180
18 БрСуФ6-1	8.5	17.3	0.11	—	9 500	940	—	35	1.3	1100—1140
19 БрСуСФ6-12-0,3	8.0	17.8	0.11	—	8 000	940	—	—	1.3	1100—1140
20 БрСуНЦСФ3,5-3,5-3,5-20-0,2	9.1	17.4	0.13	—	7 500	950	—	30	1.25	990—1030

1) Alloy; 2) g/cm^3; 3) cal/cm•sec•°C; 4) ohm•mm^2/m; 5) kg/mm^2; 6) melting temperature (°C); 7) annealing temperature (°C); 8) flowability (cm); 9) linear shrinkage (%); 10) casting temperature (°C); 11) BrAZh9-4L; 12) BrAZhMts10-3-1.5; 13) BrAZhN10-4-4; 14) BrAMts9-2; 15) BrAZhN11-6-6; 16) BrAZhS7-1.5-1.5; 17) BrSuN6-2; 18) BrSuF6-1; 19) BrSuSF6-12-0.3; 20) BrSuNTsSF3.5-3.5-3.5-20-0.2.

and do not have dispersed porosities, which ensures production of compact castings. These bronzes tend to have a columnar structure. Their drawbacks include formation of aluminum-oxide films in the liquid metal, which causes discontinuities in the castings; it is consequently necessary to avoid interrupting the metal flow when filling the mold.

Tin casting bronzes and others of this type with a broad crystallization range exhibit little shrinkage (1.4%) and consequently do not require large lost heads and permit production of very complex castings (with sharp transitions from thick to thin sections) without shrinkage flaws. Such castings, however, do not have high hermeticity, since the interdendritic pores admit water at high pressures. The lead and zinc present in the alloy reduce the crystallization range. Casting bronzes have sufficiently high mechanical (Tables 1 and 2) and physical (Tables 3 and 4) properties and corrosion resistance and good antifriction characteristics. Tin-zinc bronzes, which contain small quantities of Sn (from 0.5 to 7%) and Pb (from 1 to 6%) and a considerable amount of Zn (from 5 to 35%), are distinguished by high flowability, a good mold-filling ability, and good cuttability; they are consequently employed in artistic casting (see Decorative bronze). Tin bronzes (GOST 613-50) are produced with secondary tin bronzes (GOST 614-50) as the charge; the latter are obtained by reprocessing of scrap and other wastes (see Secondary bronze, Antimony bronze).

References: Bochvar, A.A., Metalloveneniye [Metalworking], 5th Edition, Moscow, 1956; Smiryagin, A.P., Promyshlennyye tsvetnyye metally i splavy [Commercial Nonferrous Metals and Alloys], 2nd Edition, Moscow, 1956; Turkin, V.D. and Rumyantsev, M.V., Struktura i svoystva tsvetnykh metallov i splavov [Structure and Properties of Nonferrous Metals and Alloys], Moscow, 1947; Mashinostroyeniye. Entsiklopedicheskiy spravochnik [Machine Building. An Encyclopedic Handbook], Vol. 4, Moscow. 1947.

O.Ye. Kestner

CAST IRON — is an iron-carbon alloy, the percentage of the latter surpassing its solubility in gamma-iron (more than 2%, usually), and with a certain content of permanent impurities, as Si, Mn, P, and S (non-alloyed cast iron), and also an alloy which contains specially added alloying ingredients (Cr, Ni, Mo, Cu, Al, more than 2% Mn, more than 4% Si) in addition to the above-mentioned permanent impurities — see Alloyed cast iron. Cast iron containing a great quantity of elements which narrow the region of gamma-iron (Si, Al) may contain less than 2% carbon, even 1% only.

In contrast to steel, where carbon is separated in the form of iron carbide (cementite, Fe_3C) or of carbides of the alloying ingredients, the carbon in the case iron structure may be separated either totally in bound state or totally in free state as graphite (lamellar or spheroidal graphite) or as temper carbon, or in a partially bound and partially free state. The form in which the carbon is precipitated in the cast-iron structure depends on the chemical composition of the cast iron, the cooling rate of the castings and the conditions of the heat treatment.

Cast iron is classified with regard to its chemical composition, its microstructure, the technology of production, and the purpose. With regard to the chemical composition, nonalloyed and alloyed cast iron are distinguished the latter being subdivided into low-alloy cast iron with a total content of up to 3-4%, medium-alloy (from 3-4 to 10%), and high-alloy with more than 10% of alloying ingredients.

With regard to the microstructure, one distinguishes: gray iron, in which structure the carbon is coagulated in the form of lamellar or spheroidal graphite; white iron, in which the carbon is separated in bound state; chilled cast iron, whose castings have a surface zone with the structure of white iron, and a core with the structure of gray iron; mottled iron, in which the carbon is separated partially in bound state, and partially as a graphite (lamellar or spheroidal); malleable iron, obtained by tempering white iron resulting in a decomposition of the cementite and separation of flocular graphite, the temper carbon; and cast iron with special structure: austenitic, martensitic, bainitic, and ferritic cast iron.

With regard to the technology of production one distinguishes: common (nonmodified) cast iron; cast iron modified by graphitizing or carbide-forming additions (see Modified cast iron); and heat treated cast iron (see Heat treatment of cast iron).

With regard to the purpose, the cast iron grades are distinguished according to the requirements made of the castings and the service: gray iron for general and special castings in machine building; cast iron for castings with increased ductility, and cast iron with special physicochemical and mechanical properties.

The widespread utilization of cast iron as a machine-building material is based on its high casting properties (a good flowability, a small shrinkage, and a relatively low melting point), and – in the case of the nonalloyed cast iron – also on its cheapness. In comparison with steel, cast iron has a lower strength, plasticity and impact resistance, a higher toughness under cyclic loads, a lower sensitivity to notches and to the quality of the machined surface, a greater wear resistance, and significantly better casting properties. The strength of the best pearlite cast-iron grades with spherical graphite is comparable to the strength of steel. The high wear resistance and cyclic toughness of cast iron and its good workability favor its widespread application in machine building. Cast iron is used for a large number of castings both for common purposes and for such with special properties.

A.A. Simkin

III-9ch

CAST IRON FOR PISTON RINGS – is a variety of the Antifriction cast iron; it is characterized by a combination of wear-resistance with high elasticity, which gives the required working properties to the piston rings of internal-combustion engines, compressors, steam engines, etc. There are two types of cast iron for piston rings: the type used in casting individual rings, and the type for casting blank hoops. Non-alloyed and low-alloy gray phosphorous iron with a pearlite base is used as cast iron for piston rings (see the Table). The grades for individual castings are characterized by an increased content of C and Si and

Chemical Composition of Cast Iron for Piston Rings

Отрасль машиностроения 1	2 Вид заготовки	3 Содержание элементов (%)									
		C	Si	Mn	P	Cr	Ni	Mo	W	Ti	Cu
Авиастроение 4	Обечайки 5	2,9—3,2	1,4—1,9	0,6—1,0	0,4—0,65	0,3—0,6	0,6—1,6	0,05—0,35	0,25—0,7	—	—
	То же 6	2,9—3,2	1,9—2,1	0,6—1,0	0,25—0,40	0,6—0,9	0,4	0,6—0,9	—	—	—
	То же	2,8—3,25	1,7—2,2	1,0—1,3	0,4—0,7	0,4—0,7	0,4	—	0,5—1,0	0,15—0,[illegible]	—
	Индивид. кольца 7	3,7—4,0	2,4—2,8	0,6—0,9	0,6—0,9	≤0,2	0,4	—	—		—
Автотракторостроение 8	Обечайки 5	3,0—3,3	1,6—2,1	0,8—1,4	0,4—0,7	≤0,35	0,4	—	—	—	—
	Индивид. кольца	3,7—3,9	2,4—2,6	0,5—0,75	0,3—0,5	0,25—0,35	—	—	—	0,10—0,15	0,15—0,[illegible]
Дизелестроение 9	Обечайки диаметром: 10										
	11 до 200 мм	3,2—3,5	1,6—2,0	1,0—1,3	0,3—0,6	≤0,3	≤0,3	—	—	—	—
	201—300 »	3,0—3,4	1,4—1,7	1,1—1,5	0,3—0,6	≤0,3	≤0,3	—	—	—	—
	301—500 »	2,9—3,3	1,2—1,5	1,1—1,5	0,3—0,6	≤0,3	≤0,3	—	—	—	—
	501—700 »	2,9—3,2	1,0—1,5	1,1—1,5	0,3—0,6	≤0,3	≤0,3	—	—	—	—
	12 более 700 »	2,8—3,2	1,0—1,4	1,1—1,5	0,3—0,6	≤0,3	≤0,3	—	—	—	—
13	Индивид. кольца сечением:										
	до 50 мм²	3,8—4,0	2,7—3,2	0,9—1,1	0,4—0,7	≤0,3	≤0,3	—	—	—	—
	51—150 »	3,5—3,95	2,6—3,1	0,6—0,9	0,3—0,6	≤0,3	≤0,3	—	—	—	—
	151—300 »	3,5—3,90	2,2—2,7	0,5—0,8	0,3—0,6	≤0,3	≤0,3	—	—	—	—
	301—400 »	3,4—3,90	1,7—2,2	0,5—0,9	0,3—0,6	≤0,3	≤0,3	—	—	—	—
	более 400 »	3,3—3,85	1,2—1,7	0,5—0,8	0,3—0,6	≤0,3	≤0,3	—	—	—	—
Паровозо- и тепловозостроение 14	Обечайки	2,9—3,2	1,3—1,7	1,0—1,3	0,3—0,5	≤0,3	1,6	—	—	—	—
15 Компрессоростроение	То же	2,8—3,1	1,6—1,9	0,7—1,0	0,4—0,8	≤0,4	0,4	—	—	—	—

1) Branch of machine building; 2) type of the part; 3) percentage of the elements; 4) aircraft building; 5) blank hoops; 6) the same; 7) individual rings; 8) automobile and tractor building; 9) diesel engine building; 10) blank hoops with a diameter of; 11) up to; 12) more than; 13) individual rings with a cross section of; 14) steam locomotive and internal combustion locomotive building; 15) compressor building.

a reduced content of Mn in comparison with the grades for blank-hoop casting. Rings of high-strength cast iron with the following compositions: 3.0-3.4% C_{obshch} (total); 0.7-1.0% C_{svyaz}; 3.0-3.4% Si; 1.4-1.6% Mn; $\leq$0.1% P; <0.1% Cr; 1.8-2.2% Ni, and 0.03-0.08% Mg are used experimentally in high-power diesel engines.

The individual rings are cast in raw-sand molds, the blank hoops in sand molds or by the centrifugal method in hot metal molds (400-500°) lined with refractory clay. Cast iron for piston rings is melted in cupola furnaces, by a duplex process (cupola furnace and electric furnace), or in electric furnaces. Iron for the casting rings in metal molds is modified by graphite powder from waste electrodes or black casting graphite (0.1-0.3%). After a raw grinding, the blank hoops are tempered at 500-550° to remove internal stresses (see Heat treatment of cast iron).

The wear resistance of the piston rings is obtained by a metal base of fine-lamellar pearlite with uniformly distributed inclusions of a double and partially triple phosphide eutectic, and by the presence of isolated precipitations of lamellar graphite. The upper rings are coated with porous chromium (0.12-0.18 mm) to increase wear resistance. The run in is provided by a conical working surface, application of soft coatings, porous pickling and other special measures. The chrome-coating of the rings is treated to electrolytic iron-plating to improve the run in of chrome-plated rings.

References: Grechin, V.P., Porshnevyye kol'tsa [Piston Rings], in the Book: Spravochnik po mashinostroitel'nym materialam [Handbook on Machine-Building Materials], Vol. 3, Moscow, 1959; Girshovich, N.G., Sostav i svoystva chuguna [Composition and Properties of Cast Iron], in the Book: Spravochnik po chugunnomu lit'yu [Handbook on Iron Casting], 2nd Edition, Moscow-Leningrad, 1960.

A.A. Simkin

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[Transliterated Symbols]

= obshch = obshchiy = total

= svyaz = svyazannyy = bound

CAST MAGNESIUM ALLOYS are magnesium alloys intended for the production of details by the methods of mold casting. With respect to mechanical properties, the cast magnesium alloys are arbitrarily divided into three groups: 1) medium-strength alloys (ultimate strength σ_b at 20° no less than 16 kg/mm^2); 2) high-strength σ_b at 20° not less than 21 kg//mm^2) 3) high-temperature, suitable for operation at elevated temperatures (to 250-400° depending on the chemical composition). For chemical composition and properties of the cast magnesium alloys in comparison with other metallic materials see Magnesium Alloys.

The medium-strength alloys ML3 and ML7-1 of the Mg-Al-Zn system are not stregthened by heat treatment. The alloy ML3 (σ_b = 16-18 kg/mm^2; $\sigma_{0.2}$ = 5 – 6 kg/mm^2; δ = 6 – 8%) has outstanding hermeticity. The ML7-1 alloy(σ_b = 16 – 18 kg/mm^2; $\sigma_{0.2}$ = 6 – 8 kg/mm^2; δ = 4 – 8%) is characterized by high creep resistance in comparison with the ML5 alloy and is used for details operating for long times at temperatures of 150 – – 200°. This alloy has satisfactory casting properties and weldability. Castings are obtain by casting into sand forms. The high strength cast magnesium alloys include the ML4, ML5, ML6 alloys of the Mg – Al – Zn system and the ML12 and ML15 alloys of the Mg – Zn – Zr system. For highly loaded details wide use is made of the ML5 alloy. (σ_b = 23 – 26 kg/mm^2, $\sigma_{0.2}$ = 8.5 – 10 kg/mm^2, δ = 5 – 10%) which has good processing properties.

The ML4 alloy (σ_b = 22 – 25 kg/mm^2; $\sigma_{0.2}$ = 8 – 10 kg/mm^2;δ = 5 – – 10%), which is used little by Soviet industry, somewhat exceeds the ML5 and ML6 alloys in corrosion resistance, but is considerably inferior to them in processing properties, particularly with respect to tendency to formation of hot cracks in castings and microporosities.

The ML6 alloy (σ_b = 23 – 26 kg/mm^2; $\sigma_{0.2}$ = 13 – 16 kg/mm^2; δ = 1 – – 2%) exceeds the ML5 alloy in yield strength, but has found limited use because of its low plasticity.

The ML4, ML5, ML6 alloys lose strength rapidly with increase of the temperature and therefore are used for details operating for long periods to temperatures no higher than 150° and for short times to 250°.

The ML12 alloy (σ_b = 22 – 25 kg/mm^2; $\sigma_{0.2}$ = 12 – 14 kg/mm^2; δ = 5 – 8%) of the Mg-Zn-Zr system differs from the ML5 and ML6 alloys in the combination of high yield point and elongation, more uniform mechanical properties in castings, higher casting density, as a result of which castings produced from it exceed castings from the ML5 alloy in strength particularly when cast in heavy sections. A deficiency of this alloy is poor weldabiltiy and a tendency to the formation of hot cracks.

The ML15 alloy (σ_b = 21 – 23 kg/mm^2; $\sigma_{0.2}$ = 13 – 15 kg/mm^2; δ = 3 – 5%), containing lanthanum in addition to zinc and zirconium, is inferior to the ML12 alloy in plasticity and ultimate strength at 20°, but exceeds the latter in high temperature strength and processing properties – the alloy can be argon-arc welded, has low tendency to formation of microporosity and hot cracks in castings. The ML12 and ML15 alloys exceed the ML5 alloy in creep resistance and are used for details operating for long periods at temperatures to 200° and for short times to 250° (ML15 alloy details can be used at temperatures to 350° with leading up to 5 minutes). Both alloys have somewhat higher corrosion resistance in comparison with the ML5 alloy. The ML12, ML15 alloys are recommended for casting into sand forms and chill molds; ML5 and ML6 are recommended for casting in sand forms, into chill molds and for pressure casting. The cast magnesium alloys are used primarily in the heat treated condition: the ML5 alloy after solution treatment, the ML12 and ML15 alloys after aging.

The high-temperature alloys include the ML9, ML10, ML11 alloys which are alloyed with the rare-earth metals, the ML14 and VML1 alloys with additions of thorium and the VML2 alloy. The ML9 alloys (σ_b = 20 – 24 kg/mm^2; $\sigma_{0.2}$ = 14 – 15 kg/mm^2; δ = 2 – 4%) and ML10 alloys (σ_b = 22 – 25 kg/mm^2; $\sigma_{0.2}$ = 12 – 14 kg/mm^2; δ = 4 – 6%), developed on the basis of the Mg – Nd – Zr system, are used for highly loaded details operating for long periods at temperatures to 250° and for short periods to 350°. With regard to strength properties at room temperature, these alloys are not inferior to the higher strength ML12 and ML15 magnesium alloys, and at elevated temperatures exceed them considerably in both short-time and long-time creep tests ($\sigma^{200°}_{0.2/100}$ = 9.0 kg/mm^2 for ML10 and 4.5 kg/mm^2 for the ML15 alloy). At temperatures to 300° the ML9 alloy exceeds all the cast magnesium alloys with respect to yield strength, including the alloys with thorium, and also exceeds the aluminum alloys with respect to specific values of the ultimate and yield strengths at 250°, and beginning at 300° it exceeds them in absolute value.

The ML11 alloy (σ_b = 14 – 16 kg/mm^2; $\sigma_{0.2}$ = 8 – 10 kg/mm^2; δ = 3 – 6%) containing cerium mischemetal is close to the ML9 and ML10 alloys with respect to creep resistance under conditions of 100-hour tests at 250°, but is inferior to them with respect to properties in short-time tension, particularly at room temperature.

The VML2 alloy (σ_b = 22 – 26 kg/mm^2; $\sigma_{0.2}$ = 11 – 12 kg/mm^2; δ = 4 – 8%), which does not contain radioactive nor toxic additives is used for long term operation at temperatures of 250-300° and short term use to 400°. At 300-400° its yield point is higher than that of the VML1 magnesium-thorium alloy.

The ML14 alloy (σ_b = 19 – 21 kg/mm^2; $\sigma_{0.2}$ = 9 – 10 kg/mm^2; δ = 6 –

– 10%), of the Mg-Th-Zr system is recommended for long term operation at 300-350° and for short term operation to 400°.

This alloy has low mechanical properties in short-time tension at 300-350°, but has high creep resistance under conditions of long-term testing. The magnesium-thorium alloy VML1 (σ_b = 19 – 21 kg/mm^2; $\sigma_{0.2}$ = = 9 – 10 kg/mm^2; δ = 4 – 10%) is intended for details operating for short periods at temperatures of 300-400°. It has high ultimate at these temperatures, but is inferior to the ML14 alloy with respect to creep strength.

The high-temperature cast magnesium alloys have somewhat higher corrosion resistance in comparison with the ML5 alloy, the best of them being the VML12 alloy. These alloys have low tendency to microporosity formation in castings. Cast details made from them are characterized by high hermeticity. The castings have uniform mechanical properties, which vary little as a function of section thickness. The mechanical properties of the alloys measured on specimens cut from details are close to the properties of individually cast specimens. The alloys are easily argon-arc welded. In the majority of cases they are used after heat treatment – solution treatment and aging, with the exception of the ML11 alloy which is often used without heat treatment. The alloys with high hermeticity include the high strength ML15 alloy, the high temperature ML9, ML10, ML11, ML14, VML1, VML2 alloys and the medium strength ML3 alloy.

The high corrosion resistant alloys include the ML4 pch (pch indicates high purity) and ML5 pch alloys, all the alloys based on the Mg--Zr system and the ML2 alloy based on the Mg-Mn system (σ_b = 8 – 10 kg/ /mm^2; δ = 3 – 6%). The cast magnesium alloys are resistant to intercrystalline corrosion and to stress corrosion cracking.

Details made from the cast magnesium alloys are protected from corrosion by inorganic films and paint/lacquer coatings. Details intended for operation in particularly difficult conditions are subjected to anodizing (or parkerizing), priming and painting. Particular attention is devoted to protection of locations of contact of magnesium details with other alloys (see Corrosion of the Magnesium Alloys).

For the production of the cast magnesium alloys use is made of crucible induction furnaces of capacity to 500 kg, crucible furnaces with oil, gas or electric heating of capacity to 1.5-2 metric tons. To prevent combustion during smelting, the surface of the molten metal is protected by fluxes consisting of a mixture of chloride and fluoride salts of the alkali and alkaline-earth metals. Widest use is made of the V12 chloride universal flux (95% flux No 2 following AVTU 109-48 and 5% calcium fluoride following GOST 7167-54) and the FL1 chloride--free flux which is used in place of the chloride fluxes in the final operation of theproduction of the ML4 pch and ML5 pch alloys. In the production of alloys containing the rare-earth metals and thorium, a special flux is recommended which reduces the loss of these metals. Protective additives are used to prevent combustion of the metal during casting: to the casting mixture there are added the VM additive (urea, a coagulant and boric acid) or a fluoride addtive (85% ammonium fluoride acid and 15% boric acid; this additive is ver toxic), sulfur and boric acid are added to the core mixture, boric acid is added to the paint for chill molds. Castings from the magnesium alloys are obtained by casting into sand and shell molds, into chill molds, by pressure casting, by the lost wax process, and by casting into gypsum molds.

As a rule, the mechanical properties of the alloys on specimens out from castings are lower than those of individually cast specimens. According to the accepted standards, the average values of the ultimate strength on specimens cut from castings must be no less than 75 and 85%

of the ultimate strength of individually cast specimens of the alloys of the Mg - Al - Zn and Mg-Zr systems, and the elongation must be no less than 50 and 60% respectively. The yield strength of the alloys in castings and individually cast specimens is practically the same.

In the design of sprue and header systems for mold casting, account is taken of the easy oxidizability of the magnesium alloys in the liquid condition, the considerable shrinkage (1.1-1.3 for the ML5 alloy and 1.3-1.5 for alloys based on the Mg-Zr system), the low thermal capacity and latent heat of fusion in comparison with the aluminum alloys, the low specific weight (1.76-1.84 g/cm^3 depending on the composition) and, consequently, the low metallostatic pressure, high hot brittleness, tendency to formation of microporosity, lower fluidity (length of fluidity test rod is 290-300 mm for the ML5 alloy and 250-320 mm for the alloys of the Mg-Zr system). The header system is designed on the basis of the principle of an expanding metal flow, i.e., gradual increase of the section areas of the basic elements of the system from the standpipe to the casting. The best combination of total sections of the standpipes, skimmers and feeders is 1:2:4.

Castings made from the cast magnesium alloys may be delivered without heat treatment and as-heat-treated in various conditions. The designation for the forms of heat treatment are: T1 - aging after casting; T2 - annealing after casting; T4 - solution treatment; T6 - solution treatment and artificial aging.

In melting, casting, thermal treatment and mechanical working of the cast magnesium alloys it is necessary to observe the rules for fire prevention safety (see Magnesium Alloys). These alloys are used for the fabrication of various details for flight vehicles - aircraft wheel components, control details and wing details for airplanes, jet engine parts (compressor castings, accesory drive housings, oil pumps), etc.

In the auto industry they are used for engine crankcases, transmission housings, wheel components, pump housings, clutches, etc.; in machine design they are used for machine tool beds, planer guides, milling cutter heads, making it possible to reduce not only the machine weight but also the inertia forces in the moving parts of the machines; in the textile industry they are used for warping machine shafts, bobbins, spools and reels for textile machines; in the electric and electronic industries they are used for electric motor parts, magnetic tape recorder cases, dictaphones, recorder, etc., particularly in those cases when a nonmagnetic material is required. They are used to fabricate supports for television cameras, movie cameras, mobile x-ray equipment, various vibration-resistant panels for instruments and damper parts. They are used to fabricate parts for portable instruments and tools, in particular power saws for felling timber, pneumatic drilling machines, vacuum cleaners, tampers, etc; in the tractor industry they are used for casting transmission housing, in shipbuilding for the production of bumpers, and also in many other branches of engineering.

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N.M. Tikhova

CAST MAGNETS - see Alni Alloys.

II-64n

CAST NIOBIUM is niobium which is produced by the method of electric arc and electron beam remelting in a vacuum (10^{-4} to 10^{-5} mm Hg). During vacuum remelting the harmful impurities (O, N and others) are evaporated, since their vapor pressure is considerably higher than that of the niobium vapor. Deoxidation may take place as a result of evaporation of the lower niobium oxides and flotation of the nonmetallic inclusions, and 10-20% of the oxygen may be removed in the form of carbon monoxide. The time that the metal remains in the liquid condition under the vacuum and also the metal superheat have considerable influence on the refining of niobium during arc and electron beam melting. After electric arc remelting with a rate of 720 grams per minute, niobium containing 0.25% O and 0.05% C has a hardness (HB) of 138 kg/mm^2, and after electron beam remelting at the same rate it is 80-100 kg/mm^2. Niobium is cast into ingots weighing 1000 kg and more. Hot deformation is used to form bars, rods, tubing blanks and other mill products from the ingots. The electric arc and electron beam remelting methods using slag may be used to obtain shaped castings which can be poured into graphite forms or chill molds (see Pressure Working of Niobium).

References: Kolchin, O.P., Niobiy i tantal [Niobium and Tantalum], Moscow, 1959; Kieffer, R., Kieffer B., "Metal," 1961, Vol. 15, No. 5, pages 394-402; Ogiermann, G., Scheibe, W., idem., No. 1, pages 3-8; "Aviation Week," 1961, Vol. 74, No. 2, page 73.

B.V. Fedin

CAST PHENOL PLASTIC – are nonfilled resins of the resol type obtained by condensation of phenol and formaldehyde with addition of basic or acid catalysts, and cured in open molds. The cast phenol-aldehyde plastics have different properties depending on the phenol – formaldehyde ratio, the condensation conditions and the catalysts used.

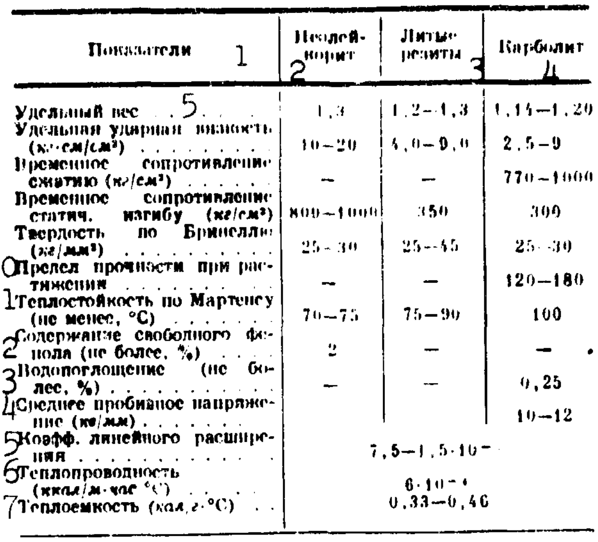
The cast phenol plastic Neoleucorite is obtained by condensation of phenol with formaldehyde and an alkaline catalyst (sodium hydroxide), and a subsequent neutralization of the alkaline medium by lactic acid. The curing of the Neoleucorite is carried out in open plaster or lead molds, raising the temperature gradually and keeping it at 80-100° for 80 hours. Neoleucorite is available as 50-100 mm thick cut-sheets or as rods. The properties of Neoleucorite are given in the article Neoleucorite.

Cast resistes are prepared by condensation of phenol and formaldehyde in presence of a catalyst (potash); they are modified by glyptal resin. They are available as 50-100 mm thick cut-sheets and cylindrical rods with a diameter of 15-20 mm.

Neoleucorite and cast resites are raw materials used for the manufacture of commodities; they may be ground, cut, drilled, turned, and polished.

Carbolite is prepared by condesnation of phenol or cresol and formaldehyde using zinc acetate (as a catalyst). The curing of the carbolite is carried out in open molds in the presence of petroleum sulfoacids (Petroff's contact) at 30-100°. Carbolite is used for the production of electric insulating objects. The conditions for the machining of cast carbolite are similar to those of the neoleucorite.

Physicomechanical Properties of Neoleucorite, Cast Resite, and Carbolite



Показатели 1	Неолейкорит 2	Литые резиты 3	Карболит 4
Удельный вес 5	1,3	1,2—1,3	1,14—1,20
6 Удельная ударная вязкость (кг·см/см²)	10—20	4,0—9,0	2,5—9
7 Временное сопротивление сжатию (кг/см²)	—	—	770—1000
8 Временное сопротивление статич. изгибу (кг/см²)	800—1000	350	300
9 Твердость по Бринеллю (кг/мм²)	25—30	25—45	25—30
10 Предел прочности при растяжении	—	—	120—180
11 Теплостойкость по Мартенсу (не менее, °C)	70—75	75—90	100
12 Содержание свободного фенола (не более, %)	2	—	—
13 Водопоглощение (не более, %)	—	—	0,25
14 Среднее пробивное напряжение (кв/мм)			10—12
15 Коэфф. линейного расширения	$7,5-1,5\cdot10^{-}$		
16 Теплопроводность (ккал/м·час °C)	$6\cdot10^{-4}$		
17 Теплоемкость (кал/г·°C)	0,33—0,46		

1) Characteristics; 2) neoleucorite; 3) cast resites; 4) carbolite; 5) specific gravity; 6) specific resilience (kg•cm/cm^2); 7) temporary compression strength (kg/cm^2); 8) temporary static bending strength (kg/cm^2); 9) Brinell hardness (kg/mm^2); 10) tensile strength; 11) heat resistance according to Martens (not less than, °C); 12) free phenol content (not more than, %); 13) water adsorption (not more than, %); 14) mean breakdown voltage (kv/mm); 15) coefficient of linear expansion; 16) heat conductivity (kcal/m•hr•°C); 17) specific heat (cal/g•°C).

Cast phenol plastics are bonded by joiner's glue, by cold-curing phenol adhesives, and by a solution of polyvinyl chloride in dichloroethane.

The resin 30 is a phenol-formaldehyde resin modified by a polyamide which is added in order to improve the elasticity of the product; it is used for the production of dies and of master patterns. The warranted shelf life of the resin in closed glass or iron-plate packing is 1 year. The casting composition contains the resin 30 (100 parts by weight), commercial formalin (4 parts by weight), a curing agent (Petroff's contact, 7 parts by weight), and a plasticizer (oleic acid, 1-3%). The composition is prepared by a careful mixing of the components. The finished composition is poured into plaster or wood molds covered with a separating agent. The molds are set under a vacuum of not less than 150 mm mercury column for 2-5 minutes in order to remove the air bubbles enclosed during mixing and pouring. The filled molds are kept at room temperature until the resin is thickened. In contrast to the neoleucorite, the cast resites, and the carbolite, only a small quantity of heat is liberated during the exothermic curing reaction of the resin 30; the temperature of the resin rises only to 36-38° after the curing agent is added, and drops subsequently to the normal level. The resin compound becomes rubber-like or solid within 16-24 hours and is then exposed to a heat treatment under one of the following condi: tions: 1) 8 hrs at 30°, 24 hrs at 50°, 24 hrs at 60°, and 12 hrs at 40°, or 2) 8 hrs at 30°, 24 hrs at 50°, and 12 hrs at 40°. The hat treatment is continued for 24-68 hours, depending on the shape and the weight of the object. The curing and cooling must be carried out gradually to improve the quality of the products. The cured resin 30 has a compression strength of 1100-1200 kg/cm^2, a static bending strength of 800-900 kg/cm^2, a resilience of 9-12 kg•cm/cm^2, a Brinell hardness of 20-22 kg/mm^2, a shrinkage of 0.25-0.3%, and it may be used at temperatures up to 200°. The resin 30 is recommended for the production of dies for the cold-pressing of metals and for the production of dies for the cold-pressing of metals and for the production of casting equipment. Fillers (crushed waste plastics or wood shavings) are added when large-sized (tall) models are manufactured. Rods, metallic one-piece casings or casings made from thin wire are used for the manufacture of such kind of models, and also for thin-walled objects and objects with a complex shape. The metal surface is previously covered with a thin layer of an epoxy resin to avoid the effect of the acid contained in the resin. The cast models require no machining. The models made from resin 30 have a wear-resistance which is comparable to that of models made from aluminum. The resistance to abrasion is higher than that of models made from epoxy resins. The models made from resin 30 are up to 70% cheaper than such ones made from aluminum.

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M.S. Krol'

CAST POLYACRYLATES — products of polymerization of methacrylic acid and copolymerization of acrylic and methacrylic acids with styrene or acrylonitrile. Cast polyacrylates are produced in the following grades: PT, MS, and MSN. They are produced as granules 3.5-4.0 mm in diameter. For the characteristics of cast polyacrylates, see the table (page).

Characteristics of Cast Polyacrylates

1 Показатели	2 Марки		
	ПТ	МС	МСН
3 Удельный вес	1,18—1,2	1,14	1,1
4 Предел прочности (кг/см²) при:			
5 сжатии	—	1000	900—1000
6 изгибе	1200—1800	950—1000	—
7 Удельная ударная вязкость (кг·см/см²)	12—19	13—15	15—20
8 Твердость по Бринелю (кг/мм²)	17—18	16—17	16—18
9 Теплостойкость по Мартенсу (°C)	88—95	75—78	72—75
10 Водопоглощение за 24 часа (%)	—	0,26	0,28
11 Тангенс угла диэлектрич. потерь при 10^6 гц	0,02—0,03	0,02	0,018
12 Диэлектрич. проницаемость при 10^6 гц	2,7—3,2	2,7	2,9
13 Уд. поверхностное сопротивление (ом)	—	$2{,}5 \cdot 10^{[illegible]}$	—
14 Уд. объемное сопротивление (ом·см)	$10^{[illegible]}$—$10^{[illegible]}$	$3{,}5 \cdot 10^{[illegible]}$	$4 \cdot 10^{[illegible]}$
15 Электрич. прочность (кв/мм)	—	22	24

1) Characteristic; 2) grade; 3) specific gravity; 4) ultimate strength (kg/cm^2) in; 5) compression; 6) bending; 7) specific impact resistance ($kg \cdot cm/cm^2$); 8) Brinell hardness (kg/mm^2); 9) Martens thermal stability (°C); 10) water absorption in 24 hours (%); 11) dielectric loss tangent at 10^6 cps; 12) dielectric constant at 10^6 cps; 13) specific surface resistance (ohms); 14) bulk resistivity (ohm·cm); 15) electrical strength (kv/mm).

Cast polyacrylates have high transparency, are resistant to oil, gasoline, light, and weather and can take on various colors and tints, from very light to very dark; MSN cast polyacrylate dissolves in dichloroethane, methylene chloride, and benzene, and may be used in varnishes of 5-10 concentration to varnish products. Cast polyacrylates are easily injection-molded into products; grades MS and MSN are also manufactured into products by extrusion and molding. Cast polyacrylates are widely used in the manufacture of industrial products (parts for the aircraft and automotive industries, electronics and radio parts, instrument housings, and similar products) as well as for household goods.

N.P. Gashnikova

CAST RESITE - see Cast phenolic plastics.

CAST SCALE-RESISTANT STAINLESS STEEL is highly alloyed steel for fabricating cast detail parts operating at high temperatures and having high scale resistance.

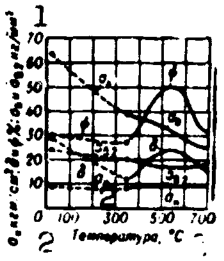


Fig. 1. Variation of mechanical properties of Kh18N9TL steel with temperature increase. 1) a_n, kgm/cm^2, δ and ψ, %, σ_b and $\sigma_{0.2}$, kg/mm^2; 2) a_n; 3) temperature, °C.

TABLE 1

Chemical Composition of Cast Scale-Resistant Stainless Steels

Сталь 1	2 Содержание элементов (%)									ГОСТ или ТУ 5
	C	Si	Mn	Cr	Ni	Mo	S	P	4 другие элементы	
							3 не более			
6 Х9С2Л	0.35—0.5	2—3	<0.7	8—10	<0.6	—	0,03	0,035	—	ГОСТ 2176—57 7
8 Х6С2МЛ	<0.15	1.5—2	<0.7	5—6.5	<0.6	0.45—0.6	0,03	0,035	—	То же 9
10 Х18Н9ТЛ	<0.14	<1	1—2	17—20	8—11	—	0,03	0,035	Ti<0.8	»
11 Х18Н12М3ТЛ	<0.12	<1	1—2	16—19	11—13	3—4	0,03	0,035	0,3—0,6 Ti	»
12 Х24Н12СЛ	<0.4	0.5—1.5	0.3—0.8	22—26	11—13	—	0,03	0,035	—	»
13 Х18Н24С2Л	0.3—0.4	2—3	<1.5	17—20	23—25	—	0,03	0,035	—	»
14 Х25Н19С2Л	<0.2	2—3	<1.5	23—24	18—20	—	0,03	0,035	—	»
15 ЛА-1	<0.16	<0.55	<0.7	14—16	14—16	1.8—2.2	0,02	0,025	0.8—1.2 W, 0.15—0.35 Ti, 2.8—3.2 Co	ПМТУ 36-54 16
17 ЛА-6	0.11—0.15	<0.55	0.5—1	13—15	13—15	1.7—2.1	0.02	0.025	1.25—1.65 W, <1.2 Nb	—

1) Steel; 2) element content (%); 3) not more than; 4) other elements; 5) GOST or TU; 6) Kh9S2L; 7) GOST; 8) Kh6S2ML; 9) same; 10) Kh18N9TL; 11) Kh18N12M3TL; 12) Kh24N12SL; 13) Kh18N24S2L; 14) Kh25N19S2L; 15) LA-1; 16) PMTU; 17) LA-6.

On the basis of structure, the cast scale-resistant stainless steels are divided into several groups: hardenable martensitic (see

Cast High-Temperature Constructional Steel), ferritic, semiferritic and martensitic (see Cast Stainless Steel), austenitic.

TABLE 2

Mechanical Properties of Cast Scale-Resistant Stainless Steels (no less than)

Сталь 1	2 Термич. обработка	σ_b	$\sigma_{0,2}$	δ	ψ	4 $a_н$ (кгм/см²)	5 ГОСТ или ТУ
		3 (кг/мм²)		(%)			
6 Х9С2Л	7 Закалка с 1050° в воде	70	56	—	—	—	ГОСТ 2176—57 8
9 Х6С2МЛ	Закалка с 780° в воде	56	40	20	50	—	То же 10
11 Х18Н9ТЛ	Закалка с 1100° в воде	45	20	25	32	10	•
Х18Н12М3ТЛ 12	Закалка с 1150° в воде	50	22	30	30	10	•
13 Х24Н12СЛ	Закалка с 1150° в воде	50	25	20	28	—	•
Х18Н24С2Л 14	Закалка с 1150° в воде	56	30	20	25	—	•
15 Х25Н19С2Л	Закалка с 1100° в воде	50	25	25	28	—	•
ЛА-1 16	Закалка с 1160° на воздухе и старение при 750—800°	40	20	15	—	3.5	ПМТУ 36-56 18
19 ЛА-6	20 Закалка с 1180° на воздухе и старение при 800 и 750°	40	20	18	35	4	—

1) Steel; 2) heat treatment; 3) (kg/mm^2); 4) a_n (kgm/cm^2); 5) GOST or TU; 6) Kh9S2L; 7) quench from – in water; 8) GOST; 9) Kh6S2ML; 10) same; 11) Kh18N9TL; 12) Kh18N12M3TL; 13) Kh24N12SL; 14) Kh18N24S2L; 15) Kh25N19S2L; 16) LA-1; 17) quench from – in air and aging at –; 18) PMTU; 19) LA-6; 20) quench from – in air and aging at – and –.

TABLE 3

Physical Properties of Cast Scale-Resistant Stainless Steels

Сталь 1	$\alpha \cdot 10^6$ (1/°C)	2 λ (кал/см·сек·°C)	3 $t_{пл}$
Х18Н9ТЛ 4	16.8 (25—100°) 17.6 (25—500°) 18.3 (25—700°)	0.038 (100°) 0.055 (500°) 0.064 (700°)	1400—1425°
Х25Н19С2Л 5	15.5 (20—300°) 17.2 (20—800°) 21.3 (850—1000°)	0.043 (20°)	1340—1370°
ЛА-1 6	15.2 (20°) 19.2 (400°) 26.5 (800°)	0.031 (100°) 0.115 (500°) 0.143 (700°)	
ЛА-6 6	15.1 (20—100°) 18.2 (20—500°) 19.2 (20—700°)	0.035 (100°) 0.052 (550°) 0.061 (700°)	

1) Steel; 2) – (cal/cm-sec-°C); 3) $t°_{pl}$; 4) Kh18N9TL; 5) Kh25N19S2L; 6) LA.

The chemical composition of some typical grades of cast scale-resistant stainless steels is shown in Table 1.

The mechanical properties of the cast scale-resistant stainless steels are determined on specimens cut from blanks cast from the same

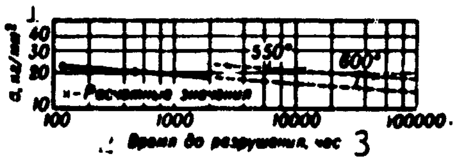


Fig. 2. Stress-rupture strength of the Kh18N9TL steel. 1) σ, kg/mm²; 2) computed values; 3) time to failure, hours.

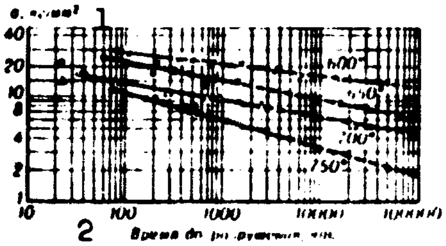


Fig. 3. Stress-rupture strength of the Kh25N19S2L steel (quench from 1160°, aging at 300-750°). 1) σ, kg/mm²; 2) time to failure, hours.

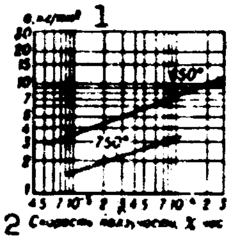


Fig. 4. Creep strength of the Kh25N19S2L steel. 1) σ, kg/mm²; 2) creep rate, %/hr.

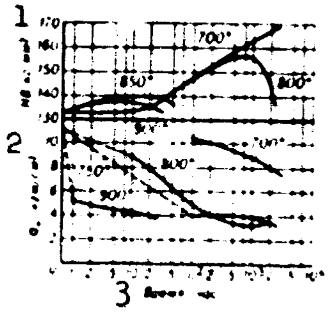


Fig. 5. Variation of hardness and impact strength of the LA-1 steel after aging (quench from 1160°, aging at 770-800°). 1) HB, kg/mm²; 2) a_n, kgm/cm²; 3) time, hours.

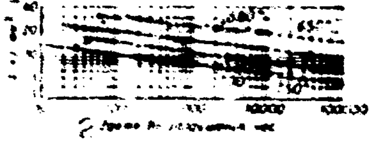


Fig. 6. Stress-rupture strength of the LA-1 steel. 1) σ, kg/mm²; 2) time to failure, hours.

metal melt as the parts, and heat treated together with them.

The Kh9S2L and Kh6S2ML steels belong to the silchrome group of the pearlitic class which harden into martensite and which have not only high oxidation resistance, but also good wear resistance. Introduction of molybdenum into the composition of the silchromes reduces the temper brittleness of this steel.

The variation with temperature of the mechanical properties of the Kh18N9TL steel of the austenitic class after air quench from 1100° and aging at 800° is shown in Fig. 1, and the stress-rupture strength is shown in Fig. 2. The creep strength (residual deformation 1% after 100,000 hours) of the Kh18N9TL steel at 600° is 12 kg/mm^2, and the stress rupture strength after 100,000 hours at 600° is 13 kg/mm^2.

The stress-rupture strength and the creep resistance of the Kh25-N19S2L austenitic steel are shown in Figs. 3 and 4. The creep limit at 650° after 100,000 hours is 8 kg/mm^2, the stress-rupture strength at these same conditions is 9.7 kg/mm^2, and at 600° is 16 kg/mm^2. The variation of the hardness and the impact strength of the LA-1 austenitic class steel after aging is given in Fig. 5, the stress-rupture strength is shown in Fig. 6.

A drawback of the Kh24N12SL and Kh25N19S2L steels is the tendency to embrittlement under the influence of extended time at 800°, associated with the formation of the σ-phase.

The temperature of beginning of intensive oxidation is 900° for the Kh9S2L steel, and from 700 to 800° for the Kh6S2ML steel. The 1Kh-18N9TL steel is not prone to intercrystalline corrosion, with respect to scale formation it permits long-term use at temperatures to 750°; the beginning of intensive oxidation in air occurs at a temperature of 850°. The Kh24N12SL steel has high resistance to gaseous corrosion, and with respect to scale formation permits use to 900°. The Kh25N19S2L steel in an air medium has a weight increase after 100 hours (g/m^2-hr): 0.14 (800°), 0.25 (900°), 0.42 (1000°), 0.77 (1100°); beginning of intensive oxidation is at a temperature of 1100°. The LA-6 steel is not prone to intercrystalline corrosion, thanks to the presence of the stabilizing element niobium; in this respect this steel has an advantage over the LA-1 steel.

Processing properties. Casting of the cast scale-resistant steels is performed using the lost wax method, in ceramic and shell forms; ring-shaped parts are centrifugally cast into a shell mold. The fluidity is high. Casting free shrinkage is 2-2.5%. Weldability is good. Welding and corrective welding of casting defects is performed using arc welding. Machinability is satisfactory.

The Kh9S2L steel is used for parts operating with low loads at temperatures to 700°; the Kh6S2ML steel is used for parts operating at temperatures to 750° (parts for cracking plants, pump parts, etc.). The Kh18N9TL steel is used for parts operating at temperatures to 600° (gas pipeline outlet headers, equipment for petroleum refining installations, cementation boxes); the Kh18N12M3TL steel is used for parts operating at temperatures to 800°; the Kh25N19S2L steel is used for parts of steam and gas turbines and boiler installations operating at temperatures to 650°; the Kh24N12SL steel is used for parts operating for extended times at high loads with temperatures to 600° (compressor blades and nozzle rings for gas turbines); the Kh18N24S2L steel is used for parts operating with low loads and temperatures to 1000° (furnace conveyors, boiler equipment, fastener details, etc.), and also for parts operating with high loads and temperatures to 800°; the LA-6 steel is used for parts of turbine and boiler equipment operating in a steam medium with high operating stresses and temperatures to 600-650°; the LA-1 steel is used for large turbine parts operating for extended time periods in the stressed condition at temperatures to 650°.

References: Khimushin, F.F., Zharoupornyye stali i splavy [Heat-Resistant Steels and Alloys], Moscow, 1949; Liberman, L.Ya. and Peysikhis, M.I., Spravochnik po svoystvam staley, primenyayemykh v kotloturbostroyenii [Handbook on Properties of Steels Used in Boiler and Turbine Construction], 2nd edition, Moscow-Leningrad, 1958; Stalnoye lit'ye [Steel Casting], Handbook edited by N.P. Dubinin, Moscow, 1961; Mikhaylov-Mikheyev, P.B., Metall gazovykh turbin [Gas Turbine Metal], Moscow-Leningrad, 1958; Metallovedeniye i termicheskaya obrabotka stali i chuguna [Metal Science and Heat Treatment of Steel and Iron], Handbook, Moscow, 1956.

N.M. Tuchkevich

CAST STAINLESS STEEL is steel which is used for fabricating cast parts which have resistance to atmospheric corrosion. The cast stainless steel, just as the stainless steel used in the wrought condition, is highly alloyed, and depending on the structure and alloying may belong to the ferritic, semiferritic, martensitic, and austenitic classes. The corrosion resistance of the cast stainless steel is provided by the chrome content (more than 12%). Further increase of the chrome content to 17% and more makes the steel acid resistant and scale resistant. The corrosion resistance of the cast stainless steel also depends on the carbon content and the heat treatment. In castings made from the ferritic chrome steel (more than 15-18% chromium), after slow cooling or long-term heating at 450-500° there develops a brittleness – the so-called "475° brittleness" which practically eliminates the use of this steel for highly loaded parts. Most widely used in machine design for shaped castings is the cast stainless steel of the semiferritic class of the 1Kh13L type, the Kh17N3SL, 2Kh13L and Kh13N3VFL steels of the martensitic class, and the Kh18N9TL steel of the austenitic class (for composition and properties of the Kh18N9TL steel, see Cast Scale-Resistant Stainless Steel).

The mechanical properties are determined on specimens cut from bars cast from the same metal melt as the parts, and heat treated along with them. To determine the mechanical properties of castings made using the lost wax process, use is made of prepared specimens made from lost wax models or special blanks. When cast using the lost wax process, the 2Kh13L steel after heat treatment using various regimes has

TABLE 1

Chemical Composition of Cast Stainless Steel

Сталь 1	2 Содержание элементов (%)									ГОСТ или ТУ 3
	C	Si	Mn	Cr	Ni	W	V	S	P	
								4 не более		
1Х13Л 5	<0,15	0,7	0,6	12–14	<0,6	—	—	0,03	0,035	6 ГОСТ 2176–57
2Х13Л 7	0,16–0,24	0,7	0,6	12–14	<0,6	—	—	0,03	0,035	8 То же
Х13Н3ВФЛ 9	0,09–0,15	0,2–0,5	0,2–0,8	11,5–13,5	2,3–3	1,6–2,2	0,18–0,28	0,03	0,03	10 АМТУ 433-59
Х17Н3СЛ 11	0,05–0,12	0,8–1,5	0,3–0,8	15–18	2,8–3,8	—	—	0,03	0,035	То же

*In addition, 0.003-0.006% V; T content up to 0.05% is also permitted.

1) Steel; 2) element content (%); 3) GOST or TU; 4) no more than; 5) 1Kh13L; 6) GOST; 7) 2Kh13L; 8) same; 9) Kh13N3VFL; 10) AMTU; 11) Kh17N-3SL.

TABLE 2

Mechanical Properties of Cast Stainless Steel

Сталь 1	2 ГОСТ или технич. усл.	3 Термич. обработка	σ_b	$\sigma_{0,2}$	δ	ψ	$a_н$ 4	HB ($d_{отп}$, мм) 5
			6 (кг/мм²)		(%)			
1Х13Л 7	8 ГОСТ 2176–57	9 Отжиг при 950°, закалка с 1050° в воде, отпуск при 750°	56	40	20	50	8	—
10 2Х13Л	11 То же	То же	63	45	16	40	6	—
12 Х13Н3ВФЛ	13 АМТУ 433-59	14 Закалка с 1050° в масле или на воздухе, отпуск при 540–620°	120	100	7	20	1,5	3,7–3,4
15 Х13Н3ВФЛ	То же	Закалка с 1050° в масле или на воздухе, отпуск при 680–720°	90	75	9	30	2	[illegible]
16 Х17Н3СЛ	»	Закалка с 1050° в масле, отпуск при 540–560°	95	75	8	20	2,5	[illegible]–3,2
		17 Отпуск при 670–690°	85	65	6	10	—	[illegible]

1) Steel; 2) GOST or specification; 3) heat treatment; 4) a_n, kgm/cm^2; 5) HB (d_{otp}, mm); 6) (kg/mm^2); 7) 1Kh13L; 8) GOST; 9) anneal at 950°, water quency from 1050°, temper at 750°; 10) 2Kh13L; 11) same; 12) Kh-13N3VFL; 13) AMTU; 14) oil or air quency from 1050°, temper at –; 15) Kh13N3VFL; 16) Kh17N3SL; 17) temper at –.

TABLE 3

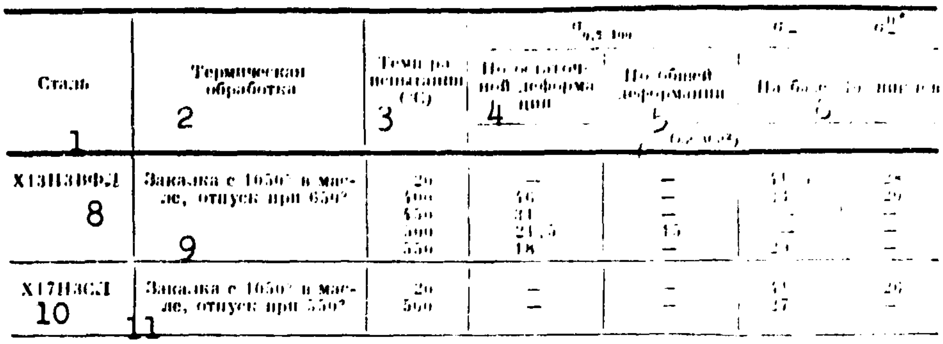
Mechanical Properties of 2Kh13L Steel After Various Heat Treatment (cast by lost wax process)

Термич. обработка 1	σ_b	δ	ψ	HB
	(кг/мм²)	(%)		2 (кг/мм²)
3 Отжиг при 850°	61–80	14–16	[illegible]	[illegible]
4 Закалка с 1050° в воде, отпуск при 550°	100–130	12–14	45–56	[illegible]
Закалка с 1050° в воде, отпуск при 600°	82–90	12–16	44–55	[illegible]
Закалка с 1050° в воде, отпуск при 650°	76–83	12–18	50–55	[illegible]
Закалка с 1100° в воде, отпуск при 700°	65–68	16–18	[illegible]	[illegible]

1) Heat treatment; 2) (kg/mm^2); 3) anneal at 850°; 4) water quench from –, temper at –.

TABLE 4

Creep and Endurance Strengths of Kh13N3VFL and Kh17-N3SL Steels (in rotating bending)



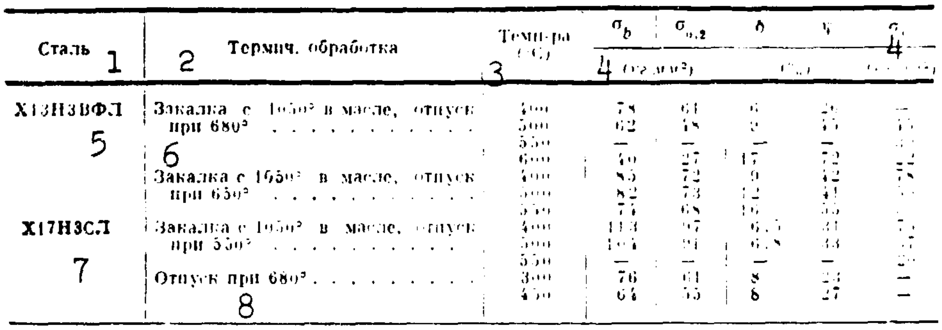
Сталь 1	Термическая обработка 2	Темп-ра испытания (°C) 3	$\sigma_{0,2/100}$ По остаточной деформации 4	$\sigma_{0,2/100}$ По общей деформации 5	σ_{-1} На базе 10^7 циклов 6	$\sigma_{-1}^{н}$*
(кг/мм²)						
Х13Н3ВФЛ 8	Закалка с 1050° в масле, отпуск при 650° 9	20	—	—	51	25
		400	46	—	44	29
		450	31	—	—	—
		500	21,5	15	—	—
		550	18	—	24	—
Х17Н3СЛ 10	Закалка с 1050° в масле, отпуск при 550° 11	20	—	—	51	26
		500	—	—	27	—

*Semicircular notch of radius 0.75 mm on specimens with diameter at base of notch 7.5 mm, and for specimen tested at 20° this diameter was 8 mm.

1) Steel; 2) heat treatment; 3) test temperature (°C); 4) on basis of residual deformation; 5) on basis of over-all deformation; 6) on basis of 10^7 cycles; 7) (kg/mm^2); 8) Kh13N3VFL; 9) oil quench from 1050°, temper at 650°; 10) Kh17N3SL; 11) oil quench from 1050°, temper at 550°.

TABLE 5

Mechanical Properties of Kh13N3VFL and Kh17N3SL Steels at High Temperatures



Сталь 1	Термич. обработка 2	Темп-ра (°C) 3	σ_b	$\sigma_{0,2}$	δ	ψ	σ_{-1} 4
			4 (кг/мм²)		(%)		(кг/мм²)
Х13Н3ВФЛ 5	Закалка с 1050° в масле, отпуск при 680°	400	78	61	6	29	—
		500	62	48	9	45	15
	6	550	—	—	—	—	[illegible]
		600	40	27	17	72	[illegible]
	Закалка с 1650° в масле, отпуск при 650°	400	85	72	9	42	28
		500	82	73	12	41	[illegible]
		550	74	68	16	55	[illegible]
Х17Н3СЛ 7	Закалка с 1050° в масле, отпуск при 550°	400	113	97	6,5	31	[illegible]
		500	104	91	6,8	33	[illegible]
		550	—	—	—	—	[illegible]
	Отпуск при 680° 8	300	76	61	8	24	—
		450	64	55	6	27	—

1) Steel; 2) heat treatment; 3) temperature (°C); 4) (kg/mm^2); 5) Kh13-N3VFL; 6) oil quench from 1050°, temper at –; 7) Kh17N3SL; 8) temper at 680°.

the mechanical properties shown in Table 3. The creep and endurance limits of the Kh13N3VFL and Kh17N3SL steels at various temperatures are shown in Table 4. The mechanical properties of the Kh13N3VFL and Kh17N-3SL steels at high temperatures are shown in Table 5. The physical properties are given in Table 6.

Cast stainless steel has high resistance to atmospheric corrosion, in river and reservoir water after heat treatment and polishing, satisfactory resistance in contact with food products and in solutions of nitric acid. The Kh17N3SL steel has high resistance to atmospheric corrosion at temperatures to 500° and scale resistance at temperatures to 800°; intensive oxidation begins at 850°. The 2Kh13L steel has scale resistance at temperatures to 750°. The Kh13N3VFL steel is oxidation resistant at temperatures to 700°.

TABLE 6

Physical Properties of 1Kh-13L, Kh13N3VFL, Kh17N3SL Steels

Сталь 1	γ (г/см³) 2	$\alpha \cdot 10^6$ (1/°C)	λ 3 (кал/см·сек·°C)
1Х13Л 4	7,74	11 (20—100°) 12 (20—500°)	—
Х13Н3ВФЛ 5	7,8	—	0,047 (20°) 0,053 (200°) 0,059 (400°) 0,064 (600°) 0,067 (800°)
Х17Н3СЛ 6	7,8	11 (20—200°) 13,6 (200—300°) 15,1 (400—500°)	0,047 (100°) 0,051 (200°) 0,059 (400°) 0,066 (600°) 0,071 (800°)

1) Steel; 2) γ (g/cm^3); 3) λ (cal/cm-sec-°C); 4) 1Kh13L; 5) Kh13N3VFL; 6) Kh17N3SL.

Technological properties. With high chromium and iron content, the fluidity of cast stainless steel increases as a result of lowering of the melting point and the thermal conductivity. Ferritic steel with low carbon content requires greater superheating in pouring into forms as a result of its high viscosity. The fluidity of the Kh17N3SL steel is good. The linear free shrinkage of this steel is 2.5%. A coarse grained structure is obtained in castings with slow cooling of the metal in the process of crystallization of the chrome ferritic steel. Casting of parts from the cast stainless steels is performed into sand and shell forms. Casting of small thin-wall parts (compressor blades and other detail parts and components) is performed into ceramic forms and using the lost wax process.

The 1Kh13L steel is used for parts with high plasticity which are subject to impact loads (turbine blades, hydraulic press valves, cracking plant fittings, household articles), and also for parts subject to the action of relatively mild aggressive media (atmospheric precipitates, aqueous solutions of salts, organic acids at room temperature), and for parts of water turbines, marine propellers. The 2Kh13L steel is used for the same parts, but with higher hardness (HB 220-250); the Kh17N3SL steel is used for turbine and compressor blades with greater strength and plasticity than those made from the 1Kh13L and 2Kh13L steels, and for parts operating in a moist air medium with temperatures to 500°; the Kh13N3VFL steel is used for the same parts but operating at temperatures up to 550°.

References: Nekhendze, Yu.A., Stal'noye lit'ye (Steel Casting), Moscow, 1948; Stal'noye lit'ye (Steel Casting), Handbook for Casting Production Foremen, edited by N.P. Dubinin, Moscow, 1961.

N.M. Tuchkevich

CAST TUNGSTEN - see Tungsten Alloys.

CELLULOSE ACETATE AND CELLULOSE ACETOBUTYRATE PLASTICS – see Plastics based on cellulose esters.

CELLULOSE ESTER ADHESIVE – is a solution of cellulose esters, mainly nitrocellulose, in organic solvents. Cellulose ester adhesives are used to join fabrics and certain grades of leather substitutes. The adhesive grade AK-20 (a mixture of nitrocellulose and colophony ester in the RDV solvent) dries within 8 hours at normal temperature. The strength of a joint of fabric with wood (in the peel test) is not less than 60 kg/m. The shelf life of the glue is 1 year.

D.A. Kardashev

I-56v

CELLULOSE HYDRATE ARTIFICIAL FIBER — fibers from wood or cotton cellulose: viscose, cuprammonium (from regenerated cellulose). They are produced in the form of filament thread or infinite length, staple fiber and also as strips, bristles, sponges and straws. More than 90% of the entire output of cellulose hydrate fibers is comprised of viscose fibers.

G.G. Finger

CEMENTING OF GLASS, CERAMICS, PORLELAIN, AND ASBESTOS. Inorganic materials are usually bonded with glues and cements of inorganic origin, which ensure heat-resistant joints. Liquid glass containing various mineral fillers, mixtures of magnesium chloride and magnesium oxide, litharge-glycerin amalgums, iron and sulfur cements, etc. are most frequently employed as cements. Epoxy, type BF, polyurethane, and certain other polymer glues can also be employed for bonding glass, ceramics. porcelain, asbestos, asbestos-cement materials, etc. Phenol-caoutchouc glues and compositions containing silicoorganic compounds are used for cementing fiberglas heat-insulating materials. Silicate glass is joined with liquid and film adhesives. Polyvinylbutyrl films and films consisting of polymerized methacrylic and acrylic esters, polyvinylacetate, polyisobutylene, and unsaturated polyesteric copolymers based on maleic or fumaric acid and styrene, etc. are used when the cemented joints (seams) must be transparent, as in the manufacture of triplex automobile safety glass. In most cases liquid and film glues contain plasticizers (phthalates, sebacinates, etc.). If seam transparency is not obligatory silicate-glass products can be bonded to nonmetallic and metallic materials with epoxy and polyurethane glues. Joint strength is increased by roughening the surfaces to be cemented.

D.A. Kardashev

CEMENTING OF METALS. Use of cemented joints in metal assemblages permits reliable, strong, simple bonding of different metals of varying thickness; it eliminates the need to drill holes and the danger of concentration of stresses around rivets, bolts, or spot welds, since a cemented joint distributes the load uniformly over the entire joint area; individual portions of the assembly do not "bulge" (a characteristic of welded joints resulting from the change in the properties of the metal in the vicinity of the weld). Cemented joints prevent corrosion phenomena, create hermeticity, do not require additional sealing, reduce the weight of the assembly, and permit use of rather thin metals. Cementing is effective when it is necessary to provide thermal and sometimes electrical insulation. Cemented joints are stronger than riveted or welded joints at moderate temperatures, under vibration loads, and when the metal is thin. The drawbacks of cementing include the comparatively low heat resistance of joints made with organic glues, a tendency to age with time, the lack of a simple, reliable method for checking joint quality, and the necessity of heating the components to be joined in most cases; moreover, cemented joints have low strength under nonuniform tension. Before application of the glue the surface of the metals is cleaned of various contaminants, especially oil and grease. The strength of a cemented joint is increased by forming an oxide film on the surface of the metal. It is recommendeo that stainless-steel components be subjected to chemical pickling.

Liquid glues are most frequently used for joining metals, being applied to the surfaces to be cemented with a brush, by spraying (when cementing large flat or curved surfaces), with glue rollers, or by immersing the components in the flue. Film glues are widely used for cementing flat or slightly curved surfaces, first applying an underlayer of the same glue. The thickness of the glued layer, 0.05-0.25 mm, can in practice vary from 0.01 to 0.75 mm. The solvent, whose presence leads to formation of a low-strength porous seam, is removed by so-called open holding without heating or at elevated temperatures. Various methods are used for heating and for creating pressure during setting in cementing metal assemblages. The choice of a method is dictated by the size and shape of the components and the technological characteristics of the glue. Pressure is exerted on the cemented joint with screw clamps, spring clamps, bolts, vacuum devices, or special presses. Rubber bags and various types of autoclaves are used for cementing by the vacuum method. Flat-bed presses with various press forms are used in the mass production of flat components or components with a slight curvature. The temperature of the metal surfaces to be joined, the press plates, the press forms, etc. is determined with pyrometers, thermometers, paints sensitive to changes in temperature, etc.

Glues are becoming more and more important in the manufacture of three-layer assemblages of the "Sandwich" type, which consist of two and a core. Plastic foam, cellular materials of thin metal (foil), paper, plastics (e.g., glass textolite), wood, etc. are used for the core. Aluminum sheets from 0.3 to 1.6 mm thick serve as the facing material. Steel is employed if high mechanical strength, heat resistance, and abrasion resistance are required. The combination of a light-filler core and facings creates a strong, light assemblage suitable for use in the manufactur of automobile and railroad-car bodies, in residential construction, in the furniture industry, and in other areas of the national economy. Panels with a honeycomb filler consisting of glued six-sided cells are most widely used.

D.A. Kardashev

CEMENTING OF PLASTICS. The selection of a glue for plastics depends to a considerable extent on the chemical character of the material to be cemented, the conditions under which the joint must function, and the technological characteristics of the cementing process. Virtually all plastics can be cemented with polyurethane (PU-2), polyepoxy, or dimethylvinylethinylcarbinol glues. Cold-set glued joints are not sufficiently strong under operational conditions, especially at elevated temperatures or when exposed to the weather. Heat setting makes it possible to extend the range of glues to phenol-polyvinylacetate compositions (BF, VS-10T, VS-350, etc.) and to produce reliable joints. In addition to pure solvents, it is possible to utilize solutions of adhesive polymers in such solvents, which ensures uniform joints. The surfaces to be cemented should be clean and dry and should fit tightly against one another. The glue is applied with a brush, by immersion of the component, and by other methods. After the glue has been applied the components are held under pressure until the joint has set and then machined and finished.

Plastics based on thermoplastic resins, particularly polymers of polyvinylchloride, styrene, acrylic and methacrylic esters, etc. are readily cemented without heating, using appropriate solvents or glues, which are solutions of linear polar polymers in solvents or in monomers. Polyisobutylene is bonded to metals with glue No. 8 (a solution of thermoprene in monomeric styrene). Polyethylene, which is among the so-called inert materials and is difficult to cement, is joined with special glues having high adhesive characteristics; these glues are solutions of polymers in solvents which cause distension of polyethylene. The surface of the polyethylene is treated with a solution of synthetic rubber or a thermoplastic resin in carbontetrachloride, trichloroethylene, benzene, or toluol at 60°. After such treatment the polyethylene can be bonded with phenol-caoutchouc, resorcin-formaldehyde, and other glues whose setting temperature is below the softening temperature of the plastic. When epoxy, polyurethane, or methacrylic glues are used the polyethylene is treated with chromic acid at 120° for 1-2 sec before cementing. Polypropylene (as well as polyethylene) can be bonded with epoxy-polysulphide glues. Fluoroorganic polymers (like polyethylene) are cemented with special- or general-purpose glues, but active functional groups must first be generated at the surface of the polymer. Inert polymers (polytetrafluoroethylene and polytrifluorochloroethylene and its copolymers) are bonded with glues consisting of fluoroorganic polymers dissolved in organic solvents and containing activating additives. Glued joints in fluoroorganic polymers are of low strength. The simplest and most effective method is that based on exposure of the surface of fluoropolymer to a solution of metallic sodium in a mixture of napththylene and tetrahydrofurane. A teflon joint bonded by this method with an epoxy glue has a tensile strength of 10-120 kg/cm^2 and a sheer strength of 110 kg/cm^2. Cemented seams made in fluoroplasts by the aforementioned methods have a lower chemical stability than the plastics themselves, which considerable reduces joint quality. Fluroorganic plastics are made adhesive by irradiation, usually with cobalt 60. The surface thus becomes adhesive without any change in color. On plasticized polyvinylchloride is bonded with solutions of polyvinylchloride or additionally chlorinated polyvinylchloride in organic solvents (dichloroethane, trichloroethylene, methylene chloride, etc.). Adhesives based on caoutchouc or polyvinylchloride and solutions of caoutchouc and certain vinyl polymers in organic solvents are used for cementing plasticized polyvinylchloride, particularly various decorative and facing materials of this type. In this case it is important to select a glue which will not permit the plasticizer from the polymer to be joined to penetrate into the glue layer. The principal difficulty in cementing organic glass lies in its sensitivity to organic solvents, which cause formation of microcracks in the so-called silvering on its surface. There is a process for bonding organic glass with a 2-5% solution of this material in dichloroethane.

Organic glass can also be cemented with solutions of polymethylmethacrolate in monomeric methylmethacrolate, glacial acetic acid, formic acid, chloroform, dichloroethylene, etc. Bonding organic glass with heat-set methylolpolyamide glue (PFE-2/10) or VK-32-70 glue produces a high-strength joint.

Polyurethane, polyepoxy, phenol-polyvinylacetate, and carbonol glues and phenolic, polyetheric, and other adhesives are used for bonding thermoreactive plastics. The usual technique is employed for cementing these materials. The surfaces to be joined should be roughened for phenol-formaldehyde and other resin-based laminated materials.

If the glue contains a solvent the glue-coated components are subjected to open holding before joining in order to permit rapid evaporation of the solvent from the joint.

BF-2 glue is suitable for bonding textolite, glass textolite, laminated ligneous plastics, and combinations of these materials, two coats being applied to the materials to be joined. The glue-coated components are approximated and placed under pressure in a vice (or press) equipped with a contact or other heater. The pressing pressure amounts to 5-20 kg/cm^2. The maximum pressure is used for joining components with complex shapes. The time for which the workpiece is kept under pressure varies with temperature, usually being 50-60 min at 120-125°, 25-30 min at 130-135°, and 20-25 min at 136-140°.

Textolite, ligneous plastics, and combinations of these materials are joined to one another and to various foam plastics (PS-1, PKhV-1, FK-20, etc.), wood, and plywood with VIAM B-3, KB-3, and other phenol-formaldehyde glues that are set with acid hardeners (Petrov contact).

D.A. Kardashev

III-44s

CEMENTING OF RUBBER AND RUBBER PRODUCTS. Unvulcanized nitrile-based rubbers and rubberized fabrics are joined to unvulcanized and vulcanized nitrile rubbers with NS-30 rubber cement. The surfaces to be joined are wiped with a clean cloth, wetted with "Kalosh" gasoline, and given two coats of glue. Each coat is dried for 5-15 min at 20-30° or 5-10 min at 30-45°. The cementing temperature should not be below 23°. After cementing the components are held at room temperature for 8 hr and then vulcanized. The relative humidity of the room in which cementing is carried out should be 65-75%. The process by which unvulcanized nitrile-based rubbers and rubberized fabrics are joined to unvulcanized chloroprene-based rubbers and rubberized fabrics is similar to that described above; however, each coat of cement is dried for 5-10 min at 23-30° and 3-7 min at 30-45°. Before use the cement is thinned with appropriate solvents to the required viscosity. Vulcanized rubbers and rubberized fabrics based on natural, chloroprene, nitrile, and sodium-butadiene gums are bonded with 4N cement by cold setting, without vulcanization. Before use the cement is diluted with benzene to a viscosity of 30 sec, as determined with the VZ-1 apparatus. The surfaces to be joined are cleaned and given two coats of cement. Each coat is dried for 15-30 min at 18-30° or 10-15 min at 30-45°. The surfaces are then approximated and rolled with a metal roller. The workpiece is then held for 16 hr at a temperature of not less than 18°. Unvulcanized materials can also be bonded with 4N cement when subsequent vulcanization is employed.

D.A. Kardashev

CEMENTING OF WOOD AND PAPER MATERIALS. Various types of wood and ligneous plastics are cemented with synthetic glues (based chiefly on phenolic and carbonized resins), which produce joints resistant to water and microorganisms and considerably stronger than those made with gelatin and casein glues. Wood materials to be cemented with synthetic glues should have a moisture content of no more than 14-16%, since greater moisture causes the wood to be deformed and reduces the adhesive power of synthetic resins applied to it. The wood is dried before cementing. The surfaces of the components to be glued should fit tightly together (a deviation of no more than 0.5 mm from true parallelness is permissible). Components fabricated from laminated ligneous plastics should have a uniformly roughened surface for cementing. The glossy, lustrous surface of plywood and those areas to which the glue will penetrate are cleaned with a scraper or polished with emery paper and the sawdust is removed. The glue-ready workpieces are stored at the appropriate air temperature and humidity in a dust-free room. The glue is applied to one or both of the surfaces to be joined, depending on the cementing conditions. Both surfaces are usually coated when phenol-formaldehyde glues, which are intensively absorbed by wood, are employed; hardwoods are an exception. A total of 180-250 g/m^2 of glue is required to coat one surface and 250-340 g/m^2 to coat two surfaces.

After the glue has been applied the components should be permitted to stand before assembly; the holding time (open impregnation) for KB-3 and VIAM B-3 phenolic glues is 4-15 min. The impregnation time depends on the air temperature in the room: the higher the temperature, the shorter the holding time. The surfaces to be cemented are approximated under pressure. When cementing components of coniferous and light deciduous woods with phenolic glues the pressure should be 2-3 kg/cm^2, while that for hard deciduous woods (ash, oak, etc.) should be 3-4 kg//mm^2; when gluing birch veneer to wood components the pressure should be 2-3 kg/cm^2, while when gluing it to components of laminated ligneous plastics a pressure of 4-5 kg/cm^2 is used. A high pressure is necessary for cementing ligneous plastics (up to 4-5 kg/cm^2) or when cementing and bending are carried out simultaneously (5-6 kg/cm^2). Cementing and veneering of curved articles at pressures of up to 1 kg/cm^2 can be conducted by the vacuum method, which permits precise regulation of the pressure and ensures rapid pressing. Clamps of various types are also used to create pressure on the glued joint. The time for which the cemented components are kept under pressure depends on the rate at which the glue sets, the air temperature, the temperature of the components to be cemented, and the nature of the materials to be joined.

Cementing is accelerated by heating. Electric contact or reflector heaters, drying chambers, warm air, high-frequency currents, and infrared radiation are used for this purpose.

When using synthetic glues, particularly those of the phenol-formaldehyde type, the cementing temperature should be 50-60° and must be raised gradually.

Cementing of wood with synthetic glues is employed in the manufacture of furniture, plywood, and ligneous plastics, in the production of glued wood assemblages for various branches of the construction industry, and in everyday life. Wood is usually cemented to other nonmetallic materials with phenol-formaldehyde, carbamide, and mixed urea-melamine-formaldehyde glues, as well as with compositions of resorcin and phenol-resorcin resins. Polyurethane and polyepoxy glues are employed considerably less frequently, primarily for joining wood materials to metals. Phenol-formaldehyde and resorcin glues are the strongest and most water-resistant; they are used chiefly in the manufacture of critical components for various branches of the national economy and in the production of laminated ligneous plastics. Carbamide glues, the most common of which is MF-17, are used principally in the furniture industry and the manufacture of plywood. Glues of vegetable and animal origin and various adhesives based on sodium silicate are suitable for cementing paper, cardboard, and other sheet cellulose materials. Synthetic glues are employed primarily in the production of cellular paper materials and in the polygraphic industry.

D.A. Kardashev

CEMENTITE – is a structural component of the iron-carbide alloys an iron carbide with the chemical formula Fe_3C. Cementite is one of the metastable phases in the FE-C system, it possesses a high hardness (HB = higher than 700 kg/mm^2) and brittleness. The melting point is 1600°, the crystal lattice is orthorhombic, each carbon ion being surrounded by six iron ions which are almost equidistant from the carbon ion.

M.L. Bernshteyn

CERACEOUS DIELECTRICS – solid, low-melting-temperature crystalline substances which are white or light-yellow in color, and have low mechanical strength, electrical properties and low hygroscopicity. Ceraceous dielectrics are used as impregnating of pour-on electric insulation compounds. They have a substantial solidification shrinkage, as a result of which air inclusions appear in the article being impregnated, which sharply reduces the breakdown voltages of the insulation. By the degree of polarization ceraceous dielectrics are divided into three groups: 1) nonpolar (paraffin, ceresin, synthetic paraffin and ceresin, petroleum jelly); 2) weakly polar (ozocerite, beeswax, carnauba wax, montan wax, Japan wax, etc.); 3) polar (halide wax, oleowax).

Paraffin (GOST 784-53) is a mixture of solid saturated hydrocarbons, contained in petroleum. Paraffin is soluble in benzol, mineral oils, gasoline, carbon sulfide, ethyl ether, and when heated also in vegetable oils; it is not soluble in alcohol or water. Paraffin is practically not hygroscopic. Paraffin grades are differentiated by the melting temperature. Paraffin used in electric insulation equipment with T_{pl} of 51-55° is used for impregnation of telephone-type low-voltage capacitors, the operating temperature of which does not exceed 45°, in cable production paraffin is used in a mixture with ozocerite, polyethylene, rosin, etc., for impregnation of insulation components made from wood, electric cardboard, etc. The main physicochemical properties of paraffin are: specific gravity 0.85-0.90; Zhukov t_{pl} 49-54°; thermal expansion coefficient 0.0011-0.0035 degree^{-1}, specific volume resistivity (ρ_v) 10^{15}-10^{17} ohm-cm, specific surface resistivity (ρ_s) 10^{15}-10^{16}

ohms, dielectric permittivity (ε) 1.9-2.2, tangent of dielectric losses angle (arctan δ $(3-7)\cdot10^{-4}$, electric strength (E_{pr}) 20-30 kv/mm.

Ceresin (GOST 2488-47) is a mixture of solid hydrocarbons which are obtained from ozocerite. t_{pl} 65-70°. Ceresin has a better resistance to oxidation than paraffin; it is used for impregnation of nonhermetized radio and metal-paper capacitors, in the production of mica capacitors, in cable production as a softener of rubber mixtures, for impregantion of fibreous insulation of telephone cables.

Synthetic paraffin and ceresin are high-molecular hydrocarbons which are obtained as byproducts in the production of synthetic gasoline and oils; by their electrical properties they are close to natural paraffin and ceresin, t_{pl} 100-130°.

Petroleum jelly (GOST 5774-51) is a semi-liquid mass, a mixture of liquid and solid hydrocarbons which is obtained from petroleum and is used for impregnation of radio capacitors. The main physicochemical and electrical properties of capacitor petroleum jelly are: kinematic vis-

Main Physicochemical and Electrical Properties of Ceresin

	1 Марка			
	I	II	III	IV
2 Темп-ра каплепадения (°C)	80	75	67	57
3 Пенетрация по Ричардсону при 25° и нагрузке 100 г 4 (мм, не более)	16	18	30	[illegible]
Содержание механических примесей для всех марок (%, не более)	0.1			
5 Зольность (%, не более)	[illegible]			
6 Кислотное число (мг KOH/г, не более)	[illegible]			
7 Удельное объемное сопротивление (ом·см)	[illegible]			
8 Диэлектрическая проницаемость	[illegible]			
9 Тангенс угла диэлектрических потерь при 3000 кгц и 40°	[illegible]			
10 Дугостойкость (сек)	[illegible]			
11 Электрическая прочность (кв/мм)	[illegible]			

1) Brand; 2) drop point temperature; 3) Richardson penetration at 25° and a load of 100 g (mm, not more than); 4) content of mechanical admixtures for all brands (%, not more than); 5) ash content (%, not more than); 6) acid number (millig KOH/g, not more than); 7) specific volume resistivity (ohm-cm); 8) dielectric permittivity; 9) tangent of dielectric losses angle at 3000 kcps and 40°; 10) arc resistance (sec); 11) electric strength (kv/mm).

cosity at 60° not less than 28 centistokes, drop point temperature not lower than 37°, acid number not higher than 0.004 milligrams KOH/g, ash content not above 0.004%, ρ_v not less than $5 \cdot 10^{14}$ ohm-cm at 20° and $5 \cdot 10^{11}$ at 100°; E_{pr} at 50 cps and 20° not less than 20 kv/mm, arctan δ 0.0002 at 20°, 0.002 at 100°.

Waxes are a group of substances which is composed of various complex esters, hydrocarbons, and other organic compounds. The characteristic smell of wax is due primarily to the presence of esters of acetic, butyric and valeric acids, as well as liquid unsaturated acids and alcohols of the cholesterol groups. Waxes are divided into mineral, animal, vegetable, synthetic and artificial. Mineral waxes include: ozocerite, montan wax, peat wax, sapropelic wax, baykerit, balkhashite. Animal origin waxes are divided into liquid and solid. The main component of vegetable waxes are complex esters of high-molecular acids and of

Physicochemical and Electrical Properties
of Certain Waxes

Характеристика 1	Пчелиный воск 2	Карнаубский воск 3	Монтан-воск 4
5 Удельный вес	0.964—0.970	0.990—0.999	0.980—1.00
6 Темп-ра плавления (°С)	63—70	83—90	73—90
7 Темп-ра застывания (°С)	60,5—64	80—81	—
8 Показатель преломления при 75° . . .	1,4398—1,4454	1,463	—
9 Кислотное число (мг КОН/г)	12—22	4—9	26—30
10 Иодное число по Гюблю	8—11	10,4—13,5	17—21
11 Диэлектрич. проницаемость	2,8—2,9	2,3—2,6	2,6—2,7
12 Тангенс угла диэлектрич. потерь при 15° и 100 гц	0.02—0.03	—	0.02
13 Электрич. прочность при 20° (кв/мм) . .	25—30	—	20

1) Characteristic; 2) beeswax; 3) carnauba wax; 4) ontan wax; 5) specific gravity; 6) melting temperature (°C); 7) solidification temperature (°C); 8) refraction index at 75°; 9) acid number (millig KOH/g); 10) Hübl iodine number; 11) dielectric permittivity; 12) tangent of dielectric losses angle at 15° and 100 cps; 13) electric strength at 20° (kv/mm).

monatomic alcohols. The most extensively prevailing vegetable waxes are: carnauba, gondang, candelilla, flax and palm [waxes].

Halite wax is the product of chlorination of naphthalene, by its chemical composition it is a mixture of tri- and tetrachloronaphthalenes. It dissolves well in aromatic hydrocarbons and in gasoline, it is not soluble in water and alcohol. The properties of halite wax are substantially affected by the refining. The main advantages of halite wax over paraffin and ceresin are its high melting temperature, high dielectric permittivity and incombustibility. A shortcoming of halite wax is its toxicity; its vapor acts on the mucous membrane for which reason the use of halite wax in the industry is limited. The main physical, chemical and electrical properties of halite wax are: specific gravity at 20° 1.55-1.7, t_{pl} in a capillary 110-130°, volatility at 135° not above 2.5%, acid number not higher than 0.01 millig KOH/g, iron content not higher than 0.01%, shrinkage when cooled from 100° to 15° 1.4-2.5%, ash content not above 0.02%, specific heat at 18° 0.202 cal/g-degree, latent melting heat 19.6 cal/g, specific volume resistivity (ρ_v) 10^{13}-10^{14} ohm-cm, dielectric permittivity (ε) 4.5-5.5, tangent of dielectric losses angle (arctan δ) at 10^6 cps not more than 0.003, electric strength (E_{pr}) at 20° 8-10 kv/mm.

Oleowax (opal wax) - is a product of hydrogenation of castor oil, is insoluble in ordinary organic solvents, combines poorly with paraffin, better with ceresin, ozocerite, montan wax, carnauba wax and other resins. Due to its high dielectric permittivity (in comparison with non-polar and weakly polar ceraceous dielectrics) impregnation by oleowax yields a greater increase in the capacitor capacities, however, the capacity of such capacitors is highly dependent on the temperature and frequency. Oleowax has not come into extensive use in electrical insulation equipment.

S.Ya. Yamanov

I-10364

Manuscript Page No.	[List of Transliterated Symbols]
706	ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = All-Union State Standard
707	пр = pr = prochnost' = strength
706	пл = plavleniye = melting

CERAMIC COATING OF MOLYBDENUM – see Protective Coatings of Molybdenum.

CERAMIC COATINGS – are thin ceramic films put on metallic or other surfaces in order to improve their chemical, thermal and mechanical stability. The ceramic coatings are subdivided into high- and low-temperature coatings. The former are used in those fields of engineering where the temperatures of the processes surpass the fireproofness of special steels and alloys (600-800°); the latter serve to protect aluminum and magnesium parts. The coating protects the metal from oxidation and, being less heat conductant, it acts partially as a heat insulator of the metal, whose properties depend not only on the thickness and heat conductivity of the protective coating but also on the presence of components with a low radiation emissivity in them.

Ceramic coatings are usually obtained by enameling, fire-spraying, and also sometimes by means of binders, avoiding a foregoing firing. Anorganic and organic glues are used in the latter case. At first, the grease is removed from the metal surface, the latter is then pickled, treated by sandblasting and plated with nickel. The coating is put on by spraying of a suspension (slip) or by dipping into it; the object is then dried and fired. The firing temperature is 820-870° for fireproof steels. The thickness of the coating is 0.1-0.05 mm; a thickener layer has a lower heat endurance and is readily scaled off. A refractory coating containing about 18% alumina gives good results. Enamels of the following compositions (in % by weight): 49.2 SiO_2; 17.4 B_2O_3; 7.7 Al_2O_3; 2.9 CaO; 4.5 K_2O; 15.2 Na_2O; 1.4 MnO_2; 0.7 NiO; 0.6 CoO; and 0.4 F_2, are used as a binder. TiO_2, ZrO_2, Cr_2O_3, Fe_2O_3, SiC, SiO_2, mullite, feldspar and chromium ore are added as refractories. Application of electrolytically produced corundum or of alumina fired at a high temperature results in an effervescing lustreous protective layer. Enamel slip contains (in parts by weight): 100 frit of the above-mentioned composition; 25 alumina; 10 clay; 1.0 CoO; 0.05 crystalline citric acid; and 50 water. Heat endurance tests by immersion into water of heated specimens of usual commercial enamels with a thickness of 0.12-0.18 mm, and of enamels containing alumina with a thickness of 0.05 mm, have shown that the former are destroyed when heated to 550-600°, the latter, however, are not destroyed even at 870°. An alumina containing enamel coating with a doubled thickness is destroyed at 650°.

The vitreous phase, which plays the part of a temporary binder, runs out at elevated temperature, and the more fireproof component remains in the coating. It is recommended to compose for these purposes nonmiscible phases of three-component of four-component systems, as, for example: $Na_2O \cdot B_2O_3$ with ZrO_2, TiO_2, Cr_2O_3 or Al_2O_3. A composition containing 30-40% Na_2O, 40-45% B_2O_3, and 30-40% TiO_2 has given positive results. The radiation emission of the heated metal can be reduced by ceramic coatings. The visible radiation of exhausts, for example, which are usually red hot, can be reduced by 90% when a selection of appropriate components (especially zirconia spinels) is put on them by means of water glass. Ceramic coatings containing boronsilicate glass and a fireproof filler (Al_2O_3, ZrO_2, etc.) are used to protect molybdenum from oxidation. The coating is put on the surface of the molybdenum and fired at 1180° in an inert atmosphere.

The application of ceramic coatings from cermets is very efficient. The metal component melts out in some cases, and the ceramic coating remains unchanged. Coatings of this type are put in the cold using a 25 solution of sodium silicate or any organic glue. The metal coated on both sides with a 0.12 mm thick Ni-MgO cermet stands a long-time heating at 1540° and a short-time (3 min) one at 1930°. Steel, protected by the above-mentioned manner, stands a heating to 2750° for 15 sec. A smelt of the appropriate oxide or ceramic material is put on the metal surface by fire-spraying. This method of coating is simple and permits the use of the most diverse materials (oxides, minerals, cermets, glasses, etc.). It is necessary in the case of fire-spraying that the material melts without decomposition, is sprayed into drops, and does not form threads. Ceramic coatings from Al_2O_3, ZrO_2, and $ZrSiO_4$ are obtained by means of an acetylene-oxygene burner melting and spraying ceramic rods with a diameter of about 3 mm and at a rate of 125-250 mm/min. A pistol of special design with an air pressure of about 5.6 kg/cm^2 is used for the spraying. The molten spherical particles are projected on the surface to be coated at a distance of 5-15 cm. Colliding with the surface, the spherical drops become flattened and solidified, and forma a uniform layer. Alumina with a content of 98.6% Al_2O_3 is used for Al_2O_3 coatings. During the spraying processes, the initial α alumina is transformed into γ alumina. The formation of the low-temperature modification of Al_2O_3 is caused by the quenching of the smelt, this fact was proved by x-ray analysis. The ceramic coating has a laminar structure and a thickness of about 12 microns. The density of the coating is 3.60 g/cm^3. The total porosity is 7.6-9.7%, the closed porosity is 0.3-2.8%. The weight by volume is in the range from 3.25 to 3.35 g/cm^3 and depends on the distance between the nozzle of the burner and the surface to be coated, on the angle of spraying, the air pressure and the flame temperature. A transformation of the γ Al_2O_3 into α Al_2O_3 occurs when the specimens are heated; this was proved by the coefficient of linear expansion ($\alpha \cdot 10^7$): 30-300°-53; 30-600°-66; 30-1200°-71; 30-1480°-73. Heating of specimens to 1500° changed the density and porosity; before heating, the weight by volume was 3.33 g/cm^3, the specific gravity was

was 3.[illegible], the total porosity was 7.6%; after heating, the data of the same characteristics were 3.40 g/cm^3, 3.98, and 14.6%, respectively. The modulus of elasticity of specimens of the coatings was (0.43-0.46)$\cdot 10^6$ kg/cm^2; the bending strength was 385-364 kg/cm^2. Rods of melted and stabilized ZrO_2 are used for ceramic coatings from ZrO_2. The structure of ceramic coatings from ZrO_2 is similarly laminated as the Al_2O_3 coating. The density of the coating is 5.71 g/cm^3. The weight by volume is 5.6 g/cm^3, the open porosity is 7%, and the closed 1.9%. The heat expansion of a ZrO_2 coating depends on the heating conditions. The ceramic coating from $ZrSiO_4$ becomes dissociated in the process of spraying the rod in the flame. A vitreous and a crystalline phase are present in the coating. The lamination of the coating is less expressed as in the case of ZrO_2 coatings. The density is 3.95 g/cm^3, the weight by volume is 3.79 g/cm^3, the open porosity is 4.1%, and the closed 4.7%. The ceramic coating cracks when heated, but it maintains its shape; ZrO_2 and $ZrSiO_4$ are found in it by x-ray analysis. During the fire-spraying of a ceramic coating on metal, the temperature of the latter does not surpass 200°. Coatings from Al_2O_3, ZrO_2, and $ZrSiO_4$ stand for a short time a temperature of 1650-2480° and have a heat conductivity of 1.0-2.36 kcal/m·hr·°C. Ceramic coating from cermets are obtainable by fire-spraying: molybdenum disilicide ($MoSi_2$), chromium carbide with nickel or without it, chromium-nickel boride (Cr_2NiB_4), tungsten carbides, tungsten borides, etc. Molybdenum disilicide, in particular, is readily sprayable on graphite, and stable to oxidation up to 1600°. Molybdenum coated with such a cermet stands a heating to 1500° in an oxidative medium for several hours. Chromium carbide coatings with nickel or without it are very resistant to abrasion and do not oxidize. Chromium carbide is used for coating of valves, turbine blades, etc. Ceramic coating from chromium-nickel boride protects steel and iron from corrosion in an aluminum melt; it has a very high heat endurance and is therefore used to protect the combustion chambers of rockets. Ceramic coating from oxides of rare earth elements may perform a catalytic function in the process of combustion. The content of carbon monoxide and unburned hydrocarbons in the exhaust gases of internal-combustion motors is considerably reduced when the pistons and cylinder heads are coated with such a ceramic coating.

N.M. Pavlushkin

CERAMIC FIBER – thin threads which are obtained from molten minerals or synthetic oxides and their mixtures. A distinction is made between long (continuous) and short (staple) ceramic fibers. Yarns and fabrics (textile fibers) as well as felt and wool (thermoinsulating fibers) can be obtained from ceramic fibers. The thickness of an elementary fiber is 3-20 microns and less. Methods of obtaining ceramic fibers are the same as those used in obtaining glass fibers. The difference consists in the fact that ceramic fibers are made from refractory mixtures and compounds at high temperatures. Ceramic fibers are obtained from Al_2O_3, ZrO_2, SiO_2, mullite, kaolin and various mixtures. Ceramic fibers are most extensively obtained of Kaolin composition. A mixture of alumina with mullite with moderate additions of boron and zirconium oxide is melted in an electric furnace and then, by using steam it is drawn into a staple ceramic fiber with a diameter of about one micron and length of about 75 mm with a specific weight of 32 kg/m^3, which can be increased to 200 kg/m^3 by compacting the fibreous material under a pressure of about 0.1 kg/cm^2. The staple ceramic fibers have a low thermal conductivity, high elasticity, and resist vibrations; they retain their properties in oxidizing and reducing media up to 1500°. Up to a temperature of 1100° such a fiber does not melt and does not sinter, but gradually passes from the vitreous to the crystalline state. It is used as shock-absorbing liners between metals and ceramics, for insulation of temperature joints, sound insulation, filtration of hot gases, for heat-resistant partitions, protective clothing, conveyer belts, [illegible] which are obtained by cementing ceramic threads by an organic binder withstands heating up to 1100°. A fabric consisting of 80-85% of ceramic fibers and 20-15% of organic artificial fibers does not deform at 1100°, but loses its tensile strength. A fabric with ceramic fibers as a base reinforced by stainless steel wire retains about 50% of the original tensile strength after being held for 24 hours at 850°, and if it is reinforced by chromium-nickel wire it retains 50% of the strength after being held 24 hours at 1100°. Ceramic fibers are also used for the production of fireproof paper. The ceramic base of such paper, containing about 10% of cellulose is stable up to 1500°.

N.M. Pavlushkin

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CERAMIC MATERIALS FOR RADIO ENGINEERING – is a group of materials which serve as electrical insulators in radio engineering equipment, mainly for the operation at feeble high-frequency currents. Ceramic materials for radio engineering are different in chemical and mineralogical composition (low or very high dielectric constant, positive or negative sign of the temperature coefficient of the dielectric constant). A peculiarity of the ceramic materials for radio engineering is the long service without aging phenomena, and the applicability at elevated temperature. Ceramic materials for radio engineering may be soldered by soft or brazing solders in order to obtain a rigid contact with the metal.

The ceramic materials for radio engineering are deliverable in 8 classes according to GOST 5458-57. High-frequency materials with a dielectric constant higher than 12: Ist class, for circuit- and separating capcitors which do not stabilize the frequency; for heat compensating and separating circuit capacitors; IInd class, for high-stability capacitors; IIIrd class, for small installation units. High-frequency materials with a dielectric constant lower than 9: IVth class, for large installation units and high-stable induction coils, for high-frequency capacitors; Vth class, for small and medium size parts with a high mechanical strength and heat endurance; VIth class, for insulators used inside of vacuum devices; VIIth class for installation parts which does not stabilize the device. Low-frequency materials with a dielectric constant higher than 1000: VIIIth class, for piezoelectric converters and for low-frequency d.c. capacitors. The ceramic materials for radio engineering may be subdivided also on basis of the used raw material or the main crystalline phase (mineral) of the given material. The basic types of raw materials for the production of ceramic materials for radio engineering are: white-fired refractory clays, kaolin, feldspars, talcum, marble, etc., and also commercial alumina, electrolytically produced white corundum, barium carbonate, titania, tin dioxide, magnesia, etc.

The most important types of ceramic materials for radio engineering and their properties are quoted in the Tables 1-4.

TABLE 1

Basic Properties of Corundum-Mullite and Corundum Ceramics

1 Свойства	2 Название керамики			
	3 Радиофарфор	Ультрафарфор УФ-46 4	Ультрафарфор УФ-53 4	Корундо-муллитовая (КМ-1) 5
6 Диэлектрич. проницаемость при частоте 0,5—5 *Мгц*	6—6,5	8,0—9,2	8,0—8,5	6,8—7,4
7 Температурный коэфф. диэлектрич. проницаемости в интервале 20—80° при частоте 0,5—5 *Мгц·град*$^{-1}$	+ (150 ± 30)10^{-6}	+ (110 ± 30) 10^{-6}	+ (110 ± 30)$^{-6}$	+ (110 ± 30)$^{-6}$
8 Тангенс угла диэлектрич. потерь при частоте 1 *Мгц*:				
при 20 ± 5°	(30—40) 10^{-4}	(8—10) 10^{-4}	(3—5) 10^{-4}	(14—18) 10^{-4}
при 80 ± 5°	(50—60) 10^{-4}	(12—15) 10^{-4}	(4—8) 10^{-4}	(20—24) 10^{-4}
9 Пробивная напряженность (*кв/мм*)	20—25	20—25	25—30	30—35
10 Уд. объемное сопротивление при 100 ± 5° (*ом·см*)	10^{13}	10^{12}—10^{11}	10^{12}—10^{11}	10^{13}—10^{14}
11 Предел прочности при статич. изгибе (*кг/см*^{2})	700—900	2000—2500	2500—3000	1600—2000
12 Температурный коэфф. линейного расширения в интервале 20—100°	(4—4,5)10^{-6}	(5,0—5,5) 10^{-6}	(5,0—5,5) 10^{-6}	(3,2—3,8) 10^{-6}
13 Уд. вес	2,5—2,6	3,2—3,4	3,2—3,4	3,0
14 Класс по ГОСТ	VIb	V	V	IV, группа «б» 15

1) Properties; 2) nomination of the ceramics; 3) radio porcelain; 4) ultra porcelain UF-..; 5) corundum-mullite (KM-1); 6) dielectric constant at a frequency of 0.5-5 Mcps; 7) temperature coefficient of the dielectric constant within 20-80° at a frequency of 0.5-5 Mcps·sec^{-1}; 8) tangent of the loss angle at a frequency of 1 Mcps, at; 9) breakdown voltage (kv/mm); 10) specific volume resistance at 100±5° (ohm·cm); 12) temperature coefficient of the linear expansion within 20-100°; 13) specific gravity; 14) class according to GOST; 15) group "b".

TABLE 2

Basic Properties of Magnesia Ceramics

1 Свойства	2 Название керамики			
	3 Б-17	4 С-55	4 С-4	Шпинелевая 5
6 Диэлектрич. проницаемость при частоте 0,5—5 Мгц	6,0—6,5	6,0—7,0	6,0—7,0	7,0—7,5
7 Температурный коэфф. диэлектрич. проницаемости в интервале 20—80° при частоте 0,5—5 Мгц	$+(110\pm30)\,10^{-6}$	$+(110\pm30)\,10^{-6}$	$+(110\pm30)\,10^{-6}$	$+(110\pm30\ 10^{-6}$
8 Тангенс угла диэлектрич. потерь при частоте 1 Мгц:				
при 20±5°	$(6-8)\,10^{-4}$	$(3-6)\,10^{-4}$	$(7-8)\,10^{-4}$	$(5-8)\,10^{-4}$
при 80±5°	$(8-9)\,10^{-4}$	$(6-7)\,10^{-4}$	$(8-10)\,10^{-4}$	$(6-9)\,10^{-4}$
9 Электрич. прочность (кв/мм)	20	20	20	20
10 Уд. объемное электрич. сопротивление при 100±5° (ом·см)	10^{13}	10^{14}	10^{13-14}	10^{13-14}
11 Предел прочности при статич. изгибе (кг/см²)	1400—1500	1600—2000	1400—1500	1400—1800
12 Температурный коэфф. линейного расширения в интервале 20—100°	$(7,0-7,5)\,10^{-6}$	$(6,5-7,0)\,10^{-6}$	$(6-7)\,10^{-6}$	$(5,5-6,0)\,10^{-6}$
13 Уд. вес	2,95	3,0	2,8	3,0
14 Класс по ГОСТ	IV, группа «а» 15			

1) Properties; 2) designation of the ceramics; 3) B-17; 4) S-..; 5) spinel; 6) dielectric constant at a frequency of 0.5-5 Mcps; 7) temperature coefficient of the dielectric constant with 20-80° at a frequency of 0.5-5 Mcps; 8) tangent of the loss angle at a frequency of 1 Mcps at; 9) breakdown voltage (kv/mm); 10) specific electric resistance at 100±5° (ohm·cm); 11) static bending strength (kg/cm^2); 12) temperature coefficient of the linear expansion within 20-100°; 13) specific gravity; 14) class according to GOST; 15) group "a."

TABLE 3

Basic Properties of Ceramic Materials With Nonlinear Polarization

1 Вид керамики	2 Сегнетокерамика			6 СВТ	Сегнетокерамика ВК 7
3 Название материала	4 СМ-1	5 Т-7500	5 Т-1700		
8 Диэлектрич. проницаемость при 20°	3000—4000	3000—4000	1500—17000	1000—1200	1700—2300
9 Изменение диэлектрич. проницаемости по отношению к ее величине при 20°	17 До ~30—50% (от −60° до +80°)	17 До ~50—70% (от 60° до +80°)	17 До ~40% (от −60° до +80°)	17 До ~25% (от −60° до +100°)	18 При −40° не менее 20% номинального; при +60° не менее 70% номинального (при 30 в)
10 Тангенс угла диэлектрич. потерь при частоте 10³ гц	19 До увлажнения ≤0,03 После увлажнения ≤0,05	≤0,03 ≤0,05	≤0,03 ≤0,05	≤0,002 ≤0,004	≤0,18 ≤0,20
11 Тангенс угла диэлектрич. потерь при частоте 10⁶ гц	~0,01	~0,01	~0,01	~0,01	<0,05
12 Удельное объемное электросопротивление при 100° (ом·см)	$\geq 10^{11}$	$\geq 5\cdot10^{10}$	$\geq 10^{10}$	$\geq 10^{13}$	$\geq 10^{10}$
13 Пробивная напряженность (кв/мм)	4	2,5	2,5	6	2,5
14 Предел прочности при статич. изгибе (кг/см², не менее)	600	600	600	700	800
15 Уд. вес	5,5	5	5,5	6	6
16 Класс по ГОСТ	VIII, группа «а» 20	VIII, группа «а» 20	VIII, группа «б» 21	VIII, группа «б» 21	Вариконд 22

1) Designation of the material; 2) seignettoelectric ceramics; 3) name of the material; 4) SM-1; 5) T-....; 6) SVT; 7) seignettoelectric ceramic VK; 8) dielectric constant at 20°; 9) change of the dielectric constant in relation to its value at 20°; 10) tangent of the loss angle at 10^3 cps; 11) tangent of the loss angle at 10^6 cps; 12) specific volume resistance at 100° (ohm·cm); 13) breakdown voltage (kv/mm); 14) static

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bending strength (kg/cm^2, not less than); 15) specific gravity; 16) class according to GOST; 17) up to ... from ... to ...; 18) not less than 20% of the rated value, at –40°; not less than 70% of the rated value, at +60° (at 30 v); 19) before moistening ..., after moistening ...; 20 group "a"; 21) group "b"; 22) Varicond.

TABLE 4

Basic Properties of Ceramic Capacitor Materials With Linear Polarization

1 Тип керамики	2 Перовскитовая	3 Рутиловая	4 Титаноциркониевая		5 Станатная
6 Название материала	7 Т-150	7 Т-80	7 Т-40	7 Т-20	8 С-15
9 Диэлектрич. проницаемость при частоте 0,5—5 *Мгц*	140—150	70—80	35—40	20—25	14—16
10 Температурный коэфф. диэлектрич. проницаемости в интервале 20—80° при частоте 0,5—5 *Мгц*	$-(1300\pm200)\,10^{-6}$	$-(700\pm100)\,10^{-6}$	$-(80\pm30)\,10^{-6}$	$-(50\pm20)\,10^{-6}$	$+(30\pm20)\,10^{-6}$
11 Тангенс угла диэлектрич. потерь при частоте 1 *Мгц*:					
при 20±5°	$(3-4)\,10^{-4}$	$(4-5)\,10^{-4}$	$(3-4)\,10^{-4}$	$(3-4)\,10^{-4}$	$(3-4)\,10^{-4}$
при 80±5°	$(3-4)\,10^{-4}$	$(4-5)\,10^{-4}$	$(3-5)\,10^{-4}$	$(4-6)\,10^{-4}$	$(4-6)\,10^{-4}$
12 Пробивная напряженность (*кв/мм*)	10—12	10—12	8—10	8—10	10—12
13 Удельное объемное электросопротивление при 100±5° (*ом·см*)	$10^{12}-10^{13}$	$10^{11}-10^{12}$	$10^{12}-10^{13}$	$10^{12}-10^{13}$	$10^{12}-10^{13}$
14 Предел прочности при статич. изгибе (*кг/см*^{2})	1200—1800	1200—1500	900—1200	800—1000	800—900
15 Уд. вес	3,8	3,8	5,1	4,3	4,9
16 Температурный коэфф. линейного расширения в интервале 20—100°	$(8-9)\,10^{-6}$	$(7,5-8)\,10^{-6}$	$(5,5-6,0)\,10^{-6}$	$(5,5-6,0)\,10^{-6}$	$(8-9,5)\,10^{-6}$
17 Класс по ГОСТ	I, группа «а» 17	I, группа «б» 19	II, группа «а» 19	II, группа «б» 18	III

1) Type of ceramics; 2) perovskite; 3) rutile; 4) titano-zirconia; 5) stannate; 6) designation of the material; 7) T-...; 8) S-..; 9) dielectric constant at 0.5-5 Mcps; 10) temperature coefficient of the dielectric constant within 20-80° at 0.5-5 Mcps; 11) tangent of the loss angle at 1 Mcps at; 12) breakdown voltage (kv/mm); 13) specific volume resistance at 100±5° (ohm·cm); 14) static bending strength (kg/cm^2); 15) specific gravity; 16) temperature coefficient of the linear expansion within 20-100°; 17) class according to GOST; 18) group "a"; 19) group "b".

References: Bogoroditskiy, N.P., Pasynkov V.V., Materialy v radioelektronike [Materials in Radio Electrons], Moscow-Leningrad, 1961.

V.L. Balkevich

I-56K

CERAMIC PAINTS - are colored compounds of silicates, aluminates, borates, etc., are formed on the surface of the material and used for decoration of stoneware, for setting up a brand or conditioned colors or signs. Colored metal oxides, sometimes colored complex compounds, are the base of ceramic paints. The firing temperature and the gas medium are determinant for the formation of certain colored compounds, under-glaze and upper-glaze paints are discenred. The upper-glaze paints are applied on glazed and fired objects, and then a secondary firing is carried out in muffle furnaces at 600-850°. The under-glaze paints are resistant to the dissolving action of the glazes.

V. L. Balkevich

I-43K

CERAMICS - are stonelike inorganic materials obtained by sintering of plastic bodies of plasticized powders. Raw, fine and refractory ceramics are distinguished. The ceramic materials are subdivided in products with a porous fracture and in products with a compact fracture, according to the degree of compactness (degree of sintering), and in structural, general, and technical ceramics according to their application.

Raw ceramics (bricks, roof tiles, and Dutch tiles) are generally prepared from diverse clays (low-melting, high-melting, sometimes refractory clays also), diatomites, tripoli earths, and aggregates (quartz sand, fireclay, slag). They are porous (wall materials, roof tiles, etc.) or compact (stony ceramics), depending on the degree of compactness. Acidproof raw ceramics are used in the chemical industry (reaction towers and absorbers, tourills, suction filters, condensers, pipes, coil pipes, exhausters, pumps, etc.), in the paper, food, and textile industry and in other industrial branches (see Acidproof Ceramics).

To the fine ceramics belong: porcelain, technical ceramics (Fireproof Ceramics, Vacuum Ceramics), special ceramics (titania-, cordierite-, spodumen-, corundum- and other ceramics, and products from pure oxides), semiporcelain, and faience. White-fired clays, kaolin, quartz sand, feldspar, pegmatites, nepheline syenite, spodumene, chalk, magesite, and dolomite are used for the production of these materials. Talcum, andalusite, kyanite, commercial alumina, magnesia, titania, beryllia, etc., are used for special ceramics. According to the degree of compactness, the fine ceramics are subdivided into: sintered, compact, and very hard, such as porcelain, for example; partially sintered, porous, and lower hard, such as faience, for example. As a rule, the fine ceramics are covered with a layer of vitreous glaze; the main part of the products is white, sometimes the fracture is colored (decorative ceramics, etc.). The products from special bodies may have diverse tints depending on the nature of the raw material. See Capacitor Ceramics for the properties of titania ceramics used for capacitors, and Oxide Ceramics for those from pure oxides. Cordierite and spodumene ceramics are used for the production of heatproof objects. The cordierite products have a high mechanical strength and a low thermal expansion; the ultimate bending strenth is 950 kg/cm^2, the linear expansion coefficient lies within $10\text{-}12 \cdot 10^{-7}$ in the temperature range from 20 to 100°. Spodumene or lithium ceramics are characterized by a very high thermal stability; they are used, therefore, for the lining of induction and other furnaces, for protective tubes of thermocouples, for parts of thermostats, for laboratory vessels, tuyeres, nozzles, etc. Corundum ceramics are used in machine building, they provide, in many cases, a 3-4 times higher stability of pieces and devices. Springs formed from sintered corundum retain a good elasticity up to 1000-1100°. Helices with a diameter of 2.5-11.5 cm and a cross section of the "wire" of 1.6-6.5 mm may be prepared by boring a helical groove into an alumina cylinder. Films with a thickness of 250 A, used electronics, are prepared by anodic treatment of corundum; the films are transparent and colorless, they do not delay electrons and can be used as a support in the investigation of diverse substances. The tensile strength of the films is almost similar to that of common steel with the same dimensions. The films are fixed in rings [illegible]ar with a diamter of 50 mm. A film with a thickness of 500 microns is sufficiently stable to stand up to the sublimation of diverse metals on its surface, it passes a temperature of 500° with a small change of the transmissivity in the infrared spectral range. Films from other oxides may be prepared in the same way.

Refractory ceramics include a large group of materials used in industrial furnaces, burners and units working at temperatures higher than 1000°. Depending on the chemical composition, the refractories are subdivided into: silica, aluminosilicate, magnesia, chrome, zirconia, oxide, carbide, and nitride refractories. Fire-resistant (from 1580° to 1770°), highly refractory (from 1770° to 2000°) and materials of highest refractoriness (more than 2000°) are distinguished with respect to the fireproofness.

Ceramics are characterized by a high refractoriess, hardness, chemical stability, and long-life. The high brittleness is a negative property of ceramics. The thermal endurance is very important for practice because the possibility of using a material at conditions of alternating heat and cooling depends on it; the thermal endurance is basically determined by the mechanical strength, the coefficient of thermal expansion, and the heat conductivity. Data characterizing the effect of the above-mentioned factors are listed in the Table. The values for the bending strength, the heat conductivity, and the thermal endurance are given in relative units (the corresponding characteristics for porcelain are taken as a unit).

Ceramic materials are becoming more and more and mainfoldly applied in different fields of machine building and modern engineering. Jet propulsion fuels (nitric acid with aniline, xylidine or gasoline) do not destroy ceramic linings. A homogeneous filling poured into a ring gap between the previously fired lining and the case of the chamber has proved to be the best for combustion chambers. Such a filling is made from light-weight concretes or plaster bodies. Lining of combustion chambers made from ceramic segments has proved to be effective.

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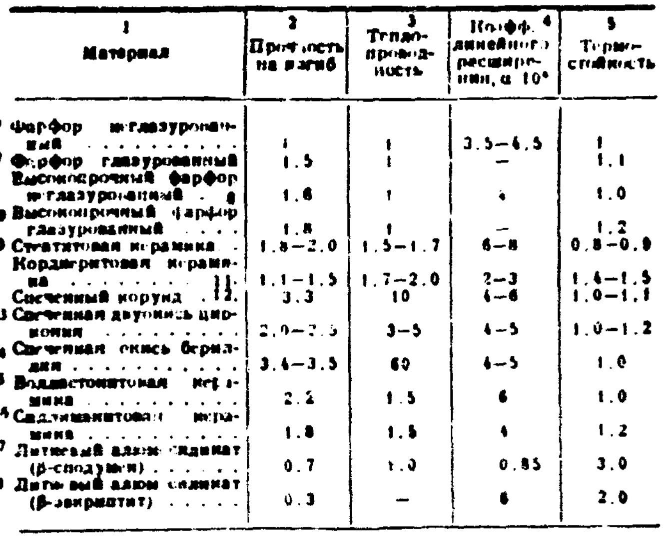
Metal coatings are put on ceramic lining in order to increase its heat endurance. Ceramic materials are also used for the production of rocket

TABLE

Thermal Endurance of Ceramic Materials



1 Материал	2 Прочность на изгиб	3 Теплопроводность	4 Коэфф. линейного расширения, α·10⁶	5 Термостойкость
6 Фарфор неглазурованный	1	1	3.5–4.5	1
7 Фарфор глазурованный	1.5	1	—	1.1
8 Высокопрочный фарфор неглазурованный	1.6	1	4	1.0
9 Высокопрочный фарфор глазурованный	1.8	1	—	1.2
10 Стеатитовая керамика	1.8–2.0	1.5–1.7	6–8	0.8–0.9
11 Кордиеритовая керамика	1.1–1.5	1.7–2.0	2–3	1.4–1.5
12 Спеченный корунд	3.3	10	4–6	1.0–1.1
13 Спеченная двуокись циркония	2.0–2.5	3–5	4–5	1.0–1.2
14 Спеченная окись бериллия	3.4–3.5	60	4–5	1.0
15 Волластонитовая керамика	2.2	1.5	6	1.0
16 Силлиманитовая керамика	1.8	1.5	4	1.2
17 Литиевый алюмосиликат (β-сподумен)	0.7	1.0	0.85	3.0
18 Литиевый алюмосиликат (β-эвкриптит)	0.3	—	6	2.0

1) Material; 2) bending strength; 3) heat conductivity; 4) coefficient of linear expansion, $\alpha \cdot 10^6$; 5) thermal endurance; 6) nonglazed porcelain; 7) glazed porcelain; 8) nonglazed high-strength porcelain; 9) glazed high-strength porcelain; 10) steatite ceramics; 11) cordierite ceramics; 12) sintered corundum; 13) sintered zirconia; 14) sintered beryllia; 15) wollastonite ceramics; 16) sillimanite ceramics; 17) lithium aluminosilicate (β-spodumene); 18) lithium aluminosilicate (β-eucryptite).

shields. Al_2O_3, ZrO_2, SiO_2, etc., are used as raw materials. Sintered Al_2O_3 is used for the parts of the gyroscope used in rockets for an exact guiding into the target. The gyrostat, the motor shaft, the balancing rings, the Cardan joint, and the bell jar are made from sintered Al_2O_3. Ceramics are used as carriers of catalysts in the form of a finely porous coating from Al_2O_3 or ZrO_2 put by fire-spraying on the ceramic body (rings, balls, small cylinders, etc.). Very thinly corrugated or objects shaped in another manner with a high specific surface for operation a high temperatures (parts for heat exchangers, equipment for catal tic processes, etc.) may be obtained from certain ceramic materials by rolling. The corrugated surface has 8 grooves per 1 cm and a wall-thickness of 0.05 mm in objects made from magnesium aluminosilicate. The honeycombed zirconia product has 3 channels on a length of 2.5 cm and a wall-thickness of 0.5 mm. Ceramic bands are produced from alumina, porcelain or steatite, and used for printed electric circuits. The width of the band is up to 200 mm, the thickness 0.8-3.0 mm, the length of the pieces depends on the firing conditions.

References: Tekhnologiya keramiki i ogneuporov [Technology of Ceramics and Refractories], edited by P.P. Budnikov, 2nd edition, Moscow, 1954, Avgustinik A.I. Keramika [Ceramics], Moscow, 1957.

N.M. Pavlushkin

II-75M

CERMET CONTACTS are interrupting contacts, used for periodic making and breaking of electric circuits, which are produced by the powder metallurgy method. The powder metallurgy technology makes it possible to produce cermet contacts from varied materials, including those whose production by the melting method is not possible (for example, The W-Cu composition). In this case significant saving of metal is achieved as a result of the high wear resistance of the cermet contacts and the reduction of production waste. Cermet contacts are made from the pure metals (W, Mo, Re, Cu, Ag and others), alloys with solid solution structure (W – Re, Cu – Cd, Ag – Cd and others), compositions of nonalloying metals or metals and nonmetals (W – Cu, Ag – Ni, Cu – C, Ag – – CdO and others). Widest application is made of the cermet contacts made from compositions which in structure are a mechanical mixture of particles which differ sharply in their physical properties. As a result of the high resistance to wear, welding and burning, the composition cermet contacts are used successfully in many cases under severe operating conditions. The composition cermet contacts are charaterized by high strength at high temperatures, high resistance to mechanical abrasion, high thermal stability (i.e., ability to retain their form and composition with heating), which leads to their excellent wear resistance in operation. In order to obtain the required combination of properties or to economize scarce metals, certain cermet contacts are fabricated in several layers from materials with differing chemical composition. In the two-layer contacts the ratio of the thicknesses of the working and nonworking layers varies from 10:1 to 1:4. The cermet contacts made from compositions having particularly high resistance to welding (Ag-CdO and others) are produced with a working layer made from

TABLE 1

Composition Cermet Contacts (GOST 3884-61)

Тип контакта 1	Химический состав (%) 2	3 ρ (ом·мм^2/м)	4 HB (кг/мм^2)	5 γ (г/см^3)	6 Область применения
		не более 6'	не менее 7		
8 СВ50	50Ag;2,5Ni; 47,5W*	0,027	100	13,1	Мощные воздушные выключатели, анодные автоматы, мощные регулирующие трансформаторы, малогабаритные высоковольтные выключатели, магнитные пускатели, выключатели бытовых приборов, стартеры двигателей внутр. сгорания, электронные реле, тепловые реле 9
8 СВ70	30Ag;3,5Ni;66,5W*	0,035	140	14,5	
10 СГ3	97Ag; 3C	0,024	27	8,7	Установочные и универсальные автоматы (в паре с контактами из композиций серебро—никель), воздушные выключатели, реле сигнализации железных дорог, аппараты управления лифтом, переключатели радиоприемников 11
10 СГ5	95Ag; 5C	0,03	22	7,9	
12 СН29Г3	68Ag; 29Ni; 3C	0,03	45	8,7	
13 СК22Н1	76,5Ag;22Cd;1Ni; 0,5Fe	0,06	60	9,5	Регуляторы напряжения, реле 14
15 СМО60	40Ag; 60Mo	0,027	120	10	Воздушные выключатели легкого и тяжелого режимов, контакторы, выключатели бытовых электроприборов, реле, вибропреобразователи 16
17 СН30	70Ag; 30Ni;	0,025	55	9,5	Установочные и универсальные автоматы (в паре с контактами серебро—графит или серебро — никель — графит), контакторы, магнитные пускатели, реле особо тяжелого режима, реле цепей сигнализации и автоматики, вибропреобразователи, высоковольтные выключатели небольшой мощности 18
17 СН40	60Ag; 40Ni;	0,032	60	9,3	
19 СОК15	85Ag; 15CdO	0,03	50	9,2	Стартеры двигателей внутр. сгорания, игнитронные прерыватели, реле среднего и тяжелого режимов, автоматич. терморегуляторы 21
20 СОМ10	90Ag; 10CuO	0,025	50	9,2	
22 МВ50	50Cu;2,5Ni;47,5W*	0,04	140	12	Металлургич. контакторы, контакторы аппаратов стыковой сварки, мощные масляные и воздушные выключатели 23
МВ70	30Cu; 3Ni; 67W*	0,05	180	14	
24 МГ3	97Cu; 3C	0,035	24	6,8	Селективные автоматы, ручные выключатели 25
МГ5	95Cu; 5C	0,047	15	6	

*Nickel not mandatory

1) Contact type; 2) chemical composition (%); 3) (ohm-mm^2/m); 4) (kg/ /mm^2); 5) (g/cm^3); 6) area of application; 6') no more than; 7) no less than; 8) SV ; 9) high power air breakers, anode controls, high-power control transformers, small high-voltage switches, magnetic starters, houshold appliance breakers, internal combustion engine starters, electronic relays, themal relays; 10) SG ; 11) assembly and universal automatic machines (paried with silver-nickel composition contacts), air breakers, railway signaling relays, elevator control apparatus, radio receiver switches; 12) SN29G3; 13) SK22N1; 14) voltage regulators, relays; 15) SM060; 16) light and heavy-duty air breakers, contactors, household electric appliance breakers, relays, electromagnetic rectifiers; 17) SN ; 18) assembly and universal automatic machines (paired with silver-graphite or silver-nickel-graphite contacts), contactors, magnetic starters, extra-heavy duty relays, signaling and automation circuit relays, electromagnetic rectifiers, low-power high-voltage breakers; 19) SOK15; 20) SOM10; 21) internal combustion engine starters ignitron interrupters, medium and heavy duty relays, automatic thermo-centrollers; 22) MV ; 23) metallurgical contactors, butt welding apparatus contactors, high-power oil and air breakers; 24) MG ; 25) selective automatic machines, manual breakers.

TABLE 2

Two-Layer Cermet Contacts - GOST 3884-61

1 Тип контакта	2 Рабочий слой		Основание 3	
	материал 4	толщина (%)* 5	материал 4	толщина (%)* 5
6 С-М25	7 Серебро	75	Медь 8	25
9 СН40-Н75	Композиция: 10 60% Ag и 40% Ni	25	Никель 11	75
12 СОК15-Ж25	Композиция: 85% Ag, 15% CdO 13	75	Железо 14	25

*Relative to contact thickness

1) Contact type; 2) working layer; 3) base; 4) material; 5) thickness (%)*; 6) S-M25; 7) silver; 8) copper; 9) SN40-N75; 10) composition: 60% Ag and 40% Ni; 11) nickel; 12) SOK15-Zh25; 13) composition: 85% Ag, 15% CdO; 14) iron.

the composition and a base made from silver or copper to facilitate brazing or welding to the contact holder. The methods of producing the cermet contacts are: pressing and sintering of finished products in a mold from metallic powder or a mixture of powders of specified composition, stamping from cermet rolled stock (for wrought materials such as W, Ag-Ni composition, and others), pressing in the form of porous blanks from a powder of a high-melting component and subsequent impregnation of the blanks with a lower-melting metal (or composition). The multilayer cermet contacts are produced by sintering blanks prepared from metallic powders of differing chemical composition which are poured sequentially, in the form of several layers, into the press form. The cermet

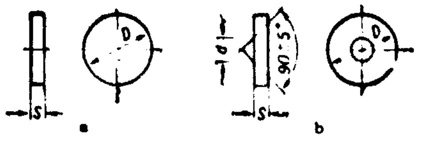


Fig. 1. Cylindrical cermet contacts with flat working surface: a) without conical point; b) with conical point.

contacts usually have a cylindrical (with flat or spherical working surface) or rectangular (with flat or cylindrical working surface) form.

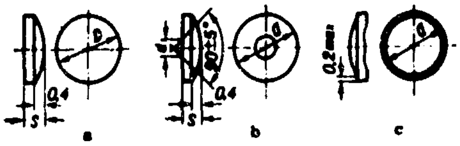


Fig. 2. Cylindrical cermet contacts with spherical working surface: a) without conical point; b) with conical point; c) with collar (collar width up to 0.2 mm allowed).

On the lower (nonworking) side of the contacts there is sometimes formed one or more conical protuberances for welding to the contact holder

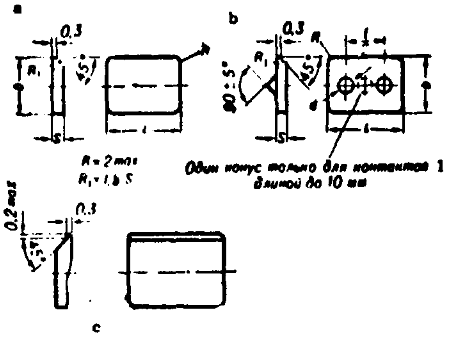


Fig. 3. Rectangular cermet contacts with flat working surface: a) without conical point; b) with conical point; c) with collar 1) one cone only for contacts of length to 10 mm.

(Figs. 1-4). Brazing of the cermet contacts to the contact holders is performed using conventional silver or copper solders. Tables 3, 4 present the basic dimensions of the cermet contacts.

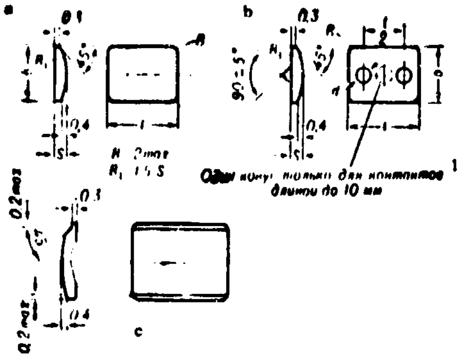


Fig. 4. Rectangular cermet contacts with cylindrical working surface: a) without conical point; b) with conical point; c) with collar. 1) One cone only for contacts to length 10 mm.

TABLE 4

Basic Dimension (mm) of Cylindrical Cermet Contacts (GOST 3884-61)

D (диаметр)1	S (толщина)2	d*	D (диаметр)1	S (толщина)2	d*
1	0,6	0,6	6	1,2; 1,6; 2,2	1,6
1,6		1	8		2,2
2	0,6; 1	1,2	10		
2,5			12	1,2; 2,2	
3			16		
4	1,0; 1,6	1,6	20		
5			25	2,2	

*d – cone base diameter

1) D (diameter); 2) S (thickness)

References: Usov V.V. and Zaymovskiy A.S., Provodnikovyye, reostatnyye i knotaktnyye materialy (Conductor rheostat, and contact materials), 3rd edition, M.-L., 1957, in: (Metally i splavy v elektrotekhnike, t. 2) (Metals and Alloys in Electrical Engineering, Vol. 2); Al'tman A.B., Melashenko I.P., Bystrova E.S., Sovremennyye metallokeramic-

TABLE 3

Basic Dimensions* (mm) of Rectangular Cermet Contacts (GOST 3884-61)

l	b	S	d**
6	3	1	1,2
	6	1; 1,6	
8	4	1,2	
	6	1,2; 1,6	
	8		
10	5		2,2
	6		
	8		
	10	1,6	
12	6	1,2; 1,6	
	8		
	10	2,2	
	12		
16	8		
	10		
	14	2,2; 3	
	16		
20	10	2,2	
	14		
	16	2,2; 3	
	20		
25	12	3	2,2
	16		
	20		
	25		
32	10		
	16		
	25		
	32		
40	14		
	20		
	32		
	40		
50	25		

*l – length, b – width, S – thickness.
**d – cone base diameter.

heskiye elektricheskiye kontakty, v kn.: Elektricheskiye kontakty (Modern Cermet Electrical Contacts, in book: Electrical Contacts), M.-L., 1958; Melashenko I.P., Metallokeramicheskiye elektricheskiye kontakty, v kn.: Spravochnik po elektrotekhnicheskim materialam, t. 2 (Cermet Electrical Contacts, in book: Handbook on Materials for Electrical Engineering, Vol. 2), M.-L., 1960; Al'tman A.B., Metallokeramkia v elektropromyshlennosti (Cermets in the Electrical Industry), M., 1961.

A.B. Al'tman

CERMET ELECTRICAL BRUSHES are components which are used as the fixed portion of a sliding contact for the current input and output on collectors and contact rings of electrical machines and which are produced using the powder metallurgy method. The cermet electrical brushes are pressed from mixtures of copper and graphite powders, frequently with the addition of lead, tin and certain other materials. In the classification of the electrical brush materials, the cermet electrical brushes are termed metallographitic. Depending on the chemical composition and the production technology, the cermet electrical brushes are divided into copper-graphite and bronze-graphite (Table 1).

TABLE 1

Characteristics of Cermet Electrical Brushes

1 Группа	2 Марка	3 Характеристика	Условия коммутации *4
5 Меднографитная	6 МГ, МГ1, МГ2,	Высокое содержание меди 7	Облегченные 8
	МГ3, МГ4, МГ6	Повышенное содержание меди 9	То же 10
	М1, М3, М6, М20, 611М	Пониженное содержание меди 11	Нормальные 12
13 Бронзографитная	МГС, 14 МГСО, МГС5, МГС6, МГ64	С легирующими присадками 15	Облегченные 8

*Recommended.

1) Group; 2) type; 3) characteristic; 4) commutation conditions*; 5) Copper-graphite; 6) MG; 7) high copper content; 8) light; 9) higher copper content; 10) same; 11) low copper content; 12) normal; 13) bronze-graphite; 14) MGS; 15) with alloying additions.

Addition of copper improves the electrical conductivity of the electrical contact material, while the addition of lead and tin make this material less rigid and more resistant to vibration and erosion. Figure 1 gives an idea of the chemical composition of the cermet elec-

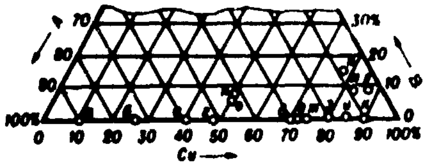


Рис. 1. Расположение некоторых металлокерамич. электрощеток на концентрационном треугольнике медь — углеродистые материалы (А) — легирующие присадки (Б): а — 611 М; б — М3 и М20; в — М6; г — М1; д — МГ4; е — МГ6; ж — МГ3; з — МГ2; и — МГ1; к — МГ; л — МГС; м — МГС0; н — МГ64; о — МГС6; п — МГС5.

Fig. 1. Location of some cermet electrical contacts on the copper-carbonaceous materials (A)-alloying additive (B) concentration triangle: a) 611 M; b) M3 and M20; c) M6; d) M1; e) MG4; f) MG6; g) MG3; h) MG2; i) MG1; j) MG; k) MGS; l) MGS0; m) MG64; n) MGS6; o) MGS5.

trical brushes. The technological process of the production of the cermet electrical brushes usually consists of two portions: preparation of the semimanufactures (blocks, plates) by pressing and sintering (firing) from a mixture of the initial materials in powder form; production of the electrical contacts of specified shape and dimensions from the semi-manufactures by machining. Along with this technology, use is made of the method of individual form pressing (with heating or with additional sintering) of the electrical contacts from a mixture of the initial powders into a finished product with the required dimensions. The shape of electrical brushes used in various operating conditions is shown in Fig. 2. The cermet electrical contacts are usually integrated with the current conductors. For technical characteristics of the cermet electrical contacts see GOST 2332-43, for dimensions see GOST 8611-57. The fields of application of the cermet electrical contacts are shown in Table 2.

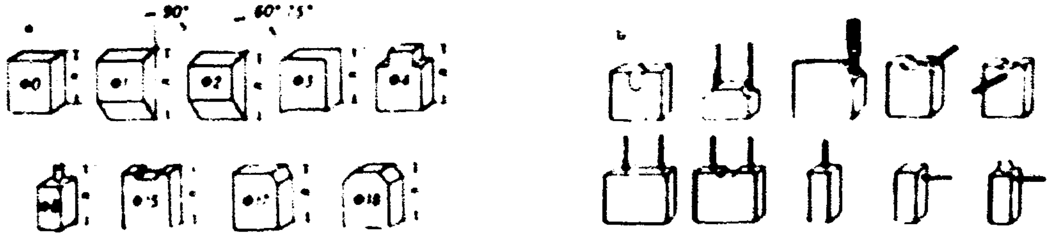


Fig. 2. Shapes of cermet electrical contacts: a) general purpose (GOST 8611-57); b) for motor vehicle motor electrical equipment.

TABLE 2

Fields of Application of Cermet Electrical Contacts

1 Электрич. машина (тип, назначение)	2 Условия работы		3 Рекомендуемые марки электрощеток
	4 плотность тока (а/см²)	5 окружная скорость (м/сек)	
6 Тяговые двигатели постоянного тока пониженного напряжения	10—12	7 До 20	М3
8 Стартеры напряжением 18—24 в	—	—	9 МГ4, М1
10 Стартеры напряжением 6—12 в	—	—	МГС 11
12 Зарядные генераторы пониженного напряжения до 40 в	До 12	До 20	М1, М6, М3*
13 То же, до 12—24 в	10—15	До 20	МГ4, М1*
14 То же, до 12 в	До 20	До 20	МГС
15 Асинхронные двигатели всех мощностей с подъемом щеток, с повышенной плотностью тока	До 20	До 15	МГС, МГ2*
16 То же, с повышенной окружной скоростью	До 15	До 25	МГС, МГ4*, МГ*, МГ2*
17 Асинхронные двигатели всех мощностей с постоянно налегающими щетками, а также кольца одноякорных преобразователей с повышенной плотностью тока	До 20	До 15	МГС
18 То же, с повышенной окружной скоростью	До 15	До 25	МГС, МГ4, М6, М1
19 То же, с нормальной плотностью тока	10—12	До 25	МГ4, М6*, М1*
20 Кольца возбуждения синхронных генераторов и двигателей всех мощностей и напряжений со средней окружной скоростью	10—12	До 25	МГ4, М6*, М1*, М3*

*Recommended as second choice.

1) Electrical machine (type, purpose); 2) operating condition; 3) recommended type of electrical contact; 4) current density (a/cm²); 5) peripheral velocity (m/sec); 6) low voltage dc traction motors; 7) to; 8) starters, 18-24 volt; 9) MG-; 10) starters, 6-12 volt; 11) MGS; 12) low voltage charging generators to 40 volts; 13) same, to 12-24 v; 14) same, to 12 v; 15) asynchronous motors of all capacities with brush lift, with high current density; 16) same, with high peripheral velocity; 17) asynchronous motors of all capacities with continuous brush contact, and allso rings of single-armature converters with high current density; 18) same, with high peripheral speed; 19) same, with normal current density; 20) exciting rings of synchronous generators and motors of all capacities and voltages with medium peripheral velocity.

References: Belkin M.D. and Shtykhnov G.S., Shchetki dlya elektricheskikh mashin, ikh proizvodstvo i primeneniye (Brushes for Electrical Machines, Their Production and Application), M.-L., 1952; Fialkov A.S., Tekhnologiya i oborudovaniye elektrougol'nogo proizvodstva (Technology and Equipment for Electro-carbon Production). M.-L., 1958; Zhestyanikov V.M., Elektrotekhnicheskiy ugol' and elektrougol'nyye izdeliya (Electrotechnical Carbon and Electro-Carbon Products), in book Spravochnik po elektrotekhnicheskim materialam (Handbook on Electrotechnical Materials), Vol. 2, M.-L., 1960; Livshits P.S., Shchetki dlya elektricheskikh mashin (Brushes for Electrical Machines), M.L., 1961.

A.P. Al'tman

CERMET FILTERS are porous products for filtering mechanical impurities from liquids and gases which are produced by the powder metallurgy method. Powders of any metals may be used for producing cermet filters, but at present powders made from bronze, stainless steel, iron, nickel, titanium and low-carbon steel are used (Table 1). The advantages of the cermet filters in comparison with other filters are: simplicity of productions, higher mechanical strength and permeability, possibility of filtering to particle size 3-5 μ, uniformity of filtering properties over entire filter area, possibility of producing corrosion resistant and refractory filters, comparative simplicity of regenerating contaminated filters.

Cermet filters are produced by pressing in forms, by free pouring into graphite forms or by rolling powder into strip with subsequent sintering. Table 2 presents the characteristics of bronze filters. Figures 1, 2, 3 show the variation of the permeability of iron cermet filters as a function of wall thickness, pore size and pressure drop across the filter.

TABLE 1

Basic Properties of Cermet Filter Materials

1 Фильтрующий материал	2 Химич. состав	3 σ_{-b} (кг/мм²)	3 σ_b (кг/мм²)	δ (%)	Рабочая температура (°C) 4
5 Бронза	92% Cu, 8% Sn	10–1[illegible]	[illegible]	[illegible]	[illegible]
6 Низкоуглеродистая сталь	0,04% C, 0,15% Mn, 0,15% Ni	[illegible]	[illegible]	—	300–[illegible]00
7 Нержавеющая сталь	17–20% Cr, 8–11% Ni, [illegible] Ti	—	[illegible]	[illegible]	400–500

1) Filtering material; 2) chemical composition; 3) σ (kg/mm²); 4) operating temperature (°C); 5) bronze; 6) Low-carbon steel; 7) stainless steel.

TABLE 2

Characteristics of Bronze Cermet Filters

1 При фильтровании воды					2 При фильтровании воздуха				
3 скорость фильтрования (л/мин·см²)	4 толщина стенки (мм)				3 скорость фильтрования (л/мин·см²)	4 толщина стенки (мм)			
	1.5	2.25	3	3.75		1.5	2.25	3	3.75
	5 потеря напора (кг/см²)					6 потеря напора (мм вод. ст.)			
15	0.35	0.4	0.5	0.78	0.045	0.02	0.03	0.08	0.15
30	0.7	0.85	1.4	1.75	0.9	0.25	0.5	1.5	[illegible]
45	1	1.6	2.1	2.8	9	5	10	20	35
					18	20	22	50	110
					45	100	120	120	175

1) Filtering water; 2) filtering air; 3) filtration rate (liters/min-cm²); 4) wall thickness (mm); 5) head loss (kg/cm²); 6) head loss (mm Hg).

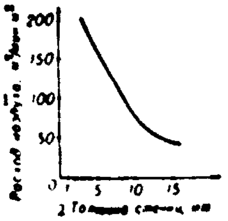


Fig. 1. Variation of iron cermet filters with wall thickness for Δp = = 600 mm H_2O. 1) Air flow, m³/min-m²; 2) wall thickness, mm.

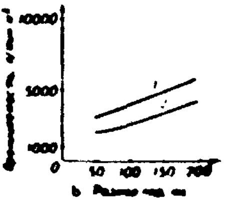


Fig. 2. Variation of permeability of iron cermet filters with pore size for Δp = 0.5 atm: 1) TS-1 fuel with viscosity 1.29 centistokes; 2) diesel oil with viscosity 3.5 centistokes; a) Permeability, liters/min-m²; b) pore size, microns

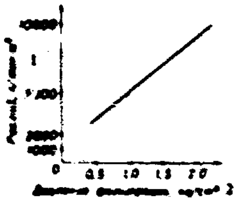


Fig. 3. Variation of permeability of iron cermet filters with filtration pressure (TS-1 fuel). 1) Flow, liters/min-m²; 2) filtration pressure, kg/cm².

The cermet filters are produced in the form of discs and plates, cylinders, sleeves, cones with wall thickness $\geq$ 0.5 mm. In selecting the construction of a cermet filter it is necessary to keep in mind that the discs have uniformity of the properties over the entire surface, while filters in the form of cylinders have differing properties along the length, and that the nonuniformity incrases with the cylinder length; therefore the cylinder length must not exceed 2-3 $\underline{d}$. Cylindrical filters of greater length may be obtained by welding, brazing or bonding of cylindrical filters of shorter length. Figure 4 shows the general form of several typical cermet filters.

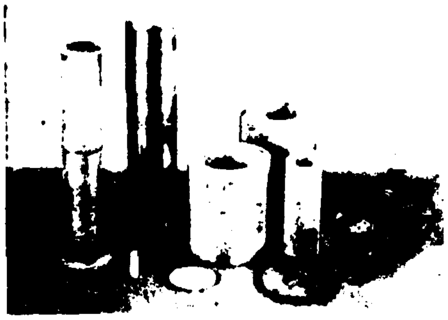


Fig. 4. Form of cermet filters.

The cermet filters are easily machined (facing, drilling, threading). However, maching of the filtering surface is not recommended.

The most important fields of application of the cermet filters are given in Table 3.

TABLE 3

Fields of Application of Cermet Filters

1 Пром-сть	2 Область применения	3 Материал фильтра
4 Химическая	5 Очистка концентрированных щелочных растворов и кислот. Разделение воды и масла в эмульсиях. Фильтрование ацетатноцеллюлозных растворов при изготовлении искусственного волокна	6 Серебро, нержавеющая сталь. Малоуглеродистая сталь с последующим хромированием
	7 Фильтрование смол, основ для лаков и пластмасс, фильтрование при произ-ве каучука, фильтрование суспензий и эмульсий	Нержавеющая сталь 8
	9 Очистка жидкого и газообразного кислорода от графитовой пыли, очистка жидкого кислорода от твердой двуокиси углерода	Бронза 10
11 Нефтяная	12 Фильтрование нефти и газов от песка; при каталитич. крекинге нефти	13 Низкоуглеродистая сталь
14 Металлургическая	15 Очистка доменного газа, фильтрование аммиака	16 Малоуглеродистая сталь с последующим хромированием
17 Энергетическая	18 Очистка питат. воды для котлов, пыле- и золоулавливание, сепарация пара в паропроводах	Нержавеющая сталь 8
19 Авиационная и судостроительная	20 Фильтрование жидкого горючего и смазочных масел	Малоуглеродистая сталь с последующим хромированием 16
21 Автомобильная	22 Очистка дизельного топлива. Фильтрование выхлопных газов	Бронза, никель 23
24 Атомная	Очистка специальных жидкостей и газов 25	Нержавеющая сталь, никель 26

1) Industry; 2) field of application; 3) filter material; 4) chemical; 5) purification of concentrated alkaline solutions and acids. Separation of water and oil in emulsions. Filtration of cellulose acetate solutions in production of artificial fibers; 6) silver, stainless steel. Low-carbon steel with subsequent chromium plating; 7) filtration of resins, bases for lacquers and plastics, filtration in rubber, production filtration of suspensions and emulsions; 8) stainless steel; 9) removal of graphite dust from liquid and gaseous oxygen, removal of solid carbon dioxide from liquid oxygen; 10) bronze; 11) oil; 12) filtering sand from oil and gases; in catalytic cracking of petroleum; 13) low-carbon steel; 14) metallurgical; 15) purification of blast furnace gas; filtering ammonia; 16) low-carbon steel with subsequent chrome plating; 17) power; 18) purification of boiler feedwater, dust and ash collection, separation of steam in steam pipes; 19) aviation and shipbuilding; 20) filtering liquid fuel and lubricating oils; 21) motor vehicle; 22) filtering diesel fuel. Filtering exhaust gases; 23) bronze, nickel; 24) Atomic; 25) purification of special liquids and gases; 26) stainless steel, nickel.

II-80M4

References: Rakovskiy V.S., Saklinskiy V.V., Poroshkovaya metallurgiya v mashinostroyenii (Powder Metallurgy in Machine Design), 2nd edition, M., 1963; Bal'shin M.Yu., Poroshkovaya metallurgiya (Powder Metallurgy), M., 1948; Agte K. and Otsetek K., Cermet Filters, Their Production, Properties and Application, translated from German, L., 1959.

Ye.I. Pavlovskaya

CERMET HARD ALLOYS are alloys of high-melting compound (primarily carbides of tungsten and titanium) with metals of the iron group which are prepared using the powder metallurgy method. The structure of the cermet hard alloys consists of grains of carbide or a solid solution of carbides and a cementing phase which is a solid solution based on a metal of the iron group. With an increase of the carbide phase content, there is an increase of the hardness and the wear-resistance of the cermet hard alloys and also an increase of the brittleness. In addition to the chemical composition, the properties of the cermet hard alloys are strongly affected by the grain size of the carbide and cementing components. The chemical composition and properties of the cermet hard alloys are presented in Table 1, 2, 3; the fields of application are shown in Table 4.

TABLE 1

Chemical Composition of Cermet Hard Alloys (tungsten-cobalt group)

[1] Сплав	[2] Содержание компонентов (%)	
	WC	Co
[3] BK-2	98	2
BK-3	97	3
BK-6	94	6
BK-8	92	8
BK-10	90	10
BK-11	89	11
BK-15	85	15

1) Alloy; 2) component content (%); 3) VK.

TABLE 2

Chemical Composition of Cermet Hard Alloys (Titanium-tungsten-Cobalt Group)

[1] Сплав	[2] Содержание компонентов (%)		
	WC	TiC	Co
T5K10	85	5	9
T14K8	78	14	8
T15K6	79	15	6
T30K4	66	30	4
T60K6	34	60	6

1) Alloy; 2) component content (%).

TABLE 3

Propertieь of Cerment Hard Alloys

1 Сплав	2 Свойства		
	3 γ (г/см³)	НВ	$\sigma_{изг}$ 4
		5 (кг/мм²)	
6 ВК-2	15 —15,4	90	100
ВК-3	14,9—15,3	89	100
ВК-6	14,6—15	88	120
ВК-8	14,4—14,8	87,5	130
ВК-10	14,2—14,6	87,5	130
ВК-11	14 —14,4	86	150
ВК-15	13,9—14	86	160
Т5К10	12,3—13,2	88,5	115
Т14К8	11,2—12	89,5	115
Т15К6	11 —11,7	90	110
Т30К4	9,5—9,8	90	90
Т60К6	6,5—7	90	75

1) Alloy; 2) properties; 3) γ (g/cm3); 4) σ_{izg}; 5) (kg/mm2; 6) VK.

TABLE 4

Fields of Application of Cermet Hard Alloys

1 Сплав	2 Применение
3 ВК-2	4 Инструмент для чистовой и получистовой обработки чугуна, цветных металлов и сплавов, а также неметаллич. материалов, при непрерывном резании. Инструмент для резки стекла
ВК-3	5 То же, что и для ВК-2, и, кроме того, инструмент для волочения проволоки и геологоразведочного бурения
ВК-6	6 То же, что для ВК-2 и ВК-3, и, кроме того, инструмент для правки шлифовальных кругов
ВК-8	7 Инструмент для чернового точения и др. видов резания чугуна, цветных металлов и неметаллич. материалов; волочильный, буровой, калибровочный инструмент

8 Продолжение

1 Сплав	2 Применение
ВК-10	9 Инструмент для волочения прутков и труб
ВК-11	10 Инструмент для перфораторного бурения горных пород малой и средней крепости, для обработки камня
ВК-15	11 Инструмент для перфораторного бурения крепких горных пород, для штамповки и волочения в условиях повыш. нагрузок
Т5К10	12 Инструмент для чернового точения и др. видов обработки стали при неравномерном сечении среза и прерывистом резании
Т14К8	13 Инструмент для черновой и получистовой обработки стали
Т15К6	14 Инструмент для черновой, получистовой и чистовой обработки стали при непрерывном резании
Т30К4 Т60К6	15 Инструмент для чистового точения стали с малым сечением стружки

1) Alloy; 2) application; 3) VK-; 4) tools for finishing and semifinishing working of iron, nonferrous metals and alloys, and also nonmetallic materials using continuous cutting. Tools for cutting glass; 5) same as for VK-2, and also tools for wiredrawing and geological exploration drilling; 6) same as for VK-2 and VK-3 and also tools for dressing grinding wheels; 7) Tools for rough turning and other forms of cutting of iron, nonferrous metals and nonmetallic materials; drawing,

boring, sizing tools; 8) continuation; 9) tooling for rod and tube drawing; 10) tools for drilling rock of low and medium hardness, for stoneworking; 11) tools for drilling hard rock, for stamping and drawing under conditions of high loading; 12) tools for rough turning and other forms of steel working with nonuniform cutoff section and intermittent cutting; 13) tools for rough and semi-finishing working of steel; 14) tools for rough, semifinishing and finishing steel working with continuous cutting; 15) tools for finish turning of steel with small chip section.

For the cermet hard alloys in the range 20-500° α is $6 \cdot 10^{-6}$ – – $10 \cdot 10^{-6}$ 1/°C, coercive force is 124-136 oersteds.

In addition to the alloys listed, in several countries cermet hard alloys are produced with different composition, containing carbides of tantalum, niobium, vanadium.

References: Kieffer R. and Schwartskopf P., Hard Alloys, translated from German, M., 1957; Rakovskiy V.S., Samsonov G.V., Ol'khov I.I., Osnovy proizvodstva tverdykh splavov (Fundamentals of Hard Alloy Production), M., 1960; Tret'yakov V.I., Metallokeramich. tverdyye splavy (Cermet Hard Alloys), M., 1962.

V.S. Rakovskiy

CERMET HEAVY ALLOYS are alloys having a density of more than 16.5 g/cm^3 which are prepared by the powder metallurgy method. The basis of the cermet heavy alloys consists of tungsten, their composition also includes cobalt, nickel, copper, chromium and other components. Sinterng of the pressed mixture is accomplished at a temperature of 1400-1700°. Sometimes the tungsten powder alone is compacted and the pressed products are subjected to low-termperature sintering with subsequent impregnation with molten metals (cobalt, nickel).

Table 1 presents the chemical composition of the most widely used cermet heavy alloys, and Table 2 shows the properties of these alloys.

TABLE 1

Chemical Composition of Cermet Heavy Alloys

1 Элемент	2 Содержание, (%)
3 Вольфрам	Основа 4
5 Кобальт	5–15
6 Никель	2–12
7 Медь	0–10
8 Хром	0–2

1) Element; 2) content; (%); 3) tungsten; 4) base; 5) cobalt; 6) nickel;
7) 7) copper; 8) chromium.

TABLE 2

Properties of Cermet Heavy Alloy

1 Свойства	Показатели свойств 2
3 γ (г/см³)	16,2–17
4 HB (кг/мм²)	220–250
4 σ_b (кг/мм²)	75–100
4 σ_{-b} (кг/мм²)	270–290
5 $a_н$ (кгм/см²)	0,45–0,60
4 E (кг/мм²)	22000–25000
6 Допустимая рабочая темп-ра (С°)	150–180

1) Property; 2) property index; 3) (g/cm3); 4) (kg/mm^2); 5) (kgm/mm^2); 6) permissible operating temperature (°C).

The figure shows the typical microstructure of the cermet heavy alloys. The material is used for balancing weights in instruments, assemblies, on airplanes, rockets and numerous other devices, and may be used for the fabrication of products of varied shape, including extremely complex forms. The heavy alloy cermets are easily machined using tools with hard alloy facing, but are difficult to braze, weld and plastically deform.

References: Rakovskiy V.S. and Saklinskiy V.V., Poroshkovaya metallurgiya v mashinostroyenii (Powder Metallurgy in Machine Design), 2nd edition, M., 1963; Bal'shin M.Yu., Poroshkovaya metallurgiya (Powder Metallurgy), M., 1948.

V.S. Rakovskiy

II-74M

CERMET HIGH TEMPERATURE ALLOYS are alloys prepared by the powder metallurgy method which withstand high loadings at high temperatures (on the order of 1000-1500°) for an extended time period. For the characteristics and properties of the cermet high temperature alloys see Tables 1,2.

TABLE 1

Characteristics of Modern Cermet High Temperature Alloys

1 Тип сплава	2 Основная хар-ка	3 Композиция
I	Твердый сплав 4	Сплав карбидов или боридов тугоплавких металлов с металлами железной группы или 5 тугоплавкими металлами
II	6 Металло-окисный сплав	Сплав металлов или твердых соединений с тугоплавкими окислами 7
III	Металлич. сплав 8	Сплавы на основе тугоплавких металлов, чаще всего молибдена, с добавками небольшого количества легирующих элементов (Ti, Zr, Cu и др.) 9
IV	Углеродисто-кремниевый сплав 10	Композиция, состоящая из графита и карбида кремния, иногда с добавками карбида бора, нитрида кремния и наличием небольшого количества свободного углерода 11

1) Type of alloy; 2) basic nature; 3) composition; 4) hard alloy; 5) alloy of carbides or borides of refractory metals with metals of the iron group or refactory metals; 6) metal oxide alloy; 7) alloy of metals or hard compounds with refractory oxides; 8) metallic alloy; 9) alloys based on refractory metals, most frequently molybdenum with additions of a small quantity of alloying elements (Ti, Zr, Cu and other); 10) carbon-silicon alloy; 11) composition consisting of graphite and silicon carbide, sometimes with additions of boron carbide, silicon nitride and the presence of a small quantity of free carbon.

The first three types of alloys begin to oxidize actively even at temperatures of 700-1000°, therefore, their use at high temperatures for long times is possible only under the condition of application of

TABLE 2

Properties of Cermet High Temperature Alloys

¹ Свойства	² Един. измер.	³ Сплавы I типа	³ Сплавы II типа	³ Сплавы III типа	³ Сплавы IV типа
γ	⁴ г/см³	4,5—7,5	4,5—5	8,5—12,0	2,5—3,5
HB	⁵ кг/мм²	250—400	100—150	220—280	80
σ_b	⁶ То же	50—80	25—40	70—80	5—8
$\sigma_{изг}$ ⁷	»	70—150	30—70	140—160	15—20
σ_{-b}	»	200—400	100—200	190—210	30—40
σ_{-b}(1200°)	»	25—40	15—25	40—50	8—10
$\sigma_{изг}$(1200°)	»	40—80	20—35	60—70	10—12
$\sigma_{100\ изг}$ при⁸ 1200°	»	25—35	15—20	—	8—10
σ_{100} при⁸ 1200°	»	8—15	4—8	15—22	3,5—6
σ_{-1} (на базе 10^7 циклов)⁹	»	20—30	15—25	40—50	6—8
$a_н$	¹⁰ кгм/см²	0,3—0,8	0,3—0,6	10—12	0,2—0,3
δ	%	0	0	20—25	0
δ (200°)	»	0,1—0,2	0,05—0,1	10—12	0
$\alpha \cdot 10^6$ в интервале¹¹ 20—800°	1/°C	4—8	4—6	3,5—5,5	3,5—5

1) Properties; 2) unit of measurement; 3) type alloys; 4) g/cm^3; 5) kg/mm^2; 6) same; 7) σ_{izg}; 8) at; 9) (on the basis of 10^7 cycles); 10) kgm/cm^2; 11) in range.

protective coatings in the form of metallic alloys or ceramics. Alloys of type IV may be used for long time periods at temperatures above 1000° without protective coatings.

The thermal stability criteria (Table 3) are of great importance for the cermet high temperature alloys and are usually defined by the number of thermal cycles which the alloy withstands without failure when it is heated rapidly (in 20-30 seconds) to 1200-1500° and cooled rapidly to 100-200°.

So far the high temperature cermets have not found wide industrial application; they are utilized only in certain branches of engineering (see Table 4).

References: Kieffer R. and Schwartzkopf P., Hard Alloys (translation from German), M., 1957; High-Temperature and Corrosion-Resistant Cermet Materials, collection of repoets at 2nd Seminar at Planzee (Austria), translated from German, M., 1959; High Temperature Engineering, ed. by I.E. Campbell, translated from English, M., 1959.

V.S. Rakovskiy

TABLE 3

Thermal Stability of High Temperature Cermet Alloys

1 Тип сплава	2 Термостойкость по количеству теплосмен 1200°—200°—1200°
I	150—250
II	100—200
III	400—500
IV	3 Свыше 1000

1) Alloy type; 2) thermal stability from number of temperature cycles ; 3) more than.

TABLE 4

Principal Areas of Application of Cermet High Temperature Alloys

1 Тип сплава	2 Области применения	3 Степень освоения
I	4 Детали аппаратуры, работающие в условиях коррозии (лопатки и роторы морских насосов, детали химич. аппаратуры, уплотнит. детали аппаратуры и др.)	5 Применяются в пром. масштабе
	6 Детали реактивных самолетов, ракет и их двигателей (сопловые вставки, лопатки реактивных двигателей и др.)	7 Применяются в опытном порядке
II	8 Детали реактивных самолетов, ракет и их двигателей	9 Применяются в опытном порядке
	10 Пластины для оснащения режущего инструмента	Применяются в пром. масштабе 11
III	12 Детали реактивных самолетов, ракет и их двигателей (лопатки двигателей, сопловые вставки и др.)	Применяются в опытном порядке 13
IV	Детали ракет 14	15 Применяются в полупром. масштабе

1) Alloy type; 2) application area; 3) degree of use; 4) parts for apparatus operating in corrosive conditions (blades and rotors of marine pumps, chemical equipment, seals, etc.); 5) used industrially; 6) parts for jet airplanes, rockets and their engines (nozzle inserts, jet engine blades, etc.); 7) used experimentally; 8) parts for jet airplanes, rockets and their engines; 9) used experimentally; 10) wafers for equipping cutting tools; 11) used industrially; 12) parts for juet airplanes, rockets and their engines (engine baldes, nozzle inserts, etc.); 13) used experimentally; 14) rocket parts; 15) used on semi-industrial scale.

CERMET MAGNETS are permanent magnets produced by the powder metallurgy method. They are used to create a permanent magnetic flux in magnetic flux in magnetic circuits. In comparison with the magnets produced by the method of conventional metallurgy, the cermet magnets ahve the following advantages: precise chemical composition is ensured, which improves th uniformity of the magnet properties; production of magnets with hardware is facilitated (pole terminals, pivots, sleeves); machining volume is reduced; production costs are reduced. The cermet magnets are produced in varied shapes, varying sizes, weights to several kilograms. Cermet mangnetic systems are also produced consisting of permanent magnets connected to pole terminals, magnetic screens, etc. (Fig. 1). The groupings and basic properties of the cermet magnets are given in the table. The cermet magnets have a structure typical of the cast allcys of analogous chemical composition, sometimes differing in higher porosity and finer grain. The cermet magnets with hig porosity (above 2-3%) are inferior to cast magnets in magnetic properties. The variation of the magnetic characteristics of the cermet magnets as a function of porosity (P, %) is described by the empirical equations:

Fig. 1. Cermet magnets made from alloys of the Fe-Ni,Al system (on the right – magnetic systems, magnets indicated by arrow).

$$W_{max} = W_{max_0} - \left(\frac{W_{max_0}}{[illegible]} - 8\%\right) P,$$

$$B_r = B_{r_0} - \left(\frac{B_{r_0}}{[illegible]} - 2\%\right) P.$$

where W_{max} (ergs/cm^3) and B_r (gausses) are respectively the maximal magnetic energy and the residual induction of the cermet mangets, W_{max0} and B_{r0} are the same characteristics for magnets without porosity.

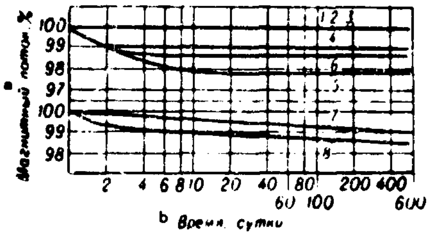
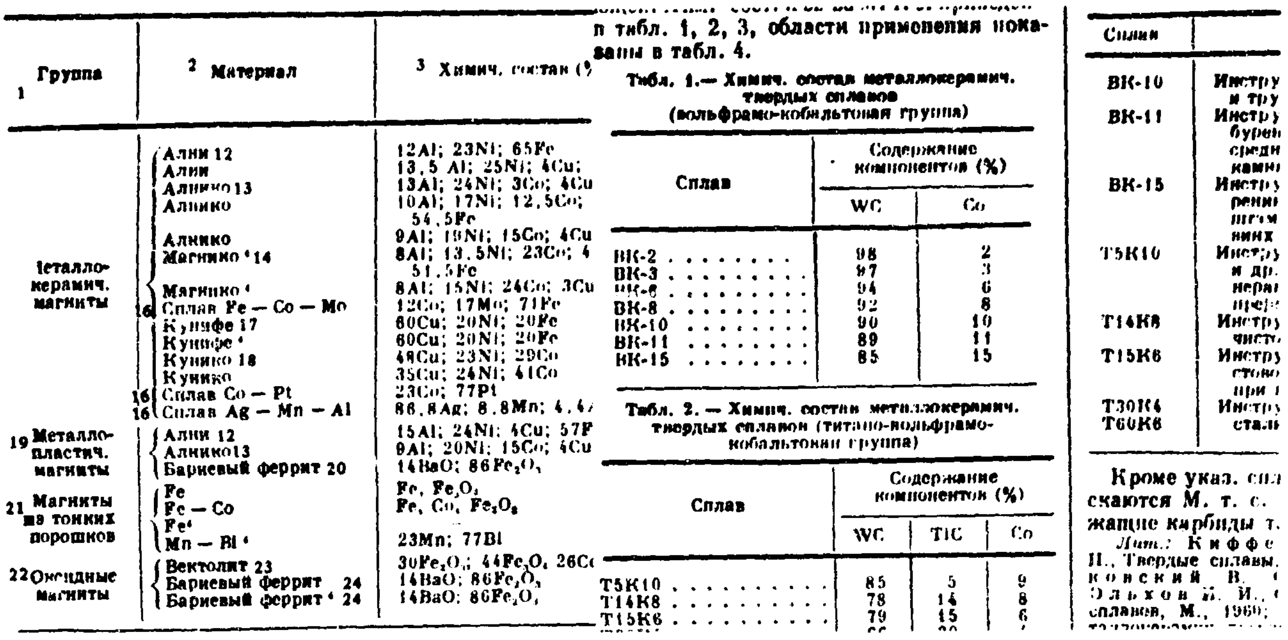


Fig. 2. Variation of magnetic flux of cermet magnets with time (at 20°) 1) Alni 13-25-4; 2) Alnico 10-17-12.5; 3) magnico 8-15-4 (all aged by 5%); 4) Alni; 5) Alnico; 6) magnico; 7) Co-Pt alloy; 8) Cunico 48-23-29 alloy (all unaged). a) Mangetic flux, %; b) time, days.

Usually there are 3-5% pores in the cermet magnets; when the porosity is reduced to about ~1% the cermet magnets are equivalent to the cast varieties in magnetic properties. Cermet magnets with properties of the cast magnets may be obtained by additional alloying of the cermet alloys with special additives (cobalt, zirconium, etc.). Aging by 3-5% provides high timewise stability of the magnetic flux (Fig. 2). Thanks to the fine-grain structure, the cermet magnets made from alloys of the system Fe – Ni – Al exceed the cast magnets in mechanical strength by several fold. The cermet magnets of this system have the following ultimate strengths: in tension 10-15 kg/mm^2, in compression 120-150 kg/mm^2, in bending 30-40 kg/mm^2. Cermet magnets made from the wrought alloys (Cunife and others) are approximately equivalent to the magnets in mechanical strength. The cermet magnets made from alloys of the system Fe – Ni – Al are easily ground with abrasives, also permit machining after preparatory sintering.

The second group includes the metalloplastic magnets which are pressed from prepared hard magnetic alloy powder mixed with resin. These magnets consist of fine hard magnetic particles bound by inter-

Composition and Properties of Cermet Permanent Magnets*



1 Группа	2 Материал	3 Химич. состав (%
Металлокерамич. магниты	Алии 12	12Al; 23Ni; 65Fe
	Алии	13,5 Al; 25Ni; 4Cu;
	Алнико 13	13Al; 24Ni; 3Co; 4Cu
	Алнико	10Al; 17Ni; 12,5Co; 54,5Fe
	Алнико	9Al; 19Ni; 15Co; 4Cu
	Магнико[4] 14	8Al; 13.5Ni; 23Co; 4 51.5Fe
	Магнико[4]	8Al; 15Ni; 24Co; 3Cu
	16 Сплав Fe — Co — Mo	12Co; 17Mo; 71Fe
	Кунифе 17	60Cu; 20Ni; 20Fe
	Кунифе[4]	60Cu; 20Ni; 20Fe
	Кунико 18	48Cu; 23Ni; 29Co
	Кунико	35Cu; 24Ni; 41Co
	16 Сплав Co — Pt	23Co; 77Pt
	16 Сплав Ag — Mn — Al	86,8Ag; 8.8Mn; 4.4
19 Металлопластич. магниты	Ални 12	15Al; 24Ni; 4Cu; 57F
	Алнико13	9Al; 20Ni; 15Co; 4Cu
	Бариевый феррит 20	14BaO; 86Fe$_2$O$_3$
21 Магниты из тонких порошков	Fe	Fe, Fe$_3$O$_4$
	Fe — Co	Fe, Co, Fe$_3$O$_4$
	Fe[4]	—
	Mn — Bi[4]	23Mn; 77Bi
22 Оксидные магниты	Вектолит 23	30Fe$_2$O$_3$; 44Fe$_3$O$_4$ 26Co
	Бариевый феррит 24	14BaO; 86Fe$_2$O$_3$
	Бариевый феррит[4] 24	14BaO; 86Fe$_2$O$_3$

в табл. 1, 2, 3, области применения показаны в табл. 4.

Табл. 1.— Химич. состав металлокерамич. твердых сплавов (вольфрамо-кобальтовая группа)

Сплав	Содержание компонентов (%)	
	WC	Co
ВК-2	98	2
ВК-3	97	3
ВК-6	94	6
ВК-8	92	8
ВК-10	90	10
ВК-11	89	11
ВК-15	85	15

Табл. 2. — Химич. состав металлокерамич. твердых сплавов (титано-вольфрамо-кобальтовая группа)

Сплав	Содержание компонентов (%)		
	WC	TiC	Co
T5K10	85	5	9
T14K8	78	14	8
T15K6	79	15	6

Сплав	
ВК-10	Инстру и тру
ВК-11	Инстру бурен средн камн
ВК-15	Инстру рени пгом вних
Т5К10	Инстру и др. нерат пре
Т14К8	Инстру чист
Т15К6	Инстру стово при
Т30К4 Т60К6	Инстру стал

Кроме указ. спл скаются М. т. с. жащие карбиды т.

Лит.: Киффе П., Твердые сплавы, конский В. Эльхов И. И., сплавов, М., 1960;

*Limiting or average property values shown.
**At point of magnetization curve corresponding to $(B\text{-}H)_{max}$.
***In field, H = 4BHc.
****Anisotropic material.

1) Group; 2) material; 3) chemical composition (%); 4) residual induction B_r(gausses); 5) coercive force H_c (oetsteds); 6) maximal magnetic energy W_{max} (ergs/cm^3); 7) magnetic induction^2 B_d(gausses); 8) magnetic field intensity^2 H_d (oersteds); 9) reversible permeability coefficient μ_r (gauss/oersted); 10) magnetization intensity^2 $4\pi I$ (gausses); 11) density γ (g/cm^3); 12) Alni; 13) alnico; 14) magnico^4; 15) cermet magnets; 16) alloy; 17) cunife; 18) cunico, 19) metalloplastic magnets; 20) barium ferrite; 21) fine powder magnets; 22) oxide magnets; 23) vectolite; 24) barium ferrite.

layers of resin or other bonding material. Becuase of the high binder content (25-30 percent by weight) they have low magnetic properties, but they surpass magnets of the other groups in simplicity of the production process. The third group includes the magnets pressed from high coercivity powders, whose particles approach the ferromagnetic domain in magnitude. The fourth group includes magnets made from powders of the metal oxides. As a result of the high coercive force, the oxide magnets made from barium ferrite have outstandingly high resistance to demagnetization under the influence of heating, impact and external magnetic fields. They also have exceptionally high specific electrical resistance (about 10^{10} ohm-mm^2/m). Their disadvantage is the high thermal coefficient of induction (−0.2 percent per 1°C). The ultimate bending strength of the magnets made from barium ferrite is 7-11 kg/mm^2 (isotropic magnets) and 3-4 kg/mm^2 (anisotropic magnets). After complete sintering these magnets can only be worked by grinding, but after pressing or preliminary sintering at moderate temperature they can be machined easily. The cermet magnets are used in instruments, radio telephone apparatus, electrical machines and other devices. Widest usage is made of the cermet magnets made from alloys of the system Fe – Ni – Al and the oxide magnets made from barium ferrite.

References: Zaymovskiy A.S. and Chudnovskaya L.A., Magnitnyye materialy (Magnetic Materials), M.L., 1957 (Metally i splavy v elektrotekhnike, t. 1) (Metals and Alloys in Electrical Engineering, Vol. 1); Al'tman A.B., Metallokeramicheskiye postoyannyye magnity (Cermet Permanent Magnets), in book: Poroshkovaya metallurgiya (Powder Metallurgy), Yaroslavl', 1956; Al'tman A.B., Gladyshev P.A. and Lasis G.I., Magnitnyye svoystva postoyannykh magnitov iz poroshkov (Magnetic Properties of Permanent Magnets Made from Powders). Vestin. elektropromyshlennosti (News of the Electrical Industry), 1961, No 2; Gershov I.Yu. Cheryskiy I.A., Oksidnyye postoyannyye magnity iz bariyevogo ferrita (Oxide Permanent Magnets of Barium Ferrite), in book: Electrotekhnicheskiye metallokeramicheskiye izdeliya (Electrical Cermet Products), M., 1959; Shol'ts N.N., Shchepkina L.Ya., Metod izgotovleniya i svoystva oksidnykh bariyevykh magnitov (Method of Production and Properties of Oxide Barium Magnets), in book: Ferrity. Fizicheskiye i fiziko-khimicheskiye svoystva (Ferrites. Physical and Physico-Chemical Properties), Minsk, 1960.

A.B. Al'tman

CERMET SLIP – is a concentrated suspension of high-disperse powders of various metals, oxides or high-melting compounds. It is used to cast cermet objects which have a complex configuration. Depending on the composition of the fluid (the dispersing medium), there are aqueous or organic cermet slips. In the first case, the slip is a suspension of the above-mentioned powders in water. In the latter case, high-molecular thermoplastic organic substances, mainly hydrocarbons of the paraffin series (commercial paraffin or paraffin-based melts) are the dispersing medium with a t°_{pl} higher than 50°.

Depending on the chemical nature of the dispersing medium, 2 principal methods are used for slip casting. The method of casting objects by means of aqueous slips is based on the fact that the suspension is desiccated when it contacts a water-absorbing porous body, i. e., the water is sucked off by this body, and the separated disperse (solid) phase is tightened and forms a solid body (the casting). The slip casting consists, in the case, of sucking off the water of the slip mold due to capillary effects by a dry porous (usually, plaster), the disperse phase becoming gradually tightened and forming the casting. The obtained casting is dried and further sintered in the same manner as that of pressed objects.

The method of casting organic slips is based on the fact that the dispersing medium (molten paraffin in the given example) solidifies at a temperature lower than 50°, and, therefore, the whole body becomes solid. Hence, the cermet slip poured into the mold and cooled below the temperature mentioned above, forms a solid body (the object). The sintering is carried out under a covering powder (alumina, for example) or in solid profiled absorbers (dryers) in order to remove the organic components and to prevent a deformation of the objects. The removal of the organic substances is carried out at 300-700° in an oxidizing medium, after which the objects are sintered under the conditions usual for pressed objects.

The suspensions tend to sedimentate, i.e., the solid phase precipitates due to gravity, and this occurs the quicker the height of the specific gravity and the coarser the particles. The particles of the solid phase must not be greater than 5-8 microns, in order to achieve a sufficient stability of the suspension. The suspensions are characterized also by a tendency to aggregate, i.e., the particles of the solid phase precipitate not separately but in the form of aggregates composed from a great number of particles. The sedimentation of suspensions which tend to aggregate occurs quickly; such suspensions are not suitable for slip casting, and therefore suspensions used for slip casting are prepared by the addition of stabilizing substances. Alkalis, acids, soaps, protective colloids and some other substances are used as stabilizers of aqueous slips.

The pH of the medium, i.e., the concentration of the hydrogen ions, has an immediate effect on the casting properties of aqueous slips. The viscosity and, therefore, also the fluidity of the slip may be controlled by changing this factor, for example, by adding microquantities of NaOH. Curves of viscosity as a function of the pH are shown in Figs. 1 and 2 for aqueous suspensions of nickel and iron. The stabilization of organic cermet slips is achieved by the addition of high-viscous organic compounds, with polyethylene, for example, by lowering the temperature, or by the addition of surface-active substances. The casting of organic cermet slips is carried out under pressure or in open molds, depending on the size of the objects and their purpose.

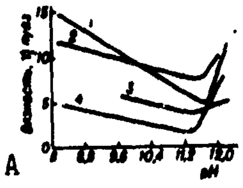


Fig. 1. Viscosity of an aqueous nickel suspension as a function of the pH of the medium. Quantity of solid phase in the suspension (in weight-%): 1) 82.7; 2) 80.6; 3) 78.7; 4) 76.9. A) Viscosity, η, in poises.

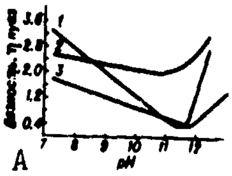


Fig. 2. Viscosity of an aqueous iron suspension as a function of the pH of the medium. Quantity of solid phase in the suspension (in weight-%): 1) 87.7; 2) 85.5; 3) 83.3. A) Viscosity, η, in poises.

References: Abramson, I.D., Vovaya tekhnologiya izgotovleniya keramicheskikh sterzhney dlya tochnogo lit'ya pustotelykh detaley po vyplavlyavemym modelyam [New Technology of Preparation of Ceramic Rods for the Precise Casting of Hollow Objects Using Cast Patterns], Moscow, 1958; Avgustinik, A.I., Keramika [Ceramics], Moscow, 1957.

I.D. Abramson

CHAFER – is a nonfinished technical cotton fabric with plain weave. It is manufactured in both warp and weft from a yarn No. 17/4.

Chafer is manufactured in the following widths: article 2081 with a width of 146; 150, 160, and 167 ± 2-3 cm; article 2086 with 286 ± ± 3 cm; article 2090, impregnated, with 112 ± 3 cm.

The raw fabric is manufactured according to GOST 642-41, the impregnated fabric according to VTU 2223-53.

The weight of 1 m^2 chafer is 500 ± 25 g. The breaking load of a 50 × 200 m strip is at least 730 kg along both the warp and the weft. The thickness of the fabric is 1.1 ± 0.08 mm. When the standard strength is maintained, the elongation amounts to 26 ± 3% along the warp, and 14 ± 2% along the weft. The length of one piece is at least 42 m.

Great quantities of chafer are used in the tire industry to reinforce the borders of the tire treads, and in the manufacture of fenders, and – in the industry of technical rubberware – in the manufacture of rubberized piptes and hoses.

Chafer in raw state or also impregnated with diverse compositions inhibiting the adhesion to rubber is used in the manufacture of rubberware as a packing material. Raw chafer is used for ligatures.

S.Ye. Strusevich

CHAIN STEEL – is a Martin steel of the St.3Ts grade used in the manufacture of chain-cables and other chains by forge welding. The chemical composition is: $\leq 0.18\%$ carbon, 0.3-0.6% manganese, traces of silicon, $\leq 0.04\%$ sulfur, $\leq 0.04\%$ phosphorus, $\leq 0.03\%$ nickel, and $\leq 0.1\%$ chromium. The chain steel is manufactured according to GOST 924-51, and is used mainly in ship building. $\sigma_b = 37\text{-}45$ kg/mm^2; $\delta_{10} \geq 24\%$. The tensile strength of the welded joints must be not less than 80% of the initial strength of the metal. Chain steel must possess a fair degree of plasticity which is tested by bending a cold specimen 180° around a mandrel, the diameter of which is equal to the half diameter (or thickness) of the specimen.

M.L. Bernshteyn

II-67M

CHALK is an earthy, pasty white mineral consisting almost exclusively of calcium carbonate (often up to 99%). Many engineering properties of chalk are determined by its structure. Chalk consists of spherical and irregular particles of diameter less than 10 microns (on the average three microns), very weakly cemented together. Specific weight is 2.65-2.70. Heat capacity is 0.204 cal/g-deg. Thermal conductivity is 0.00065 cal/sec-cm-deg. Dissociation temperature is 925°. Mohs hardness is less than 1. In addition to completely white chalk (Ostwald whiteness 75-90%), yellowish (Fe oxide impurities) or grayish (clayey impurities) chalks are encountered less frequently. After removal of the natural moisture, chalk absorbs no more than 0.3% of the moisture from the air. In an aqueous medium chalk is easily dispersed to complete passage through a sieve with 10,000 openings per square centimeter. For use in the paint and lacquer industry ther is great importance in the high covering power (average chalk consumption 0.25 kg/m^2) and the high oil absorption (oil consumption to obtain pastes with chalk is 20-25% of the weight of the dry chalk). Commercial chalk may be in lump form, more convenient for transport, and in powder form. Depending on the method of pulverization chalk in powder form is divided into ground (dry disintegration) and technical (wet disintegration). Ground chalk is obtained by grinding on crusher mills and screening on grading screens or in more advanced grinding equipment with impact action – disintegrators; technical chalk is obtained by elutriation or flotation. It is used in 1) the paint and lacquer industry (white pigment), 2) the rubber, paper industries and in the production of plastics, etc. (inert white filler). The high covering power and the white color of chalk is used in water-soluble paints (gelatine, casein, etc.); in these paints chalk is a basic white pigment or a bleaching agent for any colored pigments, and also is used as a filler for the ground coats. Softness and wearability lead to the use of chalk as a writing material. In the rubber industry use is made of activated floated chalk to strengthen the rubber; used as a paper filler, chalk imparts greater density, whiteness, smoothness, receptivity to printing, lower transparency. As a chemical and structural raw material chalk may be replaced by other calciferous minerals. Chalk is used in the sugar industry to purify sugarbeet juice, as a binding agent (lime andportland cement), in glass manufacture, in the production of silicate brick, as a polishing compound material and for the production of electrode coatings (electric arc welding).

Reference: Trebovaniya promyshlennosti k kachestvu mineral'nogo syr'ya (Industry Requirements for Quality of Mineral Raw Materials), edition 6 – Ivanov A.I., Mel (Chalk), M.-L., 1946.

P.P. Smolin

I-85v

CHEMICAL FIBER – fiber obtained by chemical processing of natural or synthetic high-molecular compounds. Depending on the composition of the polymer used for their production, chemical fibers are divided into 2 groups: artificial, that is, from natural high-molecular compounds (cellulose and its esters, proteins, etc.) and synthetic, that is those made from synthetic polymers. The extensive development of the chemical fiber industry is due to the high economic efficiency of production, accessibility of the starting raw materials, possibility to obtain products with previously specified properties and substantial expansion of the assortment of products which can be obtained from this raw material. Chemical fibers are produced in the form of filament thread or cord thread (twisted elementary strands of infinite length), staple fiber (nontwisted elementary strands from 30 to 150 mm long) and monofiber (thread consisting of a single fiber of infinite length).

References: Rogovin, Z.A., Osnovy khimii i tekhnologii proizvodstva khimicheskikh volokon [Fundamentals of the Chemistry and Technology of Chemical Fiber Production]. 2nd edition, Moscow, 1957; "KhV," [Chemical Fibers], No. 1, page 1, 1961.

Z.A. Zazulina

I-86v

CHEMICAL FIBER – fiber obtained by chemical processing of natural or synthetic high-molecular compounds. Depending on the composition of the polymer used for their production, chemical fibers are divided into 2 groups: artificial, that is, from natural high-molecular compounds (cellulose and its esters, proteins, etc.) and synthetic, that is, those made from synthetic polymers. The extensive development of the chemical fiber industry is due to the high economic efficiency of production, accessibility of the starting raw materials, possibility to obtain products with previously specified properties and substantial expansion of the assortment of products which can be obtained from this raw material. Chemical fibers are produced in the form of filament thread or cord thread (twisted elementary strands of infinite length), staple fiber (nontwisted elementary strands from 30 to 150 mm long) and monofiber (thread consisting of a single fiber of infinite length).

References: Rogovin, Z.A. Osnovy khimii i tekhnologii proizvodstva khimicheskikh volokon [Fundamentals of the Chemistry and Technology of Chemical Fiber Production]. 2nd edition, Moscow, 1957; "KhV," [Chemical Fibers], No. 1, page 1, 1961.

Z.A. Zazulina

CHEMICAL-LABORATORY GLASS – glass which has a high chemical and thermal stability and does not become cloudy when treated in a glass-blowing-burner flame.

The following requirements are imposed on this type of glass: a low tendency toward crystallization over a broad temperature range, lack of roughness during manufacture and subsequent glass-blowing-burner treatment in gaseous reducing and oxidizing media, high chemical resistance to various reagents and aggressive media, a low coefficient of linear expansion, and workable vitreous-mass characteristics at low temperatures. Chemical-laboratory products should not be subject to destructive surface cracking on severe heating and cooling. The chief components of chemical-laboratory glass are SiO_2, B_2O_3, Al_2O_3, ZrO_2, ZnO, CaO, MgO, BaO, Na_2O, and K_2O. Glass with a definite composition and a given set of characteristics is used, depending on the purpose of the product. Chemical-laboratory glass is intended for the manufacture of articles of varying shape and capacity and for a number of instruments widely employed in the laboratory. Chemical-laboratory products include beakers, flasks, cylinders, pyknometers, desiccators, crystallizers, covers, condensers, boxes, glass filters, and funnels. A number of glass formulations are utilized in the manufacture of Klinger glasses, high-hot-strength household articles, vacuum meters, viscosity meters, gas analyzers, equipment for distilling various liquids, etc. Chemical-laboratory glass is also used to produce glass filters (porous disks or plates fused into glass cylinders or funnels) and water glasses in the form of thick-walled tubes and flat Klinger glasses, which are intended for measuring the water level in low- and high-pressure steam boilers. Borosilicate glass with a low alkali-oxide content is used for water-measuring tubes meant to withstand pressures of up to 35 atm, while high-aluminoborosilicate and borosilicate glasses with minimal alkali-oxide contents are used for high-pressure boilers.

References: Tekhnologiya stekla [Glass Technology], edited by I.I. Kitaygorodskiy, 3rd Edition, Moscow, 1961; Izdeliya steklyannyye khimiko-laboratornyye [Glass Chemical-Laboratory Products], Official Edition, Moscow, 1960 (SSSR, Gos. standarty [USSR, State Standards]).

G.G. Sentyurin

CHEMICALLY RESISTANT LACQUER AND PAINT COATINGS, coatings based on the perchlorvinyl, epoxy, organo-fluorine and phenolic resins, and also polyethylene, the copolymer of vinyl chloride and vinylidene chloride, chlorinated rubber, and others, are resistant to the action of chemically aggressive media. Almost all the chemically resistant coatings have time-limited resistance to the highly concentrated acids (particularly to HNO_3) and to the alkalis. The chemically resistant coatings are used primarily for protection from the long-term or periodic action of the unconcentrated acids, alkalis, solutions of salts and industrial gases (SO_2, HCl, CO_2 and others), and only in certain cases are they used for short-term protection from the action of the highly concentrated acids. The chemical resistance of the chemically resistant coatings does not in itself determine their suitability for the protection of particular metals. The most important factors which characterize the protective effect of the chemically resistant coatings are their adhesion with the surface being protected and their permeability for the aggressive media. With increase of the temperature of the chemical medium, the protective properties of the chemically resistant coatings are reduced considerably. These coatings are applied in several layers in order to obtain a continuous (pore-free) coating. In order to create good bonding with the coatings, the surfaces of the ferrous metals are subjected to hydro sandblasting or shot blasting and are then phosphatized, while the nonferrous metals are chemically or electrochemically oxidized. In the case of the application of multi-layer coatings, the continuity of the coating is verified periodically. The drying temperature is of essential importance; with increase of the temperature there is improvement of the stability of the coatings in the aggressive media.

The surface being painted is smoothed off with the PKhVSh-23 spackle (for weakly acid media) or with the epoxy primer-spackles E-4021 and E-4022 (for an alkaline medium).

As a rule, after preparation the chemically resistant coatings are applied by a paint sprayer in several coats on the corresponding primers. To increase the protective effect, several layers of the KhSL or VKhL-4000 lacquer are applied on the KhSE and VKhE chemically resistant coatings. Prior to use of the painted articles they are air-dried for 5-7 days.

The highest resistance to many aggressive media, in particular to highly concentrated nitric acid, is shown by the coatings based on polychlortrifluorethylene which withstands without change the attack of 98% nitric acid at 50° for 30 days. Polychlortrifluorethylene is used as a coating in the form of a suspension consisting of a suspension of the fine-ground product in organic liquids. The suspension is applied by dipping, brushing or by a paint sprayer. After volatilization of the solvent, there remains on the surface the dry polymer. In order to obtain a continuous layer of the polymer the dried layer is fused. Prior to fusing the polymer is heated for 10 minutes at 260-275°. In order to obtain complete continuity, 8-10 coats are applied with a total thickness of 80-120 microns. After application and fusion of the last coat, the coating is subjected to water quench. The coating quality depends to a considerable degree on the surface preparation. In addition to polychlortrifluorethylene use is made of the copolymers of chlortrifluorethylene with vinylidene fluoride, which dissolves well in many solvents. On the basis of these copolymers we obtain lacquer/paint materials which have high resistance to many aggressive media.

II-59k2

References: Lyubimov B.V., Spetsial'nyye lakokrasochnyye pokrytiya v mashinostroyenii [Special Lacquer and Paint Coatings in Machine Construction], M.-L., 1959; Kazin A.D., Korzin N.V., Okraska oborudovaniya i metallokonstruktsiy na khimicheskikh zavodakh [Painting Equipment and Metal Structures in Chemical Plants], M.-L., 1949; Chegodayev D.D., Ftoroplasty [Fluorine Plastics], L., 1956.

I.I. Denker

CHILLED IRON – is an iron casting with a zonal structure; its structure zone consists of white iron or mottled iron up to a certain depth (given by the technical specifications), and the core consists of gray iron; the surface zone and the core are joined by a transition zone (cementite + graphite). Chilled-iron castings are subdivided into: hard castings in which almost the whole carbon content of the surface zone is bound as carbides, forming white iron; medium hard castings, the surface zone of which contains the carbon partially as graphite, and partially as carbides, forming mottled iron.

Chilled iron is used in the manufacture of parts which are exposed to wear, mainly for the production of rollers for various purposes, and for similar parts (mill rollers, rollers for the equipment of the paint-and-varnish industry and paper industry, etc.). The chilled rollers are casted from medium-alloy, low-alloy, and non-alloyed cast iron which may be both nonmodified or modified, with lamellar or spheroidal graphite (see Modifying of cast iron).

The chilled zone of chilled-iron castings is obtained by an accelerated cooling of those surfaces which must be chilled. Thus, for example, the chilled zone on the body of the rollers is obtained by cast-iron chill molds placed in the middle part of the mold; the chill molds may be grooved and detachable along a vertical plane for grooved rollers, and smooth for rollers with a smooth body. The journals of the rollers are cast in dry-sand molds. The melting of the cast iron is usually carried out in flame furnaces in the case of large rollers, and in cupola furnaces in that of small rollers. The molds for casting double-layer rollers (chilled iron-steel) are provided with vents on the level of the upper journal end to pour off the liquid chilled iron which is pressed out when the steel is rinsed by cast iron.

Double-layer rollers are used for the hot-rolling of steel; the outer layer of these rollers consists of low-alloy chilled iron (about 1 8% Mn and 0.8% Cr) and the core consists of steel with 0.4%C.

Modifying improves the distribution of the lamellar graphite in the core and reduces the depth of the chilled and the transition zones. Addition of 0.0002-0.0006% tellurium into the ladle increases the depth of the chilled zone and reduces at the same time that of the transition zone. The internal stresses caused by the different cooling rate of the various zones of chilled-iron castings may be avoided by cooling the castings (rollers, for example) in the mold up to 50-100° and subsequent storage for 6-12 months, or by heating up to 500-550° and subsequent slow cooling.

Rollers of chilled iron with spheroidal graphite came in use at the beginning of the 50's of the 20th Century. The chemical composition of this chilled iron is characterized primarily by an increased silicon content, and its structure is characterized by small coagulations of spheroidal graphite in the outer zone; the outer and the transition zones have a great depth.

Rollers of chilled iron containing spheroidal graphite may be manufactured with various structures in the metal base of the central zone, depending on the purpose of the rollers: those with a pearlite-ferritic structure may be used in place of steel rollers; those with a pearlitic structure in place of steel rollers or rollers of medium-hard cast iron; those with a pearlite-cementitic structure in place of rollers of medium-hard cast iron. Rollers of cast iron with spheroidal graphite and an acicular structure of the metal base, obtained by alloying, are also manufactured. The chemical composition of chilled iron is quoted in the Tables 1-3.

TABLE 1

Chemical Composition of Chilled Iron with Lamellar Graphite Smelted in Flame Furnaces (for metallurgical rollers)

Валки 1	2 Содержание элементов (%)								4 Глубина отбела (мм)	5 Твердость по Шору
	C	Si	Mn	P	S	Cr	Ni	Mo		
				3 не более						
Листовые 6	2,7—3,3	0,4—0,5	0,2—0,5	0,5	0,10	—	—	0,2—0,4	8—30	58—68
7 Двухслойные*:										
8 наружный слой	2,8—3,6	0,4—0,7	0,4—1,0	0,5	0,1	0,5—0,7	3,5—4,5	0,3—0,4	10—30	70—85
9 сердцевина	3,2—3,4	0,5—0,8	0,3—0,7	0,5	0,14	0,2—0,4	1,5—2,5	0,1—0,2	—	—
10 Полутвердые низколегированные	до 3,4	0,7—1,3	до 0,5	0,3	0,10	0,4—0,8	0,6—1,2	—	—	35—50
11 Полутвердые нелегированные	12 до 3,3	0,4—0,7	до 0,8	0,5	0,10	—	—	—	—	30—40

*Smooth rollers obtained by substitution of low-alloy iron for medium-alloy iron in the non-solidified core; the outer zone has a carbide-martensitic structure.

1) Rollers; 2) percentage of elements; 3) not more than; 4) depth of the chilled zone (mm); 5) shore hardness; 6) for sheet rolling; 7) 7) double-layer* rollers; 8) outer layer; 9) core; 10) medium-hard low-alloy; 11) medium-hard non-alloyed; 12) up to.

TABLE 2

Chemical Composition of Chilled Iron with Lamellar Graphite for Rollers Used for Rolling of Non-Metallic Materials

Валки 1	2 Содержание элементов (%)							5 Глубина отбела (мм)	6 Твердость по Шору
	C макс 3	Si	Mn	P	S	Cr	Ni		
				4 не более					
7 Отбеленные	3,6	0,4—0,8	0,2—0,8	0,35	0,14	—	—	20—40	60—68
8 Полутвердые	3,5	0,4—0,8	10 до 1,0	0,2	0,15	—	—	—	32—45
9 То же из легиров. чугуна	3,8	0,8—1,5	10 до 0,3	0,3	0,15	0,6—1,0	0,8—1,2	—	35—40

1) Rollers; 2) percentage of elements; 3) maks; 4) not more than; 5) depth of the chilled layer (mm); 6) shore hardness; 7) chilled; 8) medium-hard; 9) the same of alloyed cast iron; 10) up to.

TABLE 3

Chemical Composition of Chilled Iron with Spheroidal Graphite (for section-mill rollers according to ChMTU 4893-54)

Валки 1	2 Содержание элементов (%)							НВ (кг/мм^2) 4
	C	Si	Mn	P 3 не более	S	Ni	Cr	
Крупносортные . 5.	3,2—3,5	1,2—2,2	0,5—1,0	0,3	0,02	—	—	220—280
6 То же из хромоникелевого чугуна . . .	3,2—3,5	0,8—1,6	0,5—1,0	0,3	0,02	0,8—1,6	0,4—0,8	280—340
7 Среднесортные из хромоникелевого чугуна	до 3,6	0,8—2,0	0,5—1,0	0,2	0,02	0,8—1,2	0,4—0,8	300—340
8 Мелкосортные	до 3,6	0,8—2,0	0,5—1,0	0,2	0,02	—	—	250—320

1) Rollers; 2) percentage of elements; 3) not more than; 4) (kg/mm^2); 5) for large-size profiles; 6) the same, of chrome-nickel iron; 7) for medium-size profiles, of chrome-nickel iron; 8) for small-size profiles; 9) up to.

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A.A. Simkin

Manuscript Page No.	[Transliterated Symbols]
774	ЧМТУ = ChMTU = Chernometallurgicheskoye tekhnicheskoye usloviye = Technical Specification of the Ferrous Metallurgy

CHLORAIN — see Polyvinylidenechloride fiber.

III-8kh

CHLORIN — is a synthetic carbochain fiber made from supplementarly chlorinated polyvinylchloride (perchlorovinyl) containing 64% bound chlorine; it is manufactured in the USSR, in the GDR (termed PC), and in France (Chlorin). The breaking strength of Chlorin is poor, it is 20-25 km for silk filament and 13.5-15 km for staple fiber; the breaking elongation is 25-20% and 40-35%, respectively. The strength in wet state does almost not differ from that in the dry state. Chlorin is easily deformable under small loads within an elongation range of 5-10%. The resistance of Chlorin to alternating strains, especially to double bending, is about 10 times higher than that of viscose rayon and 20 times higher than that of acetate fiber.

The heat resistance of Chlorin does not surpass 90°. Chlorin has a low resistance to aging by heat. Heating at 90° for 1 hour causes the loss of 25% of the initial strength; a long heating at 100° causes the degradation of the Chlorin, the fiber becomes rigid and brittle. A shrinkage of the Chlorin sets in at 55-65°. Chlorin is noncombustible.

The low lightproofness and the gradual decomposition under the action of ultraviolet rays', accompanied by liberation of HCl, is a major shortcoming of the Chlorin. The specific electrical volume resistance of Chlorin is not less than 10^{16} ohm•cm at 20°; the surface resistance of the film is not less than 10^{13} ohms; the dielectric constant ε is 3.0 at a voltage of 200 v and a frequency of 50 cps; the tangent of the loss angle is 0.11. The low value of ε, the high water-repellence (Chlorin absorbs 0.3% moisture at a relative moisture content of 65%, and the high friction coefficient (1.5-2 times higher than that of cotton) promote a ready electrization of the Chlorin under friction, and the accumulation of static electrical charges on it. This property which makes the normal manufacturing of Chlorin difficult and which is eliminated by applying antistatic agents to the Chlorin, which increase temporarily the electrical conductivity of the fiber, proves to be valuable in some cases and is utilized for the manufacture of medical underwear, which become statically-charged by wearing, for patients suffering from sciatica, rheumatism and radiculitis. The heat conductivity of Chlorin is poor. The water-repellence of Chlorin and the absence of chemical groups with chemical affinity to dyestuffs make coloring it difficult, and the low heat resistance hinders the application of more efficient high-temperature coloring methods. Coloring of Chlorin may be realized by adding a coloring pigment during the preparation of the spinning solution.

Chlorin surpasses all natural and synthetic fibers excluding Ftorlon and Teflon with regard to the resistance to chemical reagents. Chlorin resists H_2SO_4 (specific gravity 1.84), HCl (specific gravity (1.17), HNO_3 (specific gravity 1.51) and a 40% KOH solution at temperatures up to [illegible]°; it has a medium resistance to these reagents up to [illegible]°, and also to aqua regia, phosphoric and hydrofluoric acids and strong oxidizers (chromic mixture, hypochlorites, permanganate) at [illegible]°. Chlorin does not resist acetone and other ketones, benzene, cyclohexanone, cyclic ethers, dioxane, chlorinated hydrocarbons of the aliphatic and cyclic series, amines of the aliphatic series, and pyridine.

Chlorin is used for the manufacture of: filter fabrics for aggressive fluids, diaphragm and electrode envelopes, cords for stuffing-boxes and packings, and overalls (mixed with natural fibers). Filter material with an increased tightness [illegible] non-shrinking after multiple heat treatment, [illegible] obtainable by heat treatment of normal woven chlorine fabrics. Medical underwear and mixed fabrics, drape, for example (GDR), are manufactured from Chlorin. The thermoplasticity of Chlorin make it possible to manufacture decorated fabrics by pressing on hot printing cylinders, and the shrinkability by heat treatment enables one to manufacture compressed and goffered fabrics from a mixture of Chlorin and other fibers.

The low lightproofness and heat resistance hinder widespread application of the Chlorin.

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Yu.Vs. Vasil'yev

CHLORINATION OF ALUMINUM ALLOYS – is the treatment of aluminum alloys in molten state by gaseous chlorine (refining by chlorine) in order to eliminate gaseous and solid nonmetallic inclusions. The equipment for the chlorination consists of a cylinder with chlorine, Tischenko's desiccator bottles containing sulfuric acid, a mercury manometer, and a quartz pipe. All these parts of the equipment are joined together by a steel pipe, and in the place which requires a flexible junction, by a rubber tubing. The cylinder with chlorine and the bottles must be placed in a separate room. The chlorination process is carried out in a bucket while removing the waste gases by exhaustion. The treatment by chlorine is carried out at a pressure of about 100 mm mercury column. The refining period depends on the quality of the charge. It is longer in the case of a strongly contaminated charge but must not surpass 10-12 min in order to prevent the growth of the grains in the cast material. The chlorine refining period for AL4 and AL5 alloys, for example, amounts to 10 minutes, that for AL1 and AL8 alloys – 7 min, and for alloys of the Duralumin type up to 7 minutes. Aluminum chloride is the result of the reaction of the chlorine with aluminum, and hydrogen chloride is formed by interaction of chlorine with the hydrogen dissolved in the metal. Aluminum chloride is present in the melt in a vaporized state. The gaseous and nonmetallic inclusions become adsorbed on the bubbles of aluminum chloride and hydrogen chloride and are removed with them by escaping on the surface. Chlorination is one of the most efficient adsorption methods of refining aluminum alloys; the corresponding measures of accident prevention must be taken, however, due to the toxicity of the chlorine. Chlorides (zinc chloride, manganese chloride, etc.) are also used instead of chlorine for the adsorption refining of aluminum alloys. Added to the molten metal, the chlorides react with aluminum according to the scheme: $3\ MeCl + Al = AlCl_2 + Me$. The gas bubbles and the solid inclusions become adsorbed in the escaping bubbles of aluminum chloride. The efficiency of the treatment by chlorides is considerably lower than that of the refining by gaseous chlorine.

References: Al'tman, M.B. [et al.], Plavka i lit'ye splavov tsvetnykh metallov [Melting and Casting of Nonferrous Metals], Moscow, 1963; Gorshkov, I.Ye., Lit'ye slitkov tsvetnykh metallov i splavov [Casting of the Ingots of Nonferrous Metals and Alloys], 2nd Edition, Moscow, 1952.

M.B. Al'tman

CHLOROPRENE LATICES (Neoprene latices, Nairit L) are latices obtained by emulsion polymerization of chloroprene or its mixtures with small quantities of other monomers. From the chloroprene latices obtained by the polymerization of a single chloroprene there can be prepared high-strength and elastic rubber products (tensile strength of 200 kg/cm^2 and over, relative elongation about 1000%) without reinforcing fillers. Just as the natural latex, the chloroprene latices give with ion deposition and gelatinization a strong and elastic gel which is widely used for the preparation of various rubber products using these methods. The products made from these latices exceed the corresponding products made from natural latex in ozone resistance, oil resistance, gas impermeability and flame resistance, but are inferior to them in cold resistance.

An important characteristic of the chloroprene latices is the capability of products made from them to vulcanize without the introduction of special vulcanizing agents with simple heating. The usual vulcanizing agents - sulfur, thiuram, Captax - not only are ineffective in the vulcanization of the chloroprene latices, but even retard the process; more complete vulcanization is achieved in the presence of zinc oxide, litharge, red lead or organic substances - paradinitrobenzene and the dithiocarbamates. In contrast with the other types of latices, large quantities of fillers cannot be introduced into the chloroprene latices without deterioration of the physico-mechanical properties of the products. Small quantities of carbon black or silic acid (5-10% by weight of the polymer) increase the strength and modulus of the vulcanizates, which is utilized in the preparation of sponge products made from these latices.

In connection with the presence in polychloroprene of active chlorine atoms, in the chloroprene latices there takes place a gradual splitting off of the hydrogen chloride, which leads to deterioration of the technological properties of the latices and finally to coagulation. Splitting off of the hydrogen chloride from the polychloroprenes must be kept in mind in the usage of the chloroprene latices in combination with materials containing cellulose; in these cases we must introduce into the latex mixtures neutralizing substances - borax, soda, etc. As a rule, the chloroprene latices have a strongly alkaline reaction. They are widely used for the preparation of thin-wall rubber products by the method of ion deposition - pilot balloon and radiosonde envelopes, industrial gloves, etc.; products with improved oil resistance are prepared from the copolymer chloroprene-nitrile latex, during the synthesis of which acrylonitrile is added to the chloroprene. Other areas of application of the chloroprene latices are rubberizing of fabrics, impregnation and bonding of paper, preparation of leather substitutes and sponge products, mine fire extinguishing, etc. These latices form an excellent base for glues, in particular the latices which can be synthesized at low temperatures; the latter, in particular, are used in the leather-footwear industry.

References: Synthetic Rubber, ed. by G.S. Whitby, transl. from Eng. L., 1957; Litvin O.B., Sinteticheskiye lateksy [Synthetic Latices], M.-L., 1953; Hartsfield E.P., "Rubber and Plast. Age", 1957, v. 38, No. 11, p. 970; Proizvodstvo i primeneniye sinteticheskikh lateksov [Production and Use of Synthetic Latices], L.-M., 1953; Sintez lateksov i ikh primeneniye [Synthesis of Latices and Their Use], coll. of articles, ed. by A.V. Lebedev et al., M., 1961.

A.I. Yezriyelev, A.V. Lebedev

CHLOROPRENE RUBBER – is the product of the polymerization of chloroprene in emulsion or of the copolymerization of chloroprene with a small amount of other monomers, such as styrene, isoprene or acrylonitrile. It is delivered under the trademark Nairit (USSR), Neopren (U.S.) and Perbunan C (German Federal Republic). Chloroprene rubber is worked on the usual equipment of the rubber industry, similar to natural rubber. Chloroprene rubber can be masticated by mechanical treatment, at the best, in a rubber mixer in presence of chemical plasticizers, a combination of diphenyl guanidine and Captax, for example. Introduction of 1-2% nickel dibutyl dithiocarbamate increases somewhat the stability of the chloroprene rubber and the resistance to thermal aging, it decreases also the scorching tendency and increases the resistance of the vulcanized product to ozone. Chloroprene rubber and compounds on its basis are very adhesive, this fact facilitates the assembling of multi-layer products. Nonfilled and black-carbon filled chloroprene rubbers are characterized by a high strength and elasticity, a good tear resistance, resistance to alternating deformations, to the growth of cuts and an adequately sufficient resistance to abrasion. The strength and elasticity of chloroprene rubbers are near to that of NK rubbers. Chloroprene rubbers are fire-resistant, they do not maintain combustion and extinguish themselves when ignited, they are light- and ozone-proof, oil-, benzene- and heat-proof, they have a low permeability for gases and are resistant to acids, alkalis and salts. The electric insulating properties of the chloroprene rubber are inferior to that of the butyl, natural, divinyl, and silicon rubbers. The somewhat increased water adsorption deteriorates the dielectric properties of the chloroprene rubber. Fillers, such as carbon blacks, kaolin, chalk, baryte, and metal oxides, do not increase the strength of chloroprene rubber compounds, but they improve their resistance to abrasion and promote the maintenance of the strength at elevated temperatures. Chloroprene rubbers for general and special purposes are produced in industrial scale. Nairit (N) grade A, with a plasticity according to Karrer of 0.65-0.72, and grade B, with a plasticity of 0.58 and 0.60, belong to the chloroprene rubbers for general purposes. The physicomechanical properties of nonfilled compounds of N are listed in Table 1, those of carbon-black filled in Table 2.

TABLE 1

Properties of Nonfilled Nairit Compounds

Показатели 1	
Модуль при 300%-ном удлинении (кг/см²) . . . . 2.	19–23
Сопротивление разрыву (кг/см²) 3.	300–330
Относительное удлинение (%) . 4.	950–1000
Остаточное удлинение (%) . . . 5.	15–20
Сопротивление раздиру (кг/см) . 6.	37–45
Твердость по ТМ-2 . . . . 7.	46–48
Эластичность по отскоку (%) . 8.	48–50
Температура хрупкости (°С) . . 9.	34–36
Коэфф. морозостойкости при 100%-ном удлинении и −35° . . . 10.	0.19–0.21
Коэфф. старения (после 5 суток при 100°): 11	
по сопротивлению разрыву 12.	0.89–0.92
13 по относительному удлинению	0.73–0.77

1) Characteristics; 2) modulus at 300% elongation (kg/cm^2); 3) tensile strength (kg/cm^2); 4) relative elongation (%); 5) residual elongation (%); 6) tear resistance (kg/cm); 7) TM-2 hardness; 8) resilience (%); 9) brittleness point (°C); 10) coefficient of frostproofness at 100% elongation and −35°; 11) aging coefficient (after 5 days at 100°); 12) for tensile strength; 13) for relative elongation.

N rubbers are resistant to swelling in gasoline, being inferior in this respect to divinyl nitrile rubbers and thiokols, but superior to the other types of synthetic rubbers; they show almost no change under the action of acids, alkalis and salt solutions; they are resistant to light and atmospheric effects and withstand for 3 hrs a concentration of ozone at which natural rubbers are degradated within 3 min. This combination of valuable technical properties provide a wide field of application for N rubbers. Owing to its good adhesiveness, high elasticity and resistance to alternating deformations, N is used for the production of flat belts, V-belts, and conveyor belts, including non-combustible belts for coal mining. The lifetime of V-belts and ventilator belts from N is 2-3 times longer than the lifetime of the same belts made from natural rubber. Delivering and sucking hoses for the petroleum industry, diverse packings for motorcars and aircraft, protecting coating for ship-, mining- and technical cables are made from N. N is successfully used in the production of high-quality substitutes of leather, for lining of chemical apparates, especially of such for concentrated hydrochloric acid.

TABLE 2

Properties of Nairit - Carbon-Black Compounds

1 Показатели	Смесь промазочная * 2	Смесь набельная ** 3	Смесь протекторная *** 4
5 Модуль при 300%-ном удлинении (кг/см²)	62	[illegible]	79
6 Сопротивление разрыву (кг/см²)	114	[illegible]	142
7 Относительное удлинение (%)	600	450	650
8 Остаточное удлинение (%)	12	16	18
9 Свойства при 100°			
6 Сопротивление разрыву (кг/см²)	47	35	[illegible]
7 Относительное удлинение (%)	350	320	360
10 Свойства после старения в течение 120 час. при 100°			
6 Сопротивление разрыву (кг/см²)	113	78	131
7 Относительное удлинение (%)	467	300	495
11 Сопротивление раздиру (кг/см)	47	41	69
12 Твердость по ТМ-2	54	72	58
13 Эластичность по отскоку (%):			
14 при 20°	40	33	45
» 60°	48	45	57
» 100°	54	[illegible]	63
15 Теплообразование при многократном 40%-ном сжатии (°С)	79	104	107
16 Температура хрупкости (°С)	-41	-33	34
17 Коэф. морозостойкости при 100%-ном удлинении и -35	[illegible]	[illegible]	0.32

* 40 parts by weight of lamp carbon black, 10 parts by weight of dibudibutyl phthalate, 7 parts by weight of vaseline oil;

** 7.5 parts by weight of dibutyl phthalate, [illegible] parts by weight of vaseline oil;

*** 20 parts by weight of burner carbon black, 10 parts by weight of anthracene carbon black, 2 parts by weight of dibutyl phthalate, 5 parts by weight of vaseline oil.

1) Characteristics; 2) friction compound*; 3) calico compound**; 4) protecting compound***; 5) modulus at 300% elongation (kg/cm^2); 6) tensile strength (kg/cm^2); 7) relative elongation (%); 8) residual elongation (%); 9) properties at 100°; 10) properties after aging at 100° for 100 hrs; 11) tear resistance (kg/cm); 12) TM-2 hardness; 13) resilience (%); 14) at; 15) heat building during multiple compression by 40% (°C); 16) brittleness point (°C); 17) coefficient of frostproofness at 100% elongation and −35°.

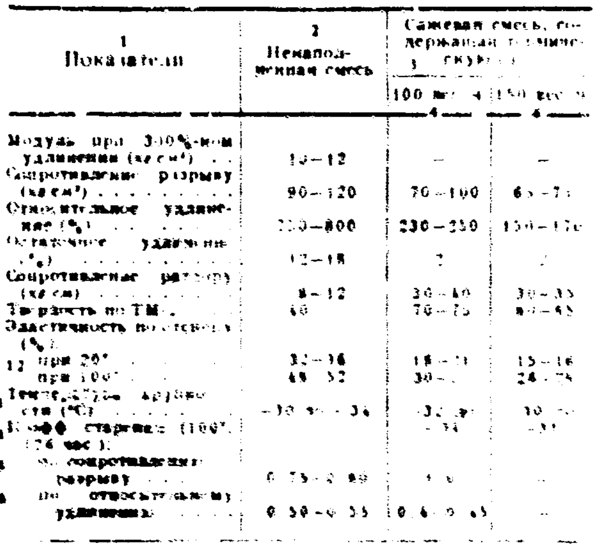
The copolymer of chloroprene with styrene is nairit S (NS) (USSR), or Neopren RT (U.S.), a rubber for general purposes near, with regard to its properties, to N, but with better workability, a lower tendency to scorch and a somewhat higher frostproofness. The brittleness point of NS rubbers is 3-5° lower than that of N compounds. NS rubbers are inferior to N rubbers with regard to their physicomechanical characteristics. The tensile strength of nonfilled rubbers is 250-280 kg/cm^2 at a relative elongation of 700-800%. They are also somewhat inferior to N rubbers in the chemical stability, especially in the resistance to ozone. With regard to the other characteristics, NS rubbers do not differ to a great extent from N rubbers. NS is practicable for the same purposes as N. The better workability permits the use of it in the production of autocar tires for trying roads; tires for stony roads, especially in countries with a torrid climate, are also prepared from it. The copolymer of chloroprene with acrylonitrile is delivered under the trademarks Nairit N (NN) (USSR) and Neoprene Q (U.S.). NN is characterized by a very good resistance to gasoline and oil. The swelling of NN kept for 24 hrs at room temperature in mineral oil amounts to 5-7% by volume, and is equal to 12-15% by volume in the case of gasoline. NN rubbers prove an elevated thermal and chemical resistance, their physicomechanical properties do not differ essentially from those for N rubbers. The low frostproofness is an essential disadvantage of NN. The brittle-

[illegible] point for [illegible] phthalate improves the frost [illegible] the swelling of NN rubbers in oils and gasoline [illegible] of the plasticizer. Diverse oil- and gasoline resistant products are made from NN. The liquid chloroprene rubber is a new type of chloroprene rubbers, it is delivered under the commercial term liquid Nairit (ZhN) (USSR) and Neoprene KNR (U.S.). ZhN is easily masticable on rolls, forming a readily soluble polymer which gives high-concentrated solutions (70-75%). Chemical plasticizers, usually 0.15-0.25 parts by weight of mercaptobenzothiazole (Captax) and diphenyl guanidine (DFG) per 100 parts by weight ZhN, are used to promote the mastication. 1-2 parts by weight of tetramethyl thiuram disulfide (Thiuram D) or tetraethyl thiuram disulfide (Thiuram E) are additionally introduced in order to increase the activity.

The physicomechanical properties of vulcanized ZhN are quoted in Table 3.

TABLE 3

Physicomechanical Characteristics of ZhN



1 Показатели	2 Ненаполненная смесь	3 Сажевая смесь, содержащая термическую сажу	
		100 вес. ч. 4	150 вес. ч. 4
5 Модуль при 300%-ном удлинении (кг/см²)	10–12	—	—
6 Сопротивление разрыву (кг/см²)	90–120	70–100	65–75
7 Относительное удлинение (%)	[illegible]0–800	230–250	150–170
Остаточное удлинение (%)	12–18	[illegible]	[illegible]
9 Сопротивление раздиру (кг/см)	8–12	30–40	30–35
10 Твердость по ТМ-2	40	70–75	80–85
11 Эластичность по отскоку (%):			
12 при 20°	32–36	18–[illegible]	15–16
при 100°	48–52	30–[illegible]	24–28
13 Температура хрупкости (°C)	−30 до −36	−32 до −34	−30 до −33
14 Коэфф. старения (100°, 76 час):			
15 по сопротивлению разрыву	0,75–0,89	[illegible]	—
16 по относительному удлинению	0,50–0,55	0,6–0,65	—

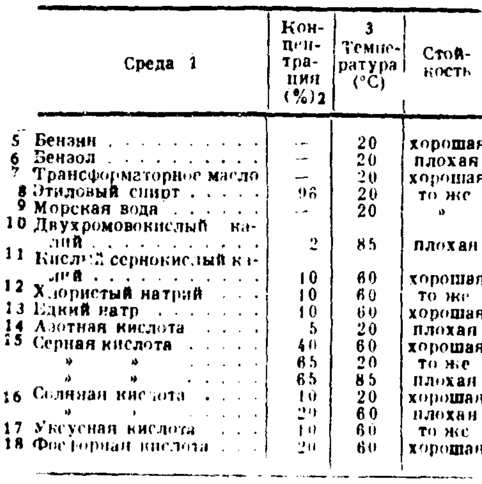
1) Characteristics; 2) nonfilled compound; 3) compound containing thermal black; 4) parts by weight; 5) modulus at 300% elongation (kg/cm²); 6) tensile strength (kg/cm²); 7) relative elongation (%); 8) residual

elongation (%); 9) tear resistance (kg/cm); 10) TM-2 hardness; 11) resilience (%); 12) at; 13) brittleness point (°C); 14) aging coefficient (110°, 126 hrs); 15) for tensile strength; 16) for relative elongation.

A solution of ZhN in a composition of 76% solvent, 19% turpentine, and 5% n-butanol is used for rubberizing diverse equipments. 90% solutions are used to apply coatings with a palette-knife, 65-70% solutions for painting, 50-60% for dipping or spraying. The vulcanization of the films is carried out with hot air (at 100-142°), live steam, hot water, or irradiation with an infrared lamp. A previous priming with chloronairit glue or epoxy-primer is used owing to the insufficient adhesion of ZhN to metals. ZhN coatings reliably protect metals from corrosion by the aqueous solutions of many acids, alkalis and salts, but they are not resistant to oxidizing agents, aromatic and halogen-containing solvents. The upper limit of the working temperature of the coatings is 70°, a short working at 90-100° is permissible.

The chemical stability of coatings on basis of ZhN is characterized by the following data:

TABLE



Среда 1	Концентрация (%) 2	3 Температура (°C)	Стойкость 4
5 Бензин	—	20	хорошая 19
6 Бензол	—	20	плохая 20
7 Трансформаторное масло	—	20	хорошая 19
8 Этиловый спирт	96	20	то же 21
9 Морская вода	—	20	»
10 Двухромовокислый калий	2	85	плохая 20
11 Кислый сернокислый калий	10	60	хорошая 19
12 Хлористый натрий	10	60	то же 21
13 Едкий натр	10	60	хорошая 19
14 Азотная кислота	5	20	плохая 20
15 Серная кислота	40	60	хорошая 19
» »	65	20	то же 21
» »	65	85	плохая 20
16 Соляная кислота	10	20	хорошая 19
» »	20	60	плохая 20
17 Уксусная кислота	10	60	то же 21
18 Фосфорная кислота	20	60	хорошая 19

1) Medium; 2) concentration (%); 3) temperature (°C); 4) resistance; 5) gasoline; 6) benzene; 7) transformer oil; 8) ethanol; 9) sea water; 10) potassium bichromate; 11) potassium monosulfate; 12) sodium chloride; 13) sodium hydroxide; 14) nitric acid; 15) sulfuric acid; 16) hydrochloric acid; 17) acetic acid; 18) phosphoric acid; 19) good; 20) poor; 21) the same.

ZhN surpasses varnish and plastic coatings with respect to the wear by abrasion. ZhN solutions are practicable to rubberize pieces and products with a complicates shape (nets, bellows, springs, etc.) which cannot be protected by sheet rubber. Owing to the absence of seams, the coatings are practicable in vacuum. ZhN is used to rubberize propellers of trawlers, steel jackets of refrigerators and condensers made from nonferrous metals, the inner hollows of diaphragm valves, and of tools to prevent sparks casued by impacts, etc. ZhN is also practicable for hermetic sealing of the vacuum-condensor pipes of steam turbines. Chloroprene rubber polymerized at low temperature [Nairit NT (NNT) (USSR), Neopren AC and Neopren AD (U.S.)] is used for the production of adhesives. Nonfilled rubber on NNT basis have the following physicomechanical characteristics: modulus at 300% elongation 50-60 kg/cm^2; tensile strength 340-380 kg/cm^2; relative elongation 910-960%; residual elongation 10-12%; Shore hardness 82-89; resilience (%): 38-40 at 20°, 63-65 at 100°; aging coefficient at 100° and 120 hrs: for the tensile strength 0.96-1.08, for the relative elongation 0.87-0.90; brittleness point −38°. The compounds for the preparation of adhesives contain 15-20 parts by weight zinc oxide, 4 parts by weight colophony, 1.5 parts by weight thiuram, and 1.5 parts by weight iron chloride per 100 parts by weight of NNT. Iron chloride serves as an accelerator of the vulcanization. 10-15 parts by weight of magnesium silicate or resorcine may be introduced in order to increase the adhesion of the adhesive at elevated temperature. The heat resistance of the adhesive film may also be increased by introduction of phenolformaldehyde resins or of divinylnitrile rubbers; armatic and chlorinated hydrocarbons are used as solvents. A mixture of ethyl acetate and gasoline in 1:1 ratio has the lowest toxicity. Adhesives on NNT basis prove a high stability of the joints which is not inferior to that obtained by means of natural guttapercha.

I-39K7

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I.V. Borodina

CHLOROSULFONATED POLYETHYLENE – is a polyethylene derivative with a mean molecular weight of 20,000. It contains 27% chlorine and 1.5% sulfur. Chlorosulfonated polyethylene is produced in the USSR under the name KhSPE, and abroad under the name Hypalon. The chlorosulfonated polyethylene is obtained in the form of white rubberlike crumbs. Its specific gravity is 1.1; it is completely soluble in aromatic and chlorinated hydrocarbons; it swells, but does not dissolve in ketones and ethers; it is insoluble in aliphatic hydrocarbons, alcohols and glycols.

The viscosity of the chlorosulfonated polyethylene is 28-31 according to Mooney (it is equal to 30-50 for neoprene and natural rubber). The low viscosity of the chlorosulfonated polyethylene involves a rapid formation of a sheet and a good distribution of the ingredients during rolling. Chlorosulfonated polyethylene is manufactured on the usual equipment; a previous plasticization is not necessary; the temperature for the preparation of compounds is about 40°. It is desirable to carry out the calendering at a temperature not higher than 60°, although an increase in the temperature up to 100° is permissible (chlorosulfonated polyethylene possesses the highest plasticity at this temperature). Chlorosulfonated polyethylene is miscible with all rubbers; it imparts to them an improved resistance to ozone.

Metal oxides (PbO, MgO, ZnO) and their hydrates, stearates, naphthenates, aliphatic and aromatic diamines, urea and thiourea, amides and thioamides, carbamates and thiocarbamates, guanidine, ethanolamines, etc., serve as vulcanizers for chlorosulfonated polyethylene. The organic vulcanizers are applied together with an acceptor. Vulcanization occurs by interaction of the vulcanizers with the chlorosulfonic groups of the polymer or with the chlorine atoms. Zinc dibutyl dithiocarbamate, tetramethyl thiuramdisulfide, mercaptobenzothiazole, and diphenyl guanidine are used as rubber accelerators. Vulcanizates with good mechcanical properties are obtainable without addition of fillers to the compound. An increased dosage of carbon black increases insignificantly the tensile and tearing strength, and causes a rise of the brittleness point from −40° to −17° (the brittleness point of rubbers containing 10-12% filler is −57°, −62°, that of rubbers with 25% filler is −20°, −30°). An addition of 30-50 parts by weight of carbon black for 100 parts by weight of the rubber reduces, however, the shrinkage of the compounds and enables it to obtain a smooth surface by calendering. Addition of powdered silica gel is recommended for the manufacture of heat resistant vulcanizates. Naphthene oils combined with factice are the best plasticizers.

Rubbers based on 95 parts by weight chlorosulfonated polyethylene and 5% natural rubber and containing 25 parts by weight lamp black possess a tensile strength of 146 kg/cm^2 and a relative elongation of 230%; the tensile strength of rubbers made from 100% chlorosulfonated polyethylene without black is equal to 80 kg/cm^2.

The vulcanizates of chlorosulfonated polyethylene excellently resist the growth of cracks and alternating stresses; they are also highly resistant to aging by ozone, they do not crack at any ozone concentration and surpass, in this respect, the vulcanizates of nairite and butyl rubber by 10 times. Chlorosulfonated polyethylene surpasses all other polymers including neoprene in respect to the resistance to atmospheric effects. The chlorosulfonated polyethylene vulcanizates possess a sufficient stability to the action of oils, swelling only by

1/3 more than the filled vulcanizates of neoprene.

Fabrics coated by chlorosulfonated polyethylene are resistant to chemical reagents and atmospheric effects; they are colorable, the color is permanent, and they possess a high gastightness. Fine, flexible, many-colored and lustrous coatings on molded and extruded rubber products may be prepared from chlorosulfonated polyethylene. The dye fastness and chemical stability of chlorosulfonated polyethylene make possible its application for the production of dyestuffs for metals, wood, brickworks and stoneworks. The resistance of the chlorosulfonated polyethylene to scratches, wearing and notches enables one to use it for the production of floor tiles. Chlorosulfonated polyethylene can also be used for the production of the white sides of tires due to its dye fastness, the excellent resistance to natural aging, and the high resistance to ozone.

References: Andrianov, Yu.F., Burova, I.K. and Budlevskaya, S.Ye., "Kauchuk i rezina" [Caoutchouc and Rubber], 1961, No. 8; Koshelev, F. F. and Klimov, N.S., Obshchaya tekhnologiya reziny [General Technology of Rubber], 2nd Edition, Moscow, 1958.

Z.M. Krutova

Manuscript Page No.	[Transliterated Symbols]
791	ХСПЭ = KhSPE = khlorsul'firovannyy polietilen = chlorosulfonated polyethylene

III-17kh

CHROMAL – ia an alloy with a high electrical resistance (ρ = 1.4 ohm•mm^2/m) used for the manufacture of heating elements of electric furnaces. The chemical composition is as follows: 65% Fe, 30% Cr, and 5% Al. The alloy is scale-resistant up to 1250°. Chromal is produced as the grade 0Kh27Yu5A according to GOST 9232-59. See <u>Alloys for heating elements</u>.

<u>References</u>: Semenova, N.V. and Zhukov, L.L., "Stal'" [Steel], 1959, No. 7, page 652.

F.F. Khimushin

CHROME BRONZE — is a bronze which contains a small quantity (up to 1%) of chromium and a number of other additives. Chrome bronze is characterized by a high electrical and thermal conductivity and also by heat resistance and a higher recrystallization temperature. Chromium is slightly soluble in copper; the solubility attains 0.65% at the temperature of the eutectic (1072°), it drops rapidly at lower temperatures and amounts to only 0.02% at 400°. Chrome bronze is easily workable by pressing in hot and cold state. The strength, hardness and also the electrical and thermal conductivity of the alloys are considerably increased after heat treatment (quenching in water at a temperature of 980-1000° and tempering at 480° for 4 hrs).

Additions of small quantities of other metals, especially of zirconium, which forms with chromium a high-melting chemical compount (Cr_2Zr) insoluble in copper, also improve the properties of chrome bronze. Heat-resistant bronzes (MTs5, MTs5A) are developed by additive chromium and zirconium. When small quantities of zinc and cadmium are added to the chrome bronze grades EV and MTs5B, the heat-resistance is increased while the high electrical and thermal conductivities are unchanged; the heat-resistance of these bronzes, however, is lower than that of chrome bronzes with zirconium. Impurities of lead, bismuth and antimony are harmful because they seriously impair the technological properties of chrome bronze.

Binary chrome bronzes and ones with a more complex composition are used for the production of parts which must possess heat-resistance and high electrical and thermal conductivities, especially for the design of the electrodes in spot and contact-roller welding devices, for commutators of electric motors, etc. See *Malleable heat-resistant bronze*.

References: Zakharov, M.V., "Metallovedeniye i obrabotka metallov" [Metal Science and Metal Working], 1956, No. 5; Smiryagin, A.P., Promyshlennyye tsvetnyye metally i splavy [Commercial Nonferrous Metals and Alloys], 2nd Edition, Moscow, 1956.

O.Ye. Kestner

III-25kh

CHROME COATINGS — are layers of pure chromium deposited electrolytically from aqueous solutions on the surface of diverse metal objects. Electrolytic chrome-plating is widely used in machine building due to the special properties of the electrolytic chromium. Electrolytically deposited chromium possesses a very low coefficient of friction, this fact causes a high wear-resistance (resistance to abrasion) of the chromium surface in the case of sliding friction. The coefficient of friction of the chrome-plated surface amounts only to a fraction of that of hardened steel. The coefficient of friction on gray iron, bronze and babbit, for example, has the following values:

Chrome-plated surface: 0.06; 0.05, and 0.08.

Hardened steel: 0.22; 0.11, and 0.19.

The friction coefficient (with lubrication) of a chrome-plated surface on the AK-4 aluminum alloy is:

0.021 for a chrome-plated ground roll.

The chromium coating hardly tarnishes. It maintains its luster and reflectance even in a moist medium; it is resistant to the effects of higher temperatures, and an observable oxidation, accompanied by temper colors, sets in only at 480-500°. Chromium coatings are not solderable, and paint and varnish coatings do not stick on them due to the low adhesion. Chromium is not significantly wettable by fluids and molten metals.

For special purposes, the chromium may be passivated by boiling in oxidizing agents such as nitric acid or a solution of potassium permanganate. Hydrochloric acid and even hot sulfuric acid do not affect chromium for a long time after such a treatment.

The uses of chrome-plating may be subdivided into four groups:

Decorative coating, a lustrous coating applied in the form of several layers on the surface of steel or other metals.

Heatproof coating is applied mainly to prevent the formation of cinder on the surface of steel parts working at high temperature (the chromium layer is thicker than 50 μ). Depending on the heat-resistance of the metal, such a coating may work at 850-900° for a long time (up to 100 hrs).

Hard wear-resistant coating is applied to prolong the service life of parts working under sliding or rolling friction (cylinders of diesel and other internal combustion engines) and also to prolong the service life of steel tools.

Hard porous chrome-plating is used for parts submitted to sliding friction on places with insufficient lubrication, for piston rings and engine cylinders, for example. The porous chromium coating retains the lubricant on its surface and becomes broken in rapidly.

The dense and porous chromium coatings are used to restore the dimensions of worn parts (repair variant), and also those of new parts whose dimensions were reduced below the standard during machining.

The chrome-plated parts are heated at 180-200° in a neutral or oily medium (or in a case) to remove the brittleness. The chromium coating is polished by a medium-hard precision SM-2 grindstone (with a grain size of 60-80) under a flood of the coolant at a disc-speed of 15-20 m/sec. Polishing removes a significant chromium layer (50-100 μ) in the case of hard dense coating as well as in that of a porous coating. Porous chromium (after the formation of the pores) is frequently honed in the presence of a coolant (emulsoles or, better, kerosene). The honing (polishing of the porous chromium) is sometimes carried out before the pores are formed.

All commercial iron-base alloys, and also cast iron grades, aluminum and titanium alloys may be chrome-plated. Chrome-plated parts working under sliding friction and under significant loads must have a finished surface of the 7-9th class of quality. Practical experience proves that chrome-plated parts with a surface quality of the 10th class and higher frequently seize up.

References: Bilfinger, R., Tverdoye khromirovaniye [Hard Chrome-Plating], translated from German, Moscow, 1947; Tupitsyn, G.I., Svoystva poristykh khromovykh pokrytiy [The Properties of Porous Chromium Coatings], Moscow, 1945 (Dissertation); Levitskiy, G.S., Khromirovaniye detaley mashin i instrumenta [Chrome-Plating of Machine Parts and Tools], 2nd Edition, Kiev-Moscow, 1956; Pertsovskiy, M.L., Poristoye khromirovaniye [Porous Chrome-Plating], Moscow-Sverdlovsk, 1949; Akimov, G.V., Teoriya i metody issledovaniya korrozii metallov [Theory and Methods of the Investigation of Metal Corrosion], Moscow-Leningrad, 1945.

G.I. Tupitsyn

CHROMEL – is an alloy of the NKh9.5 grade used in pyrometry as the positive thermoelectrode in chromel – alumel (KhA) and Chromel – Copel (KhK) thermocouples, and also the alloy of the NKh9 grade for compensatory leads. The chemical composition of chromel is listed in Table 1; the temperature dependence of the physical properties of the NKh9.5 chromel is listed in Table 2.

TABLE 1

Chemical Composition of the Chromel (GOST 492-52)

1 Сплав	2 Осн. компоненты (%)		3 Примеси (%, не более)													4 Применение
	Cr	Ni+Co *	Fe	Si	Mg	Mn	Cu	Pb	S	C	P	Bi	As	Sb	Всего	
НХ9,5 5	9,0–10,0	Остальное 6	0,4	0,2	0,05	0,3	0,2	0,002	0,02	0,3	0,003	0,002	0,002	0,002	1,40	Проволока для термоэлектродов термо-пар 7
НХ9 8	8,5–9,5	То же 9	0,4	0,2	0,05	0,3	0,2	0,002	0,02	0,3	0,003	0,002	0,002	0,002	1,40	Проволока для компенсац. проволов 10

*Co is added as a trace element to the nickel in order to secure the required value of the thermo-emf. A Co content within 0.6-1.0% is specified in the new edition of the GOST.

1) Alloy; 2) main components (%); 3) impurities (%, not more than); 4) application; 5) NKh9.5; 6) the rest; 7) wire for the thermoelectrodes of thermocouples; 8) NKh9; 9) the same; 10) wire for compensatory leads.

Chromel wire, just like wire from alumel and copel alloys, is available in four grades, according to GOST 1790-63, based on the value of the thermo-emf when coupled with pure platinum at a 0° temperature of the free ends and the corresponding standard temperatures of the free ends and the corresponding standard temperatures of the working ends.

TABLE 2

Temperature Dependence of the Physical Properties of the NKh9.5 Chromel Grade

Темп-ра (°C) 1	ρ_t (ом·мм²/м) 2	ρ_t/ρ_0	3 Температурный коэфф. электросопротивления	4 Термоэдс в паре с чистой платиной при темп-ре свободных концов 0° (мв)
0	0,612	1,00	0,000490	0,00
100	0,642	1,05	0,000467	3,00
200	0,672	1,09	0,000411	6,20
300	0,703	1,15	0,000357	9,55
400	0,725	1,19	0,000276	12.95
500	0,745	1,22	0,000228	16,30
600	0,762	1,24	0,000236	19,70
700	0,780	1,28	0,000230	23,05
800	0,798	1,30	0,000238	26,25
900	0,817	1,33	0,000220	29,45
1000	0,835	1,36		32,55

1) Temperature (°C); 2) ρ_t (ohm•mm^2/m); 3) temperature coefficient of the electrical resistance; 4) thermo-emf when coupled with pure platinum at a 0° temperature of the free ends (mv).

TABLE 3

Dependence of the Physico-mechanical and Electric Properties of the Chromel Grade NKh9.5 on the Degree of Cold Deformation

1 % деформации	2 HB (кг/мм²)	σ_b (кг/мм²) 3	δ* (%)	4 ρ (ом·мм²/м)	Электропроводность по отношению к меди (%) 5	6 γ (г/см³)
0	206	80	36,0	0,66±0,05	2,47	8,71
10	225	82	18,0	0,674	2,47	—
20	244	84	11,0	0,674	2,47	8,71
30	263	92	5,0	0.666	2,50	—
40	286	100	5,0	0,652	2,55	8,72
50	300	104	4,0	0,642	2,59	—
60	305	108	3,0	0,636	2,62	8,70
70	311	112	3,0	0,632	2,63	—
80	320	114	2,0	0,628	2,65	8.63

*A 100 mm long rod.

1) Percentage of deformation; 2) HB (kg/mm^2); 3) σ_b (kg/mm^2); 4) ρ (ohm•mm^2/m); 5) electrical conductivity in comparison to copper (%); 6) γ (g/cm^3).

III-19kh2

The effect of cold deformation on the change of the physicomechanical and electric properties of the NKh9.5 chromel grade are quoted in Table 3 (Tables 1, 2, and 3 see [original] page 421).

References: Berkovskiy, I.Ya. and Kolokolova, A.G., Nikelevyye splavy [Nickel Alloys], Moscow-Leningrad, 1941; Slavinskiy, M.P., Fizikokhimicheskiye svoystva elementov [Physicochemical Properties of Elements], Moscow, 1952; Smiryagin, A.P., Promyshlennyye tsvetnyye metally i splavy [Commercial Nonferrous Metals and Alloys], 2nd Edition, Moscow, 1956; Hessenbruch, W., Metalle und Legierungen für hohe Temperaturen [Metals and Alloys for High Temperatures], Berlin, 1940.

A.L. Shpitsberg

CHROME-PLATING OF ALUMINUM ALLOYS – is the electroplating of parts made from aluminum alloys by a chromium layer in order to protect them from mechanical wearing (hard or wear-resistant chrome-plating) or for decorative purposes (decorative and protective chrome-plating). The hard, 50 μ thick chromium layer provides a high wear and corrosion resistance for parts made from aluminum alloys working under friction. The chrome-plating is recommended for simple-shaped parts which are not submitted to impact loads in service. Impacts cause hollows, and the chromium may splinter off. The possibility of the coating cracking, due to the great difference in the linear expansion coefficients of chromium ($\alpha_{20} = 8.24 \cdot 10^{-6}$) and aluminum ($\alpha_{20} = 22.4 \cdot 10^{-6}$), must be taken into account in the case of parts working at high temperatures. A separation of the chromium layer does not take place in this case. The decorative and protective chrome-plating of aluminum alloys is carried out on a nickel underlayer (see Nickel-plating of aluminum alloys).

References: Layner, V.I., Gal'vanicheskiye pokrytiya legkikh splavov [Electro-Plating of Light Alloys], Moscow, 1959.

N.V. Garshina

CHROME-PLATING OF STEEL – is the saturation of the surface of low-carbon steel with chromium in order to improve the corrosion resistance and acidproofness. Chrome-plating of medium-carbon and high-carbon steel also greatly improves its hardness and wear-resistance. The chrome-plating is carried out with a powdered mixture composed of 50% ferrochrome, 45% Al_2O_3, and 5% NH_4Cl. The process is also performed in vacuum furnaces at a vacuum of $1 \cdot 10^{-2}$-$1 \cdot 10^{-3}$ mm mercury column, in a gaseous medium (H_2 + HCl or HCl), or in a ceramic body (previously impregnated with chromium chlorides). A 0.10-0.12 mm thick chrome-plated layer (a solid solution of chromium in α iron with a microhardness of about 160 kg/mm^2) is formed on 08 steel at 1000° within 8-10 hours; a 0.02-0.03 mm thick layer (chromium carbide, $Cr_{23}C_6$, with a microhardness higher than 1300 kg/mm^2) is formed on U10 steel. Chrome-plating of steel is used in the manufacture of chains for wood-cutting motor-saws, of steel-punches for knocking bolts out, of nozzles, of barette and smooth-cut files, and of parts working in the atmosphere and in aggressive media.

<u>References</u>: Dubinin, G.N., Diffuzionnoye khromirovaniye splavov [Diffusion Chrome-Plating of Alloys], Moscow, 1964; Gorbunov, N.S., Vakumnyy metod termokhromirovaniya [Vacuum Method of Thermal Chrome-Plating], Moscow, 1955.

A.N. Minkevich

CHROME-PLATING OF TITANIUM ALLOYS – is the application of a chromium layer on the surface of titanium alloys by means of electrodeposition; it is used to improve the antifriction properties and to obtain an underlayer for other metals.

A difficulty of electroplating is the method with which to activate the surface of titanium and its alloys: it must replace the natural oxide film by a film which protects the metal from oxidation and which has a higher chemical activity. Of all the methods of preparing the surface of titanium and its alloys for plating with chromium and for copper-plating (see Copper-plating of titanium alloys), the electropolating methods are the most thoroughly investigated ones. Chemical pickling in a solution of sulfuric acid at a raised temperature, in concentrated hydrochloric acid, in a mixture of hydrochloric or nitric acids with hydrofluoric acid, in a mixture of solutions of sulfuric and phosphoric acids, in a solution of hydrofluoric acid in ethylene glycol, etc., are recommended for this purpose. A film of titanium hydride, with a higher electrical conductivity than the oxide film, is formed on the surface of titanium and its alloys during the pickling in acids, and the electroplating is applied subsequently on this film. The other principal method for activating the surface is treatment with a solution of zinc salts and hydrofluoric acid in ethylene glycol, resulting in an electrochemical or contact deposition of a thin zinc layer (with a thickness of a few μ) which does not adhere to the basic metal but maintains the active state of the surface and becomes dissolved in the chromium electrolyte when the chrome-plating begins. This method, however, is less reliable and is more rarely applied. Pickling at a-c in solutions of acetic and hydrofluoric acids, electrochemical treatment in a melt of salts, treatment with surface-active agents, etc. are also recommended.

The chrome-plating of titanium alloys is carried out, after activation of the surface, in the same manner as the chrome-plating of steel (see Chrome-plating of steel). Tempering at 750-850° in air takes between 30 min and 2 hours and is carried out immediately after the chrome-plating in order to improve the cohesion between the chromium and the basic metal. The tempering results in a destruction of the hydride film (when it is present) and a diffusion of the chromium into the titanium, forming interlayers which secure a good adhesion of the chromium coating on the basic metal. The plating of titanium and its alloys with chromium or other metals by means of electrodeposition may cause a considerable brittleness in any layer of the basic metal due to its hydrogenation during the pretreatment of the surface by pickling and also during the chrome-plating process itself due to the formation of intermetallic compounds in the intermediate diffusion zone during the tempering. The chrome-plating is carried out in one stage when the chromium serves as an underlayer for other metals. The tempering may be carried out immediately after the chrome-plating or after the other metal layer is applied.

Chrome-plating of titanium alloys to improve the antifriction properties is carried out in two stages. First, a dull 15-20 μ thick chromium layer is applied, the diffusion tempering follows, and then a second chrome-plating with a lustrous chromium layer of the required thickness is carried out after the chromium oxide has been removed from the surface (by grinding or electrochemical pickling).

References: Layner, V.I., Gal'vanicheskiye pokrytiya legkikh splav-

ov [Electroplating of Light Alloys], Moscow, 1959; Burdina, S.M. and Samartsev, A.G., "Zhurnal prikladnoy khimii," 1960, Vol. 33, No. 5, page 1141; Batashev, K.P., Osazhdeniye gal'vanicheskikh pokrytiy na titan i yego splavy [Deposition of Electrocoatings on Titanium and Its Alloys], Leningrad, 1959; Missel, L., "Metal Finish," 1958, Vol. 56, No. 9, pages 49-51; Levy, C., ibid., 1960, Vol. 58, No. 5, pages 49-55.

I.S. Anitov

CHROME STEEL FOR PERMANENT MAGNETS — see Alloyed steel for permanent magnets.

CHROMIUM, Cr, is a chemical element of the VIth group of Mendeleyev's Periodic System, the atomic number is 24, the atomic weight is 51.996. The natural chromium is composed of 4 stable isotopes: Cr^{50} (4.31%), Cr^{52} (83.76%), Cr^{53} (9.55%), and Cr^{54} (2.38%); various artificial radioactive isotopes of Cr had been prepared using nuclear reactions, the most significant of them are: Cr^{49} ($T_{1/2}$ = 41.7 min), and Cr^{51} ($T_{1/2}$ = 27.8 days). Chromium is similar to Mo and W with respect to a number of physicochemical properties.

The chromium resources in the crust are large and surpass the total of all other high-melting metals. Crhome-iron ores, widespread in the USSR, are the basic natural chromium ores. Metallic chromium is prepared mainly by aluminothermal and silicothermal methods. High-grade chromium is obtained by electrolysis and subsequent refining in dry hydrogen at 1500-1600°. Other methods for the preparation of metallic chromium are not significant for the industry. Refined chromium is remelted in electrical induction or arc vacuum furnaces in an atmosphere of a purified inert gas (argon or helium or a mixture of them).

Machine parts of chromium are obtained by precise casting or by deformation. Depending on the purpose and the conditions the deformation is carried out between 700 and 550°. The heating of the metal at high temperatures is carried out in an atmosphere of purified hydrogen or inert gas; the deformation is done in air. Chromium sustains a reduction of more than 90% during one passage of the tool. The pressing of a billet of 100 mm diameter into a rod is carried out (at 1500°) under the following specific pressures: reduction by 80% at 75 kg/mm^2; by

85% at 90 kg/mm^2; by 90% at 120 kg/mm^2, and by 95% at 150 kg/mm^2. The specific pressure is reduced and the life of the tool is increased when a lubricant is used.

Rods, strips, sheet-bars and sheets with a thickness up to 0.8 mm are made from chromium by deformation. Chromium sheets with a thickness up to 0.3 mm plated with stainless steels and alloys, are also manufactured.

Chromium is satisfactorily machinable by all cutting methods; machining with abrasive tools, however, may cause cracks on the surface of the parts. The finished objects are pickled in order to detect surface flaws (see Corrosion of Chromium). The cutting of the sheets by means of shears, and the bending are carried out at 600-700°.

Chromium is weldable with chromium, stainless steels and alloys by means of electron-beam, argon-arc, and resistance welding after preheating of the metal.

The physical properties of chromium depend on the nature and quantity of impurities. The stable chromium lattice is a body-centered cube with a lattice constant of 2.8787 A. Chromium with other lattice types may be obtainee by electrolysis. With time, however, especially after heating of the metal, a polymorphous transformation of the nonequilibrium into the equilibrium lattice takes place.

Refined chromium has a t°_{pl} of 1910°, and a t°_{kip} of 2469°. Impurities lower the t°_{pl}. The t°_{pl} becomes lowered by heating in hydrogen atmosphere and, especially, in nitrogen. Chromium possesses a high vapor pressure (in atm): 10^{-9} (at 1000°); 10^{-7} (at 1150°); 10^{-5} (at 1270°); 10^{-4} (at 1520°); 10^{-3} (at 1590°), and 10^{-2} (at 1810°). The solid liquid and gaseous phases of chromium are in equlibrium at the t°_{pl} when the gaseous phase has a pressure of 63.5 mm mercury column. At a higher pressure, a transition of chromium from the solid into the liquid phase occurs, and at a lower pressure it transforms directly from the solid into the gaseous phase, avoiding the liquid phase. The sublimation heat is 84-95 kcal/g-atom. The evaporation rate of the chromium at a pressure of 10^{-6} mm mercury column is equal to (in g/cm^2.sec): $9.86 \cdot 10^{-7}$ (at 1355°); $7.3 \cdot 10^{-6}$ (at 1455°), and $1.92 \cdot 10^{-5}$ (at 1561°). The temperature dependence of the evaporation of chromium in an absolute vacuum is (in cm/year): 10^{-5} (at 750°); 10^{-3} (at 870°), and 10^{-1} (at 1000°). The boiling point depends on the pressure as follows: 2469° (at 760 mm mercury column); 1787° (at 10^{-1}); 1637° (at 10^{-2}); 1511° (at 10^{-3} (at 10^{-4}); 1311° (at 10^{-5}) 1220° (at 10^{-6}), and 986° (at 10^{-10}). The evaporation rate of the solid chromium may be greatly reduced by alloying. The density of chromium is 7.2 g/cm^3.

The free energy is (in cal/°C·mole): 2.33 (at 25°); 4.32 (at 227°); 5.89 (at 427°); 7.81 (at 727°); 9.39 (at 1027°); 11.52 (at 1527°); 12.53 (at 1727°); and 15.71 (at 2500°). The enthalpy of chromium is (in cal/mole): 0.62 (at 127°); 3.38 (at 527°); 7.52 (at 1027°), and 12.47 (at 1550°). The entropy is (in cal/mole·°C): 1.78 (at 127°); 6.53 (at 527°); 11.52 (at 1027°), and 13.71 (at 1550°). The characteristic temperature changes within the range of 490-580°, depending on the state of the metal. The Hall constant is $1.455 \cdot 15^{-2}$ v·cm/amp·oersted. Optical properties: reflectance of chromium (in %) depending on the wavelength of the incident light (silver taken as 100%): 14 (at 1300 A); 37 (at 2000 A); 67 (at [illegible] A); 70 (at 7000 A); 63 (at 10,000 A), and 88 (at 40,000 A). The work function for the emission of thermal electrons is 4.6 ev; the photoelectric work function is 4.37 ev. The recrystallization temperature of chromium depends, just as that of other metals, on many factors. The recrystallization temperature of chromium prepared according to the industrial technology lies within 800-850°. λ (in kcal/ /cm·sec·°C) is: [illegible] (at 100°); 0.18 (at 500°), and 0.16 (at 900°). Of interest is the increase of the heat conductive of chromium with rising temperature: $\alpha \cdot 10^6$ (per 1°C) is: 7.5 (within 20-100°); 8.8 (within 20-600°) and 10.0 (within 20-1000°). c (in cal/mole•°C) is 5.52 (at 20°); 5.75 (at 500°); 5.85 (at 900°); 9.40 for the liquid metal, and 5.04 for chromium vapor. ρ (in ohm•cm^2/m) is: 0.128 (128 (at 20°); 0.42 (at 600°); 0.86 (at 1200°), and 1.46 (at 1600°). Chromium is not transformed into a superconducting state when the temperature is reduced to 0.7°K. The electrochemical equivalent of chromium (in mg/coulomb) is 0.08983 for the trivalent, and 0.17965 for the hexavalent metal. The normal electrode potential of the trivalent chromium is 0.5 v; the hydrogen overvoltage is 0.38 v. The radiation factor lies within 0.39 and 1.27 $\kappa cal/cm^2 \cdot hr \cdot k^4$ (at 100-1000°); the blackbody factor is 0.08-0.26 for the nonoxidized, and 0.7-0.8 for the oxidized metal. (The values change depending on the external conditions and the state of the metal). The cross section for the thermal neutron absorption is equal to 2.9 ± 0.1 barn/atom.

Chromium is paramagnetic. The susceptibility is equal to $1.65 \cdot 10^6$ cm^3 at 20°. Chromium has an antiferromagnetic structure up to 44-200°, depending on the state of the metal and the percentage of impurities.

An anomalous change of certain physical properties of chromium takes place at 37°; a sudden decrease of E, and increase of the internal friction coefficient, etc. Impurities and alloying reduce the temperature of the anomalous change of certain physical properties. The self-diffusion of chromium occurs both frontally and along the grain boundaries at a temperature of 1000-1350°. The rate of the self-diffusion along the boundaries is considerably higher than that of the frontal selfdiffusion. The activation energy of the selfdiffusion process of chromium is 76 kcal/g-atom in the grains, and 46 kcal/g-atom along the grain boundaries. The mean value of the surface tension of chromium in an atmosphere of purified inert gas or hydrogen is equal to 1590 ± 50 erg/cm^2 at 1950°.

Commercial-grade chromium is used as a component for the alloying of steels and alloys. Chromium and its chemical compounds are applied in diverse engineering branches: in ceramics, chemistry, glass-melting, powdermetallurgy, etc. The solution of the problem of the plasticity of chromium has made it possible to begin using it as a structural material. Chromium-base heat-resisting alloys were developed which work for a short time or under alternating conditions up to 1500-1600°. Parts made from chromium withstand a temperature of 1100-1200° for a long time permitting a short-time overheating up to 1500-1600°. A semicommercial manufacture of semifinished products from chromium (rods, strips, and other profiles obtained by pressing) is in existence at present.

Chromium vapor, dust, and compounds are toxic for the human organism. The skin and the mucous membranes of the respiratory tract are mainly affected involving invlammatory processes. 0.1 mg/m^3 is the permissible limit of dust concentration in the air of the working section of a shop. Ventilation, overalls, careful washing of the skin with warm water, washing of the nose and gargling of the throad with a solution of common salt, inhalation, systematic medical examination, regular wet wiping of the room including walls and ceiling, are the precautionary measures applied.

The mechanical properties of chromium (see Table) were determined with a metal produced by means of the industrial technology. Electrolytically refined chromium was used as a charge. The specimens were prepared from a deformated and heat-treated metal.

The σ_b depends at 1000° on the loading rate as follows: 10 (at 1 sec); 9.5 (at 10 sec); 8 (at 30 sec); 7.5 (at 100 sec); and 6.0 (at

1 sec); 9.5 (at 10 sec); 8 (at 30 sec); 7.5 (at 100 sec); and 6.0 (at 300 sec); K (the modulus of hydrostatic-type compression) is $17.1 \cdot 10^3$ kg/mm^2; μ is equal to 0.24. $\sigma_{0.2}$ for 100 hrs at 1150° is equal to 0.3-0.5 kg/mm^2; σ_{-1} based on 10^7 cycles is equal to 24 kg/mm^2 (at 20°) and 2 kg/mm^2 (at 1150°).

Chromium has a high thermal endurance: cylindrical specimens (with a diameter of 5 mm) withstand 500 thermal shocks (heating by electric current at 1150° for 15 sec, cooling in air up to 100° within 30 sec) without failure when not loaded or under a bending load of 2 kg/cm^2; the mechanical properties at 20° and 1000° show virtually no change after 500 thermal shocks. Alternating heating up to 1100° with cooling does not involve irreversible changes of the shape of cylindrical specimens. At temperatures up to 150-200°, chromium (especially its plasticity) is sensitive to cuts and to the state of the surface; its properties become independent on the state of the surface at higher temperatures. Pickled and electropolished chromium specimens possess increased plasticity properties at 20° and lower temperatures. The industrial technology of today permits one to produce a chromium which is plastic up to −50° on bending, and up to 0° on drawing; a metal with a higher plasticity was prepared under laboratory conditions. The problem of the cold-shortness, i.e., a low resistance to impact loads, is still not

1 Свойства	2 Темп-ра (°C)				
	20	200	800	1150	1500
σ_b (кг/мм^2) 3	30—35	35	17—19	5—7	2—3
$\sigma_{0,2}$ (кг/мм^2)	18—20	—	—	—	—
4 $\sigma_{пц}$ (кг/мм^2)	14—17	—	—	—	—
δ (%)	5—10	25	70—85	70—90	20—30
ψ (%)	2—3	20	70—90	90—95	65—70
$a_н$ (кгм/см^2) 5	0,1—0,2	1,5—2	4—5	2—3	—
$E \cdot 10^{-3}$ (кг/мм^2):					
6 динамический 3	28	26	20	16	—
статический 7	19	—	—	—	—
$G \cdot 10^{-3}$ (кг/мм^2)	7.3—11.1	—	—	—	—
HB (кг/мм^2)	100—110	—	70	—	—
σ_{10}	—	—	10,5	2,5	—
σ_{100}	—	—	9,0	1,3	—

1) Properties; 2) temperature (°C); 3) kg/mm^2; 4) σ_{pts}; 5) kgm/cm^2; 6) dynamic; 7) static.

dissolved. The cold-shortness of chromium up to 100-150° is, therefore, its main shortcoming.

The brittle state is determined by the dependence of the plasticity characteristics on the nature of the stressed state, the loading rate, and other factors. The temperature of the transition of chromium from the cold-short into the nonbrittle state is not constant because besides the above-mentioned factors, the content of impurities, the state of the metal, etc., play a role also. The transition from the cold-short state into the nonbrittle state proceeds in a small temperature range without hysteresis. The other physicochemical properties experience no anomalous changes in the mentioned temperature range. The failure of chromium occurs at both low and high temperatures mainly along the grains (on drawing or on bending). On torsion, a mixed failure along the boundaries and across the grains may take place. Experimental data prove the hypothesis that the shortness of chromium at normal temperature is not one of its basic properties.

In a first approximation, the cold-shortness of chromium may be explained by the relation between the tensile strength and the resistance to the initial plastic deformation. The tensile strength must remain almost constant within a wide temperature range, lowering only at sufficiently high temperatures. The surface energy of solids, in a physical sense connected with the tensile strength, follows this law. The metal is in a plastic state within the temperature range in which the tensile strength is higher than the resistance to the primary plastic deformation. The metal is transformed into a brittle state when the resistance to the primary plastic deformation becomes higher or equal to the tensile strength due to the effect of certain factors (temperature, impurities, nature of the stressed state, loading rate, etc.). The resistance to the primary plastic deformation drops at rising temperatures more rapidly than the tensile strength. Therefore, chromium passes from the cold-short into the nonbrittle state when the temperature rises to a certain level (this temperature is frequently termed temperature of the shortness threshold), independently on the nature of the stressed state and the loading rate. A chromium, plastic and non-cold-short not only at positive but also at negative temperatures, can be prepared. For this purpose, a_H at 20° must be increased to 1.0-2.0 kgm/cm^2.

References: Sully, A., Khrom [Chromium], translated from English, Moscow, 1958; Marvin, J., Chromium, Vol. 2, N.Y., 1956.

I.O. Panasyuk and A.I. Kozlov

Manu-script Page No.	[Transliterated Symbols]
814	пц = pts = proportsional'nost' = proportionality

CHROMIUM ALLOYS – are heat-resistant alloys whose strength characteristics at temperatures of 1100-1200° have intermediate values between those of heat-resistant alloys based on Fe and Ni, and those of the higher-melting metals (Nb, Mo, W).

The alloys VKh-2 and VKh-2I are plastic at 20° and possess the following mechanical properties: σ_b (kg/mm^2) = 35-45 (at 20°); 20-25 (at 800°), 15-18 (at 1150°), and 4-5 (at 1500°). $\sigma_{0.2}$ (kg/mm^2) = 20-25 (at 20°), 16-18 (at 800°), and 10-14 (at 1000°). HB = 120-130 kg/mm^2 (at 20°). E (kg/mm^2) = $28 \cdot 10^{-3}$ (at 20°), and $23 \cdot 10^{-3}$ (at 1000°). At a temperature of 1150°, the alloys withstand stresses of 8-10 kg/mm^2 for 10 hours, 4-5 kg/mm^2 for 10 hours, 4-5 kg/mm^2 for 100 hours, and 2 kg/ /mm^2 for 100 hours. δ is about 30% for both alloys after fracture. γ = = 7.2 g/cm^3. The alloys are sufficiently heat-resistant in the whole range of working temperatures.

Rods, strips, sheets and blanks of parts are made from the alloys of this type by methods of deformation and precision molding. Sheets plated with stainless steel and alloys are also produced. The plated surface may be removed by pickling when necessary. Plated sheets have a better technological efficiency. In both cases, the cutting and bending of parts is carried out at 500-600γ. The alloys VKh-2 and VKh-2I are characterized by a high resistance to corrosion in the atmosphere of industrial districts, under tropical conditions, in sea water, nitric acid, oxidants based on nitric acid, and other aggressive media.

Blanks obtained by the methods of deformation and molding are submitted to heat treatment before the machining.

The alloys are sufficiently machinable by all cutting methods. A low resilience and a sensitivity to notches up to a temperature of 150-200γ are the main disadvantages of these alloys. Parts made from the VKh-2 alloy require protection from brittleing caused by the chemical reaction of the surface layers of the metal with the nitrogen of the gaseous phase when working in air at high temperatures for a long time. Parts made from the VKh-2I alloy do not require surface protection up to 1300° (the increase in weight amounts to 0.25 g/m^2 per hour after heating for 100 hours).

High-chromium alloys of the VKh-3 type are sufficiently stable under stresses up to 20 kg/mm^2 for more than 100 hours at 1030°, and at 1150° under stresses up to 15 kg/mm^2. σ_{-1} based on 10^7 cycles of asymmetrical bending has the following values (in kg/mm^2): 20 (at 20°), and 15 (at 1150°). $\sigma_{0.2}$ = 6 kg/mm^2 at 1150° for 100 hrs. λ (cal/m$\cdot$sec × × °C) is 0.21 (at 100°) and 0.13 (at 900-1000°). $\alpha \cdot 10^6$ (1/°C) is: 8.1 (at 20-100°) and 10.5 (at 20-1000°). c (cal/g$\cdot$°C) is 0.098 (at 100°), 0.12 (at 500°), and 0.19 (at 1200°). γ = 7.6 g/cm^3. Alloys of this type are of interest for stationary equipment working under stable conditions, especially under compressing loads. The alloys do not oxidize and do not become brittle even after a long time working at 100-1200° in an oxidizing atmosphere, in air, and in steam. The high-chromium alloys are not malleable. The objects are manufactured by precision molding and, further, undergo heat treatment and a subsequent machining. In this case there exists a danger of surface cracks.

The plastic chromium alloys of the VKh-4 type, which are not cold-brittle at 20°, possess a HB up to 300 kg/mm^2.

The VKh-4 alloy is characterized by the following properties: σ_b (kg/mm^2) is 110-115 (at 20°), 20-22 (at 1000°), and 10 (at 1200°), $\sigma_{0.2}$= 85-90 kg/mm^2 (at 20°). a_H = 4-5 kgm/cm^2 (at 20°). γ = 7.9 g/cm^3.

The mechanical properties of both the cast and the deformed alloy are almost the same after heat treatment. Parts obtained by casting or by deformation are submitted to heat treatment before the machining. The alloy possesses good casting properties (the casting shrinkage during crystallization is 2.1%); it is heat resistant up to 1200° in air (the increase in weight amounts to 0.7 $g/m^2 \cdot hr$ after 100 hours heating); it is sufficiently weldable, it resists corrosion in atmosphere, sea water and a number of other aggressive media, and does not require surface protection from brittleness. The VKh-4 alloy is almost equivalent to the malleable nickel-base alloys with respect to its strength properties; it surpasses them, however, by its higher melting temperature.

Rods, strips, shaped blanks, and sheets are made from the VKh-4 alloy. The alloy is easily machinable by cutting.

Certain chromium alloys and chromium compounds are of interest for instrument manufacture. Two chemical compounds, CrSb and $CrSb_2$, for example, originate in the chromium – antimony system. The CrSb compound is an antiferromagnetic with a Neel point of 420 ± 10°. This compound has maximum electrical resistance at 420°; the resistance increases up to 420° and drops at higher temperatures in the same manner as in semiconductors: $4.2 \cdot 10^{-4}$ (at 20°); $7.8 \cdot 10^{-4}$ (at 420°), and $5.5 \cdot 10^{-4}$ (at 550°) ohm•cm.

Some alloys of chromium with tellurium and platium are ferromagnetic. The chromium alloy containing 48.5% tellurium is ferromagnetic up to 60°. The magnetic intensity of the alloy attains the saturation (about 300 gauss) at 20° in an external magnetic field of 8000 oersted. The magnetic intensity increases linearly to about 175 gauss when the force of the external magnetic field rises to 5000 oersted. A number of chromium-germanium alloys are ferromagnetic in the temperature range of 77-110°K and have a Curie point about 100-110°K. The ferromagnetism of the alloys is probably caused by the ferromagnetism of the formed $CrGe_2$ phase. Alloys with 66.6 and 70 atom-% germanium possess the highest ferromagnetic properties.

The chromium alloys are melted in arc and induction vacuum furnaces in an atmosphere of purified inert gas (argon, or helium) or in a mixture of the gases. The arc is strongly dispersed in argon; in helium, however, it is ignitable only with difficulty and then does not burn stably.

Objects made from chromium alloys withstand a single or cyclic overheating up to 1500-1600° for a short time, i.e., to a temperature which is considerably higher than the melting point of the heat-resistant iron and nickel-base alloys. A certain chromium alloy may prove itself to be the sole suitable structural material for objects working at high temperatures (higher than 1000°) in an oxidizing atmosphere where alloys requiring a surface protection from gas corrosion (erosion effect of the working medium) are not applicable. Parts made from chromium alloys work most efficiently under stationary heating conditions and in the absence of impact loads.

Chromium and its alloys are of great interest for chemical and power machinery due to their high corrosion resistance and their reliability under the stationary conditions.

References: Sully, A. Khrom [Chromium], translated from English, Moscow, 1958; Marvin, J., Chromium, Vol. 2., N.Y., 1956; "Prod. Engng.," 1961, Vol. 32, No. 38; "J. Inst. Metals," 196 -1961, Vol. 89, Part 3, page 101.

I.O. Panasyuk

CHRYSOBERYL — is a mineral with the composition Al_2BeO_4, beryllium aluminate, in which the oxygen ions are placed according to the principle of the most simple hexagonal packing: the beryllium ions are surrounded by four, and the aluminum ions by six oxygen ions.

Varieties: alexandrite, chromium-containing, bright-green; cymophane, with a wavy opalescence in sunlight. The crystal system is rhombic. The crystals have a tabular shape, they are sometimes short- or long-prismatic. Tabular concretions with a hexagonal shape are formed frequently. The specific gravity is 3.50-3.84. The cleavability along the (001), (010), and (100) planes is uneven. The fracture is conchoidal. The Mohs hardness is 8.5. The mineral is yellow, different tints of green or brown; it is rarely colorless. The streak is colorless. Refraction indices: N_g 1.733-1.758; N_m 1.747-1.749 N_p 1.744-1.747; $N_g - N_p = 0.009$. Polished microsections are colorless. Chrysoberyl does not decompose in acids, but it becomes decomposed by melting in powdered state with KOH and $KHSO_4$.

The green color of the chrysoberyl in daylight changes into violet-red at artificial illumination. This property is based on the fact that the mineral passes the bluish-green rays (in the 460-500 mμ range) and the red rays from 620 mμ up to the boundary of the visible spectrum), and the artificial light source is poor in green rays. Chrysoberyl and its variety, alexandrite, are synthesized by melting BeO and Al_2O_3 together in the presence of B_2O_3, AlF_3, etc., as mineralizers. The mineral is quite rare. It may be used as a source for the production of beryllium.

M.D. Dorfman

CHUGAL' – see Cast-iron – Aluminum alloy.

III-105p

CLARIFICATION OF OPTICS – application of thin transparent films to the surfaces of optical glass in order to reduce (or eliminate) reflection of light from them. In order to completely eliminate reflection it is necessary that the index of refraction of the film $n_{pl} = \sqrt{n_{stekla}}$ and that the optical thickness of the film equal 1/4 of the wavelength of that portion of the spectrum in which maximum passage is desired. Clarifying films can be produced by treating the surfaces of the glass with aqueous acid solutions or by applying special substances to its external surface. Two- and three-layer films are also employed. The latter reduce reflection over a broad spectral region. Clarification permits a substantial increase in the light-gathering power of optical instruments, in some of which (periscopes) the losses due to reflection amount to 60-80% as a result of the large number of reflective surfaces.

References: Grebenshchikov, I.V. et al., Prosvetleniye optiki. Umen'sheniye otrazheniya sveta poverkhnost'yu stekla [Clarification of Optics. Reducing Reflection from Glass Surfaces], Moscow-Leningrad, 1946.

L.S. Priss

CLEAR FILMS FOR SAFETY GLASS – elastic binder films based on polyvinylbutyral and a plasticizer (dibutylphthalate, dibutylsebacinate, triethylene glycol butyrate, butylrinolate, etc.). The elasticity of these materials depends on the amount of plasticizer.

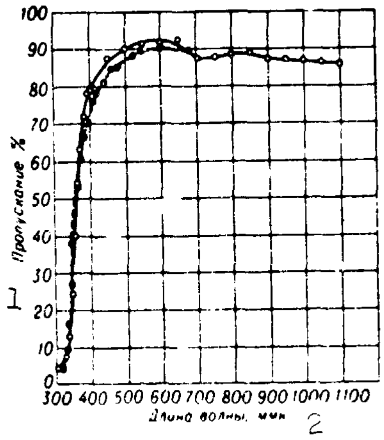

Figure. Spectral transmissivity of polyvinylbutyral films: – o – plasticized, – ● – unplasticized. 1) Transmissivity, %; 2) wavelength, mμ.

Clear films for safety glass are produced by: 1) spraying a colloidal solution of polyvinylbutyral with plasticizer; 2) slitting a polyvinylbutyral-plasticizer mixture in an extrusion machine; 3) rolling a mixture of polyvinylbutyral and a calculated quantity of plasticizer on frictionless rollers and then calendering the plasticized mass to obtain a film of the requisite thickness. The physicomechanical characteristics of such films include: specific gravity – 1.05, modulus of elasticity – 18,000 kg/cm^2 at 20° and 28,000 kg/cm^2 at -60°, ultimate tensile strength – 200-300 kg/cm^2, relative tensile elongation – 150-250%, adhesion – 60-100 kg/cm^2 to silicate glass and 100-150 kg/cm^2 to organic glass (in the presence of special underlayers), thermal coefficient of linear expansion – $6 \cdot 10^{-5}$, water absorption from air – up to 18%, depending on the amount of plasticizer and the degree of acetylation. The figure shows the spectral transmissivity of a polyvinylbutyral film for the visible portion of the spectrum. These materials are used in the manufacture of shatter-proof glass for vehicle windows (automobiles, aircraft, etc.).

Z.I. Mikheyeva

II-44k

COATING LACQUER is a colloidal solution of synthetic or natural resins in organic solvents or monomers with the addition in certain cases of plasticizers, stabilizers and accelerators, which in thin layers is capable of forming hard continuous films. In the pure form or in combination with other paint and varnish coatings they are intended for the protection of products from the action of the surrounding medium and for decorative purposes. Two groups of coating lacquers are differentiated on the basis of the composition of the film-forming agent: 1) those which form nonconverting films as a result of the evaporation of solvents contained in the lacquer composition, i.e., those which form coatings without chemical transformations; 2) those which form conversion films as a result of complex physico-chemical processes of oxidation, condensation and polymerization or as a result of the simultaneous processes of polymerization and condensation (see Lacquer and Paint Coatings).

On the basis of operating conditions the coating lacquers are divided into the atmospheric-resistant, capable of withstanding direct solar radiation and the entire complex of atmospheric conditions (for example, the 9-32, AS-82, AS-16 acrylic lacquers, the No. 170A alkyd lacquer, the melamine-alkyd, nitrocellulosic, polyurethane and certain other lacquers), and the non-atmospheric resistant whose films deteriorate, darken, crack, etc., from the action of direct solar radiation but withstand well the action of other atmospheric factors: No. E-4100 epoxy, BS-1 phenolic, KhSL vinyl perchloride, No. 177 bituminous, ChS, 7S glyptal lacquers.

The coating lacquers for external coatings), must have a good luster, must be hard, elastic, moisture resistant, wear resistant, must have good adhesion and special properties such as: oil, kerosene and gasoline resistance, resistance to the action of chemical reagents. The majority of the films are not resistant to the action of mould and fungi, the introduction of antiseptics is difficult because of the change of color of the lacquer. In order to improve the resistance to sunlight, additions are made to the lacquer of 20-30 percent of paint, enamel with provision for good mixing. The need for hot drying is determined by the nature of the film-forming agent of the coating lacquer, and the drying possibilities are determined by the dimensions and the material of the product. The alkyd, melamine-alkyd, polyurethane, epoxy lacquers require drying at 100-150°, and with increase of drying temperature the quality of the coating film improves.

V.V. Chebotarevskiy

I-92K

COBALT, Co – is a chemical element of the VIIIth group of Mendeleyev's Periodic System; number of element 27; atomic weight 58.9332. The natural cobal consists of one stable isotope with the mass number 59. The cobalt content in the earth's crust is about 0.004% by weight. It is used as a basis for the production of highly heat-resistant alloys, and also as an alloying component in the production of steels and special alloys.

Apart from the data quoted in Table 1, up to 0.001% of magnesium, silicon, phosphorus, aluminum or zinc, and up to 0.003% of cadmium, tin, antimony, lead or bismuth is permissible in the KO cobalt grade. Cobalt exists in two allotropic modifications: α (ε) at low temperatures, with a hexagonal crystalline structure, and β (γ) at high temperatures with a face-centered cubic lattice. The transformation from α into β cobalt begins at 477°, it progresses slowly and is completed at 600°; the inverse transformation sets in at 403°.

TABLE 1

Chemical Composition of Cobalt (GOST 123-57)

1 Кобальт	3 Содержание элементов (%)							
	2 Co (не менее)	4 Примеси (не более)						
		C	S	Mn	Fe	Ni	Cu	As
К0	99.98	0.005	0.001	0.001	0.003	0.005	0.001	0.0005
К1	99.25	0.03	0.004	0.07	0.2	0.3	0.04	0.002
К2	98.0	0.1	0.01	0.15	0.5	0.5	0.1	0.005
К3	97.0	0.2	0.05	0.2	0.7	1.5	0.15	0.01

1) Cobalt; 2) not less than; 3) percentage of elements; 4) impurities (not more than).

The physical properties of cobalt are: atom diameter (according to Goldschmidt) 2.507 A; lattice constant (K12) 3.54 A; t°_{pl} = 1493°; t°_{kip} =

= 3100°; E = 20,750 kg/mm^2; $\alpha \cdot 10^6$ (at 20-100°) = 12.08.

The hardness of cobalt as a function of the temperature after two different heat treatments is shown in Fig. 1. The creeping characteristics at 500° and σ = 8.4; 3.5; 7.0, and 11.5 kg/mm^2 is given in Fig. 2. The quoted data show that at room temperature cobalt possesse about the same strength as iron has a very low degree of plasticity. Cobalt has a very low resistance to high temperatures; at 800° and σ = 7 kg/ /mm^2, for example, the breaking time (after tempering at 800° for 1 hr) amounts to 1 hour.

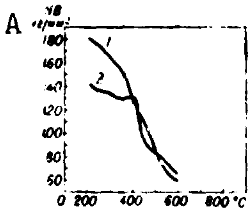

Fig. 1. Variations in the strength of cobalt due to the temperature: 1) Hardening at 800°, 1 hr holding time, quenching in water; 2) hardening at 1200°, holdting time 1 hr, quenching in water. A) kg/mm^2.

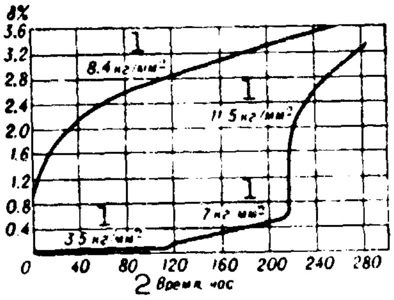

Fig. 2. Creeping of cobalt at 500° under different stresses. 1) kg/mm^2; 2) time, hr.

References: Mayants A. D., Kobalt [Cobalt], Moscow-Leningrad--Sverdlovsk, 1934; Burkhard A., Mekhanicheskiye i technologicheskiye svoystva chistykh metallov [The Mechanical and Technological Properties of Pure Metals], translated from German, Moscow-Leningrad, 1941; Mechanical Properties of Metals and Alloys, "Nat. Bur. Standards Circ.," 1943,

I-92K2

C447; Morral F.R., "J. Metals," 1958, Vol. 10, No. 10, page 662; Chubb W., ibid., 1955, Vol. 7, No. 1, page 189.

TABLE 2

Mechanical Properties of Cobalt (chemical composition in %, not less than: 99.4 Co; 0.22 Ni; 0.15 Fe; 0.01 Cu; 0.03 C; 0.06 Mn; 0.029 S, and 0.10 Si)

1 Термич. обработка	Темп-ра (°C) 2	σ_b	$\sigma_{0,2}$	δ	ψ	HB (кг/мм²) 3
		3 (кг/мм²)		(%)		
4 Нормализация при 800°	20	37	33	2,3	2.95	—
5 Отжиг при 800°, выдержка в течение 50 час., охлаждение со скоростью 60° в час	20	47	30	3.5	4.6	154
6 Закалка с 1200° в воде	20	28	21	3.9	8.1	148
То же	400	21	—	4.2	11	—
» »	450	18	—	4.5	2.0	—
7 » »	500	19	—	7.2	2.4	—
» »	800	8.7	—	0.65	2.8	56
8 Литой без термич. обработки	20	24	—	—	—	124

1) Heat treatment; 2) temperature (°C) 3) kg/mm²; 4) normalization at 800°; 5) tempering at 800°, 50 hrs holding time, cooling at a rate of 60° per hour; 6) hardening from 1200° in water; 7) the same; 8) cast without heat treatment.

F.F. Khimushin

COBALT CASTING ALLOYS – are heat-resistant alloys for the production of parts working at high temperatures, blades of jet-turbine engines, for example, produced by a precise-casting method. They are used as heat and wear-resistant materials for the building up of exhaust valves of internal-combustion engines, and of other parts (see Stellite and Valve Steel).

Cobalt casting alloys are hardened mainly by carbide phases. 0.20-0.60% carbon, and also chromium, molybdenum or tungsten are introduced in order to provide a sufficient quantity of carbides. Niobium is also introduced into certain alloys. The carbides $(Cr, Me)_7C_3$ or $(Cr, Me)_{23}C_6$, where Me is molybdenum or tungsten, are formed depending upon the content of these elements. Boron is added to certain alloys in order to harden the grain boundaries during working at high temperatures (Table 1). Binary carbides of the type $(Co, Ni)_3(W, Mo, Nb)_3C$ may be formed if the tungsten or molybdenum content attains the upper limit. The carbide of the NbC type is formed singularly or in combination with others in phases containing niobium. The carbides are distributed between the axes of the dendrites. Their degree of dispersity and their shape depend on the casting temperature and the crystallization rate; the carbide becomes coarse-disperse and the axes of the dendrites and the grains increase when the casting temperature is raised and the crystallization rate is reduced. Reduced casting temperature and accelerated crystallization rate favor the formation of more disperse carbides. In this case the axes of the dendrites and the macro-grains disintegrate and the alloys become more compact. The solid solution of these alloys is hardened by chromium, tungsten or molybdenum; it has mainly a face-centered structure which corresponds to the high polymorphous γ modification of cobalt, stable above 500°. Chromium, molybdenum and tungsten raise the temperature of the polymorphous transformation. Aside from the solid γ solution, a solid solution which corresponds to the low-temperature ε modification of the cobalt with a hexagonal structure may also be present in the alloy (in the LK-4, HS-21, HS-23, and HS-151 alloys). Only the solid γ solution is present in alloys which contain 10% and more nickel. Iron is an undesirable impurity.

TABLE 1

Chemical Composition of Cobalt Casting Alloys

Сплав 1	2 Содержание элементов (%)				
	C	Cr	Mo	W	Ni
3 ЛК4	0,15—0,25	25,0—28,0	4,5—5,5	—	3,0—3,7
ЛК4Я 4	0,23—0,30	25,0—28,0	5,0—6,0	—	≤ 3,0
5 4К66Я	0,35—0,45	21,0—24,0	—	8,0—11,0	≤ 2,0
Виталлиум (HS-21) 6	0,20—0,35	25,0—30,0	4,5—6,5	—	1,5—3,5
HS-31 (X-40)	0,45—0,60	23,0—28,0	—	6,0—9,0	9,0—12,0
HS-36 (L-251)	0,35—0,45	17,5—19,5	—	14,0—15,0	9,0—10,0
HS-151	0,55	19,0—21,0	—	12,0—13,0	< 3 (Ni + Fe)
WI-52	0,4	19,5	—	11,0	≤ 1,0
HDA8151	0,5	20,0	—	12,5	—

7 Продолжение

Сплав 1	2 Содержание элементов (%)				
	Fe	Nb	B	Mn	Si
3 ЛК4	1,5	—	—	≤ 0,5	≤ 0,6
4 ЛК4Я	≤ 2,0	—	0,02 (Ce 0,05)	≤ 0,5	≤ 0,5
5 4К66Я	≤ 1,0	1,5—2,0	0,02	≤ 0,3	≤ 0,4
6 Виталлиум (HS-21)	2,0	—	—	0,3	0,6
HS-31 (X-40)	≤ 2,0	—	—	0,6	0,7
HS-36 (L-251)	≤ 2,0	—	0,02—0,05	≤ 1,5	≤ 0,5
HS-151	—	—	0,10	≤ 1,0	[illegible]
WI-52	≤ 0,5	1,5	0,02	0,3	0,3
HDA8151	—	—	0,05	0,6	[illegible]

1) Alloy; 2) percentage of elements; 3) LK4; 4) LK4Ya; 5) 4K66Ya; 6) Vitallium; 7) continuation.

Cobalt casting alloys have good casting qualities: the crystallization range is relatively small, the proportion of the low-melting structure and the action of the carbides in the crystallization process is high (these alloys, therefore, may be satisfactorily welded). Addition of boron improves the casting properties of the alloys, but it may, however, deteriorate their weldability. The weldability of the alloys deteriorate when the carbon content is increased. The cobalt casting alloys are somewhat better than the malleable alloys of the same composition in regards to heatproofness. The temperature level of the heat resistance of cobalt casting alloys is significantly lower than that of nickel casting alloys owing to the fact the hardening of the former is caused mainly by carbide phases, that of the latter, however, by intermetallic phases.

Cobalt casting alloys are aged in the temperature range of 735-815° in order to increase the static and long-life strengths, the plasticity decreases in this case due to the segregation of carbides, sometimes, the alloys undergo a double heat treatment (hardening and aging).

The development of cobalt casting alloys abroad shows a definite trend. The first variant of the Vitallium alloy (HS-21) with a relatively low carbon content (0.27%) was replaced by harder and more heat-resistant alloys with a higher carbon content (HS-34 with 0.35% C), and also by the alloys (HS-31 and HS-36. Thereupon 7.5% to 15% tungsten was substituted for the molybdenum in the alloys. The hardening based on Me_7C_3, $Me_{23}C_6$ and Me_6C carbides was replaced in the casting variant of the S-816 alloy by a hardening by means of niobium carbides as the single phase of segregation. The carbides $Co_3 (W, Nb)_3C$ and $(Cr, W)_{23}C_6$ are present together with NbC in the WI-52 alloy. Alloys hardened by boron, with a reduced chromium content, containing not less than 0.40% carbon, have been recently developed. The mechanical properties of certain cobalt casting alloys are quoted in the Tables 2 and 3.

The large content of thermally stable carbides in the cobalt casting alloys determines their relatively low heat resistance at low temperatures but with regard to heat resistance at high temperatures of them are nearly equal to some of the nickel alloys hardened by an intermetallic phase (a). The coefficients of the linear thermal expansion are approximately the same as those of alloy ferrite and martensite steels (Table 4); the coefficient of the heat conductivity is quoted in Table 5.

TABLE 2

Mechanical Properties of Cobalt Casting Alloys

Сплав 1	2 Температура (°C)	Кратковременная прочность 3				σ_{100}	σ_{1000}	σ_{-1} (на базе 5 10^7 циклов)	Термич. обработка 6
		$\sigma_{0.2}$	σ_b	δ	ψ				
		4 (кг/мм²)		(%)		(кг/мм²) 4		(кг/мм²) 4	
ЛК4 7	20	—	70	8.0	10.0	—	—	24—28	Без термич. обработки 8
	600	—	52	12.0	15.0	30	—	—	То же 9
	700	—	47	10.0	14.0	25	—	—	»
	800	—	40	6.5	9.0	15	—	20—25	»
	900	—	27	9.0	15.0	7	—	—	»
	950	—	—	—	—	5	—	—	»
10 ЛК4Я	20	—	90	5.5	6.0	—	—	—	Старение при 750° в течение 16 ч 11
	600	—	75	11	12	—	—	—	То же
	700	—	70	12.5	13.5	30	—	—	» 9
	800	—	51	14	15	18	—	—	»
	900	—	35	18	18	14	—	—	»
	950	—	26	25	33	11	—	—	»
4К6Я 12	20	—	90	6	7	—	—	—	Старение (735°, 50 ч) 13
	700	—	75	10.5	11.5	—	—	—	То же
	800	—	55	16	18	25	—	—	» 9
	900	—	37.5	25	25	15	—	—	»
	950	—	29.5	19	19	12	—	—	»
Виталлиум (HS-21) 14	20	46	77	10.0	12.0	—	—	—	Без термич. обработки 8
	20	—	84	5.1	6.4	—	—	—	Старение (735°, 50 ч) 13
	650	27	52	16.0	17.0	30.7	30.7	[illegible]	Без термич. обработки 8
	650	50	63	2.0	6.0	—	—	—	Старение (735°, 50 ч) 13
	735	—	—	—	—	22.4	15.3	—	Без термич. обработки 8
	735	41	56	3.8	9.0	—	—	—	Старение (735°, 50 ч) 13
	815	—	—	—	—	15.4	9.9	[illegible]	Без термич. обработки 8
	815	35	42	6.8	2[illegible].0	—	—	—	Старение (735°, 50 ч) 13
	870	—	—	—		11.7	9.0	—	Без термич. обработки 8
	870	22	29	19	[illegible]	—	—	—	Старение (735°, 50 ч) 13
	980	—	23	35	52	6.6	4.5	—	Без термич. обработки 8
	980	—	23	49	83	—	—	—	Старение (735°, 50 ч) 13
HS-31 (X-40)	20	52	71	11	14	—	—	—	Без термич. обработки 8 13
	20	—	99	2.0	—	—	—	—	Старение (735°, 50 ч) 8
	650	26	34	2.9	[illegible]	39	32	39	Без термич. обработки
	735	38	53	4.6	7.6	[illegible]*	24*	—	Старение (735°, 50 ч) 13
	815	31	42	[illegible]	[illegible]	[illegible]	[illegible]	24	То же 9
	870	25	34	14	[illegible]	16	13	—	»
	980	—	—	—	—	9	[illegible]	—	Без термич. обработки 8
HS-63 (L-251)	20	—	[illegible]	[illegible]	—			—	Старение (735°, 16 ч) 8
	650	—	[illegible]	[illegible]			42	—	То же 9
	735	—	[illegible]	—	—	[illegible]	29	—	»
	815	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]—18	—	»
	870	—	[illegible]	[illegible]	—	[illegible]	13	—	»
	980	—	—				[illegible]		»

1) Alloy; 2) temperature (°C); 3) short-time strength; 4) kg/mm²; 5) based on 10 cycles; 6) heat treatment; 7) LK4; 8) without heat treatment; 9) the same; 10) LK4Ya; 11) aging at 750° for 16 hrs; 12) 4K6Ya; 13) aging (735°, 50 hrs); 14) Vitallium.

The specific gravities are: 8.3[illegible] for LK4 alloy; 8.47 for LK4Ya; 8.61 for HS-31, and 8.98 g/cm³ for 4K6Ya.

TABLE 3

Ultimate Long-Life Strength of Some Cobalt Casting Alloys

Сплав 1	650°		735°		815°		870°		980°	
	σ_{100}	σ_{1000}	σ_{100}	σ_{1000}	σ_{100}	σ_{1000}	σ_{100}	σ_{1000}	σ_{100}	σ_{1000}
S-816	39,2	30,8	25,9	20,[illegible]	19,8	14,7	12,6	9,1	7,7	4,8
S-816+D	60,2	54,6	—	—	30,6	29,7	20,9	14,7	10,2	5,5
HS-151	—	—	—	—	—	—	19,0	16,5	10,0	8,5
HDA8151	—	—	—	—	26	20,3	18,6	15,4	9,8	—
WI-52	—	—	—	—	—	—	—	14,0	10,5	—

1) Alloy.

TABLE 4

The Coefficients of the Linear Thermal Expansion of the Cobalt Casting Alloys LK4, HS-21, HS-31, HS-36, LK4Ya, and 4K66Ya

1 Темп-ра (°C)	20–315	20–425	20–540	20–650	20–815	20–870
$\alpha \cdot 10^6$ (1/°C)	13,6–14,2	14,0–14,8	14,3–15,1	14,5–15,4	15,2–16,6	15,9–16,5

1) Temperature (°C).

TABLE 5

The Coefficients of the Heat Conductivity of Some Cobalt Casting Alloys (cal/cm·sec·°C)

1 Сплав	2 Температура (°C)									
	25	100	200	300	400	500	600	700	800	900
3 ЛК4Я	0,032	0,035	0,040	0,045	0,049	0,053	0,0[illegible]	0,060	0,065	0,069
4 4К66Я	0,033	0,036	0,040	0,045	0,049	0,053	0,057	0,061	0,065	0,069

1) Alloy; 2) temperature (°C); 3) LK4Ya; 4) 4K66Ya.

N. F. Lashko

COBALT STEEL FRO PERMANENT MAGNETS - see Alloy Steel for Permanent Magnets.

III-14s

COEFFICIENT OF LIGHT ABSORPTION - the ratio of the relative decrease in the intensity of light passing through an infinitely thin layer of a material to the thickness of this layer:

$$\alpha = \frac{1}{J}\frac{dJ}{dx}.$$

The intensity J of light passing through a layer of finite thickness x is expressed by the Lambert-Baer equation:

$$J = J_0 e^{-\alpha x}.$$

The dimension of the coefficient of light absorption is cm^{-1}. This index varies widely from material to material ($2 \cdot 10^{-2}$ for water, $4 \cdot 10^{-2}$ for glass, and $2 \cdot 10^{-5}$ for graphite). The coefficient of light absorption of a given material depends on the wavelength of the light, increasing sharply in certain portions of the spectrum, which are sometimes very narrow (selective absorption).

L.S. Priss

II-32,0-1

COEFFICIENT OF PHOTOREFLECTION - the ratio of the intensity of reflected light to the intensity of incident light. For normal reflection from the boundary of two isotropic transparent media the coefficient of photoreflection equals:

$$R = \frac{1}{2}\left\{\frac{\operatorname{tg}^2(\varphi - \psi)}{\operatorname{tg}^2(\varphi + \psi)} + \frac{\sin^2(\varphi - \psi)}{\sin^2(\varphi + \psi)}\right\},$$

where φ is the angle of incidence and ψ is the angle of refraction. If the light propagates from a medium with an index of refraction n_1 to a medium with an index of refraction n_2 and $n_1 < n_2$ the coefficient of photoreflection is low, remaining virtually constant for values of φ of from 0 to 60° but then rising sharply. When $n_1 > n_2$ and $\varphi > \arcsin(n_1/n_2)$, R = 1, i.e., complete internal reflection takes place. For normal incidence ($\varphi = 0$), $R = ((n_1 - n_2)/(n_1 + n_2))$. For reflection from a metallic surface the photoreflection coefficient is determined from two parameters, the index of refraction in and the constant κ, which is proportional to the light-absorption coefficient of the metal. For normal incidence $R = ((n - 1)^2 + n^2\kappa^2)/((n + 1)^2 + n^2\kappa^2)$. The photoreflection coefficient of metals rises as the wavelength of the light increases, approximating one in the infrared region of the spectrum.

References: Landsberg, G.S., Optika [Optics], 4th Edition, Moscow, 1957 (Obshchiy kurs fiziki [General Course in Physics], Vol. 3).

L.S. Priss

COEFFICIENT OF REFLECTION – the ratio of the radiant energy reflected by a body to the radiant energy incident on it: $r = E_{otr}/E_{pad}$. The reflection coefficient of an Absolutely black body is zero, while that of an absolutely white body is 1; for real bodies $1 > r > 0$. The coefficient of reflection is sometimes called the albedo.

G.A. Zhorov

COEFFICIENT OF SENSITIVITY TO CONCENTRATION – see Stress concentration.

COEFFICIENT OF TRANSPARENCY – the ratio of the intensity of the light passing through a layer of a material 1 cm thick with no change in direction to the intensity of the incident light. In this case the light is regarded as passing through the substance itself, not being affected by the surfaces bounding the layer. The concept of transparency should not be confused with that of transmissivity. Thus, the coefficient of transparency for white paper is zero, even though it transmits a great deal of light. The coefficient of transparency of fused quarts is 0.999, while that of optical glass is 0.990-0.995.

L.S. Priss

I-97K

COHESION – is the attraction between the molecules (atoms, ions) within the volume of a given body. The cohesion of solid bodies is considerably greater than the cohesion of fluids which, in turn, is higher than the cohesion of gases. The degree of the cohesion is characterized by the so-called theoretical strength of the materials. calculated on the basis of the laws valid for the intermolecular forces. The expression "cohesive strength" is sometimes used in engineering in place of the expression "rupture strength.

G.M. Bartenev

COLD RESISTANCE is the capability of the polymers and materials based on them to retain high elasticity and other value properties, for example hermeticity, flexibility and nonbrittleness, at low temperatures. The cold resistance of the highly elastic materials (rubbers) is determined by the loss of high elasticity at low temperatures and is characterized by the cold resistance coefficient K at a specified temperature or by the corresponding temperature T_K for a specified cold resistance coefficient (usually K = 0.1). The cold resistance coefficient is determined by defined by the ratio $K = \varepsilon/\varepsilon_{20}$, where ε is the amplitude or magnitude of deformation at the given low temperature, and ε_{20} is the same at 20°. The deformation may be measured by static or dynamic methods. Beginning at low temperatures at which processed or raw rubber is in the blassy state and up to 20-25°, K varies from about 0.001 to 1. To each given value of K there corresponds a temperature T_K. Usually, for rubber use is made of the temperature $T_{0.1}$ as the index of cold resistance, this being the temperature at which the rubber loses 90% of its high elasticity. This temperature is preactically independent of the specimen size, of the sliding conditions on the specimen ends, on the form of deformation (tension, compression, or shear), and on the degree of deformation. T_K depends on the mechanical testing condition (dynamic tests are made on a frequency instrument, and static tests are made on dynamometric scales). This relationship is expressed by the formula $1/T_K = A - B\lg\nu$, where A and B are constants of the material, ν is the frequency of the periodic deformation, T_K is expressed in °K. The process of mechanical (but not structural) vitrification is associated directly with the cold resistance of raw and processed rubbers. The essence of mechanical vitrification consists in the loss of the high elastic properties with increase of the deformation frequency or with temperature reduction at a given frequency of the applied force. The material transitions from the highly elastic state into the state with high modulus of elasticity which is customary for solid bodies. The cold resistance of articles made from the plastics is determined by cracking and transition to the brittle state (loss of induced elasticity), i.e., it is characterized by the brittleness temperature T_{khr} (see Brittleness Temperature). This temperature depends on the rate of mechanical and thermal loading. Therefore the cold resistance of the polymer materials and articles must be determined under conditions which are very close to service conditions.

Low-molecular plasticizers are introduced into the polymers to improve the cold resistance.

References: Bartenev G.M., Novikova N.M., Tr. N.-i. in-ta rezin. prom-sti (Transactions of the Scientific Research Institute of the Rubber Industry), 1958, collection 5, page 96; Kir, 1960, No. 7, page 28; Bartenev G.M., DAN SSSR, 1956, Vol. 110, No. 5, page 805; PM, 1960, No. 9.

G.M. Bartenev

COLD-SHORTNESS – is the brittle destruction of metals at lowered temperatures without appreciable plastic deformation. The temperature dependence of the tensile strength of metals is different that the temperature dependence of the shearing strength. The Soviet Scientist A. F. Ioffe was the first who had noticed this fact. The scheme of Ioffe (see Fig. 1 in the article Coldshortedness of steel) explains well the transition from the ductile to the brittle destruction as a function of the test temperature. The Soviet Scientist N.N. Davidenkov had begun his extensive and fruitful investigations on the cold-shortness in 1930.

The tendency of metals to cold-shortness is usually characterized by the critical brittle temperature, at which the plasticity and the energy absorbed in deformation rapidly decrease (loss of ductility), and also the nature of the fracture is changed: a crystalline structure replaces the fibrous macrostructure of the metal; a destruction along the grain boundaries occurs in a number of cold-short metals.

The phenomenon of the cold-shortness may not be connected with the action of any single factor; the lowering of the temperature, the increase of the deformation rate and the type of the stressed state (the degree of rigidness) belong to the decisive external factors; the type of the crystal lattice (more precisely, the interatomic distance characterizing the "cram of the housing conditions" of impurity atoms or compounds), the contamination of the metal by foreign atoms or impurities, the structure and size of the grains (the greater the grain the lower the tensile strength), the chemical composition and some technological factors affecting not only the structure but also the state of the surface (cinder, residual stresses, for example), belong to the intrinsic factors. The scale factor plays a peculiar role: the tendency to brittle fracture rises with an increasing size of the part, which may be related to both an increase of the margin of elastic energy and an increase of the probability that a dangerous crack-type flaw is present.

Many metals with a body-centered or hexagonal lattice are especially susceptible to brittle fracture at low temperatures. This peculiarity, however, must not be connected with the type of the lattice itself but with the fact that the spacing of the crystal lattice of such metals is small (the "atom housing" is relatively cramped), which involves an intense deformation of the crystal lattice by foreign atoms, especially by interstitial atoms and impurities. Hence, a compression of the lattice by cooling of those metals involves a significant increase in the yield strength, and according to Ioffe, the cold-shortness phenomenon is the more expressed the steeper the curve of the yield strength rises at lowering temperatures.

It was experimentally proved that nickel decreases the tendency of steel to brittle fracture by lowering the threshold of the cold-shortness. The Soviet Scientist R.I. Entin and others explain this phenomenon by the fact that the alloying of iron by nickel weakens the fastening of the dislocations by the interstitial atoms (carbon and nitrogen) and accelerates and facilitates in this way the plastic deformation. The fact that nickel involves a more homogeneous distribution of the carbon in the steel is also significant.

The theory of impurities has proved to be the most fruitful one for the explication of cold-shortness phenomena. It was just the theory of impurities which led to the preparation of chromium and molybdenum in a plastic state.

The problem of cold-shortness is of great national importance economically. Not attacking sufficient important to this problem has already contributed to the wreck of a considerable number of large ships of the "Liberty" type (1943-1945, U.S.). The highest number of wrecks occurred during the winter months and during voyages in northern latitudes in heavy sea, and the main cause was the fact that the "Liberty" ships were constructed from a rimming steel of the st.4 type which had a high tendency to cold-shortness.

The significance of the investigations becomes evident when one considers the increasing role of the Northern and Eastern regions in the national economy of the USSR. This problem has a peculiar significance also in the work of mastering the cosmos (see Cosmos materiolog).

S.T. Kishkin

COLD-SHORTNESS OF CHROMIUM — see <u>Chromium</u>.

COLD-SHORTNESS OF MOLYBDENUM — see Molybdenum.

COLD-SHORTNESS OF STEEL – is the tendency of steel to brittle fracture at low temperatures. Just as the cold-shortness of certain other metals may be explained by the well-known scheme of A F. Ioffe (Fig. 1) the cold-shortness of steel also. The resistance of steel to brittle fracture (breaking) remains either invariable or increases slightly; the yield strength, however, increases considerably at lowered temperatures. The destruction of metals occurs under a more or less significant plastic deformation at temperatures higher than the T_{kr} (the critical brittle temperature or the temperature of cold-shortness), whereas a brittle destruction without plastic deformation takes place at temperatures below the T_{kr}. All the factors which change the resistance to brittle destruction and the yield strength affect the temperature of cold shortness. An increased rate of the testing of steel (passing over from static to dynamic load) promotes an essential increase of the yield strength at a relatively small increase of the resistance to brittle destruction involving a rise of the temperature of cold-shortness (Fig. 2). A notch in the specimen acts in much the same manner due to the strongly hindered plastic deformation. The temperature of cold-shortness depends to a considerable extent on the heat treatment. Hardening with a subsequent tempering promotes, as a rule, the drop of the temperature of cold-shortness of structural steel because the resistance to brittle destruction increases by hardening more than the yield strength increases (Fig. 3). Aging of the steel causes the temperature of cold-shortness to rise due to the increase in the yield strength together with an only small change of the resistance to brittle destruction. This applies to both the aging of low-carbon steel and that of alloyed steel. An increase of the ferrite, pearlite or martensite grain (the former austenite grain) involves a decrease in the resistance to brittle destruction at a relatively small change of the yield strength, and the temperature of cold-shortness is increased (Fig. 4).

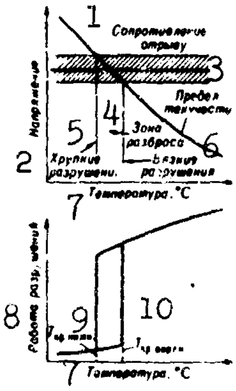

Fig. 1. Scheme of A.F. Ioffe explaining the possibility of a brittle and a ductile destruction of the same material depending on the test temperature ($T_{kr.verkhn.}$ and $T_{kr.nizhn.}$ are the temperatures of the upper and lower thresholds of cold-shortness, respectively).

1) Breaking strength; 2) stress; 3) yield strength; 4) spread zone; 5) brittle destructions; 6) ductile destructions; 7) temperature, °C; 8) stress; 9) $T_{kr.nizhn.}$; 10) $T_{kr.verkhn.}$.

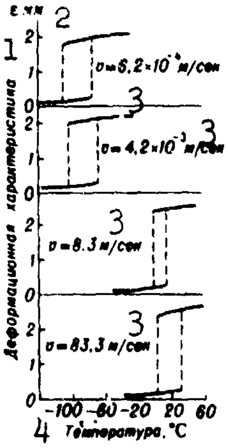

Fig. 2. Effect of the testing rate (v) on the threshold of cold-shortness of carbon steel (0.2% C). (Notched specimens in bending test).

1) Characteristic of deformation; 2) mm; 3) m/sec; 4) temperature, °C.

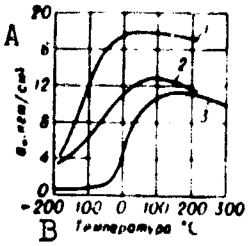

Fig. 3. The impact resilience of chrome-molybdenum steel (0.31% C; 0.34% Mo; 1.05% Cr) in relation to the heat treatment and the test temperature. 1) Hardening at 850°, tempering at 650°; 2) hardening at 850°, tempering at 550°; 3) annealing at 850°. A) a_H, kgm/cm^2; B) temperature, °C.

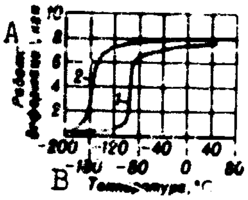

Fig. 4. Effect of the grain size of carbon steel (0.22-0.25% C) on the threshold of cold-shortness: 1) Coarse-grained steel (grain diameter 89 μ; 2) fine-grained steel (grain diameter 41 μ). A) Stress, kgm; B) temperature, °C.

The tempering shortness of steel caused by changes on the boundaries of the former austenite grains promotes the decrease in the resistance to brittle failure and, therefore, a rise of the temperature of the cold-shortness. Steel of the same chemical composition but produced by different metallurgical methods or even deoxidized by different substances may have a different temperature of cold-shortness. The size of the specimen and the type of stress during the test affect to a considerable degree the temperature of cold-shortness. The resistance to brittle failure decreases and the temperature of cold-shortness rises when the dimensions of the specimen are increased (due to the effect of the scale factor). A drop of the temperature of cold-shortness takes place at a "softer" stressed state, i.e., when relatively strong tangential stresses act in presence of the same normal stresses. Hence, the temperature of cold-shortness is very low when the material is compressed, it becomes higher under torsion and is the highest on drawing or bending. Specimens with a coarse surface possess a higher temperature of cold-shortness.

The temperature of cold-shortness is usually determined by the impact test of a series of notched specimens at different temperatures. A relatively sharp transition from ductile to brittle failure occurs in iron and annealed steel when the test temperature is lowered. This transition is smooth and spread over a relatively broad temperature range in the case of hardened and tempered steel. The test of steel at low temperatures and the determination of the temperature of cold-shortness make it possible to ascertain such peculiarities of the metal state which are not detectable by the standard tests at room temperature. It is not possible to determine an absolute temperature of cold-shortness because the latter depends on the shape and the dimensions of the specimen and on the type of the stressed state. The permissible working temperature of any steel parts may be gathered only indirectly from temperature of cold-shortness determined on specimens: the lower the temperature of cold-shortness the more reliable the parts manufactured from the given steel will be at low temperatures. It must be emphasized, however, that the temperature of cold-shortness characterizing the relative capability of steel to work at low temperatures does not determine the tendency to brittle failure at normal temperatures caused by cuts and other factors promoting the brittleness. Thus, for example, high-strength structural steel, which has a considerably lower temperature of cold-shortness characterizing the relative capability of steel to work at low temperatures does not determine the tendency to brittle failure at normal temperatures caused by cuts and other factors promoting the brittleness. Thus, for example, high-strength structural steel, which has a considerably lower temperature of cold-shortness than iron and tempered soft steel, proves to have a significantly higher tendency to brittle failure at room temperature under the effect of cuts, hydrogen, corrosion, etc. (see High-strength structural steel).

Cold-shortness occurs in iron, carbon and alloyed steel including stainless steel with ferrite, pearlite, sorbite and martensite structures, i.e., steel based on the α-Fe and γ-Fe crystal lattice. Austenitic steel and iron-base alloys, both rusting and stainless ones, having a γ-Fe crystal lattice, are not liable to cold-shortness. A drop of the test temperature does not involve a strong decrease of the plasticity and ductility of these materials. The austenitic steel is an exception, because a conversion of austenite into martensite takes place at low test temperatures and, therefore, this steel may also become cold-short.

References: Davidenkov, N.N., Dinamicheskiye ispytaniya metallov [Dynamic Metal Tests], 2nd Edition, Leningrad-Moscow, 1936; Fridman, Ya.B., Mekhanicheskiye svoystva metallov [Mechanical Properties of Metals], 2nd Edition, Moscow, 1952; Shevandin, Ye.M., Sklonnost' k khrupkosti nizkolegirovannykh staley [The Tendency of Low-Alloyed Steels to Brittleness], Moscow, 1953; Polak, Ya.M., Khrupkiye razrusheniya stali i stal'nykh detaley [Brittle Failures of Steel and of Steel Parts], Moscow, 1955.

Ya.M. Patak

Manuscript Page No.	[Transliteratured Symbols]
850	кр = kr = kriticheskaya = critical
851	кр.вэрхн. = kr.verkhn. = kriticheskaya verkhnyaya (temperatura) = upper critical (temperature)
851	кр.нижн. = kr.nizhn. = kriticheskaya nizhnyaya (temperatura) = lower critical (temperature)

COLD-WORKED ALUMINUM ALLOYS – semifinished products fabricated from aluminum alloys subjected to cold deformation (cold working). Cold working greatly increases the hardness, yield strength, and ultimate strength of the material and reduces its relative elongation. The extent of the changes in these properties during cold working depends on the nature of the alloy and the degree of deformation. The hardening produced by cold working decreases as the deformation temperature increases. The hardening due to cold working can be reduced or completely eliminated by heating, which ensures regression (relaxation) and recrystallization. Sheets of thermally unhardenable alloys (AD, AD1, AMg, AMg3, and AMts) are produced in three states (annealed, semicold-worked, and cold-worked) with varying properties. The cold-worked state is obtained by cold rolling, while the semi-cold-worked state is achieved by less intensive cold working or incomplete annealing of intensively cold-worked material.

In fabricating semifinished products from thermally hardenable alloys cold working takes the form of straightening (degree of deformation – 0.5-1.5%) or is carried out to increase the yield and ultimate strengths (degree of deformation – 5-15%). Straightening is conducted with freshly quenched material and promotes both production of the requisite geometric shape and a material decrease in the internal stresses which develop during quenching. Tension-straightening is consequently obligatory for extruded articles. Quenched and aged sheets must be smoothed and tension-straightened. Straightening of the freshly quenc d material increases the mechanical properties of semifinished products fabricated from alloys of the duralumin type, especially when they are quenched from the annealed state. Cold working of the freshly quenched alloy may raise the strength characteristics of stampings. For this purpose the component is understamped by 10-15%, quenched, and brought to the desired shape by cold deformation in the final die. Cold rolling to a deformation of 5-6% is employed after quenching to increase the strength characteristics of sheet material (D16TN). In some cases a material increase is obtained in the yield strength and ultimate strength of quenched and naturally aged sheets by intensive cold working (cold rolling to a deformation of 15-20%) followed by artificial aging (D16T1N1). When functioning at elevated temperatures cold-worked material may begin to soften earlier than non-cold-worked alloy. It is consequently unwise to use cold-worked semifinished products for prolonged operation at elevated temperatures (at or above the artificial-aging temperature). The decrease in plasticity caused by cold-working to a deformation of 5% or more reduces the technological characteristics of the alloy and may increase its susceptibility to stress concentrators (scratches, notches, sharp transitions, curves). The extent of this reduction in plasticity depends on the cold-working method (it is less for rolling and greater for extension). The increase in notch sensitivity under the influence of cold working depends on the character of the alloy. It is preferable to use cold-worked materials with an elevated sensitivity to stress concentrators in the compressive zone of the assemblage.

Ye.D. Zakharov

COLD-WORKED SPRING STEEL – steel hardenable by cold plastic deformation and having high elasticity and durability. Steel of this type is used in the form of patented cold-drawn wire and cold-rolled strips for manufacturing various unquenched springs. Cold-drawn wire of classes I, II, IIA, and III is produced in accordance with GOST 9389-60 from carbon steel, principally of types 65, 70, 75 and 85 (GOST 1050-60), for whose chemical composition see the article entitled Heat-treatable spring steel. Type of steel used is selected in accordance with the class of wire and its production technology and is generally not specified by TU. Wire of class I can also be produced to the customer's specifications from carbon tool steel of group A (GOST 1435-45) with limited chromium, nickel and copper contents. Cold-worked cold-rolled strips are produced in accordance with GOST 2283-57 from carbon tool steel, whose chemical composition is given by GOST 1435-54, and from 65G, 60G, 50G, U8G, U8GA, 60S2, 60S2A, 65S2BA, 50KhFA, and 70S2KhA alloy steels, for whose chemical composition and mechanical characteristics see the article entitled Heat-treatable spring steel. Wire is manufactured in diameters of from 0.14 to 6 mm (classes I and IIA) and up to 8 mm (classes II and III), while strips are fabricated in thicknesses of from 0.10 to 3 mm. Figure 1 shows the mechanical characteristics of cold-drawn wire as a function of its diameter.

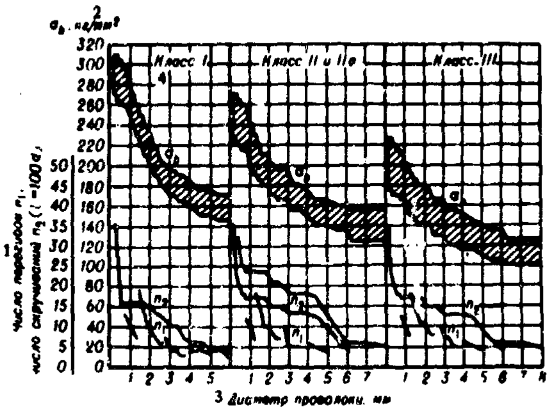

Fig. 1. Variation in ultimate strength, number of bending cycles, and number of twists for cold-worked carbon spring steel as a function of diameter of cold-drawn wire (according to GOST 9389-60). 1) Number of bending cycles, n_1, number of torsion cycles, n_2(l = 100d); 2) kg/mm^2; 3) wire diameter, mm; 4) class.

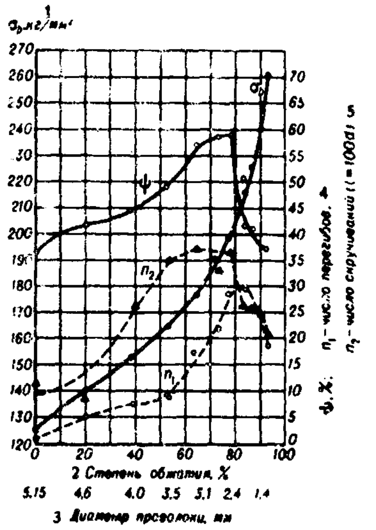

Fig. 2. Mechanical characteristics, number of bending cycles, and number of torsion cycles for type U8A patented steel as a function of reduction in area during cold drawing. 1) kg/mm^2; 2) reduction in area, %; 3) wire diameter, mm; 4) n_1 — number of bending cycles; 5) n_2 — number of torsion cycles (l = 100d).

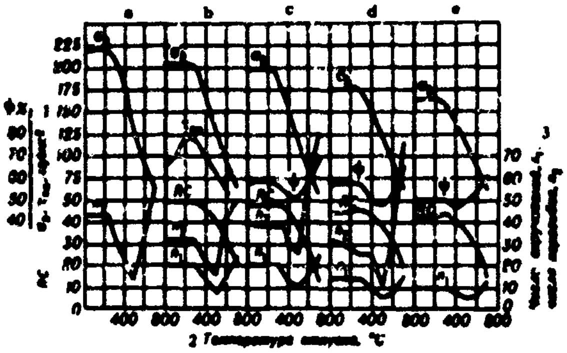

Fig. 3. Variation in the mechanical characteristics of type 70 cold-worked spring steel as a function of tempering temperature (1 hr). Speimens: a) 0.5 mm; b) 1 mm; c) 2 mm; d) 3 mm; e) 4 mm. 1) kg/mm^2; 2) tempering temperature, °C; 3) number of bending cycles, n_1, number of torsion cycles, n_2.

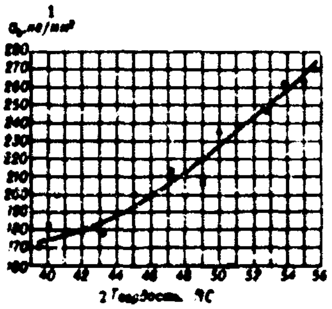

Fig. 4. Ultimate strength of cold-drawn wire as a function of hardness. 1) kg/mm^2; 2) hardness, RC.

According to GOST9389-60, wire of classes I, II, IIA and III replace all other types of spring wire previously manufactured. Wire of class IIA corresponds in physicomechanical characteristics to type OVS wire, which was formerely produced in accordance with GOST 1546-53.

The high mechanical characteristics of spring wire are achieved by patenting (see Patenting of steel) and subsequent cold deformation with a total reduction in area of more than 70%. Figure 2 shows the influence of reduction in area during cold deformation on the ultimate strength, plasticity, and technological characteristics of patented high-carbon U8A steel; Figure 3 shows the influence of tempering temperature on the mechanical and technical characteristics of cold-worked wire of type 70 steel.

Cold-worked spring steels of the same hardness have approximately the same tensile strength (Fig. 4).

The tensile elastic limit of cold-drawn wire is approximately 40-50% of its σ_b.

After winding the finished springs are usually tempered at 260-320°, a holding time of 1 hr being recommended. Tempering is employed to relieve internal stresses and raise the elastic limit and relaxation resistance of the steel.

Low-temperature tempering of the finished springs substantially increases the elastic limit of cold-worked spring steel (to 70-75% of its σ_b).

The permissible stresses for helical compression springs fabricated from cold-worked spring steel can for practical purposes be taken as 0.3-0.6 σ_b, depending on the character of the load and the diameter of the wire.

Cold-worked strips of spring steel are produced with ultimate strengths of 75-120 kg/mm^2 (carbon steel) and 80-120 kg/mm^2 (alloy steel).

Springs fabricated from steel of this type are protected against corrosion in the same manner as springs manufactured from heat-treatable steel.

References: Spravochnik po mashinostroitel'nym materialam [Handbook of Machine-Building Materials], Vol. 1, Moscow, 1959; Yukhvets, I. A., Stal'naya provoloka [Steel Wire], in book: Mashinostroyeniye. Entsiklopedicheskiy spravochnik [Machine Building. An Encyclopedic Handbook], Vol. 3, Part 2, Moscow, 1947.

A.L Selyavo

COLLAPSE TESTING – determination of the ability of tubes to undergo deformation in the transverse direction and detection of surface defects; collapse tests are conducted in accordance with GOST 8695-58 and consist in flattening a tube between parallel plates until they are a predetermined distance apart. A piece of tube 20-50 mm long serves as the specimen. The test can be conducted directly on the tube, first cutting a piece from one end with a cut perpendicular to the longitudinal axis and to a depth of no less than 0.8 of the outside diameter. In testing welded tubes the seam is located so as to be an equal distance from each of the flattening plates. Collapse tests are carried out at the ambient temperature, but at no less than –10°. The flattening rate is 20-50 mm per min (see Technological testing).

N.V. Kadobnova

COLOR - is the capacity of bodies to cause a definite visual perception corresponding to the spectral composition of reflected or emitted radiation. The human eye reacts to electromagnetical waves having a length of from 3800 to 7500 A (the visual part of the spectrum). The mixture of luminous fluxes in a proportion which corresponds to the different sections of the visible part of the spectrum gives a light which is perceived as white. The predominance of light waves of a certain wavelength in this mixture gives a colored light; the wavelength determines the tint or the chromaticity, the degree of the predominance of waves of a certain length determines the saturation of the color, and the total radiation intensity determines the brightness. The color of objects which do not emit light results mainly from the absorption of a certain spectral part of the incident light, and depends, therefore, on the spectral composition of the illumination.

References: Ashkenazi, G.I., Tsvet v priorode i tekhnike [Color in Nature and in Engineering], Moscow-Leningrad, 1955.

L.S. Priss

COLORIMETRY – is a method by which a color is measured and its quantity determined. This determination may be absolute or relative. The simplest form of a relative determination is to compare the color to be determined with a set of standardized colors which have been compiled into a special chart (a color handbook). For more exact measurements, colorimeters are used, special devices based on the method of reproducing a color identical to that which is to be measured. This is achieved in colorimeters for relative measurements by passing white light through a column of a colored liquid with a variable height; in colorimeters for absolute measurements, the white light is mixed with light of a definite wavelength or three colors (red, green and blue-violet) are mixed. In the latter case, each color is determinable by a set of three numbers, the color coordinates. Both systems of absolute measurements are equally good, and a simple change from one to the other is possible. The concentrations of solutions are determinable on the basis of their color intensity (method of colorimetric analysis).

References: Peshkova V.M., Gromova M.I., Prakticheskoye rukovodstvo po spektrofotometrii i kolorimetrii [A Practical Manual on Spectrophotometry and Colorimetry], Moscow, 1961.

L.S. Priss

COLOR METHOD OF FLAW DETECTION – is a nondestructive method for testing the surface quality of materials and objects by means of color. A brightly red-colored liquid of the D or E grade (VTU 2-60 of the L'vov SNKh) is applied on the previously degreased surface and, through the action of the capillary forces, penetrates into the hollow of the flaw (a cavity, pore, or crack). A white paint of the NTs 523 or NTs 524 grade (VTU 3-60 of the L'vov SNKh) is applied to the surface, after the surplus of the fluid has been removed. The flaws become apparent as clear red lines or spots. The color method of flaw detection is extremely sensitive; it is expedient, therefore, that it be used in the local testing of the most important parts. See Capillary flaw detection.

S.I. Kalashnikov

Manuscript Page No.	[Transliterated Symbols]
865	ВТУ = VTU = Vremennoye tekhnicheskoye usloviye = Provisional Technical Specification
865	СНХ = SNKh = Soviet narodnogo khozyaystva = Council of National Economy

COLORIZATION OF STEEL – is a heat treatment consisting in heating ground or polished steel up to 200-300°, resulting in the formation of an orange- or bluish-colored oxide film on its surface. The colorization of steel is usually carried out as a finishing operation in the production of high-strength steel band after its grinding. Apart from its decorative effect, the colorization of steel gives the surface an increased corrosion resistance, especially after greasing (the grease penetrates into the pores of the oxide film).

M.L. Bernshteyn, I.N. Kidin

COLUMBIUM – see <u>Niobium.</u>

COMBUSTION OF TITANIUM – burning of titanium and its alloys in pure oxygen or in oxygen-containing media. The conditions necessary for ignition of titanium are: critical pressure, which depends on the state of the medium (temperature and the velocity at which it moves), its oxygen concentration and the alloy brand; the presence of surface deprived of a passive protective film (for example, on failure, substantial deformation or damage of the surface). The nature of titanium combustion has not as yet been sufficiently studied. A major role in this process belongs to physio-chemical features of titanium alloys, that is, high oxide-formation heat; low thermal conductivity (the thermal conductivity of titanium iodide comprises 0.036 cal/cm·sec°·C, that is, it is by a factor of almost 15 lower than that of copper); the solubility of oxides in the molten metal (in the IV subgroup, in addition to titanium only zirconium, which is also inflammable in an oxygen medium, has this property). Alongside with the physio-chemical properties of titanium a certain role in the combustion process is plaed by mechanical factors, that is, the character of the stressed state (tension, flexure, shear, etc.), the kind of fracture (fine- or coarse-crystalline), the degree of shaping deformation, and also the surface finish. All other conditions remaining equal, specimens with a smooth, sterile-clean surface have the highest critical pressure. Increasing the temperature of the medium and the rate of oxygen flow results in a substantial reduction in the critical ignition pressure. Alloying has a relatively minor effect on reducing the inflammability of titanium alloys. Titanium iodide has the highest critical ignition pressure (50-70 atm); the VTI commercial-grade titanium ignites at a pressure of 20-25 atm; industrial alloys, depending on the brand, ignite at pressure of 7-15 atm. As the alloy composition is made more complex, the critical ignition pressure is, as a rule, reduced. Titanium alloys used for the manufacture of components and articles which operate in oxygen containing media should be produced with a substantial safety factor to avoid the formation of surface cracks in service. The most radical method for protecting metals from contact with the oxygen medium is the creation on their surface of a protective shell which does not ignite in the presence of oxygen and which is more plastic than the titanium or its alloy. Such shells are created either by cladding (for example, by aluminum, copper, niobium), or by producing neutral films by other methods.

References: "Light Metal Age," v. 17, No. 3-4, pages 6-7, 1959; Adamson [et al.], in the book: Transactions of the Second International Conference on Peaceful Uses of Atomic Energy, Geneva, 1958; Izbrannyye doklady inostrannykh uchenykh [Selected Reports of Foreign Scientists]. [Vol. 6], page 174, Moscow, 1959.

Ye.A. Borisova

III-15kh

COMMERCIAL CHROMIUM – is a metallic chromium containing usually 97-99.5% of the main element and produced by an industrial method.

Depending on the production method, thermite, electrosilicothermic, vacuum, electrolytic and other varieties of commercial chromium are distinguished.

Commercial chromium melted from chromium oxide by the furnace-less thermite method is produced as blocks weighing up to 10 kg and is subdivided into three grades (GOST 5905-51) according to its chemical composition:

Марка 2	1 Содержание элементов (%)							
	Cr (не менее) 3	C	Si	S	P	Al	Fe	Cu
		4 не более						
5 Х0 . .	98,5	0,03	0,4	0,02	0,02	0,5	0,6	0,06
Х1 . .	98,0	0,05	0,5	0,04	0,03	0,7	0,8	0,06
Х2 . .	97,0	0,06	0,5	0,05	0,05	0,8	1,2	0,1

1) Percentage of elements; 2) grade; 3) Cr (not less than); 4) not more than; 5) Kh.

The electrosilicothermic method produces commercial chromium by reduction of chromium oxide or chromium ore whose iron-content was removed with silicon (crystalline silicon, or, more reasonable, ironless chromium-silicon) in an arc-furnace. The chemical composition of the electrosilicothermic commercial chromium is as follows: 97-98.5% Cr; 0.05-0.1% C; 0.5-1.5%; 0.2-1.5% Si; traces of Al and less than 0.01% S. With regard to the quality, the electrosilicothermic chromium is equivalent to the thermite chromium. The electrosilicothermic method, however, has significant economic advantages (a cheaper reducing agent, the possibility to use a cheaper raw material, etc.).

The vacuum method yields commercial chromium by reduction of chromium oxide with carbon in a vacuum (0.1-1 mm mercury column) in solid state (the temperature of the process is 1400°). The two-stage method is more efficient: a carbon-containing semiproduct is obtained by reduction of chromium oxide or of ironless chromium ore with carbon, and the semiproduct is decarbonized in a vacuum. The metal (in the form of briquets) contains about 99% Cr, 0.02-0.03% C, and 0.4-1% O. The total automation and mechanization of the technological process is easily realizable.

There exist a number of technological methods for the production of commercial chromium by electrolysis (electrolysis of aqueous solutions and melts of chromium chloride, etc.).

Commercial chromium obtained by electrolysis contains usually 99% Cr. The content of metallic impurities is low; the gaseous impurities (mainly oxygen) may attain 1%.

Commercial chromium is also obtainable by reduction of chromium oxide and chromium chloride with magnesium, and also of chromium chlorides with hydrogen and by other methods. The reduction of chromium chloride by hydrogen is of a great interest because chromium chloride may be relatively easily purified, a fact which permits one to obtain commercial chromium with a higher degree of purity (in the form of a sponge) by the subsequent reduction.

Commercial chromium is used as a basic alloying component in the production of special alloys; e.g., Ni-base and Co-base alloys, etc. (see Malleable fireproof nickel alloys, Castable fireproof nickel alloys, Malleable cobalt alloys, Castable cobalt alloys, Heat resistant malleable nickel alloys, Alloys with special physical properties).

High-grade chromium is prepared by the intense refining of commercial chromium.

References: Yelyutin, V.P. [et al.], Proizvodstvo ferrosplavov [Production of Ferroalloys], 2nd Edition, Moscow, 1957; "Tsentr. in-t informatsii chernoy metallurgii" [Central Information Institute for Ferrous Metallurgy], Information No. 40 (562), Moscow, 1959; Sully, A.H., Khrom [Chromium], translated from English, Moscow, 1958; Karsanov, G.V. [et al.], Polucheniye metallicheskogo khroma elektrosilikotermicheskim sposobom [Preparation of Metallic Chromium by the Electrosilicothermic Method], "Stal'" [Steel], 1962, No. 2.

G.V. Karsanov

COMPENSATOR – see Thermomagnetic Alloys.

COMPLEX DYNAMIC MODULUS is characteristic of the elastic hysteresis properties of the ploymer materials, representing the ratio of the stress amplitude (f_0) to the deformation amplitude (ε_0) with cyclic sinusoidal stress. With a phase shift between the stresses and deformation, the complex dynamic modulus is expressed by a complex number: $E^* \equiv E' + iE''$ and is the vector sum of the real (E') and imaginary (E'') components:

$$E^* = f_0/\varepsilon_0 = \sqrt{E'^2 + E''^2} = E'\sqrt{1 + \operatorname{tg}^2 \psi}.$$

where ψ is the phase shift angle between the stresses and the deformations.

The physical basis of the description of the behavior of mechanical systems under forced vibrations with the aid of complex parameters is the expansion of the periodic function describing the variation of the stress in time into two components: one coincides in phase with the deformation function and the other is shifted relative to it by the angle $\pi/2$. E' and E'' are coefficients of proportionality between the amplitude values of the stress and deformation respectively for components which do and do not coincide in phase. E' and E'' depend on the frequency (ω) of the dynamic loading and the temperature T. Increase of ω affects E' and E'' similarly to a reduction of T. The characteristic form of variation of E' and E'' with ω and T is shown on the figure. The region of high ω and low T corresponds to the hard vitrified state. Low ω and high T lead to a rubber-like highly elastic state. The inflection point on the E' curve and the maximum of E'' correspond to the transition from one state to another. Depending on the polymer struc-

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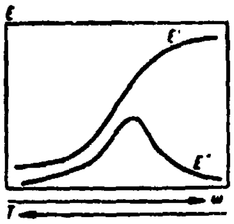
ture, the values of the transition parameters may vary over wide limits.



References: Strelkov S.P., Vvedeniye v teoriya kolebaniy (Introduction to the Theory of Vibrations), M.-L., 1950: Gehman S.D., "Rubber Chem. and Technol." 1957, v. 30, No. 5, p. 1202; Reznikovskiy M.M., KhNiP, 1959, Vol. 4, No. 1, page 79.

M.M. Reznikovskiy

COMPRESSION TEST. This test is most frequently used for materials which are brittle under stretching (cast iron, silicate glass, ceramics, wood, for example) and for materials applied in constructions which are working under compression. The tests are carried out on universal machines or presses with specimens of cylindrical or prismatic shape; the butts of the specimens must be strictly perpendicular to the longitudinal axis and must have a surface machined with a roughness of the ∇7 degree. The longitudinal stability of the specimen during the test until destruction is secured by selecting a ratio $h/d = 1.5$-2, where h and d are the height and the diameter of the specimen, respectively. When the test is carried out by a stress-gauge, the dimensions of the specimen depend on the possibility of placing the stress-gauge (usually with a base of 25-50 mm) on it. Sheet specimens are tested in devices which ensure the stability (Fig.). The modulus of elasticity, the proportional and yield limits can be determined with a sufficient exactness in the compression test. Compression characteristics as the compression strength and the relative contraction depend on the intensity of the friction on the butts; the friction may be decreased by lubrication, conical cups, specimens with conical butts and by increasing the h/d ratio within the permissible limits. The majority of brittle materials becomes destroyed under compression by shearing, sometimes by breaking; some plastic materials (copper, aluminum, for example) are not destroyed when compressed; the compression strength of sandwich plastics (glass-textolite, etc.) is considerably lower when compression is carried out along the layers, than when stretching is applied. Compression tests of materials (mainly sheet materials) at high temperatures become more and more adopted in order to determine the basic calculation characteristics: E_{szh}, σ_{pts}, and $\sigma_{0.2}$. The test is carried out in a device placed in a heating furnace which is set into a common testing machine.

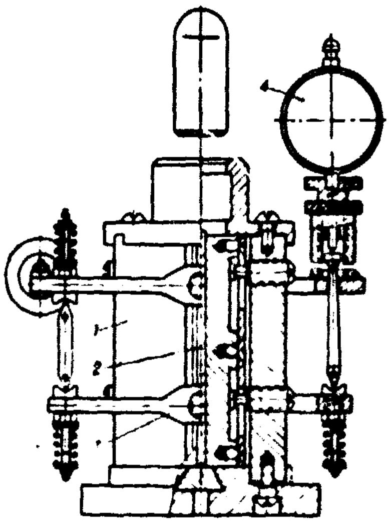


Fig. Scheme of the device for the compression test of sheet materials. 1) Stand; 2) specimen; 3) strain-gauge; 4) indicator.

References: Fridman Ya. B., Mekhanicheskiye svoystva metallov [The Mechanical Properties of Metals], 2nd edition, Moscow, 1952; Danilov Yu. S., Kadobnova N.V., and Mironov L.G., Pribor dlya ispytaniya ploskikh obraztsov na szhatiye [Device for the Compression Test of Flat Specimens], "Zavodskaya laboratoriya," 1958, No. 10, page 1271.

N.V. Kadobnova

COMPUTATIONAL LENGTH - basis for measuring the elongation of a specimen in a tensile test, is laid off at a section with a constant cross section. The computational length is denoted by l_0 and is usually chosen as equal to $5.65\sqrt{F}$ or $11.3\sqrt{F}$, (where F is the cross sectional area of the specimen at the computational length), which corresponds to 5d and 10d for round specimens (where d is the specimen's diameter).

N.V. Kadobnova

III-143s

CONCENTRATED NECKING – the ratio of the reduction in specimen cross-sectional area after fracture to the cross-sectional area of the uniformly deformed region of the specimen. This quantity is expressed as a ratio for percentage: $\psi_{sosr} = (F_b - F_k)/F_b \cdot 100\%$, where F_k is the cross-sectional area of the specimen after fracture and F_b is its cross-sectional area in the region of uniform deformation (see Uniform necking). Concentrated necking characterizes the local plasticity and is determined only for materials that neck.

N.V. Kadobnova

CONDITIONING OF SPECIMENS – is the conforming of specimens to the conditions which are prescribed by specifications and standards. The conditioning of specimens is generally carried out before the testing of fibers. fabrics, leather, and other hygroscopic materials, whose properties change under the effect of the surrounding air and temperature. An air temperature of 20±5°, and a relative humidity of 65±5% is prescribed according to GOST 3811-47 for the determination of the mechanical properties of textile materials. The specimens must be kept under standard conditions for at least 24 hours before the test is carried out. Conditioning dryers are used to determine the amount of the moisture in fibers: the moisture content is determined in the apparatus itself at the drying temperature.

S.A. Reytlinger

CONDUCTIVE LACQUER AND PAINT COATINGS are used for screening or removal of the electrostatic charges whose accumulation can lead to the formation of spark discharges, and also in the preparation of conductors in certain types of printed circuits. In addition, the conductive coatings are used for corrosion protection of metallic surfaces subjected to spot welding. The conductive coatings are obtained by various methods, for example, by means of mixing conductive binders with nonconductive pigments or else binders of the usual type in combination with conductive pigments. To obtain the conductive coatings using the first method, there are added to the lacquer which has been selected as the binder strong electrolytes, for example, the acids or salts of the metals which are soluble in the binder. As pigments, use can be made of any pigments, but in practice use is made of the aluminum, bronze and copper powders which give the surface being painted a metallic appearance. The electrical conductivity of such conductive coatings changes with time, and also under the influence of elevated temperatures. The presence of electrolytes in the paint film can be the cause of corrosion. In the preparation of the conductive coatings by the second method, the electrical conductivity is achieved as the result of the use of pigments which possess electrical conductivity (silver powder, graphite and prepared copper powder). The aluminum, bronze, zinc and iron powders give coatings which are not conductive. The conductive coatings prepared with the use of the conductive pigments have better stability thatn those obtained with the aid of the electrolytes. Industry produces in accordance with TU MKhP 1821-48 the composition No. 119

II-57k1

(conductive enamel) - a paint consisting of a mixture of pigments in a binder of pentaphthalic lacquer with the addition of a dessicant and solvent. This composition is used for the coating of metallic surfaces being welded to protect them from corrosion and is applied by brush or by an atomizer. Prior to use, the enamel is thinned to working consistency with the RS-2 solvent. The paint is a dark-gray color; the viscosity measured on the VZ-4 is no less than 60 seconds. The drying duration at 18-23° is no longer than 24 hours, at 100° it is no more than 1 hour. The film of the dried enamel must not be sticky; in external appearance it must be matte and must not contain granules or unground particles, must have good adhesion. A metallic plate painted with the enamel and dried for 5 days at 18-23° or after hot drying must not corrode with exposure to water vapors at room temperature for 24 hours. The metallic surfaces covered with the enamel must be weldable, both with the fresh enamel layer and in the course of 48 hours after application.

Prior to use the enamel is stirred, thinned to the working consistency and filtered through a sieve having 2400 openings per square centimeter.

References: Printed Circuit Techniques, transl. from Eng. ed. by K.N. Trofimov, M., 1948; DRP 643193-30.03., 1937; DRP 715530-23.12., 1941.

B.I. Ivanov

CONFIDENCE INTERVALS OF MECHANICAL PROPERTIES - see Scattering of Mechanical Properties.

I-108K

CONSTANTAN – is an alloy which belongs to the group of resistor-alloys, characterized by a high thermoelectromotive force, a low temperature coefficient, and a constant electric resistivity. The alloy has the trademark MNMts-40-1.5. It is used mainly in the production of rheostats, thermocouples, and heating devices having working temperatures of up to 500°.

TABLE 1

Chemical Composition (GOST 492-52)

1 Основные компоненты (%)			2 Примеси (%, не более)								
Mn	Ni+Co *	Cu	Fe	Si	Mg	Pb	S	C	P	Bi	As
1,0—2,0	39,0—41,0	Остальное 3	0,5	0,1	0,05	0,005	0,02	0,1	0,005	0,002	0,002

* Cobalt is present as an impurity of nickel.

1) Main components; 2) impurities (%, not more than); 3) the rest.

TABLE 2

Physicomechanical Properties

Свойства 1	Показатель 2	Состояние материала 3
4 $t_{пл.}$ (°C)	1260	—
5 γ (г/см³)	8,9	—
6 α (1/°C)	$14,4 \cdot 10^{-6}$	—
7 c (кал/г·°C)	0,0977	—
λ (кал/см·сек·°C)	0,05	—
8 ρ (ом·мм²/м)	0,48	—
9 Температурный коэфф. электросопротивления в интервале 20—100°	$2 \cdot 10^{-5}$	—
E (кг/мм²) . 10	16600	—
σ_b (кг/мм²) . 10	40—50	Отожженный 11
	70—85	Наклепанный до 80% 12
$\delta_{l=100}$ (%)	30	Отожженный 11
	2—4	Наклепанный до 80% 12
HB (кг/мм²) 10	68	Литой 13
	75—90	Отожженный 11
	155	Наклепанный до 80% 12

1) Properties; 2) characteristics; 3) state of the material; 4) t_{pl} (°C);

5) γ (g/cm^3); 6) c (cal/g °C); 7) λ (cal/cm·sec·°C); 8) ρ (ohm·mm^2/m); 9) temperature coefficient of the electric resistance in the temperature range 20-100°; 10) kg/mm^2; 11) tempered; 12) cold-hardened up to 80%; 13) cast.

TABLE 3

The Physicomechanical Properties as a Function of the Tempering Temperature

1 Темп-ра отжига (°C)	2 σ_b (кг/мм^2)	$\delta_{l=100}$ (%)	3 ρ (ом·мм^2/м)	4 Электропроводность по отношению к меди (%)	γ (г/см^3) 5
6 Наклепанный	83	1	0.505	3.30	8.88
100	85	1	0.507	3.28	—
200	83	1.5	0.505	3.30	8.82
300	83	2	0.495	3.36	—
400	78	4	0.485	3.43	8.894
500	76	9	0.474	3.46	—
600	50	20	0.467	3.45	8.914
700	49	23	0.465	3.45	—
800	48	25	0.464	3.47	8.930
900	46	30	0.464	3.47	—

1) Tempering temperature (°C); 2) kg/mm^2; 3) ohm·mm^2/m; 4) electrical conductivity in comparison with copper (%); 5) g/cm^3; 6) cold-hardened.

References: Berkovskiy I.Ya., and Kolokolova A.G., Nikelevyye splavy [Nickel Alloys], Moscow-Leningrad, 1941; Smiryagin A.P., Promyshlennyye tsvetnyye metally i splavy [Commercial Nonferrous Metals and Alloys], 2nd edition, Moscow, 1956; Usov V.V., and Zaymovskiy A.S., Provodnikovyye reostatnyye i kontaktnyye materialy [Conducting, Rheostat, and Contact Materials], (3rd edition], Moscow-Leningrad, 1957 (Metally i splavy v elektrotekhnike [Metals and Alloys in Electrical Engineering], Vol. 2); Pogodin S.A., Provodnikovyye i reostatnyye splavy [Conducting and Rheostat Alloys], Leningrad-Moscow, 1936; Schulze A., Metallische Werkstoffe für Terhmoelemente [Metallic Materials for Thermocouples], Berlin, 1940.

A.L. Shpitsberg

CONSTRUCTIONAL CERMET MATERIALS are powder metallic materials for general structural application, primarily those using an iron base. The classification and properties of the basic forms of cermet materials are given in Tables 1 and 2.

Sheet, strip and other products are also prepared by means of rolling sintered blanks. In recent years the iron-copper material obtained by impregnating porous blanks made from sintered iron with liquid copper have taken on great importance; this material has high strength properties.

TABLE 1

Classification of Iron-Base Constructional Cermet Materials

1 Вид материала	2 Хим. состав	3 Применение
4 Компактное спеченное железо	Fe — основа, 5 C — 0,02—0,2%, 7 примеси — до 0,5%	Различные детали машин и приборов, в т. ч. штоки, кулачки, втулки 6
7 Компактная спеченная углеродистая сталь	Fe — основа, 5 C — 0,3—0,8%, 7 примеси — до 0,5%	То же 8
9 Компактная спеченная нержавеющая сталь	Fe — основа, 5 Ni — 12—18%, Cr — 6—8%, C — 0,2—0,5%, 7 примеси — до 1%	•
10 Железомедный сплав	Fe — основа, 5 C — 0,1—0,5%, Cu — 5—15%	Шестерни и др. детали машин и приборов 11
12 Вакуумный легированный сплав	Fe — основа, 5 Ni — 22%, Mo — 20%	Детали вакуумной аппаратуры 13

1) Material form; 2) chemical composition; 3) application; 4) sintered iron compact; 5) base; 6) various components of machines and instruments, including rods, cams, bushings; 7) sintered carbon steel compact; 8) same; 9) sintered stainless steel compact; 10) iron-copper alloy, 11) gears and other components of machines and instruments; 12) vacuum melted alloy; 13) components for vacuum apparatus.

Components and products made from these materials, with the exception of the vacuum melted alloy, may also be prepared by the conventional methods of casting with subsequent mechanical working. The advantage of producing fully dense components and products by the powder metal-

TABLE 2

Properties of Basic Forms of Iron-Base Constructional Cermet Materials

1 Вид материала	2 НВ (кг/мм²)	2 σ_b (кг/мм²)	2 σ_{-b} (кг/мм²)	δ (%)
3 Компактное спеченное железо	50—60	19—21	30—32	3,5—5
4 Компактное спеченное железо, подвергнутое деформации (60—70%)	75—80	27—29	35—40	6—7
5 Компактная спеченная углеродистая сталь (0,5—1,0% C)	95—100	30—32	52—58	4—6
6 Компактная спеченная нержавеющая сталь типа 18-8, подвергнутая деформации (60—70%)	160—170	55—60	72—75	15—17
7 Вакуумный легированный сплав . . .	270—280	100—105	160—180	6—9

1) Material form; 2) HB (kg/mm^2); 3) sintered iron compact; 4) sintered iron compact subjected to deformation (60-70%); 5) sintered carbon steel compact (0.5-1.0% C); 6) sintered type 18-8 stainless steel subjected to deformation (60-70%); 7) vacuum melted alloy.

lurgy method lies in the great savings of metal, electric power, manpower as a result of obtaining parts in finished form, avoiding the use of mechanical working.

References: Rakovskiy V.S. and Saklinskiy V.V., Metallokeramika v mashinostroyenii (Cermets in Machine Design), M., 1956; Samsonov G.V. and Plotkin S.Ya., Proizvodstvo zheleznogo poroshka (Production of Iron Powder), M., 1957.

V.V. Saklinskiy

CONVENTIONAL DEFORMATION – magnitude of the deformation of a specimen referred to its initial dimension (length, cross-sectional area, angle); is expressed by the relative value of in percents. The conventional deformation in mechanical tests is characterized: 1) in tension by elongation $\delta=\frac{l_k-l_0}{l_0}$ or $\delta=\frac{l_k-l_0}{l_0}100\%$, where l_0 is the initial computational length, and l_k is the final length (or the length at the given experiment time), or by reduction in area $\psi \frac{F_0-F_k}{F_0}$, where F_0 is the initial cross sectional area of the working part of the specimen, and F_k is the final cross-sectional area (or the area at the given experiment time). The elongation δ and reduction in area ψ are related by the relationship $\psi=\frac{\delta}{1+\delta}$; 2) in compression it is expressed by contraction $\varepsilon_{szh} = \frac{h_0-h_k}{h_0}$, where H_0 is the initial height of the specimen, and h_k is the height of the specimen after compression (or at the experiment time under consideration), less frequently by the transverse area expansion $\psi_{szh} = \frac{F_k-F_0}{F_0}$; 3) in torsion it is expressed by the relative shear $\gamma=\frac{(\varphi_k-\varphi_0)d_0}{2l_0}$, where $(\varphi_k-\varphi_0)$ is the relative angle of twist (in radians) for two cross sections in the working part of the specimen (with a diamter d_0) located at a distance l_0.

N.V. Kadobnova

COPEL – is an alloy used in pyrometry as a negative thermoelectrode in the thermocouples: chromel – copel (KhK) and iron – copel (ZhK), and also for compensation conductors. The alloy has the trademark MNMts43-0.5.

In comparison to copper-nickel alloys utilized for similar purposes, copel is characterized by a maximum thermoelectromotive force and a temperature coefficient of the electric resistance which is al-

TABLE 1

Chemical Composition

1 Основные компоненты (%)			2 Примеси (%, не более)										
Mn	Ni+Co*	Cu	Fe	Si	Mg	Pb	S	C	P	Bi	As	Sb	Всего
0.1—1.0	42.5—44.0	3 остальное	0.15	0.10	0.05	0.002	0.01	0.1	0.002	0.02	0.002	0.002	0.6

* Cobalt is present as an impurity of the nickel.

1) Main components; 2) impurities (%, not more than); 3) the rest.

TABLE 2

The Physical Properties of Copel as a Function of the Temperature

1 Темп-ра (°C)	2 ρ_t (ом·мм²/м)	$\frac{\rho_t}{\rho_0}$	3 Температурный коэфф. электросопротивления	4 Тэдс в паре с платиной при темп-ре свободных концов 0° (мкв)
0	0.504	1.000	−0.00014 (0—100°)	0.00
100	0.497	0.985	−0.00012 (100—200°)	− 4.00
200	0.491	0.974	−0.00010 (200—300°)	− 8.57
300	0.486	0.963	−0.00006 (300—400°)	−13.55
400	0.483	0.958	0.00000 (400—500°)	−18.83
500	0.483	0.958	+0.00004 (500—600°)	−23.86
600	0.485	0.963	+0.00006 (600—700°)	−29.29
700	0.488	0.969	+0.00008 (700—800°)	−34.75
800	0.492	0.975		−40.20

1) Temperature; 2) ohm·mm²/m; 3) temperature coefficient of the electric resistance; 4) thermo-emf in a couple with platinum at 0° temperature of the free ends (microvolts).

most equal to zero. These properties permit copel to be used in special electric devices. Copel is also a good material for the design of rheostats and heaters having working temperatures of up to 600°. The changes in the electrical and thermoelectrical characteristics of the copel due to temperature are quoted in Table 2.

TABLE 3

The Physicomechanical Properties as a Function of the Degree of Cold Deformation

1 % деформации	НВ (кг/мм²) 2	σ_b (кг/мм²) 2	δ (%)	ρ (ом·мм²/м) 3	4 Электропроводность по отношению к меди (%)	γ (г/см³) 5
0	109	40	38.0	0.490	3.40	8.909
10	127	48	18.0	0.498	3.34	—
20	149	52	11.0	0.504	3.30	8.990
30	168	58	7.0	0.508	3.28	—
40	174	64	5.0	0.511	3.26	8.995
50	178	66	3.5	0.513	3.24	—
60	179	68	3.0	0.515	3.23	9.000
70	182	70	2.5	0.515	3.23	—
80	187	72	2.0	0.515	3.23	9.080
90	—	72	2.0	0.513	3.24	—

1) % of deformation; 2) kg/mm^2; 3) ohm·mm^2/m; 4) electrical conductivity in comparison with copper; 5) g/cm^3.

References: Berkovskiy I.Ya. and Stepanov F.N., Termoelektrodnyye i kompensatsionyye splavy [Alloys for Thermoelectrodes and Compensators], "Proizvodstvenno-tekhnicheskiy byulleten' zavoda im. Sergo Ordzhonikidze v g. kol'chugino" [Working and Technical Bulletin of the Sergo Ordzhonikidze Plant in Kol'chugino], 1936, No. 3-4; Berkovskiy I. Ya., and Kolokolova A.G., Nikelevyye splavy [Nickel Alloys], Moscow-Leningrad, 1941; Smiryagin A.P., Promyshlennyye tsvetnyye metally i splavy [Commercial Nonferrous Metals and Alloys], 2nd edition, Moscow, 1956; Schulze A., Metallische Werkstoffe für Thermoelemente [Metallic Materials for Thermocouples], Berlin, 1940.

A.L. Shpitsberg

COPPER. Cu is a chemical element of the 1st Group of the Mendeleyev periodic system, atomic number 29, atomic wieght 63.54. As a result of the fact that Copper is encountered in thenative state, it has been used by man from the acient days (Bronze Age). The copper content in the earth's crust amounts to only 0.01 weight %. The dominant portion of the copper (about 80%) exists in the earth's curst in the form of compounds with sulfur. About 15% of the copper is found in the form of oxygen compounds (carbonates, oxides, silicates, etc.). Copper forms up to 240 minerals, but only about 40% of them are of industrial importance.

Copper is a red metal with a rose color in the fracture, having a greenish-blue color when illuminated in thin sections. Copper has a face-centered cubic lattice (a = 3.6074A). Native copper consists of a mixture of two stable isotopes: Cu^{63}, present in the amount of 69.04%, and Cu^{65} – 30.96%. Among the artificial radioactive isotopes, Cu^{61} and Cu^{64} are used as tracer atoms. Density is 8.96 (20°), t_{pl} is 1083°, t_{kip} is 2600°, heat of fusion is 3.11 kcal/gram-atom, heat of vaporization is 72.8 kcal/gram-atom, specific heat is 0.092 cal/g-°C (20°). Distincitive features of copper are the high electrical and thermal conductivities (as a current conductor it occupies 2nd place following silver). The thermal conductivity is 0.941 cal/cm-sec-°C at 20°, electrical resistivity is 0.178 ohm-mm^2/m; temperature coefficient of electrical resistance is $4.3 \cdot 10^{-3}$ (0-100°); thermal coefficient of linear expansion is $17.0 \cdot 10^{-6}$ (20-100°). Modulus of elasticity is 13.200 kg/mm^2, shear modulus is 4240 kg/mm^2. Copper is diamagnetic.

Copper is corrosion resitant and plastic, as a result of which it is easily pressure worked in the hot and cold conditions.

Mechanical Properties of Copper

1 Состояние	2 Свойства	Показатель свойств 3
4 Мягкая	σ_s (кг/мм²) 5	7
6 Твердая		38
4 Мягкая	σ_b (кг/мм²) 5	20—24
6 Твердая		40—50
4 Мягкая	δ (%)	50
6 Твердая		6
4 Мягкая	ψ (%)	75
6 Твердая		35
7 Литая	$a_н$ (кгм/см²) 8	18
4 Мягкая	HB (кг/мм²) 5	35—40
6 Твердая		90—120
4 Мягкая	σ_{-1} (кг/мм²) 5 9 на базе 10^8 циклов	6.7
6 Твердая		11

1) Condition; 2) properties; 3) property index; 4) soft; 5) (kg/mm²); 6) hard; 7) cast 8) a_n (kgm/cm²); 9) on the basis of 10^8 cycles.

The ultimate strength of copper increases with work hardening while the elongation decreses. In this case the polyhedral or dendritic structure transforms into a fibrous structure. After annealing, copper regains its normal plasticity, since recrystallization takes place and the structure again becomes equized, polyhedral, with a large quantity of twinned crystals. Annealing at a temperature of 900° and above deteriorates the strength and plasticity of copper. Temperature for full anneal is 600-700°.

In compounds copper is mono- and di-valent. The electro-chemical equivalent of di-valent copper is 1.188 g/a-°C, the standard electrode potential is -0.34 v. At normal temperature copper has low chemical activity, in moist air it is gradually covered with a thin and dense film of basic sulfate and carbonate salts which protect against further oxidation. Copper dissolves easily in nitric acid with the release of nitrogen oxides and the formation of copper nitrate. When heated in hot sulfuric acid, copper dissolves with the release of sulfur dioxide and the formation of copper sulfate. In the absence of other oxidizers, dilute sulfuric and hydrochloric acids do not attack copper. Copper is stable in solutions of nonoxidizing salts, but its corrosion increases sharply in the presence of the higher oxide salts of iron, tin and other elements (mine waters). Organic acids attack copper only slightly. The corrosion rate in sea water is only 0.05 mm/year. Copper has poor resistance to ammonia, ammonia salts and alkaline cyanide compounds. The interaction of copper with oxygen begins even at room temperature. At high temperatures the rate of oxidation increases strongly and a reddish colored cuprous oxide film is formed. The rate of penetration of oxygen into copper to a depth of 0.5 mm as a function of temperature (with total oxygen content of 0.24%) is:

1 Темп-ра (°C)	600	700	800
Скорость проникновения 2 (часы)	11000	656	65

1)Temperature; 2) rate of penetration (hours).

The diffusion coefficient (with total oxygen content in the copper of 0.41%) is:

1 Темп-ра (°C)	600	700	800
Коэффициент диф- 2 фузии (см²/сек) . . .	1.06-[illegible]	1.47-[illegible]	1.28-[illegible]

1)Temperature; 2) diffusion coefficient (cm^2/sec).

Normal copper contains up to 0.45% Cu_2O, which corresponds to 0.05% oxygen. This content prevents saturation of copper by hydrogen, which causes "growth" of copper pigs in the conventional methods of casting. Copper containing oxygen must not be heated in a reducing atmosphere, since as a result of the penetration of these gases into the metal there takes place the reaction of formation of water vapor, which causes the appearance of cracks in the metal ("hydrogen disease").

Both the properties of copper and its behavior during working depend on its purity. Slight amounts of many elements appearing in copper in the form of admixtures or additives lead to sharp decreases of the electrical and thermal conductivities of copper, hinder pressure working. Sources of impurities in copper are the ores which contain various foreign metals, impurities which enter during smelting and deoxidation of the metal, and those which enter with the use of secondary metals. With respect to the nature of the interaction with copper, the impurities may be divided into the following three groups: 1) impurities of the metals which form solid solutions with copper (Ni, Zn, Sb, Sn, Al, As, Fe, P and others); 2) the metals which are practically insoluble in copper and form low-melting eutectics with it (Pb, Bi and others); 3) the metals which form brittle chemical compounds iwth copper (S, O_2 and others). As a rule, the elements which are soluble in copper do not deteriorate the capability of copper for plastic deformation but do reduce the electrical and thermal conductivities if their content in the metal is low.

The majority of the metals and impurities of the first group do not impair the mechanical properties of copper and are widely used in the production of variuos alloys. Thus, iron, which is only slightly soluble in copper (at 635° only 0.15% Fe enters into the solid solution) refines the grain structure, retards recrystallization, improves the strength and reduces the plasticity of copper decreases in the presence of iron. The solubility of antimony in copper diminishes sharply with temperature reduction. The appearance of intermetallic compounds reduces the plastic properties of the copper, moreover antimony reduces the electrical and thermal conductivities, therefoe, copper containing no more than 0.002% Sb is used for current conductors. Aresenic reduces the electrical and thermal conductivities of copper just as strongly. However, aresenic significantly improves the refractoriness of copper and neutralizes the harmful effect of oxygen, bismuth and antimony, therefore, copper with 0.3-0.5% As content is used for the fabrication of parts operating at high temperatures and in conditions of a reducing atmosphere (for example, steam locomotive boilers).

With only trace amounts of insoluble Pb and Bi impuirites in the alloy (0.002 Bi, 0.06% PB), they form low-melting eutectics which, lying along the grain boundaries, are the cause of the formation of cracks during pressure working. In the presence of 0.005% Bi, copper fractures easily during hot working, and with increase of the concentration it becomes brittle in the cold condition as well. Copper also fractures easily during hot working with the presence of lead. Lead improves the machinability of copper considerable. Impurities of both metals (Bi, Pb) have little effect on the electro- and thermoconductivity of copper. S, O_2 and other impurities which form intermetallic compounds with copper have little effect on the electro- and thermoconductivity of copper, but they degrade its mechanical properties and the capacity for pressure working.

Sulfur, which forms the chemical compound Cu_2S with copper, is practically insoluble in solid copper. Sulfur impurity reduces the pressure workability of copper in both the hot and cold conditions, has little effect on the electro- and thermoconductivity, and sharply improves the machinability of copper; small quantities of selenium and tellurium have a similar effect. Oxygen has low solubility in copper in the solid state, and during solidification separates in the form of the copper — cuprous oxide (Cu_2O) eutectic. A small amount of cuprous oxide has no effect on the properties, but an increased content mades copper brittle in the cold condition. With the presence of more than 0.1% oxygen, copper fractures easily with hot pressure working. The recrystallization temperature of copper is increased in the presence of oxygen (pure oxygen-free copper recrystallizes at 100°). Hydrogen has considerable solubility in solid and liquid copper, but has little effect on the properties. Hydrogen has a harmful effect on copper containing oxygen, causing "hydrogen sickness" – cracking under the influence of water vapors which are formed. Phosphorous entering the copper during deoxidation is found in the form of a solid solution. It has a favorable effect on the mechanical properties and weldability of copper, improves its fluidity, but markedly reduces the electro- and thermoconductivity.

More than 50% of the copper extracted is used in the electrical industry. Since impurities reduce the electrical conductivity of copper, in electrical applications use is made of metal of the highest grades, containing no less than 98.9% Cu. As a result of its high thermoconductivity and corrosion resistance, copper is used for the most critical products (heat exchangers, refrigerators, vacuum equipments, etc.). About 30-40% of the copper is used in industry in the form of various alloys (heavy industry, electrical industry, communications, transport). The most important of these alloys are the brasses and various bronzes. Moreover, in the form of salts, copper is used for the production of mineral pigments, to combat plant blights and diseases, as microfertilizers, catalyzers for oxidation processes, in the leather and fur industries.

See Red Copper, Technical Copper, Pure Copper, Copper Alloys.

References: Bochvar A.A., Metallovedeniye (Metal Science) 5th edition, M., 1956; Spravochnik po mashinostroitel'nym materialam (Handbook on Machine Design Materials), Vol. 2, M., 1959; Smiryagin A.P., Pormyshlennyye tsvetnyye metally i splavy (Industrial Nonferrous Metals and Alloys), 2nd edition, M., 1956.

O.Ye. Kestner

COPPER ALLOYS are copper-base alloys in which the alloying elements are tin, zinc, lead, nickel, aluminum, manganese, iron, silver, gold, phosphorus, silicon and others.

Depending on the alloying components, the copper alloys may be highly electro- and thermoconductive, plastic and quite strong at high temperatures, wear and chemically resistant, highly elastic, antifriction and ocrrosion resistant. The copper alloys have a beautiful external appearance similar to the alloys of gold and silver. These alloys are divided into two groups: brasses and bronzes.

The most widely used of the copper alloys are the brasses – the copper-nickel alloys containing up to 50% zinc. Additions to the binary copper-nickel alloys of small quantities of tin, aluminum, nickel, silicon, manganese, iron, lead and other elements increase the strength, hardness, machinability, give good casting properties, etc. The complex copper-nickel alloys are termed special brasses.

The alloys of copper with tin were previously termed simply bronzes. With the appearance of alloys of copper with other alloying metals (other than zinc), which are also termed bronzes, the copper-tin alloys acquired the name of tin bronzes, and the alloys of copper with other metals began to be called by the name of the primary (other than copper) component of the alloy, for example, aluminum, beryllium, silicon bronzes, etc.

The tin bronzes are the first alloys which mankind learned to utilize. From the ancient cultures of Egypt, Greece, Rome, China and more recent times there remain many artisitic products made from bronze. The copper alloys are preduced by smelting copper with other elements or their alloys – ligatures – in flame furnaces, or more frequently electric (arc, induction, high-frequency, resistance) furnaces. To prevent oxidation during smelting, use is made of charcoal, a flux or vacuum melting. At present, certain copper alloys are produced by means of electrolysis of complex aqueous solutions or by diffusion into the surface layers of metallic products. The single-phase low-alloy alloys are more easily deformed at room temperature than the highly alloyed alloys with a two-phase structure. However, at high temperatures the two-phase alloys deform more easily and the single-phase alloys resist deformation more strongly.

The copper alloys are used in the cast and wrought conditions. The alloys have higher strength and density in the wrougth condition.

In several cases heat treatment (solution treatment and aging) improves the plasticity (solution treatment) and reduces the internal stresses (annealing).

The alloys of copper with the other metals ususally contain no more than 10% of the primary alloying element, and contain even smaller quantities of the other components (in the more complex compositions). Only the brasses, which contain considerably more than 10% zinc, are an exception. Addition to copper of tin, aluminum, silicon, beryllium and other elements considerably increases the strength while retaining the plasticity. In the presence of large quantities of an alloying element the alloys becom brittle.

Among the strongest and adequately plastic copper alloys are the aluminum bronzes containing small quantities of iron, nickel, manganese. Their ultimate strength is 50-65 kg/mm^2 with an elongation of 8-12%. These alloys have good casting properties and are easily pressure worked, have high corrosion resistance. As a result of the good mechanical and technological properties they are widely used for the production of structural parts for various purposes, and also for parts operating at high temperatures. The beryllium bonzes in the heat treated condition have still higher strength, high elastic limit and hardness; they are corrosion resistant and are easily pressure worked in the solution treated condition. The ultimate strength of the beryllium bronzes reaches 150 kg/mm^2, the elastic limit reaches 110 kg/mm^2, the hardness 400 kg/mm^2, but in this case the elongation does not exceed 1%.

The brasses, particularly the special brasses containing a small amount of aluminum, iron, manganese and other metals, also are included among the alloys having good mechanical properties, high deformability, and good casting qualities. Their ultimate varies from 30 to 50 kg/mm^2 with elongation to 25%. The ultimate reaches 90 kg/mm^2 in the work-hardened condition. As a result of the considerable quantity of zinc, these alloys are the most economical. The good mechanical and excellent processing properties have led to wide use of the brasses for the fabrication of various articles.

The tin, antimony and lead bronzes are excellent antifriction materials. The alloys of copper with a small amount (total no more than 0.5-1.5%) of chromium, zirconium, cadmium, nickel, cobalt, beryllium and otherelements represent a group of alloys with special physical properties: high thermal and electrical conductivity with good thermal resistance (ultimate at 500-600° is 15-20 kg/mm^2).

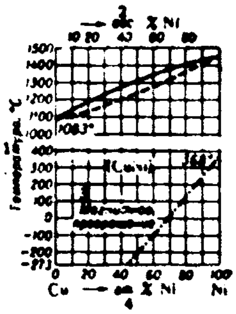
The copper alloy designation, which indicates its composition, begins with Br for the bronzes and with the letter L for the brasses. Following this for the bronzes and the initial letters of the names of the alloying components and numerals corresponding to their average content in the alloy. For example, aluminum-iron bronze with 10% Al and 4% Fe has the designation BrAZh10-4, which denotes the presence in the alloy of 10% Al and 4% Fe.

In the brass designations the letter L is followed by the initial letters of the alloying components, then there follows a numeral indicating the percentage copper content in the alloy, and then (in the same order as the letters) there follow the numerals for the percentage content of theallcying components in the alloy. Thus, for example, brass containing 70% Cu and 1% Sn is designated as LO70-1.

References: Bochvar A.A., Metallovedeniye (Metal Science), 5th edition, M., 1956; Smiryagin A.P., Promyshlennyye tsvetnyye metally i splavy (Industrial Nonferrous Metals and Alloys), 2nd edition, M., 1956; Bauer O, Hansen M., Structure of Copper-Zinc Alloys, translated from German, M., 1934; Turkin V.D., Rumyantsev M.V., Struktura i svoystva tsvetnykh metallov i splavov (Structure and Properties of Nonferrous Metals and Alloys), M., 1947; Mal'tsev M.V., Barsukova T.A., Borin F.A., Metallografiya tsvetnykh metallov i splavov (Metallography of Nonferrous Metals and Alloys), M., 1960.

O.Ye. Kestner

COPPER-NICKEL ALLOYS are copper-base alloys in which the primary alloying element is nickel. The state diagram for the copper-nickel system is shown in the figure. Copper forms with nickel a continuous series of solutions in the liquid and solid states. Alloys with predominantly copper content are nonmagnetic. Additions of nickel to copper improve the corrosion resistance in aggressive media (sea water, organic acids, etc.), the strength, hardness, electrical resistance and electromotive force (emf). Additional alloying of the copper-nickel alloys with aluminum, zinc or iron improves their corrosion resistance and strength. The copper-nickel alloys in production are by convention divided into dtructural and electric.



State diagram of the copper-nickel system. 1) Temperature, °C; 2) weight; 3) magnetic transformation 4) atomic.

The first group include the corrosion resistant binary alloys of copper with nickel of the melchior type, the ternary alloys of the Cu – Ni – Zn system of the argentan type, and the corrosion resistant hardenable alloys of the Cunial type. The second group includes the alloys of copper with nickel of the TP and TB type for compensation conductors, the Copel type high-nickel thermoelectrode alloy, the constantan type rheostat alloy, and the type MN5 low alloy nickel copper. The TP (MN0.6) alloy is recommended for production of compensation conductors for platinum/platinum-rhodium thermocouples. In a pair with copper the TP alloy develops, up to a temperature of 100°, the same thermo electromotive force (temf) as does the platinum/platinum-rhodium thermocouple.

The TB (MN16) alloy is used for compensation wires for platinum/gold and palladium/platinum-rhodium thermocouples. In a pair with copper the TB alloy has the same temf to 100° as do these thermocouples. In comparison with copper, the MN5 alloy has better corrosion resistance, greater strength and a higher recrystallization temperature. It is used to produce rod, tubing and sheet. Table 1 presents the chemical composition and forms of mill products of certain copper-nickel alloys, and Table 2 presents the technological properties. The temf characteristics of the copper-nickel alloys are presented in Tables 3 and 4.

TABLE 1

Chemical Composition and Forms of Mill Products of Certain Copper-Nickel alloys (GOST 492-52)

1 Сплав	2 Марка	3 Содержание (%) Cu	Ni	Виды полуфабриката 4
5 ТП	6 МН0.6	7 Остальное	0.57–0.63	Проволока 8
9 ТБ	6 МН16		15.3–16.3	Проволока 8
10 Никелевая медь	6 МН5		4.4–5.0	Прутки, трубы, листы 11

1) Alloy; 2) grade; 3) content (%); 4) forms of mill products; 5) TP; 6) MN ; 7) remainder; 8) wire; 9) TB; 10) nickel copper; 11) rod, tubing, sheet.

TABLE 2

Physical, Mechanical and Technological Properties of Certain Copper-Nickel Alloys

1 Сплав	γ (г/см³) 2	α·10⁶ (1/°C)	ρ (ом × мм²/м) 3	Темп-рный коэфф. электросопротивления при 20° 4	λ (кал/см·сек·°C) 5	E (кг/мм²) 6	В мягком состоянии 7: σ_b (кг/мм²) 6	δ (%)	Темп-ра (°C) 8: плавления 9	горячей обработки 10	отжига 11
12 МН0.6	8.96	—	0.031	0.0031	0.85	12000	28	50	1084	800–930	500–600
МН16	9.02	15.3	0.223	0.0027	—	8005	30	26	1170	950–1030	760–780
МН5	8.7	16.4	0.07	0.0015	0.31	—	24	[illegible]	1120	900–1000	600–650

1) Alloy; 2) (g/cm³); 3) (ohm-mm²/m); 4) temperature coefficient of electrical resistance at 20°; 5) cal/cm-sec-°C; 6) (kg/mm²); 7) in soft condition; 8) temperature (°C); 9) melting; 10) hot working; 11) annealing; 12) MN .

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TABLE 3

TEMF of Copper-Nickel Alloys in Pair with Copper as a Function of Temperature of the Hot Junction (cold junction 0°C)

Сплав 1	2 Темп-ра рабочего спая (°C)						
	100	200	300	400	500	600	800
	3 Термоэлектродвижущая сила (мв)						
4 МН0,6	+0.12	−0.66	−1.56	−2.48	−3.46	—	—
4 МН16	−2.21	−4.8	−7.93	−11.41	−14.91	—	—
5 Копель (МНМц43-05) .	−4.0	−8.57	−13.55	−18.62	−23.86	−29.29	−40.20
6 Константан (МНМц40-2,5) .	−3.4	−7.2	−11.3	−15.5	−19.9	−24.5	−33.7
7 Нейзильбер (МНц15-20) . .	−1.0	−2.03	−3.17	−4.51	—	—	—

1) Alloy; 2) temperature of hot junction (°C); 3) thermoelectromotive force (mv); 4) MN ; 5) Copel (MNMts43-05); 6) constantan (MNMts40-2.5); 7) German silver (MNMts15-20).

TABLE 4

TEMF of Iron-Copel, Copper-Copel and Chromel-Copel Thermocouples with Temperature of Free End 0°C (GOST 3044-61 and 6071-51)

1 Темп-ра рабочего спая (°C)	2 Термопары		
	железо-копель 3	медь-копель 4	хромель-копель 5
	6 ТЭДС (мв)		
−50	−2.55	−2.10	−3.11
0	0	0	0
100	5.75	4.75	6.95
150	8.85	7.42	10.69
200	12.0	10.29	14.66
250	15.05	13.36	18.76
300	18.10	16.48	22.90
350	21.29	19.72	27.15
400	24.55	23.13	31.48
450	27.75	26.60	35.81
500	30.95	30.15	40.15
550	34.16	33.81	44.54
600	37.40	37.47	49.00
650	40.72	—	53.39
700	44.10	—	57.75
750	47.57	—	62.09
800	51.15	—	65.10

1) Temperature of hot junction (°C); 2) Thermocouples; 3) iron-copel; 4) copper-copel; 5) chromel-copel; 6) TEMF (mv).

References: Mal'tsev M.V., Barsukova T.A., Borin F.A., Metallografiya tsvetnykh metallov i splavov (Metallography of Nonferrous Metals and Alloys), M., 1960; Smiryagin A.P., Promyshlennyye tsvetnyye metally i splavy (Industrial Nonferrous Metals and Alloys), 2nd edition, M. 1956.

Ye.S. Shpichinetskiy

II-60M

COPPER PLATING THE TITANIUM ALLOYS is the deposition of copper on the surfaces of parts made of the titanium alloys by the galvanic methof or by means of contact deposition. Copper plating of the titanium alloys is performed to obtain a sublayer before coating with other metals for brazing or in order to improve their electrical conductivity and thermal conductivity. The preparation of the surface prior to copper plating is accomplished primarily by the same method as in chrome plating the titanium alloys – etching in acid solutions or by the application of a zinc layer. Deposition of copper on the prepared surface may be performed in sulfate, cyanide and pyrosulfate baths. To obtain good bonding of the applied layer with the basic metal the parts are subjected to vacuum annealing after copper plating (or annelaing in an inert gas) at 650-700° for one hour, which leads to the formation of comparatively nonbrittle diffusional layers of copper in the titanium. With the application of a copper layer of more than 10-15 microns, as a result of the vacuum annealing the formation of bubbles and delamination of the coating, frequently takes place therefore, it is recommended that the copper plating operation be performed in two steps – first apply a layer 8-10 microns thick, then perform a vacuum anneal, and, finally, after pickling the surface, increase the basic copper layer to the required thickness.

Reference: Usova V.V., Layner V.I., Izv. Vysshikh uchebnykh zav. Tsvetnyye metally (News of Higher Educational Institutions. Nonferrous Metals), 1963, No. 4.

I.S. Anitov

CORDAGE are products fabricated by the twisting or plaiting of fibers, strands, strings, yarns. Cordage includes cables, ropes, cords, twines, threads. The schemes for the construction of the basic forms of cordage are shown in Fig. 1. Each form of cordage differs in construction (number and sequence of twisting of the individual elements), the yarn material and the method of fabricating it, the direction of twist of the product itself and of its elements, and the method of finishing. The weight charactersitic of the cordage is expressed by the weight per 1 or 100 meters of the product, by a metric number designating the number of kilotex, i.e., the weight per kilometer of product. The cordage construction is designated by a fraction: the numerator is the metric number of the yarn and the denominator is the number of strands twisted together. Each twisting process and the directions of twist (right Z, left S) are indicated separately (Fig. 2). For example, the construction of a cord made from right-lay No. 12 yarn by twisting in 10 strands to the left and then three strands to the right is designated by 12/10 x 3ZSZ. The size of cordage is defined by the diameter or by the circumference of the product. A most important characteristic of cordage is the tensile strength (kg) determined either on tensile machines (dynamometers) and termed aggregate strength, or as the sum of the strengths of all the fibers forming the cordage and then termed summary strength.

The most numerous group of cordage are the cables, marked by relatively large diametral dimensions and high tensile strength. Cables include hemp, manila, sisal, capron, cotton, etc. This same group includes combined products (for example, cables of the "hemp-steel" and "hercules" types) and marine ropes - lines. Cable fabricated by twisting strings into strands and then laying 3 or more strands in the direction opposite to the lay of the strands is termed hawser. Cable wound from 3 or 4 hawsers (strings) in the direction opposite to their lay is termed cable hawser. The latter, in comparison with the hawsers, have greater flexibility and are produced in sizes from 150 to 450 mm circumference. Special drive cables are made from hemp, sisal and manila for driving transmissions. In marine transport and for transmission drive, use is made of plaited cables formed by plaiting 4 strands of right lay and 4 strands of left lay. Plaited cables are completely balanced and are very flexible and strong, but are characterized by large residual elongations. To protect against rot the cables are impregnated with wood resin of the coniferous varieties at 85-105°. The resin content after impregnation is 16-20% of the initial yarn weight. The maximal anti-rot resistance of the cables is achieved with the use of impregnating compositions which form copper soap or copper-chrome-tannide lacquers with a content of no less than 0.5% copper with respect to the weight of the product. The following cables are fabricated in the USSR: untreated - for hoists and transmission drives, and resined (GOST 483-55) - for fishing tackle, ocean and river transport; sisal and manila (GOST 1088-41) for same uses as the untreated and re-

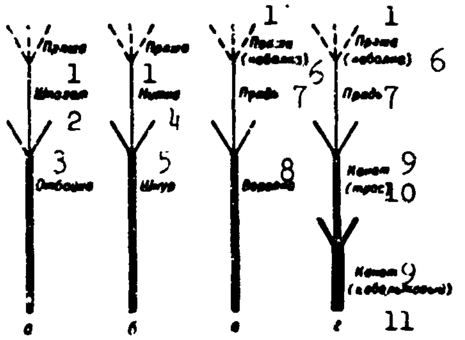

Fig. 1. Schemes for construction of cordage: a - Twine and fender rope; b - cord; c - rope; d - cable. 1) Yarn; 2) twine; 3) fender rope; 4) thread; 5) cord; 6) string; 7) strand; 8) rope; 9) cable; 10) hawser; 11) cable hawser.

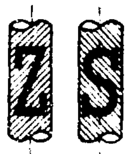

Fig. 2. Designation of twist direction: Z - right, S - left.

sined cables; capron (GOST 10293-62) for use in whaling, aviation and mine rescue operations; cotton (GOST 1766-42) used in transmission drives and power transfer to the working units of textile machines; lines (GOST 1091-41) and cables of the "hemp-steel" compound type used in ocean and river transport and in the fishing industry.

Ropes (other than marine) in contrast with cables, are fabricated from yarns made using the method of short (floss) spinning, i.e., they consist of relatively short fibers, as a result of which they have less tensile strength, lower wear resistance and lower volumetric weight. The high flexibility of the ropes in comparison with the cables is achieved as a result of the fact that their strands are given less twist. In certain cases the ropes are subjected to impregnation for the prevention of rot just as the cables are. The ropes produced in the USSR from bast fibers (GOST 1868-51) are used for: the high-quality industrial ropes are used for fishing tackle, signal blocks and hoisting mechanisms; the industrial, commercial and domestic ropes are used for binding, packaging and for the fabrication of harness; tenting ropes (VTU MTP 236-45) [Provisional Spec. International Trade Board] are used for outfitting tents. Cotton ropes of self-acting mules (TU NK [Spec. of the Peoples Commissariat] of the textile industry 30339-41) are used to drive textile machines, to equip low-power hoists; molding twine made from hemp (OST NKLP 2180) [All-Union Standard of the People's Commissariat of Light Industry 2180] is used for the tying of small items (molding, lath, etc.) in the lumbering industry.

Cord is the name given to small twisted products with diameter of 1-16 mm. They are used in aviation, on ships and for the fabrication of sporting goods. Braided cords - fall - differ from the twisted cords by their nontwist qualities, greater flexibility, but have lower strength. The following forms of cords are produced in the USSR (GOST 1765-42):

linen, linen cabling, twisted linen and cotton cords (GOST 1024-41), linen-hemp (GOST 5107-49), plaited linen (falls) and cotton cords (OST NKLP 7628/728 and 7627/727), kapron cords.

Twine products (binder twine from bast fibers (GOST 5725-51), single-thread packaging twine (STU [Sovnarkhoz Spec.] 29-1-66 of the Kursk Sovnarkhoz), sheaf-binding (OST NKLP 6707/407), hay binder (VTU of No. 1 Moscow Sovnarkhoz), cotton (TU MTP 30498-48) are intended for the binding and packaging of individual loads, for sewing bags, binding of sheafs and stacks of hay, packaging of postal packages, and also for the binding of sausages and fish preparatory to smoking. Fender cord (GOST 5758-51) is used in the furniture industry for tying springs. Cable yarn (GOST 905-41) is used as a protective covering in the cable industry. Twine products are produced in cylindrical coils with tight (precision) winding weighing 1.0-3.0 kg.

References: Spravochnik po pryadeniyu grubykh lubyanykh volokon i proizvodstvu kruchenykh izdeliy [Handbook on the Spinning of Coarse Bast Fibers and the Production of Cordage], ed. by L.N. Ginzburg, M., 1961; Ginzburg L.N., Dvernitskiy I.M., Pryadeniye lubyanykh volokon i proizvodstvo kruchenykh izdeliy [Spinning of Bast Fibers and Production of Cordage], M., 1959.

V.A. Zabelin

CORD FABRICS – technical fabrics with a plain weave, with the warp formed by a strong two-ply twisted thread (cord) and the weft is made of a lean, single ply twisted yarn. It is used for making pneumatic tire carcass covers, V-shaped driving belts, and other technical rubber products. Cord fabrics are made from cotton and chemical fibers. Cord fabrics have a high strength in the warp and moderate strength in the weft. The purpose of the weft is to protect the cord threads from crumbling away during rubberization. Cord threads should have a high rupture strength and elasticity, i.e., ability to stretch under a load and return to the initial state after the load is removed, fatigue strength (ability to withstand multiple deformations without failing), heat resistance. Cotton cord fabrics at 115-120° lose 30-35% of its initial strength, under similar conditions viscose cord fabrics lose 10-12%.

The warp of cotton cord fabrics is made from the highest quality thin-fiber cotton with a fiber length of 35-39 mm and a rupture length of 32-35 km; medium-fiber cotton with a rupture length of 24-25 km is used for the 3T and 23T cord fabrics. The first twisting of cotton cord fiber (800 turns per 1 m) is performed by the wet method, the second (400 turns) is done by the dry method. The length of a cord fabric cut is 180 and 360 m. Guideline data for cotton cord fabrics are given in Table 1 (in fatigue strength testing the warp threads of cord fabrics given in Table 1 should withstand at least 900 cycles to failure). Automotive vehicle and aircraft tires are made from capron cord fabrics with a warp of capron cord threads and weft from a single-strand cotton yarn. Viscose cord fabrics which have a higher strength are thinner for the same tensile strength which makes it possible to reduce the tire cover carcass, thus increasing its service life, improving the flexure resistance and reduce heat generation, are extensively used instead of cotton cord fabrics. Viscose cord fabric is made from super- and super-super viscose, wit a viscose cord thread warp and cotton yarn weft. The indicators of high-strength viscose cord fabrics are given in Table 2.

TABLE 1

Data on Cotton Cord Fabrics

Марка 1	Структура основной нити 2	Тонина (номер) уточной пряжи и допускаемые отклонения (%) 3	Диаметр основной нити при влажности 6,5% (мм) 4	Число нитей на 10 см 5		Ширина ткани (см) 6	Вес 1 м² при влажности 6,5% (г) 7	Сопротивление разрыву при влажности 6,5% (кг, не менее) 8	Удлинение при нагрузке 4,5 кг (%) 9	Коэфф. теплостойкости (не менее) 10	Влажность (%, не более) 11
				основа 12	уток 13						
3Т	37/5/3	40±2%	0,80±0,03	94±1	8±1	150±2	475±10	7,8	7±1	0,6[illegible]	7,5
7Т	39/4/3	60±2%	0,64±0,03	128±1	8±1	То же	472±10	7,9	6±1	0,69	То же
8Т	39/4/3	60±2%	0,64±0,03	128±1	8±1	»	472±10	7,7	6±1	0,6[illegible]	»
9Т	37/5/3	40±2%	0,80±0,03	94±1	8±1	»	475±10	9,0	7±1	0,66	» 14
10Т	37/5/3	40±2%	0,80±0,04	94±1	8±1	»	475±10	10,0	7±1	0,6	»
11ТМ	28/5/3	40±2%	0,87±0,05	94±1	8±1	»	—	11,0	6,5±1,5	—	»
23Т	37/5/3	40±2%	0,80±0,03	46±1	30±1	»	240±5	7,8	7±1	0,66	»
74Т	39/4/3	60±2%	0,64±0,03	94±1	16±1	»	350±7	7,0	6±1	0,69	»
84Т	39/4/3	60±2%	0,64±0,03	94±1	16±1	»	350±7	7,7	6±1	0,69	»
94Т	37/5/3	40±2%	0,80±0,03	70±1	16±1	»	355±7	9,0	7±1	0,66	»
723Т	39/4/3	60±2%	0,64±0,03	60±1	30±1	»	226±5	7,0	6±1	0,69	»
823Т	39/4/3	60±2%	0,64±0,03	60±1	30±1	»	226±5	7,7	6±1	0,69	»
923Т	37/5/3	40±2%	0,80±0,03	46±1	30±1	»	240±5	9,0	7±1	0,66	»

1) Brand; 2) warp thread structure; 3) thickness (number) of the weft yarn with the allowable deviations (%); 4) warp thread diameter for a moisture content of 6.5% (mm); 5) thread count per 10 cm; 6) fabric width (cm); 7) weight of 1 m^2 for a moisture content of 6.5% (g); 8) tensile strength for a moisture content of 6.5% (kg, not less than); 9) elongation under a load of 4.5 kg (%); 10) heat resistance coefficient (not less than); 11) moisture content (%, not more than); 12) warp; 13) weft; 14) same as above.

Bicycle tire carcass covers are made from cotton cord fabric, which is called bicycle tire-thread fabric; indicators of bicycle tire-thread cord fabric are given in Table 3.

III-70t2

TABLE 2

Indicators of High-Strength Viscose Cord Fabrics

1 Марка тканей	Структура ткани 2	3 Толщина (мм)	Разрывная нагрузка (кг, не менее) 4	Удлинение (%) 5		Число кручений на 1 м 6		Число нитей 7 на 10 см		8 Ширина ткани (см)	9 Вес 1 м² ткани (г)
				при нагрузке 4,5 кг 10	при разрыве 11	1-я крутка 12	2-я крутка 13	15 по основе 14	15 по утку		
14в	5,45/1×2	0,67±0,03	14,0	3,5±0,04	14±1,5	480±20	400±20	105±1	10±1	140±2	439±20
142в								85±1	14±1		359±15
145в								50±1	16±2		215±10
15в			15,0					105±1	10±1		439±20
152в								85±1	14±1		359±15
153в								50±1	16±1		215±10
17в			17,0					105±1	10±1		439±20
172в								85±1	14±1		359±15
173в								50±1	16±1		215±10

High-strength viscose cord fabric is produced in rolls 540 or 720 m long.

1) Fabric brand; 2) thread structure; 3) thickness (mm); 4) rupture load (kg, not less than); 5) elongation (%); 6) number of turns per 1 m; 7) thread count per 10 cm; 8) fabric width (cm); 9) weight of 1 m² of fabric (g).

TABLE 3

Indicators of Bicycle Tire-Thread Cord Fabric

Основа 1						2 Уток	3 Ткань		
4 структура ткани	5 диаметр нити при влажности 6,5% (мм)	сопротивление разрыву при влажности 6,5% (кг) 6	удлинение при разрыве (%) 7	число кручений 8		11 № пряжи	12 количество нитей на 10 см		ширина (см) 13
				1-я 9 крутка	2-я крутка 10		основа 1	уток 2	
20/2/3	0,43±0,05	2,5	11±2	710	355	40	144±2	8±1	140±2

1) Warp; 2) weft; 3) fabric; 4) fabric structure; 5) thread diameter for a moisture content of 6.5% (mm); 6) tensile strength for a moisture content of 6.5% (kg); 7) elongation at break (%); 8) number of turns; 9) 1st twisting; 10) 2nd twisting; 11) yarn No.; 12) thread count per 10 cm; 13) width (cm).

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CORD FILAMENT (cord fiber, cord yarn) is filament of unlimited length differing from ordinary filamentary thread in high strength and lower elongation. Cord filament is produced with low numbers (usually

Physical and Mechanical Properties of Cord Fibers

Свойства 1	2 Волокна				
	вискозное 3	найлоновое 4	капроновое 5	хлопковое 6	стальное 7
Уд. вес 8	1,52	1,14	1,14	1,50	7,80
$N_{эл}$ (м/г) 9	5000	1450	1450	3460	6,8
Диаметр эл. волокна (мм) 10	0,0145	0,0235	0,0235	0,0155	0,145
Разрывная длина (км) 11	45—50	72—90	75—80	23—27	12,5
Временное сопротивление разрыву (кг/мм²) 12	67—76	82—102	85—91	35—41	98,5
Удлинение (%) 13	10—14	15—18	15—18	7—8	2
Модуль упругости (кг/мм²) 14	1275	350	250	1150	—

1) Properties; 2) fibers; 3) viscose; 4) nylon; 5) kapron; 6) cotton; 7) steel; 8) specific gravity; 9) N_{el} (meters/gram); 10) diameter of elementary fiber (mm); 11) breaking length (km); 12) ultimate tensile strength (kg/mm^2); 13) elongation (%); 14) elastic modulus (kg/mm^2).

for the chemical fibers N_M is from 5.45 to 10.7); in addition, in the USSR it is produced with N_M of 34.5 (polyamide cord filament). Two or more cord filaments are twisted to produce cord. Initially the cord filaments are twisted to obtain 500-600 turns per meter, and then two or more twisted filaments are twisted in the opposite direction, obtaining 320-470 turns per meter.

Wide use is made of the viscose and polyamide (kapron and nylon) cord filament for the production of technical rubber articles.

References: Konkin, A.A., Rogovina, A.A., and Birger, G.Ye., KhV [Chemical Fibers], 1961, No. 1.

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CORDS — see Cordage.