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APPLICATIONS OF ALUMINUM ALLOYS IN BUILDING STRUCTURES
(SELECTED SECTIONS)

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APPLICATIONS OF ALUMINUM ALLOYS IN BUILDING STRUCTURES (SELECTED SECTIONS)

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ABSTRACT : The classification, chemical composition and mechanical characteristics of aluminum alloys produced in the USSR are presented. Aluminum alloys are divided into two categories - casting and shaping. Casting alloys are used for making various intricately shaped castings, and their chemical composition is divided into five groups. GOST 2685-53 lists the chemical composition and mechanical properties of casting alloys. Aluminum shaping alloys are those which can be successfully subjected to mechanical pressure working, i.e., rolling, forging, and pressing, and should have high plasticity. Shaping alloys are used for such products as sheets, ribbons, plates, bar stock, tubing, wire, etc., by hot or cold shaping methods. Their brand designations and chemical composition according to GOST 4784-49 are listed in Tables 3 and 4 of the document. The main alloying additives for shaping alloys, as in the case of casting alloys, are copper, magnesium, manganese and silicon. English Translation: 27 pages.

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2. CLASSIFICATION, CHEMICAL COMPOSITION AND MECHANICAL CHARACTERISTICS OF ALLOYS PRODUCED IN THE USSR [15], [16]

The nomenclature of alloys put out by the domestic industry is extensive. The physicomachanical properties of alloys depend on the chemical composition and to a large degree on the character and sequence of heat treatment and machining of the products.

Alloying admixtures to aluminum in various combinations and quantities makes it possible to obtain alloys with the most varied properties.

Copper, silicon and magnesium form compounds which are soluble in aluminum and which are instrumental in hardening the alloy on heat treatment. Copper, hardening the alloy, reduces its corrosion resistance. Silicon, increasing the strength, simultaneously reduces the plasticity. Magnesium has a hardening effect and improves corrosion resistance, however, the plasticity of the alloy in the hot state is reduced. Manganese, increasing the strength of the alloy, sharply reduces its plasticity. Iron is a harmful admixture. Its presence in the double alloy Al-Cu reduces the alloy's hardening ability after heat treatment. The presence of magnesium in this case reduces the harmful effect of the iron.

Aluminum alloys are divided into casting and shaping.

In the USSR, casting aluminum alloys are designated by AL; shaping alloys are marked as follows:

forging and stamping alloys - AK;

aluminum-magnesium alloys - AMg;

aluminum-manganese alloys - AMts;

aluminum-silicon alloy - "avial" - has the index AV;

a large group of duralumin-type alloys is designated by the letter D which is followed by a conventional number.

For clad sheets the alloy brand designation is supplemented by the letter A. All the sheets from duralumin type alloys are put out in the USSR in the clad state; sheets from the D16 alloy, which are put out without cladding (see GOST 1946-50), unlike similar clad sheets are denoted by the letter B.

Products from alloys, as a rule, are supplied in the hardened state, which is obtained by one or another treatment.

The state in which it is supplied is designated by the appropriate letter:

- M - annealed (soft);
- T - quench hardened and naturally aged;
- Tl - quench hardened and artificially aged;
- P - semihardened;
- N - hardened;
- V - high rolled shape quality.

The letters designating the state in which supplied are written after the alloy brand and are separated by a dash.

As an example, we shall present the designations of products (sheets) from aluminum alloys supplied in various states:

AMg is a sheet from the AMg alloy without any treatment;

D16A is a sheet from the D16 alloy, clad, not heat treated;

AMts-P is a sheet from the AMts alloy, semihardened;

AMg-N is a sheet from the AMG alloy, hardened;

AV-T IS A sheet from the AV alloy, quench hardened and naturally aged;

D16A-T is a sheet from the D16 alloy, clad, quench hardened and naturally aged;

V95A-T1 is a sheet from the V95 alloy, clad, quench hardened and artificially aged;

V95A-T1V is a sheet from the V95 alloy, clad, high rolled shape quality, quench hardened and artificially aged;

D16A-TN is a sheet from the D16 alloy, clad, hardened after quench hardening and natural aging;

D16A-TNV is a sheet from the D16 alloy, clad, high rolled shape quality, hardened after quench hardening and natural aging.

D16A-B-TNV is the same as above, but without cladding.

ALUMINUM CASTING ALLOYS

Casting alloys serve for making various kinds of intricately shaped castings.

Aluminum casting alloys are divided by their chemical composition into five groups.

Group 1 are alloys on the basis of the aluminum-magnesium system; brands AL8 and AL13.

Group 2 are alloys on the basis of the aluminum-silicon system; brands AL4, AL4V, AL9 and AL9V.

Group 3 are alloys on the basis of the aluminum-copper system; brands AL7, AL7V and AL12.

Group 4 are alloys on the basis of the aluminum-silicon-copper system; brands AL3, AL3V, AL5, AL6, AL10V, AL14V and AL15V.

Group 5 are alloys on the basis of the aluminum-other components system; (including nickel or zinc, or iron); brands AL1, AL11, AL16V, AL17V and AL18V.

The chemical composition of casting alloys and their mechanical properties are presented in GOST 2685-53.

The mechanical properties of casting alloys depend to a large extent on the method of casting and heat treatment. Brand AL8 alloy has the highest mechanical indicators. After heat treatment (quench hardening) its ultimate strength comprises $\sigma_{pch} = 28 \text{ kg/mm}^2$ for a relative elongation $\epsilon = 9\%$ (on a computational length of $l = 5d$). By its chemical composition this alloy belongs to the first group (the Al-Mg system). The quantity of magnesium in the AL8 alloy comprises from 9.5 to 11.5%.

Alloys of the second group, which contain silicon, are known under the name of silumins, have good casting qualities, i.e., castability, low shrinkage on cooling and hence are successfully used for making intricately shaped castings.

Other casting alloys, although they have comparatively high mechanical properties, are used less frequently than silumins, due to their poorer casting qualities.

Casting alloys are extensively used in machine building. Their use in building construction abroad is at present restricted to nodal castings for joining tubular constructions, but here they meet successful competition from shaping (forging) alloys.

Aluminum Shaping Alloys

The term shaping alloys denotes alloys which can be successfully subjected to mechanical pressure working, i.e., rolling, forging, pressing and similar operations.

These alloys should be highly plastic.

Aluminum shaping alloys serve for making various semifinished products such as shapes, sheets, bar stock, tubing, wire, etc., by hot or cold shaping methods. The designation of brands of shaping alloys and their chemical composition (according to GOST 4784-49) are presented in Tables 3 and 4.

The main alloying additives for shaping alloys, as in the case of

casting alloys, are copper, magnesium, manganese and silicon, while for the V95 alloy, in addition, also zinc and chromium. The chemical composition of the V95 alloy (which is not specified in GOST 4784-49) is as follows: copper 1.7%, magnesium 2.3%, manganese 0.4%, zinc 6%, chrome 0.2%, the balance being aluminum.

We should note still another alloy which is as yet not specified in GOST, i.e., the brand AMg6T alloy; its chemical composition is magnesium 6%, manganese 0.6%, the balance being aluminum.

The majority of shaping alloys possesses high mechanical properties. Heat treatment and machining make it possible to even more increase the strength of products from shaping alloys.

Products from alloys of the same chemical composition can have different characteristics.

The requirements put to the mechanical properties of shaping alloys are specified by All-Union GOSTs and normal standards of the Ministry of Aviation Industry of the USSR.

Typical physicommechanical properties of the most extensively used shaping alloys are presented in Table 5.

The mechanical properties of products depend not only on the alloy's brand and on its processing, but also on the method of making the semifinished products (rolling, pressing, etc.). In conjunction with this, the technical specifications for products from alloys have been elaborated separately for the different semifinished products (shaped stock, tubing, sheets, bar stock, etc.).

In accordance with AMTU 258-55, Table 6 presents data on the mechanical properties of pressed shapes which are obtained in testing specimens cut out from the shapes in the longitudinal direction; the indicators of characteristics which are obtained in testing specimens cut out in the transverse direction and along the thickness are some-

what lower.

Characteristics of pressed shapes is the increase in the indicators of strength characteristics with an increase in the web thickness.

The mechanical characteristics of sheets from the D1 and D16 alloys (according to GOST 4977-52) are presented in Table 7, while those for the V95 alloy (according to AMTU 253-48) are given in Table 5.

TABLE 3

Chemical Composition of Aluminum Shaping Alloys (according to GOST 4784-49)

1 Марка сплава	2 Основные компоненты в %									10 ванадий	11 эрициний
	3 медь	4 магний	5 марганец	6 никель	7 железо	8 кремний	9 титан				
12 АД	—	—	—	—	—	—	—	—	—	98,8 99,3	
13 АД1	—	—	—	—	—	—	—	—	—		
14 АМц	—	—	1,0-1,6	—	—	—	—	—	—		
14 АМг	—	2,0-2,8	0,15-0,35*	—	—	—	—	—	—		
14 АМг3	—	3,2	0,3	—	—	—	—	—	—	Остальное 19	
15 АМг5В	—	3,8	0,6	—	—	0,5 0,8	—	—	—		
		4,6	0,3								
		5,4	0,5								
16 АМг5П	—	4,7-5,7	0,2-0,6	—	—	—	—	—	0,02 0,2		
17 Д1	3,8-4,8	0,4-0,8	0,4-0,8	—	—	—	—	—	—		
17 Д6	4,6-5,2	0,65-1	0,5-1	—	—	—	—	—	—		
17 Д7	3,0-4	0,25-0,5	0,25-0,5	—	—	—	—	—	—		
17 Д16	3,8-4,9	1,2-1,8	0,3-0,9	—	—	—	—	—	—		
18 Д1П	3,8-4,5	0,4-0,8	0,4-0,8	—	—	—	—	—	—		
18 Д3П	2,6-3,5	0,3-0,7	0,3-0,7	—	—	—	—	—	—		
18 Д16П	3,8-4,5	1,2-1,6	0,3-0,7	—	—	—	—	—	—		
18 Д18П	2,2-3	0,2-0,5	—	—	—	—	—	—	—		
20 АВ	0,2-0,6	0,45-0,9	0,15-0,35*	—	—	—	—	—	—		
АК	—	—	—	—	—	—	0,5-1,2 4,5-6	—	—		
АК2	3,5-4,5	0,4-0,8	—	—	—	—	—	—	—		
АК4	1,9-2,5	1,4-1,8	—	1,8-2,3	0,5-1	—	—	—	—		
АК4-1	1,9-2,5	1,4-1,8	—	1,0-1,5	1,1-1,6	—	—	—	—		
АК6	1,8-2,6	0,4-0,8	—	1,0-1,5	1,1-1,6	—	—	—	—		
АК8	3,9-4,8	0,4-0,8	0,4-0,8	—	—	—	—	—	—		
АЛД	—	0,4-0,8	0,4-1	—	—	—	—	—	—		
21 Д12	—	0,5-0,9	—	—	—	—	—	—	—		
17 Д12	—	0,8-1,3	0,9-1,4	—	—	0,2-0,5	0,8-1	0,02-0,1	—		

*Manganese can be replaced by the same quantity of chromium.

1) Alloy brand; 2) main components in %; 3) copper; 4) magnesium; 5) manganese; 6) nickel; 7) iron; 8) silicon; 9) titanium; 10) vanadium; 11) aluminum; 12) AD; 13) AMts; 14) AMg; 15) AMg5V; 16) AMg5P; 17) D; 18) D1P; 19) balance; 20) AV; 21) ALD.

The mechanical properties of bar stock from various alloy brands, according to GOST 4783-49, are presented in Table 8.

The mechanical properties of tubing from brand D1, D6, D16 alloys, according to AMTU-259-48, are presented in Table 9.

TABLE 4

Content of Admixtures in Aluminum Shaping Alloys (according to GOST 4784-49)

1 Марка сплава	2 Примеси в %, не более												13
	3	4	5	6	7	8	9	10	11	12	сумма всех примесей		
14 АД	0,5	0,55	1	0,1	0,1	—	0,1	—	0,1	0,1	1,2		
14 АД1	0,3	0,35	0,6	0,05	—	—	—	—	—	0,1	0,7		
15 АМц	0,7	0,6	—	0,2	—	—	0,1	—	0,05	0,1	1,75		
16 АМг	0,4	0,4	0,6	0,1	—	—	—	—	—	0,1	0,8		
17 АМг5П	0,4	0,4	0,6	0,2	—	—	—	—	—	0,1	1,1		
18 Д1	0,7	0,7	—	—	—	0,1	0,3	0,7	—	0,1	1,8		
18 Д6	0,5	0,5	—	—	—	0,1	0,3	—	—	0,1	1,5		
18 Д7	0,8	0,8	—	—	—	0,1	0,3	0,8	—	0,1	2,0		
18 Д16	0,5	0,5	—	—	—	0,1	0,3	0,5	—	0,1	1,5		
19 Д1П	0,5	0,5	—	—	—	—	0,1	—	—	0,1	1,2		
19 Д3П	0,5	0,5	—	—	—	—	—	—	—	0,1	1,1		
19 Д16П	0,5	0,5	—	—	—	—	0,1	—	—	0,1	1,2		
19 Д18П	0,5	0,5	—	—	0,2	—	0,1	—	—	0,1	1,4		
20 АВ	0,5	—	—	—	—	—	0,2	—	—	0,1	0,8		
АК	0,6	—	—	0,2	—	—	0,1	—	—	0,1	0,9		
АК2	—	—	—	—	0,2	—	0,3	—	—	0,1	0,6		
АК4	—	—	—	—	0,2	—	0,3	—	—	0,1	0,6		
АК4-1	—	0,35	—	—	0,2	—	0,3	—	—	0,1	0,95		
АК6	0,7	—	—	—	—	0,1	0,3	0,7	—	0,1	1,1		
АК8	0,7	—	—	—	—	0,1	0,3	—	—	0,1	1,2		
22 АД	—	—	—	—	—	—	—	—	—	—	—		
18 Д12	0,7	0,7	—	0,1	—	—	—	—	—	0,1	1,5		
16 АМг3	0,5	—	—	0,05	—	—	0,2	—	—	0,1	0,85		
23 АМг5В	0,5	0,5	—	0,05	—	—	0,2	—	—	0,1	1,35		

1) Alloy brand; 2) admixtures in %, not more than; 3) iron; 4) silicon; 5) iron and silicon together; 6) copper; 7) manganese; 8) nickel; 9) zinc; 10) iron and nickel together; 11) magnesium; 12) other admixtures; 13) total of all the admixtures; 14) АД; 15) АМц; 16) АМг; 17) АМг5П; 18) Д; 19) Д1П; 20) АВ; 21) zinc and tin; 22) АД; 23) АМг5В.

For various structural elements, use is made of alloys having the most varied properties. In individual cases the deciding factors in the selection of an alloy are the machinability, weldability or corrosion resistance properties. For example, in those cases when high plasticity, corrosion resistance and good weldability are demanded of the product, use is made of the АМц and АМг not heat-treatment hardenable alloys.

By its corrosion resistance, the АМц alloy is close to pure aluminum. The alloy can be successfully welded by gas, atomic hydrogen and

resistance welding. Its machinability is poor. Due to the high plasticity of the alloy in the annealed state, it is used for components made by deep drawing.

The AMg alloy is highly corrosion resistant under atmospheric conditions and in sea water. The alloy welds well by resistance, spot and seam welding. When welded by the gas and argon-shielded arc method it tends to form cracks. The machinability of the AMgM alloy is unsatisfactory, while that of the AMgP and AMgN alloys is satisfactory. The alloy polishes well.

The AMg alloy is used for welded tanks and other components subjected to medium loads.

The AMg6T alloy, as the AMg alloy, has a high corrosion resistance.

The AMg6T alloy is not hardened by heat treatment.

The alloy welds well by argon-shielded arc and welds satisfactorily by gas and spot welding. The machinability is good.

The AMg6T alloy is used in welded structures for frame elements, power components, as well as for products obtained by cold stamping.

The AV alloy belongs among heat treatment hardenable alloys. In the quench hardened and naturally aged state its corrosion resistance is almost as good as that of the AMts and AMg alloys. In the artificially aged state, in which the material reaches its highest strength, the corrosion resistance is reduced; here, the alloy exhibits a tendency to intercrystalline corrosion to the higher extent, the more copper it contains. The alloy has satisfactory corrosion resistance in the artificially aged state when the copper content does not exceed 0.1%.

The AV alloy welds well by spot and atomic hydrogen welding, and it welds satisfactorily by gas welding. The machinability of the quench hardened and aged alloy is good, while that of the annealed alloy is poor.

TABLE 5

Typical Physicomechanical Properties of Aluminum Shaping Alloys

1 Марка сплава	2 Вид полуфабриката	3 Состояние поставки	4 Обозначение	5	6	7	8	9	10	11	12
				Предел прочности 51	Предел текучести 6	Относительное удлинение 7	Модуль упругости 8	Модуль сдвига 9	Коэффициент Пуассона 10	Средний вес 11	Коэффициент линейного расширения 12
				кгс/мм ² 17	кгс/мм ² 18	% 19	кгс/мм ² 19	кгс/мм ² 19	-	г/см ³ 21	1/град 22
13 АД и АД1	14 Листы	15 Отожженные	16 АД-М и АД1-М	8	3	35				2,71	
13 АД и АД1	.	23 Нагартованные	АД-Н и АД1-Н	14	5	6				2,71	24·10 ⁻⁶
25 АМц	.	15 Отожженные	АМц-М 26	13	5	23	7100		0,31	2,73	
25 АМц	.	23 Нагартованные	АМц-Н 27	22	18	5				2,73	23·10 ⁻⁶
28 АМг	.	15 Отожженные	АМг-М 29	19	8	23				2,67	
28 АМг	.	30 Полупонагартованные	АМг-П 31	25	21	6	7000		0,30	2,67	24·10 ⁻⁶
32 АМг6Т	.	15 Отожженные	АМг6Т-М 32	32	16	15				2,67	
33 АВ	Профили всех 34 размеров	.	АВ-М 33	12	—	24				2,7	
33 АВ	То же 35	33 Закаленные и естественно состаренные	АВ-Т 33	18	—	14				2,7	23·10 ⁻⁶
33 АВ	.	36 Закаленные и искусственно состаренные	АВ-Т1 38	33	28	12				2,7	
38 Д1	Профили 39 δ < 10 мм	15 Отожженные	Д1-М 38	Не более 25	11		7100				
38 Д1	То же 35	36 Закаленные и естественно состаренные	Д1-Т 38	40	24	15		2700			
38 Д6	Профили 39 δ = 5-10 мм	То же 35	Д6-Т 38	42	30						
38 Д6	То же 35	15 Отожженные	Д6-М 38	Не более 25	11	13			0,31	2,8	22·10 ⁻⁶
38 Д16	.	36 Закаленные и естественно состаренные	Д16-Т 38	44	31	13					
38 Д16	Профили 39 δ > 20 мм	37 Закаленные и искусственно состаренные	Д16-Т1 38	48	40	7	7150				
38 Д16	Профили всех 36 размеров	Отожженные	Д16-М 38	Не более 25	11	13					
41 В95	Листы плакированные 42 δ = 3-10 мм	.	41 В95А-М	35 То же	..	10				2,85	
	То же 35	37 Закаленные и искусственно состаренные	В95А-Т1 43	50	42	7	7100			2,85	23·10 ⁻⁶
41 В95	.	44 Закаленные, искусственно состаренные и нагартованные	В95А-Т1Н 43	53	46	6				2,85	

1) Alloy brand; 2) kind of semifinished product; 3) state when supplied; 4) designation; 5) ultimate strength; 6) yield strength; 7) relative elongation; 8) modulus of elasticity; 9) shear modulus; 10) Poisson's ratio; 11) specific gravity; 12) coefficient of linear expansion; 13) AD and AD1; 14) sheets; 15) annealed; 16) AD-M and AD1-M; 17) pch; 18) t; 19) in kg/mm²; 20) in %; 21) in kg/dcm³; 22) degree⁻¹; 23) hardened; 24) AD-N and AD1-N; 25) AMts; 26) AMts-M; 27) AMts-N; 28) AMg; 29) AMg-M; 30) semihardened; 31) AMg-P; 32) AMg6T; 33) AV; 34) shaped stock of all dimensions; 35) same as above; 36) quench hardened and naturally aged; 37) quench hardened and artificially aged; 38) D; 39) shapes with mm; 40) not more than 25; 41) V; 42) clad sheets with δ = 3-10 mm; 43) N; 44) quench hardened, artificially aged and hardened.

The AV alloy is used for components the manufacture of which requires high plasticity in the cold and hot state and which should have good corrosion resistance.

TABLE 6

Mechanical Properties of Specimens Cut Out From Pressed Shapes in the Longitudinal Direction (according to AMTU 258-55)

1 Марка сплава	2 Состояние поставки профиля	3 Обозначение	4 Толщина полки профиля в мм	5 Предел прочности при растяжении в кг/мм ²	6 Предел текучести в кг/мм ²	7 Относительное удлинение в %
				8	Не менее	
9 Д1	Закаленные и естественно состаренные	9 Д1-Т	Менее 10, 10,1-20, более 20	36, 38, 41	22, 23, 25	12, 12, 10
		13 Д1-М	Все размеры	Не более 25	—	12
		16	11 14			
17 Д6 и Д16	Закаленные и естественно состаренные	16 Д6-Т и Д16-Т	Менее 5, 5,1-10, 10,1-20, 20,1-40, более 40	40, 42, 43, 45, 49	30, 30, 31, 32, 36	10
		13 Д6-М и Д16-М	Все размеры	Не более 25	—	12
		14	14	15		
19 АВ	Закаленные и естественно состаренные	19 АВ-Т	20 То же	18	—	14
		19				
		21 АВ-Т1		30	23	10
22 В95	Закаленные и искусственно состаренные	22 В95-Т1	Менее 10, 10,1-20, 20,1-40, более 40	51, 54, 57, 58	44, 45, 47, 50	5
		13 В95-М	Все размеры	Не более 28	—	10
		14	14	15		
23 АМц	Отожженные	23 АМц-М	Все размеры	Не более 17	—	16
24 АМг	.	24 АМг-М	То же	20	—	12
25 АД1 и АД	.	27 АД1-М	.	.	11	—
		26 АД-М	.	.		20

¹For web thicknesses of 10 mm and less for $l_0 = 11,3 \sqrt{P}$, for web thicknesses of more than 10 mm for $l_0 = 5d$.

1) Alloy brand; 2) state in which shapes are supplied; 3) designation; 4) web thickness of the shape in mm; 5) ultimate tensile strength in kg/mm²; 6) yield strength in kg/mm²; 7) relative elongation in %; 8) not less than; 9) D; 10) quench hardened and naturally aged; 11) less

than; 12) more than; 13) annealed; 14) all the dimensions; 15) not more than; 16) D6-T and D16-T; 17) D6 and D16; 18) D6-M and D16-M; 19) AV; 20) same as above; 21) quench hardened and artificially aged; 22) V; 23) AMts; 24) AMg; 25) AD1 and Ad; 27) AD.

TABLE 7

Mechanical Properties of Specimens Cut Out From Clad Sheets in the Direction Across the Rolling Direction (according to GOST 4977-52)

1 Марка сплава	2 Состояние поставки листов	3 Обозначение	4 Толщина листов в мм	5 Предел прочности при растяжении в кг/мм ²	6 Предел текучести в кг/мм ²	7 Относительное удлинение при $\sigma_{0.2}$
				8 не менее		
10 Д16	Отожженные	10 Д16А-М	0,3-2,5	11 Не более 23	—	10
		10 Д16А-Т	2,6-10	То же, 24	—	10
	Закаленные и естественно состаренные	10 Д16А-Т	0,3-2,5	12 44,5	—	13
		10 Д16А-ТН	2,5-6	43,5	28	14
	Нагартованные после закалки и естественного старения	10 Д16А-ТН	6,1-10	43,5	28	10
10 Д1	Отожженные	10 Д1А-М	0,8-2,5	43,5	34	10
		10 Д1А-Т	2,6-6,5	46,5	35	8
	Закаленные и естественно состаренные	9 Д1А-М	0,3-3	11 Не более 23	—	12
		10 Д1А-Т	3,1-10	То же, 24	—	12
		10 Д1А-Т	0,3-2,5	12 37	19	15
		10 Д1А-Т	2,6-10	38	20	15

1) Alloy brand; 2) state in which sheets are supplied; 3) designation; 4) sheet thickness in mm; 5) ultimate tensile strength in kg/mm²; 6) yield strength in kg/mm²; 7) relative elongation for $\sigma_{0.2}$ in %; 8) not less than; 9) annealed; 10) D; 11) not more than; 12) same as above; 13) quench hardened and naturally aged; 14) hardened after quench hardening and natural aging; 15) N.

The most extensively used alloys of the duralumin type, the main alloying additive of which is copper, are the D1, D6 and D16. The high strength of products from these alloys is achieved by heat treatment, consisting of the quench hardening operation with subsequent aging. However, the plasticity of these alloys is noticeably reduced after heat treatment. The corrosion resistance, weldability and machinability properties of duralumins depend on the degree of alloying and on the processing method.

The D1 alloy has satisfactory corrosion resistance. Clad, quench hardened and naturally aged sheets have good corrosion resistance.

TABLE 8

Mechanical Properties of Bar Stock (according to GOST 4783-49)

1 Марка сплава	2 Термическая обра- ботка	3 Диаметр прутков в мм	4 Предел прочности при рас- тяжении в кг/мм ²	5 Предел текучести в кг/мм ²	6 Относи- тельное удлинение при $\epsilon_5 = \frac{l_5 - l_0}{l_0} \cdot 100$ в %
7 Не менее					
8 В95	9 Закалка и ис- кусственное ста- рение	10 Менее 22 23—160 11 более 160	50 54 52	38 41 41	7 6 5
Д1 12	14 Закалка и ес- тественное старе- ние	10 Менее 160 более 160 11	38 36	22 20	12 16
Д6 и Д16 13		10 Менее 22 23—160 более 160 11	40 43 42	26 28 26	12 10 8
АВ 15 АК2 АК4 АК6		16 Всех размеров	30 36 36 36	— — — —	12 10 8 12
АК8		9 Закалка и ис- кусственное ста- рение	10 Менее 22 10 23—160 более 160 11	45 46 44	— — —
АД 12 АД1 12	19 Отжиг или без термической об- работки	16 Всех размеров	Не более 11 17	—	25
АМг 18			Не более 17 23	—	10
20 АМц			Не более 17	—	20

1) Alloy brand; 2) heat treatment; 3) bar stock diameters in mm; 4) ul-
timate tensile strength in kg/mm²; 5) ultimate yield strength in kg/mm²;
6) relative elongation for $l_5 = 5.65 \sqrt{F}$ in %; 7) not less than; 8) V; 9)
quench hardening and artificial aging; 10) less than; 11) more than;
12) D; 13) D6 and D16; 14) quench hardening and natural aging; 15) AV;
16) all dimensions; 17) not more than; 18) AMg; 19) annealing or without
heat treatment; 20) AMts.

The alloy welds well by spot welding. In gas and argon-shielded
arc welding a tendency is observed toward crack formation, which can
be reduced by using appropriate welding rod materials. The D1 alloy is
used for structural elements requiring medium-strength material.

The D6 alloy has moderate corrosion resistance. The plasticity of
the alloy in the annealed and freshly quench hardened states is low.

TABLE 9

Mechanical Properties of Tubing (according to AMTU 259-48)

1	2	3	4	5	6	7
Марка сплава	Состояние поставки труб	Обозначение	Диаметр мм	Предел прочности при рас- тяжении в кг/мм ²	Предел текучести в кг/мм ²	Относи- тельное удлинение в %
				8 Не менее		
9 Д1	Закаленные и естествен- но состаренные	Д1-Т 9	Менее 120	36	20	12
			более 120	38	22	10
9 Д6		Д6-Т 9	Менее 120	40	26	12
			более 120	43	28	10
9 Д16		Д16-Т 9	Менее 120	40	26	12
			более 120	43	28	10

1) Alloy brand; 2) state in which tubing is supplied; 3) designation; 4) diameter mm; 5) ultimate tensile strength in kg/mm²; 6) yield strength in kg/mm²; 7) relative elongation in %; 8) not less than; 9) D; 10) less than; 11) more than; 12) quench hardened and naturally aged.

The machinability in the quench hardened state is good, in the annealed state it is poor.

The D6 alloy is used for power elements of constructions. In the last few years its output was sharply curtailed; it is replaced by the D16 alloy.

The D16 alloy in nonclad products has poor corrosion resistance. Clad sheets more than 1 mm thick have high corrosion resistance. In pressed shapes with large cross sections, quench hardened and naturally aged, the alloy has a tendency to intercrystalline corrosion. Artificial aging results in increasing the anticorrosion properties.

The D16 alloy welds well by spot welding. In gas and argon-shielded arc welding the alloy has a tendency to crack formation. The machinability of the alloy in the annealed state is good, while in the annealed state it is reduced.

The D16 alloy is used for structures requiring high metal strength.

The V95 alloy in the naturally aged state has poor corrosion resistance. Clad sheets more than 1 mm thick in the artificially aged

state have satisfactory corrosion resistance. The weldability of the V95 alloy by spot welding is good, while by gas welding it is poor. The machinability is good.

The V95 alloy is a high-strength alloy and is used for structural elements subjected to high loads.

In addition to the above general-purpose shaping alloys, special purpose alloys are also available. Among the latter are aluminum forging alloys, which are designated by AK. The AK2 and AK4 alloys are used for making structural components operating at elevated temperatures, i.e., pistons, cylinder heads of internal combustion engines, etc.

The AK6 and AK8 alloys are intended for producing components operating at normal temperatures. Intricately shaped components are stamped from the AK6 alloy, which has quite high plasticity in the heated state.

Rivets are made from alloys having good plasticity and sufficiently high shearing strength. These alloys usually have the additional letter P in brand designations (D1P, D16P, D18P, AMg5P).

TABLE 10

Mechanical Properties of Rivet Wire (according to AMTU 332-53)

1 Марка спла	2 Состояние проволоки	3 Сопротивление срезу в кг/мм ² не менее
4 Д1П 4 Д16П 4 Д18П 6 В65П	5 После закалки и старения	24 27 19 25
7 АМц 9 АМг5П 10 АМг 11 АД1	8 В состоянии поставки	7 16 12 6

1) Alloy brand; 2) state of wire; 3) shearing strength in kg/mm² not less than; 4) D P; 5) after quench hardening and aging; 6) V65P; 7) AMts; 8) in the as-supplied state; 9) AMg5P; 10) AMg; 11) AD1.

The mechanical properties of rivet wire (shearing strength), according to AMTU 332-53, are presented in Table 10.

Rivets from the MAg5P alloy are used for type AMg alloys. For duralumin type alloys most frequent use is made of rivets from the D18P and V65P alloys; for the V95 alloy rivets from the V94 alloy are used.

5. ASSORTMENT OF SHAPES AND PRODUCTS MADE IN THE USSR [7], [8], [9], [16]

The assortment of semifinished products made at the domestic plants from various aluminum alloys is quite extensive. From aluminum shaping alloys are made: sheets, ribbons, plates, bent and corrugated shapes; pressed shapes, tubing, wires, forgings and stampings.

The production of the given semifinished products at plants is specialized in character. Some plants produce one and some other shapes and products. At present, almost all the semifinished products from aluminum are made on the basis of state standards, which define both the main dimensions of the products, as well as their mechanical characteristics. Those semifinished products for which GOST's have not been issued are made on the basis of special technical specifications (normal standards) of the Ministry of the Aviation Industry USSR.

Sheets, Ribbons, Plates

Sheets, ribbons and plates are made by hot and cold rolling. Thin sheets (less than 5 mm thick) are cold rolled. Sheets and ribbons are rolled in thicknesses from 0.3 to 10 mm. The limiting dimensions of the sheets are width 2000 mm and length up to 7000.

The assortment of sheets from aluminum alloys is presented in GOST 1946-50.

Clad sheets are made from brand D1, D16 and V95 alloys, while non-clad sheets are made from brand AMts, AMg, AV, AD, AD1 and D16 alloys.

According to the state in which they are supplied, sheets may be: hot rolled (without heat treatment), annealed, hardened, semihardened, quench hardened and artificially or naturally aged, as well as hardened

after quench hardening and natural aging.

Plates are made in thicknesses from 12 to 80 mm. The limiting shapes of plates are: width 500-1200 mm and length up to 3000 mm.

Bent and Corrugated Shapes (Corrugations)

Bent shapes are made from sheets and ribbons up to 4 mm thick by bending them in the cold state on multiroller machines. The types of bent shapes are shown in Fig. 15.

Corrugations are made on special corrugating machines. The dimensions of the waves are: height from 6 to 15.5 mm, step from 32 to 48.5 mm. The thickness of corrugated sheets is from 0.3 to 1 mm.

Corrugations are made longitudinally and transversely. Longitudinal corrugations are up to 3000 mm long with the sheet width before corrugating being 500, 800 and 1000 mm. The transverse corrugation is up to 1000 mm with the sheet width before corrugation being 2000, 2500 and 3000 mm.

Pressed Shapes

The shapes are made by hot pressing on special presses. As was pointed out above, the cross-sectional shape of the pressed shape is determined by the configuration of the hole in the press female die. The female die replacement makes it possible to obtain shapes with different cross sections. This is one of the advantages which permit the designer to use the most effective cross sectional shapes of rolled stock.

In 1957, the Scientific Research Institute of Production Organization and Technology of the Ministry of Aviation Industry (NIAT MAP) has issued a second edition of the catalog of pressed shapes which are made at the domestic plants.

Individual types of shape cross sections which are given in the catalog are shown in Figs. 17-21.

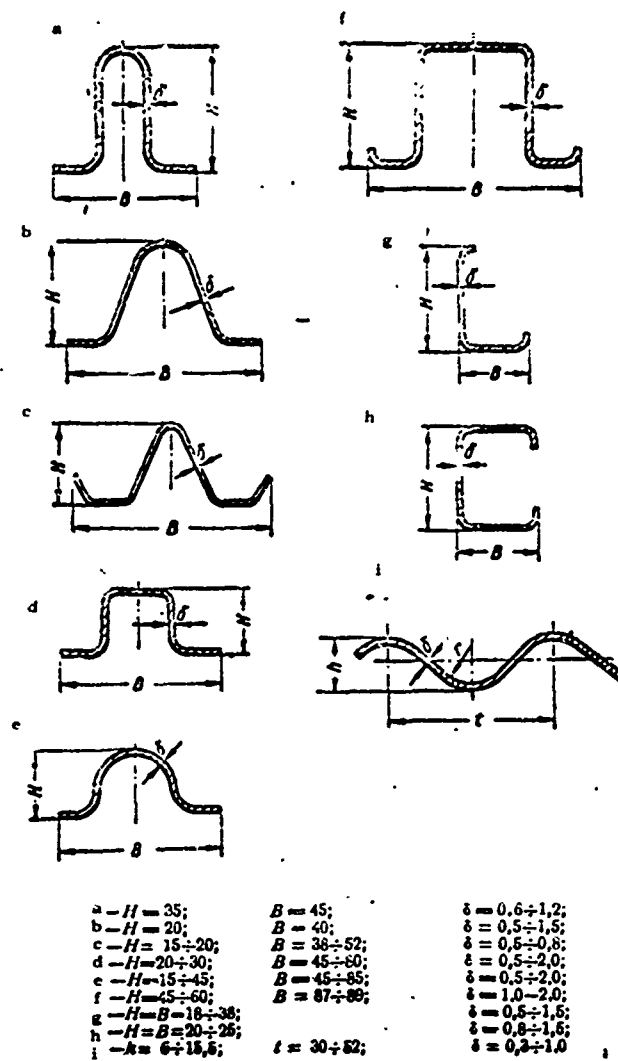


Fig. 15. Types of bent shapes.

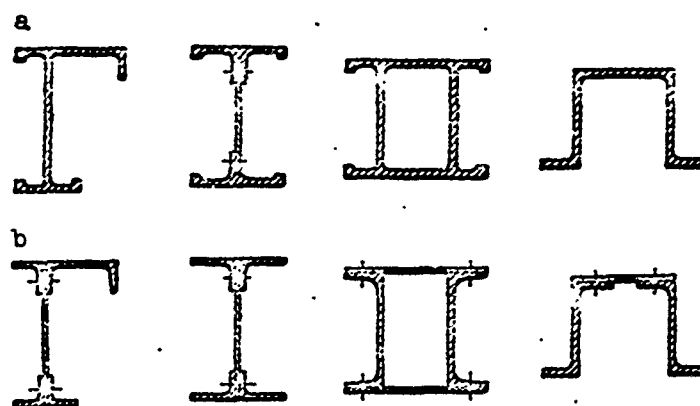


Fig. 16. Pressed shapes from an aluminum alloy (a) in comparison with composite sections from rolled steel shapes.

This catalog not only does not limit the designer, but conversely, it shows the variety of shapes which are obtained by hot pressing.

For building structures it is possible to obtain special shapes. As an example, Fig. 16 shows certain of the possible cross sections of pressed shapes (a) in comparison with composite sections of similar shape characteristic of steel designs (b).

However, it should again be said that the overall dimensions of the shape's cross section are limited by the dimensions of the container of the press and, taking into account the equipment most extensively used at plants, should be inscribable in a circle with a diameter of about 300 mm.

Pressed shapes are made from brand AD1, D1, D16, V95, AV, AK6, AMts, AMg, AMg5V, AMg6T alloys. The following are produced according to the 1957 catalog:

Equilateral angles with cross-sectional areas from 0.26 to 21.5 cm² (40 standard sizes). The smallest flange width is 12.7 mm, the greatest is 125 mm. The flange thickness is from 1 to 16 mm.

Nonequilateral angles with a cross sectional area from 0.41 to 51.5 cm² (114 standard sizes). The flange thickness is from 1 to 22 mm; here the majority of flanges are of different thickness. In addition, a number of special angular shapes (about 400 standard sizes) with a flange thickness which varies along the width, and with an angle between the flanges different than 90° are available. Examples of cross sections are shown in Fig. 17.

Z shapes of various cross sections (60 standard sizes) with areas from 0.7 to 40 cm². Examples of the cross sections are given in Fig. 18.

T and H shapes of various cross sections (more than 400 standard sizes). Examples of the cross section are given in Fig. 19. The greatest dimension of regular T shapes (the PK301-33) are: height of the T H =

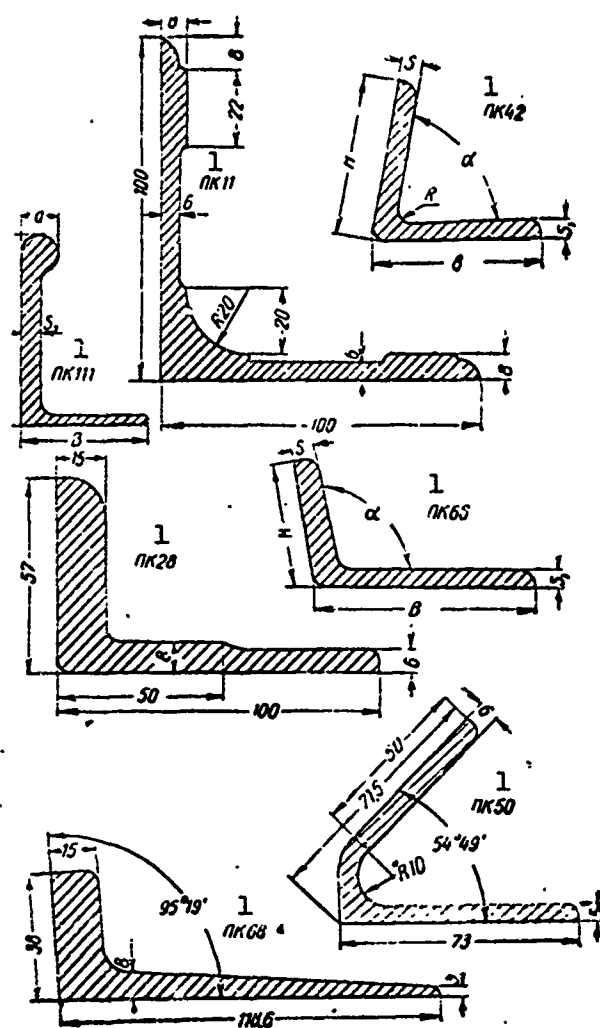


Fig. 17. Angular shapes. 1) PK.

= 170 mm, flange width $B = 208$ mm, flange thickness $S = S_1 = 8$ mm, greatest height of the H iron $H = 150$ mm.

Channels of various cross sections (more than 250 standard sizes) with cross-sectional areas from 0.5 to 70 cm². Examples of cross sections are given in Fig. 20.

Shapes of various cross sections (more than 800 standard sizes). The form of the cross sections of the shapes is varied. For example, Fig. 21 shows certain types of cross sections. Among them are closed type shapes (PK1062, PK1065, etc.).

Shapes with variable cross section. In addition to constant cross

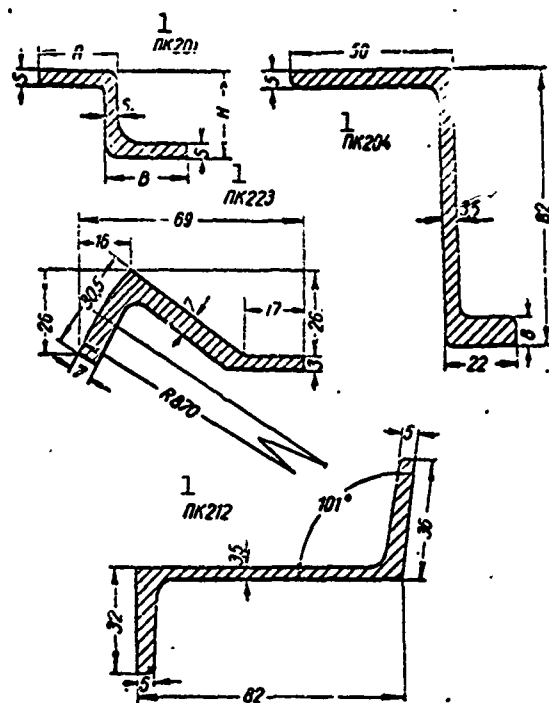


Fig. 18. Z shapes. 1) PK.

section shapes, the equipment available at plants makes it possible to produce shapes with cross section which varies along the length, both gradually as well as discontinuously.

In the first case the cross sectional shape of the rolled stock is retained along the entire length, and only the dimensions of individual elements of the shape change; for example, in the PK179 shape (see Fig. 20) the web thickness over a specific section changes gradually from 2 to 4 mm.

In the second case, the constant cross section can be changed in a specific place with respect to dimensions as well as shape; for example, the PK1765 shape which has an H shape, first changes with respect to dimensions and then becomes rectangular in cross sections. Usually, this change in the shape's cross section takes place toward the end, for which reason shapes of this type are called shapes with an ending.

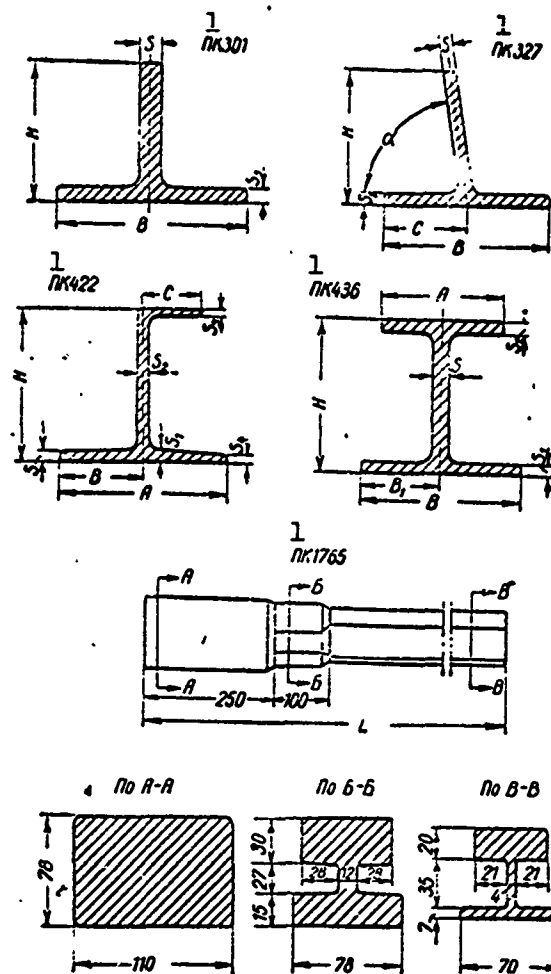


Fig. 19. T and H shapes. 1) PK.

It is also possible to produce shapes in which the cross sectional dimensions vary slowly along the length and, in addition, one of the ends of the shape becomes thicker, i.e., the shape has an ending.

It should, however, be noted that the production of shapes with variable cross section using the presently available equipment is substantially more expensive and complex in comparison with production of shapes of constant cross section.

Starting with L July 1957, a GOST was introduced for the most frequently used dimensions of shapes pressed from aluminum alloys: angles, Z shapes, T shapes, H shapes and channels (the numbers of GOSTs are given in the Appendix).

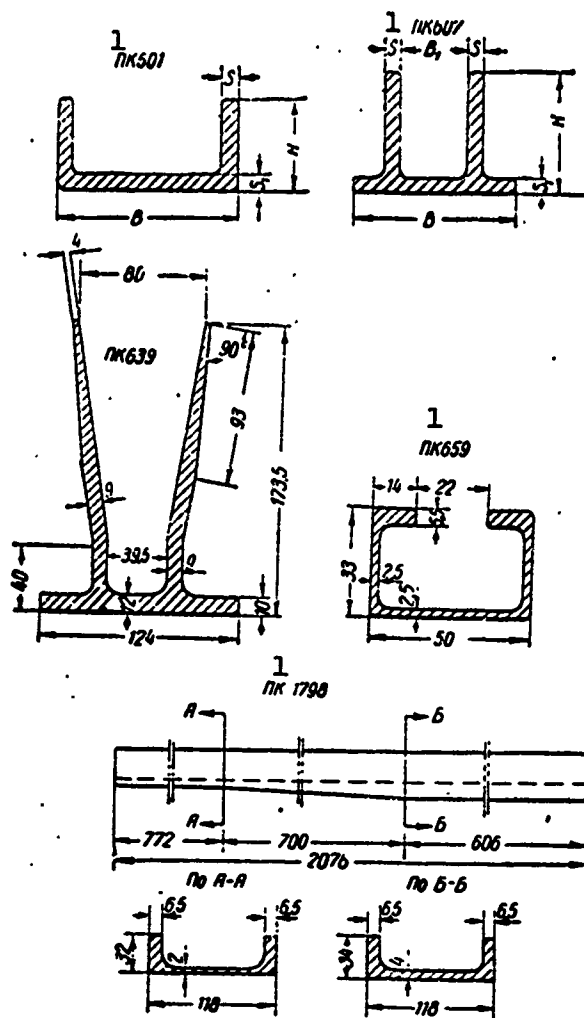


Fig. 20. Channel shapes. 1) PK.

To show the advantages of pressed shapes on a specific example, Fig. 22 shows types of cross sections specially elaborated for a typical exhibition pavilion designed in 1956 by the Moscow Architectural Workshop of the Glavstroyproyekt of the Ministry of Construction.*

The production of these shapes does not involve particular difficulties and is agreed upon with the producing plant.

Thus, in designing aluminum alloy structures the design engineer is not limited to any assortment of shapes and can, taking into account the method by which the semifinished products are made, specify cross sections which make it possible to most efficiently utilize the material.

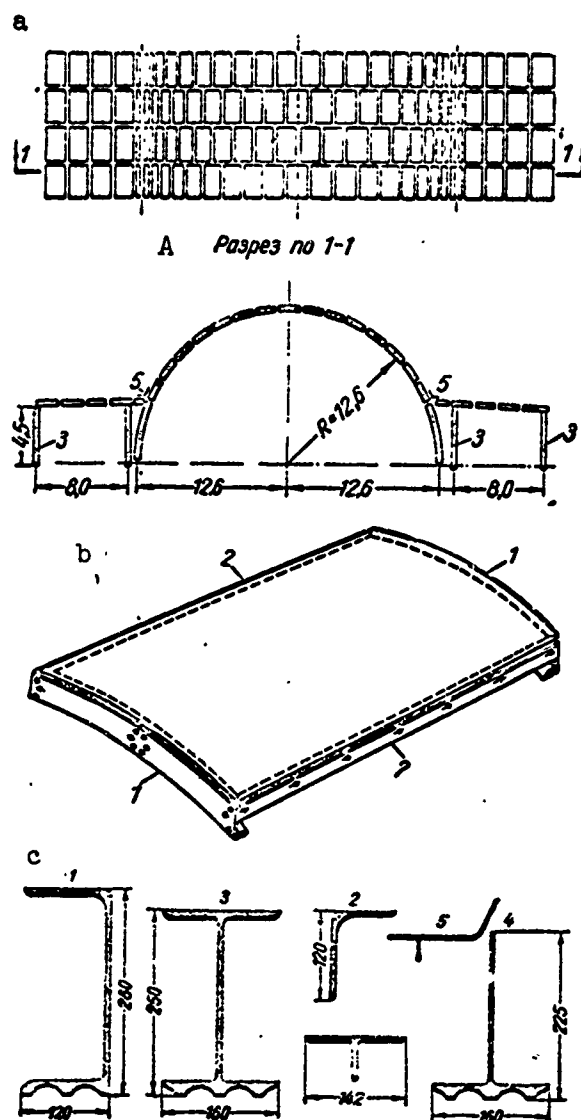


Fig. 22. Project of a typical exhibition pavillion. a) Schematic section of the building and the layout of roofing tubing; b) tubing of the roof canopy of a typical pavillion; c) types of cross sections of pressed shapes; A) Section.

Tubing

Thin-walled tubing from aluminum and aluminum alloys is made by cold drawing or cold rolling. Thin-walled tubing is made from hollow round blanks by hot pressing.

The technical specifications for tubing made by cold drawing or cold rolling are specified in GOST 4773-49.

Round tubing (drawn) is supplied with outside diameters from 6

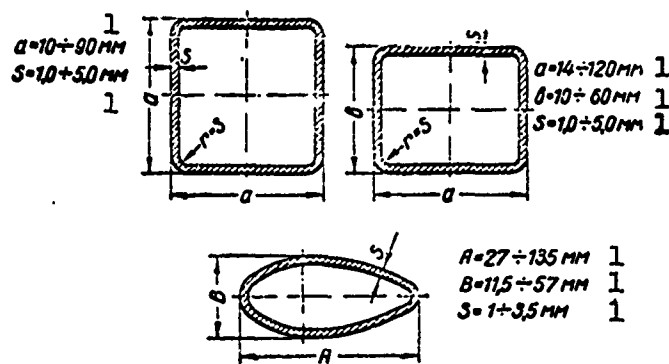


Fig. 23. Square, rectangular, and drop shaped tubing cross sections.
1) mm.

to 120 mm with wall thicknesses from 0.5 to 5 mm. The limiting length of tubes is 5.5 mm. Thick-walled pressed round pipes have an outside diameter from 25 to 280 mm with wall thicknesses from 5 to 32.5 mm.

In addition to round tubing, square, rectangular and drop shaped tubes are made. The cross-sectional dimensions of these tubes are shown in Fig. 23.

The assortment of round and intricately shaped tubing from aluminum alloys is defined by GOST 1947-56.

Round tubing is made from brand D1, D6, D16, AV, AMts, AMg, AD and AD1 shaping alloys. Tubing from the first four alloys are supplied in the annealed or quench hardened and aged state. From the remaining alloys, the tubing can be supplied in the annealed or in the hardened state. Intricately shaped tubing are made from brand D1, D6 and D16 alloys and are supplied in the quench hardened and aged form.

The ultimate strength, yield strength and relative elongation for tubing, in addition to the alloy brand and the supply state also depend on the diameter and thickness of the tubing walls. Tubing with larger diameters which have large wall thickness is stronger.

Bar Stock and Wire

Bar stock is made by hot pressing. With respect to cross-sectional shape bar stock may be round, square and hexagonal. The dimensions of bar stock are specified by GOST 7857-55. The greatest diameter is $d = 300$ mm.

Bar stock is made from brand AD, AD1, D1, D6, D16, AMg, AMts, AV, AK2, AK4 AK6 and AK8 shaping aluminum alloys according to GOST 4784-49 and from the V95 alloy.

Bar stock from brand V95, D1, D6 and D16 alloys with diameters up to 50 mm is supplied in the quench hardened and aged or in nonheat-treated state, while that more than 50 mm in diameter is supplied only without heat treatment. Bar stock from brand AMg, AMts, AD and AD1 alloys is supplied in the annealed or in the untreated state. Bar stock from brand AK2, AK4, AK6, AK8 and AV alloys is supplied only without heat treatment.

The technical specifications for hot pressed bar stock are defined by GOST 4783-49.

Bar stock for rivets with diameters from 1.6 to 10 mm (wire) is made from brand V65, D1P, D16P, D18P, AMg, AMg5P, AMts and AD1 alloys by drawing pressed blanks and is supplied according to AMTU 332-53 and AMTU 377-56. Bar stock for rivets with larger diameters is supplied on agreement between the supplier and customer.

Welding wire is made from the AMts, AMg, AMg3, AMg5P and AK alloys and is supplied in accordance with AMTU 304-54 and GOST 7871-56.

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[Footnotes]

- 22 "Novaya tekhnika i peredovoy opyt v stroitel'stve" [New Technology and Advanced Experience in Construction], No. 11, 1956.

[Transliterated Symbols]

- 27 -