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SHIPBUILDING MATERIALS

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NONMETALLIC MATERIALS

/224*

Plastics

Definition and Classification. Plastics (different types, including laminates) are manufactured on the basis of synthetic high molecular resins (high polymers) and cellulose acetate in some cases. In addition to resins, plastics contain fillers, plasticizers, stabilizers, dyes and other additions which impart them desired properties and facilitate their manufacture.

Plastics are classified according to different characteristics. Depending on their physico-chemical properties, plastics are grouped into solid, semisoft and soft.

Solid plastics have amorphous structure, possess high hardness and elasticity but relatively low tensile strength. Thermosetting plastics belong to this group.

Semisoft plastics have crystalline structure, with amorphous inclusions, and they are characterized by high hardness, elasticity and relative elongation under tension (fluoroplastics and other).

Soft plastics are soft and flexible materials, with a low modulus of elasticity. They are characterized by high relative and low residual elongation which gradually disappears at room temperature (thermoplastics).

Plastics are also grouped according to

- (a) their behavior during heating, such as thermosetting (irreversible hardening on heating) and thermoplastics (capable of withstanding multiple heating and cooling);
- (b) their chemical base, such as polyolefins, polyamides, epoxy, etc.;
- (c) application, such as structural that are used for machine parts and other structures capable of withstanding loads (load-bearing plastics); decorative and for parts not subjected to any loads, for household goods; insulating (electro-, thermo- and acoustic insulation purposes), friction

*Numbers in the right-hand margin indicate pagination in the original text

and antifriction (bearings); anticorrosion, etc.

(d) type of filler, such as powder (with and without filler) and fiber-containing, laminated plastics;

(e) production method - cast, molded, pressed, etc.

Plastics possess a complex of valuable properties, unlimited raw materials and many other positive qualities that made them very popular for a multitude of industrial uses. Figure 120 shows the production growth of plastics.

The cost of plastics decrease with their consumption (Figure 121). The world-wide production of plastics amounted to 7.5 million tons/year in 1969, and it is expected that it will jump to 15 million tons in 1975.

thousand tons

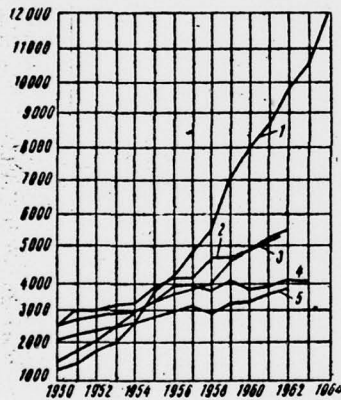


Figure 120. World-wide production increase of plastics, synthetic rubber and non-ferrous metals. 1 - plastics; 2 - rubber; 3 - aluminum; 4 - copper; 5 - zinc.

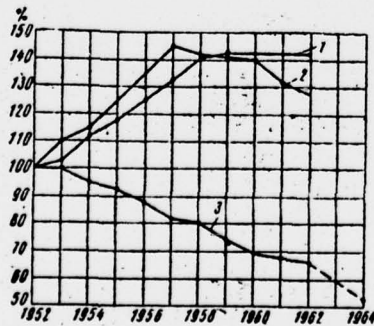


Figure 121. Price changes for steel, aluminum and fiber glass-reinforced plastics during 1952-1962. 1 - steel; 2 - aluminum; 3 - fiber glass reinforced plastics.

The application of plastics and synthetic materials in shipbuilding is far behind as compared with other industries. This is due to the newness of plastics and rigid requirements imposed on materials used in shipbuilding.

In recent years organizations responsible for classification of plastics removed some of their rigid requirements and a much broader use of plastics in shipbuilding is expected. /226 Some of the plastics can replace expensive nonferrous metals and can be successfully used for decorative and insulation purposes of ship's rooms and cabins and for many other accessories.

Items from plastics can be produced by pressing, injection molding, extrusion and other industrial methods. Products of various configuration and with different properties can be mass produced from plastics. The cost of items made of plastics is low, while the labor productivity is high.

In many instances plastics can fully replace expensive nonferrous metals and other costly materials.

Plastics are characterized by low density ($0.92-2.2 \text{ g/cm}^3$). On the average they are five times lighter than steel and copper alloys, and two times lighter than aluminum-magnesium alloys. A volume weight of some plastics (foam and porous) is only $0.01/\text{cm}^3$.

Plastics are highly corrosion-resistant in sea water. They are good dielectrics and are completely free of the electrochemical corrosion. Some plastics are stable in diluted acids and alkalis, and some can even withstand concentrated acids and alkalis.

High electro-, thermo- and sound-insulating, frictional, anti-frictional and other desirable properties can be imparted to plastics. However, plastics also suffer from significant shortcomings which limit their use. For example, the majority of plastics cannot withstand temperature of $100-120$, and some would melt at 60°C (polyethylene, p. v. c.)

Some fiber glass plastics (organo-silicone, fluoroplastics) are stable up to 350°C . Almost all existing plastics undergo thermal destruction (charring, burning, decomposition) at $250-450^\circ\text{C}$.

There are plastics that develop a cold flow at $+20^\circ\text{C}$ and this limits their application.

Some plastics undergo aging due to interaction with atmospheric oxygen which leads to oxidative destruction of polymers. Ultraviolet rays and high temperature are especially harmful for plastics.

Toxicity of plastics, i. e., their capability to produce harmful chemical substances (unpolymerized styrene, for example) during their production or use is a very serious obstacle for their use in shipbuilding.

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Regardless of the above shortcomings of plastics, they have been used liberally in recent years for many ship structures, parts and items of ship's equipment. A progressive role of plastics as a new shipbuilding material lies in the fact that many expensive materials can be replaced by them. The use of plastics also increases the labor productivity during the shipbuilding. It is especially beneficial to use them in place of non-ferrous materials (aluminum, copper, tin, zinc and their alloys).

There are also instances when plastics are used in place of ferrous metals for fabrication of hulls ^{for} some types of boats and ships, super-structures, bulkheads, enclosures, pipes, accesseries, friction bearings, etc. Experience with plastics in shipbuilding shows that accessories made of plastics are much cheaper to produce in comparison with nonferrous metals.

The use of plastics in construction of hulls led to many positive results. For example, lifeboats made of plastics are cheaper, as compared with wooden, they are not subjected to corrosion, decaying, insects and, therefore, do not require a special protection of their surface.

Ships up to 50 m long and tonnage exceeding 600 tons have been built in the USSR and abroad. Some ships are also equipped with propellers made of plastics.

However, it should be kept in mind that economical advantages of using plastics in shipbuilding are visible only during a serial production of items. In the case of a few parts, their cost increases because of high expences for moldings, equipment, labor hygiene measures, etc. Introduction of plastics into shipbuilding opens new application possibilities for this new material which could decrease the weight of ships and of different ship accessories, while improving qualities and operation characteristics of ships.

Synthetic resins (polymers) are organic high molecular compounds with very high molecular weight (several thousands to one million and higher). Polymer molecules consist of elementary chemical units (monomers) which form a long chain of repeating groups (linear polymers), or the chain could branch and form a volumetric structural network. Such molecules are called macromolecules. Macromolecules are formed as a result of chemical reactions of polymerization or polycondensation. Therefore, polymers are divided into polymerization or polycondensation groups. If monomers of different nature are involved into polymerization, the resulting products are called copolymers. 1228

Depending on temperature, resins can be solid, semisoft or liquid. This property of resins is used extensively during production processes. A transition from one state to another takes place within a definite temperature interval.

Synthetic resins are a complex mixture of compounds with molecules of different sizes. The size, composition and structure of molecules influence properties of resins.

Resins having a linear structure of macromolecules are characterized by high strength, elasticity and ability to undergo elastic strains when in solid state. The elastic strain is reversible, with some delay after the load removal. This phenomenon is called the relaxation. It is based on a fact that macromolecules do not have enough time to assume their original shape after the load is removed.

Resins consisting of macromolecules with space (volumetric) structure are characterized by high hardness, brittleness, absence of solubility, plasticity and elasticity at elevated temperatures. Phenol-formaldehyde, polyester and thermosetting resins (polymers) possess these properties.

With increasing molecular weight of a resin, its mechanical strength in solid state increases, as well as its elasticity and stability at high and low temperatures. At the same time, solubility and the external appearance of items made of a resin suffer.

Many plastics consist of only one polymer (resin). To these belong, for example, polyethylenes, polystyrenes, polyamides and others.

There are two types of synthetic resins with respect to heat: /228
(1) Thermosetting resins which are soft when heated (could be melted),
soluble in different organic solvents, without changing their chemical
nature. These resins can be processed many times and assume different /229
shapes. Polyethylene, polystyrene, polyvinyl chloride, polymethyl cry-
late, polyamides, polyurethanes, polytetrafluoroethylene, polytrifluoro-
ethylene and others belong to thermosetting resins which are produced
usually by polymerization.

Thermosetting resins are used extensively for casting of diffe-
rent items, for production of sheet and film materials (with and without
fillers) because of their high physico-mechanical and chemical properties,
simple industrial processing and low cost.

(2) Thermosetting resins prepared by polycondensation /230
processes. They solidify rapidly on heating because of irreversible
chemical transformations, and lose their ability to melt and to be dis-
solved in organic solvents.

Different synthetic resins are used in shipbuilding. Polyester
resins, which are solutions of polyesters in monomers (usually styrene
or other solvent) are used extensively as binding agents during the pro-
duction of fiber glass plastics for hulls and high-strength accessories.
The resulting product of a polyester and monomer is called the unsatu-
rated polyester resin.

Polyester resins are transparent viscous liquids of yellow color,
with a density of 1.12-1.18 g/cm³.

Table 75 presents a list of synthetic resins and areas of their
application in shipbuilding.

Polyester resins are combustible. In order to decrease it, they
are mixed with some additives which make them self-extinguishing.
And this is the most important property for shipbuilding.

Polyester resin undergo decomposition at 250-300°C.

Upon solidification, polyester resins acquire a high mechanical
strength, good corrosion and chemical stability and valuable industrial
properties. Fiber glass-reinforced plastics produced on the basis of these
resins are used for large structures, such as boats and other accessories.

In addition to polyester resins, such thermosetting resins as

Table 75. Synthetic materials for hulls and hull structures

/229

Material	Application
Polyester resin of type PN-1, PN-3	For decorative coatings during the production of fiber glass-reinforced plastics
Polyester resin of type PN-3, NPS-609-21M, PN-62	For ship hulls 50 m long and 600 tons of tonnage
Polyester resin of type NPS-609-22M, NPS-609-22S, NPS-609-26	For hulls 20 m long and 50 tons of weight displacement; ship accessories
Intergrated polyester crylate of type S-TGM-3[For production of the self-extinguishing resin NPS-609-22S
Polyester crylate of type 7-20	For raising the thermal stability of NPS-609-22M
Polyvinyl chloride of type PKHV-L5	For production of the self-extinguishing resin NPS-609-22M and NPS-609-22S
Antimony trioxide	For production of the self-extinguishing resins NPS-609-22M, NPS-609-22S and to impart noncombustible properties to resin NP-62
Intensifier NK-1 and NK-2	For intensification of the hardening of polyester resins
Liquid thiol, type 1	For curing the above resins
Different peroxides	" "
Glass cloth: ASTT(b)-C ₂ O, SE-0-1, TZhS-0, 56-0	Reinforcing material
Glass hard cloth: ZhSR-60(3), ZhSR-60(9)	
Aerosil, noncompressed A-175	Filler

Resins PN-1 and PN-3 are used for hulls by permission from appropriate authority.

phenol-formaldehyde (novolacs and resol), urea- and melamine-formaldehyde (amino-aldehyde) and others found their broad application in shipbuilding.

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These resins are used as bases for molding powder, fiber and laminated sheet materials (Getinaks, textolites, glass- and asbotextolites), glues, varnishes, etc.

Fillers

In order to increase physico-mechanical properties, lower their cost, and to improve overall properties of plastics, different organic and mineral materials (fillers or reinforcing materials) are added to their composition.

Fillers and especially reinforcing agents form a peculiar skeleton in the resin mass, which increases the strength of plastics.

A good wettability of a filler with resin is a highly important aspect. This is usually achieved when polymers and fillers are of the same polarity. The quantity of a filler should be optimal and such that it will acquire a uniform distribution and orientation of its particles in the resin composition (for example, plastics reinforced with fibers).

In the case of a poor wettability of a filler (different polarity of a resin and filler), surface active substances are used. These substances impart a good wettability and the necessary strength of plastics. When too much filler is used, the strength of plastics could be lowered because of insufficient amount of the polymer to wet all filler particles.

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Fillers can also control the propagation of cracks in plastics.

The most widely used fillers are organic, the substances containing cellulose. They increase the strength of items made of plastics, inexpensive, and preserve their low density. However, they decrease the thermal stability of plastics and impart them hygroscopicity. Sawdust, wood chips, plant and synthetic fibers, cotton cloth, paper, etc. are among the most often used organic and reinforcing materials.

The sawdust is a common filler in powder plastics. It is produced by grinding wastes of the lumber industry (chips, small pieces of wood of most coniferous species).

Plant fibers (cotton industry wastes) are almost pure cellulose. Cotton fibers have longitudinal channels filled with air and moisture

which are replaced with resins during production of plastics.

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Plant fibers are used primarily for ^{the} production of fiber plastics; cotton fibers for laminated (high dielectric properties) and decorative (getinaks) plastics. Fibers used for these purposes is 0.10 to 0.18 mm thick. Veneer sheets are used for production of plywood, laminated wood, and bearing materials; cotton cloth is used for textolites.

Polycaprolactam fibers are used for manufacturing the synthetic cloth. Textolite incorporating such a cloth is very strong and water repellent.

Mineral fillers increase strength and thermal stability of plastics, improve their dielectric properties. However, some of them also increase the brittleness of plastics. Asbest fibers, asbest cloth, glass fibers, fiber glass fabric, ground quartz, air-slaked lime, kaolin, rouge, mica, talc and graphite are the most widely used mineral fillers and reinforcing agents.

Glass fillers (fiber glass, glass fabric, etc.) are used for production of high-strength structural fiber glass reinforcing plastics. Fiber glass from 3 to 10 μ possess the highest strength. These fibers are processed into thin fibers, fabrics, plates, etc. Some of the fabrics are shown in Figure 122.

1232

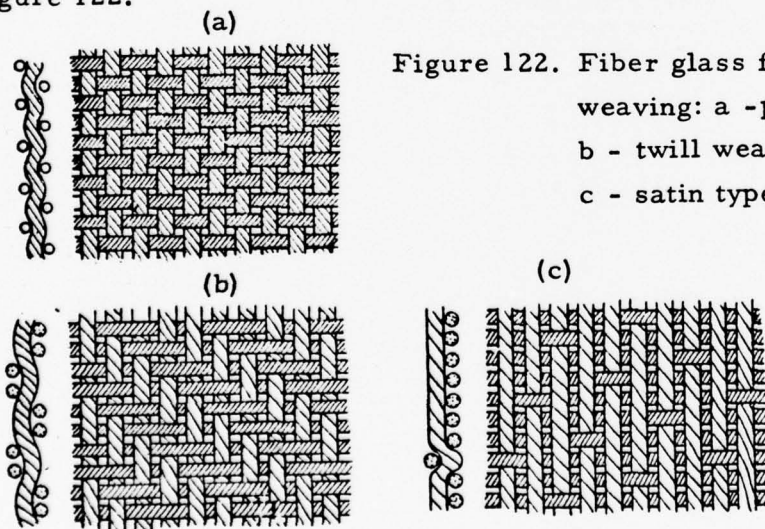


Figure 122. Fiber glass fabrics of different weaving: a - plain weaving
b - twill weaving
c - satin type weaving

Fiber glass fabrics of plain and satin type of ASTT(b)-C₂O class impart high strength to fiber glass reinforced plastics.

Filler are usually less expensive than resins and their use in

industry is beneficial from the point of view of the cost.

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Plasticizers, dyes and other agents are added to plastics in addition to fillers to impart them certain properties.

Plasticizers are added to thermoplastics to increase mainly their plasticity (flow) during industrial processes and to simplify pressing when heated. They also impart higher elasticity to produced items, while preventing the crack formation and improving the cold resistance.

However, the tensile strength, cold flow, aging, etc. deteriorate when too much of plasticizers are used. Therefore, their quantity in plastics should be kept at a minimum.

Among most often used plasticizers are high-molecular high-melting nontoxic liquids which are compatible with polymers.

When processing temperature of plastics is very high, items made of them undergo a rapid aging and thermal decomposition. Light and especially sun rays accelerate aging of plastics.

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Dyes impart a desired color to plastics. Mineral pigments or organic dyes soluble in alcohol are used as dyes.

Thermoplastic Materials

A great number of contemporary plastics used in shipbuilding belong to thermoplastic materials. Semifinished products of these materials are produced as powders, grains, granuls, small chips, films, sheets, plates, pipes, bars, filaments and others which are processed into a desirable items of different types and shapes.

Items made of thermoplastic materials (thermoplastics) are very light ($0.92-1.2 \text{ g/cm}^3$) and attractive, but they are of a low thermal stability ($60-80^\circ\text{C}$) and mechanical strength. Some of the thermoplastics develop a cold flow which increases with loads and elevated temperatures. Among other disadvantages of thermoplastics is a sharp drop in their mechanical properties at elevated temperatures and this changes the size of items made of them. In order to eliminate some of these shortcomings, different fillers (quartz, sawdust, asbesto powder) are added to thermoplastics. These additives increase thermal stability, strength and stabilize the size of items made of thermoplastics.

Some of the thermoplastics possess high chemical stability

(polyethylene, polyvinyl chloride, fluoroplastics), as well as high strength. Therefore, they can be used in ship building for various accessories and for water, oil and fuel pipes. Some experience has been acquired already in this field. /23

Items from thermoplastics are produced by injection molding, pressing, casting, stamping, blowing and by machining of plates, blocks and other blanks. Thermoplastics can be welded or glued.

Polyvinyl chloride, polyethylene, polyamides and polyurethanes are most often used thermoplastics in shipbuilding.

Polyvinyl chloride is produced as an amorphous powder by polymerization of vinyl chloride. Unplasticized and plasticized polyvinyl chlorides are available, with a color from light-yellow to dark brown. It does not have any odor and does not burn on open flame.

At 70-78°C the polyvinyl chloride is in a solid glass type state, at 80-160°C it is highly elastic and at 160-170°C it assumes a plastic state. /234

Because of its high strength, polyvinyl chloride is used as a structural material.

The thermal stability interval of polyvinyl chloride is narrow; at temperature exceeding 70°C it becomes soft and undergoes plastic strain, and at -10°C it becomes brittle. Mechanical properties of the polyvinyl chloride are reversible when heat is applied after cooling.

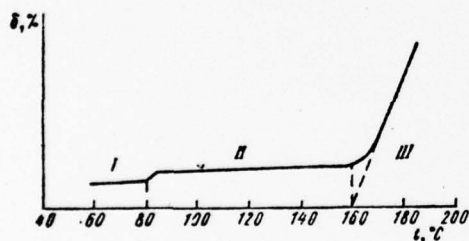


Figure 123. Effect of temperature on the state of polyvinyl chloride. I - glasslike state; II - highly elastic state; III - plastic state.

Figure 124 presents a dependence of the static strength characteristics of polyvinyl chloride on temperature.

The impact strength (Fig. 125) of polyvinyl chloride changes much more markedly with temperature as compared with its strength. It is evident from Figure 125 that the impact strength amounts to 150 kg·cm/cm² at +20°C and it drops to 30 kg·cm/cm² at -20°C.

Polyvinyl chloride is distinguished by its high chemical and corrosion stability in sea water, concentrated acids (hydrochloric, sulphurous, phosphoric), diluted nitric and hydrofluoric acids, alkaline solutions, kerosene, gasoline, alcohol, lubricating oils, solutions of salts and many metals, and industrial gases up to 60°C.

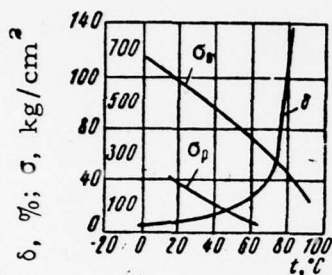


Figure 124. Effect of temperature on mechanical properties of polyvinyl chloride

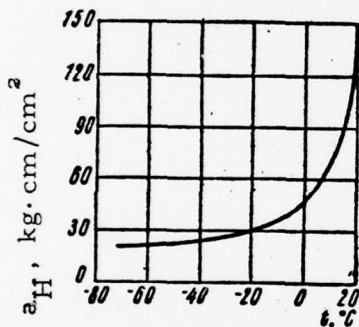


Figure 125. Effect of temperature on impact strength of polyvinyl chloride

Sheets, boards, pipes, pressed items and others can be made from p. v. c.

Three types of sheet material is made from p. v. c. according to GOST 9639-61. They are opaque V N; clear of natural color or dyed VN and nontoxic VNT.

Heated sheet material is used for ^{the} production of bath tubs, sinks, doors and other large size items by stamping, bending, pneumatic and vacuum molding. Polyvinyl chloride items can be welded and glued. Welding is usually carried out at 200-220°C, with and without filling material on a special welding stand. The strength of welds amounts to 80-90% of the strength of base material.

Polyvinyl chloride items are glued with perchlorovinyl glue. The strength of a glued joint is close to that of the welded joint.

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Polyethylene is the polymerization product of ethylene which is produced from petroleum gases. It is produced as a white powder or granules. This base material can be used for manufacturing of various items of different colors.

The polymer structure is crystalline, with amorphous inclusions which influence its physico-mechanical properties.

Polyethylene is non-toxic, without taste or odor and is harmless for a man. At 290°C it decomposes into low-molecular polymers either as liquids or gases. It burns slow on open flame without any soot.

Depending on the manufacturing methods there are polyethylenes of high (0.946-0.970 g/cm³), average (0.931-0.945 g/cm³) and low density (0.918-0.930 g/cm³).

A high density polyethylene is produced by polymerization of ethylene in hydrocarbon solvents in the presence of a catalyst (metalloorganic compounds) at 70°C and 1-5 atm. of pressure.

A low density polyethylene is the polymerization product of the gaseous ethylene at 200°C and 1000 kg/cm² of pressure. Oxygen is used usually in this case as a catalyst. A liquid polyethylene is cooled and grinded into granules of different size.

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A low density polyethylene is produced by polymerization of ethylene in the presence of either chromium oxide or silicon oxide (catalysts) at 80-170°C and 40 kg/cm² of pressure.

A high density polyethylene is much stronger, rigid and thermally stable, as compared with a low density variety. A low density polyethylene is very light in comparison with other polymers.

A high density polyethylene is divided into three groups, L, E and P, depending on its viscosity and processing ability. The polyethylene L can be cast under pressure at 200-260°C; while E can be extruded at 200-260°C, and P can be processed by pressure at 140-180°C.

All production methods can be applied to a low density polyethylene, i. e., by casting, pressing, molding, extrusion, etc.

Table 76 presents physico-mechanical properties of polyethylene of different density. It is evident from this Table that mechanical properties

(ultimate strength, yield stress, hardness and elasticity modulus) /236
of polyethylene increase with increasing density, degree of crystallization
and molecular weight.

Table 76. Physico-mechanical properties of
polyethylene of different densities

Type of polyet.	γ , g/cm ³	Thermal stability, °C	Mol. weight	Degree of crystalliz.
A	0,92-0,93	From 70 to -60	15 000- 35 000	40-65
B	0,935-0,95	» 100 » -60	25 000-100 000	65-85
C	0,96	» 100 » -60	30 000-140 000	83
D	0,94-0,955	» 70 » -60	-	75

(cont.)

	Ultimate strength kg/cm ²			δ , %	E, kg/cm ²	Shore hardness, kg
	tension	compres	bending			
A	84-175	125-210	120-170	150-600	980-2450	45-55
B	195-385	200-900	200-380	100-800	3500-7000	63-74
C	280-350	-	250-400	200-400	-	68-70
D	180-285	-	-	200-380	-	-

The stress-strain diagram (Figure 126) of polyethylene consists of three regions: (1) crystalline state; (2) a transition of chaotically distributed crystals into oriented (horizontal section), and (3) a further stress-strain of oriented polymer.

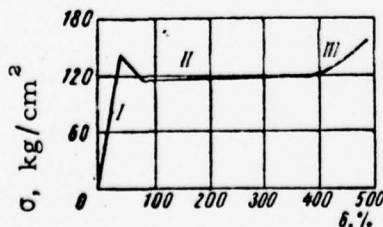


Figure 126. Stress-strain diagram of polyethylene.

I - crystalline state; II and III - oriented stress-strain.

Mechanical properties of polyethylene have a strong dependence on temperature (Figure 127). They decrease with increasing temperature and at 60°C and higher the polymer flows. A high density polyethylene is 237 soft at 80-100°C. Its strength increases at 0°C but its plasticity decreases. It becomes rigid and at -60°C assumes a brittle state.

Operation interval of items made of polyethylene is -60 to +70°C.

The drawback of polyethylene as a structural material is its flow. Even high density polyethylene starts to flow at room temperature when loaded with only 25% of its ultimate strength for a long time.

Figure 128 shows changes in a relative strain (flow) as a function of load, time and temperature.

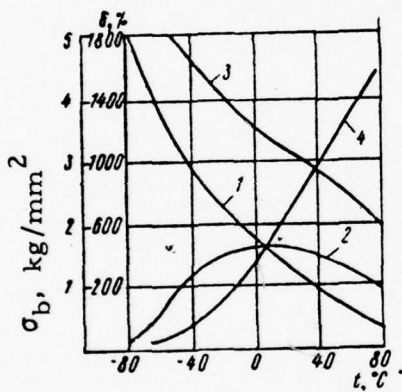


Figure 127. Effect of temperature on ultimate strength and relative elongation of polyethylene 1 and 2 - relative strength and relative elongation of the low density polyethylene, respectively; 3 and 4 - same for the high density polyethylene, respectively.

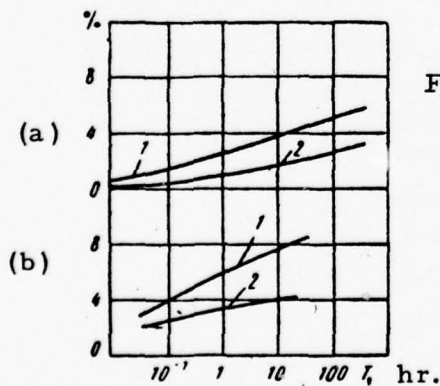


Figure 128. Flow diagram of the high density polyethylene as a function of temperature and initial load: a - at 20°C; b - at 40°C

1 - 77 kg/mm² initial load;

2 - 50 kg/mm² initial load;

T - time.

Dynamic strength (impact strength) of polyethylene practically does not exceed $5 \text{ kg} \cdot \text{cm}/\text{cm}^2$ and is stable at $+4$ to -60°C .

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Polyethylene ages with time because of atmospheric oxygen, temperature and other factors. As a result items made of polyethylene lose their strength and elasticity, become brittle and lower in their dielectric properties. Aging primarily takes place because of sun rays (ultraviolet radiation). The aging rate increases during the spring. In order to prevent aging of polyethylene due to light, carbon black (1.0 to 10%) is added to it.

When treated with radioactive substances, thermal stability and mechanical strength of polyethylene increase.

Polyethylene is corrosion stable in sea water, moist air and is characterized by a low penetrability with steam and water. At room temperature it is stable against diluted sulfurous, nitric and concentrated hydrochloric, phosphorous, acetic and other acids, ammonia and amines, solutions of different salts and alkali. However, it is unstable in gasoline. In solvents (benzene, xylol, etc.) it swells.

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Dielectric properties of polyethylene are attributed to its nonpolarity and they are the highest among all plastics. They are practically independent of temperature from -80 to $+100^\circ\text{C}$ and moisture.

Polyethylene is used for production of pipes, sheets, films, fibers, fabrics, items of complex configuration, anticorrosion coatings and for foam plastics (Figure 129).



Figure 129. Machine for the production of polyethylene pipes

Items made of polyethylene can be machined, welded by hot air or electric irons; the strength coefficient of a welded joint is 0.9-1.0. Polyethylene pipes are distinguished by light weight, corrosion stability, low resistance to fluid flow, absorption of sounds and resistance to cold. A freezing of water in polyethylene pipes causes only a slight strain, without any ruptures.

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Pipes made of high density polyethylene are approximately 1.5 times stronger than those made of the low density polyethylene and they can operate at - 60 to + 100°C.

Films made of polyethylene can be 0.03-0.30 mm thick and up to 1400 mm wide. Thin and elastic films are produced usually from the low density polyethylene. Sheets 1-6 mm thick and up to 1400 mm wide are used for production of items by stamping, bending or vacuum molding (when heated). Epoxy and polyurethane glues are used for gluing items made from polyethylene.

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In shipbuilding, polyethylene can be used as structural and anticorrosion material for different accessories and for finishing works of cabins and rooms, pipelines for sea and fresh water, fuel, and oil; for channels for cables, steel lines, etc.

Polyethylene can be used as anticorrosion coating (films or flame deposited) and replace varnishes and paints in shipbuilding.

Polyamides and polyurethanes are manufactures as cylindrical or plate-shaped particles (polyamides), or as a white powder (polyurethanes). When heated to 180-210°C they are liquid and can fill molds of different configuration. Therefore they are used for casting of items under pressure and by pressing in some cases (flat blanks). Fillers are usually not used. At room temperature, items made of these plastics have high impact strength and stable against wear.

Polyurethane resins are characterized by high adhesion; they are used for the manufacturing of varnishes and glues.

Polyamide resins are corrosion resistant in sea water and different aggressive media.

Nylon and enanthic fibers are manufactured from polyamide by the polycondensation method. They are very strong, heat-resistant and stable in aggressive media.

Machine parts, bars, pipes, plates, impregnating compounds and glues are manufactured from polyamide and polyurethane resins. Polyurethanes are also used for production of foam, insulating and structural materials.

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Table 77 presents physico-mechanical properties of thermoplastics.

Table 77. Physico-mechanical properties of thermoplastics

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Plastics	γ , g/cm ³	Water absorption in 24 hr. %	Martens thermal stability °C
Polystyrenes	1.05-1.06	0.03	75-80
Polyamides (AK-7)	1.14	1.80	60
Polyurethanes	1.21	0.1-0.25	60
Polyfluoroethylenes:			
fluoroplastc-4	2.15-2.35	0	-
fluoroplastic-3	2.09-2.16	0	70
Etrols:			
nitrocellulose	1.8-2.0	2.0	35-40
acetylcellulose	1.4	0.7-0.8	40-45
ethylcellulose	1.2	0.8	40-45

(cont.)

Ultimate strength, kg/cm ²			δ , %	a_H kg·cm/cm ²	E, kg/cm ²	HB, kg/mm ²
tension	compr.	bending				
350-395	800-1120	560-1330	-	12-20	$2.8-3.5 \cdot 10^4$	14-16
500-650	750-950	1000-1200	100	130-160	-	15-18
500-600	800-850	700-800	-	50	-	8-12
160-250	160-315	110-140	250-500	100	$3.8-4.5 \cdot 10^4$	3-4
350-400	500-570	600-800	20-40	20	-	10-13
250-300	1400-2100	350-400	-	2.5-4.5	$1.8-2.8 \cdot 10^4$	4
300-500	500-570	450-500	8-15	15-35	$2.0-2.5 \cdot 10^4$	4-7
200-300	400-600	400	20-30	20	$3.5-4.2 \cdot 10^4$	4-6

Polyamide resins are used for the production of bearing inserts, gears and parts for water-conducting equipment. Caprone bearings do not require lubrication because this material has very small friction coefficient. Caprone and nylon fibers are also used for marine cables and fishing nets.

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Natural and Synthetic Rubbers

Latex, a milk-like white juice from Brazilian Hevea trees, is the starting product for a natural rubber (NR). The latex contains 34-37% of the NR in the form of small particles 0.1-0.6 μ in diameter.

Industrial or a raw rubber is obtained by coagulation of the latex with 5% acetic acid, drying and rolling the coagulated mass into rolls.

The NR is characterized by high elasticity at - 70 to + 70°C. At temperature below - 70°C it becomes brittle and at + 80°C melts.

The NR is insoluble and does not swell in water, alcohol, acetone and other liquids, but it forms viscous solutions with aliphatic and aromatic hydrocarbons. These solutions are used for glues. The NR is used for the manufacture of the automobile and aircraft tires (up to 80%) and for different industrial applications.

Because of its scarcity and cost, the NR is replaced in many instances with the synthetic rubber (SR).

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Synthetic rubbers (SR) are prepared by polymerization of monomers such as butadiene, chloroprene, isobutylene, with addition of styrene, nitrile and others in the presence of catalysts.

The polymerization yields latex which is subjected to coagulation. The obtained product (coagulate) is washed, dried and mixed with additives which are required for vulcanization and further processing.

Butadiene is the principal agent for the SR (up to 70%).

The Soviet industry produces the following SR:

- (a) Styrene-butadiene (SKB, SKS and SKMS) which replace the NR;
- (b) Polyisoprene SR (SKM);
- (c) Butadiene acrylonitrile rubber which is elastic at - 30 to + 150°C and stable against heat, oil and gasoline;

(d) Polychloroprene rubber which is stable at high and low (up to -45°C) temperatures, as well as in oil and gasoline.

Organosilicon and organofluoric rubbers are stable at $+270$ and $+350^{\circ}\text{C}$, respectively, and up to -100°C .

Polyurethane rubbers are very strong and resistant to wear, oil and gasoline.

In addition to tires, SR is used for many industrial and household purposes.

Vulcanized rubber produced either from SR or NR is very elastic, with good physical, chemical and mechanical properties. Electrical conductivity of the vulcanized rubber is low. Depending on the production method (extent of vulcanization) and application, vulcanized rubber can be soft, semisoft and hard (ebinite). The vulcanized rubber contains from 5 to 98% of rubber. In addition, it also contains softeners (stearin), fillers (carbon black), vulcanizers (sulfur), vulcanization accelerators, antiaging agents and dyes.

Vulcanized rubber items are produced usually by molding of the rubber mixture, followed by vulcanization.

With respect to structure, there are compact, porous and sponge types of rubber. Table 78 presents properties of all three types of rubber.

Table 78. Physico-mechanical properties of certain type of rubbers

Rubber type	λ , g/cm^3	σ , kg/cm^2	δ , %	T, $^{\circ}\text{C}$	Application
Stable in acids and alkali	1.0-1.46	35-160	250-750	-50 to +80	Seals and gaskets for water-tight doors, hatch doors, portholes, propeller shafts, cushions for main and auxiliary devices
Stable in oil and gasoline	1.1-1.50	45-100	300-550	+230 to +50	
Stable in heat, cold and light	1.1-1.45	60-160	200-500	-50 +30 +140 +200	Same as above, kingston valve seal rings, fender dampers, tugboat fenders, membranes for hydraulic systems, parts for gas outlets
Antifric-tion	1.08-1.18	160	400	-30	Bearings for propeller, dead-wood and connecting shafts

In shipbuilding the following accessories made of rubber are used: bearings for propeller, deadwood and intermediate shafts, noise-absorbing cushions of various ship devices, mechanisms, equipment and structures, sealing and packing strips and gaskets for doors, hatch doors, portholes, etc., anticorrosion coatings and many other applications.

Fibrous and Laminated Plastics

Fiber plastics are produced on the basis of thermosetting resins. Cotton, asbestos and glass fibers, as well as graphite and mineral additions are used in the production of fiber plastics. Fibrous fillers make items much stronger and heat resistant.

In order to achieve a complete impregnation of the filler, the resin is diluted (varnish consistency) with inert solvents (alcohol, toluene). The impregnation is carried out in special close-type chambers (mixers). In addition to resin and fibers, mineral powders (talk, lime, kaolin) are added to a mixer, in order to achieve a needed viscosity. Dyes and some other agents are added in some cases.

Impregnated fibers are subjected to drying in a vacuum-drying chamber for elimination of solvents. Thermosetting resins are partially solidified during drying and this decreases their flow and increases the softening temperature. Fiber plastics are used for molding of simple shapes. Pressing of fiber plastics is carried out at 300-500 kg/cm².

Table 79 presents physical and mechanical properties of fiber plastics.

In order to produce structural material of high strength, as compared with fiber plastics, such fillers as sulfate paper, cotton, asbestos or glass cloth, wood veneer sheets or glass sheets are added to plastics. Fillers are impregnated very often before use with resins, assembled into desirable thicknesses and pressed into solid blocks, boards and sheets. Depending on fillers, laminated plastics can be identified as Getinakses (paper as a filler), textolite (cotton cloth), asbotextolite (asbestos cloth), glass textolite (glass cloth), wood-laminated plastics DSP (wood veneer), etc.

Resins which harden when hot are used as binding agents (phenolformaldehyde, urea melanime-formaldehyde, epoxy-phenol), as well as those that harden at low temperatures (polyester, etc).

Table 79. Physical and mechanical properties of fiber plastics

Plastics	γ, g/cm ³	Water absorption in 24 hr, %	Martens thermal stability, °C	Strength, kg/cm ²		aH, kg·cm/cm ²	E, kg/cm ²	HB, kg/mm ²
				tension	bending			
Phenolformaldehyde resin, fillers								
cotton fibers	1.35-1.45	0.4	110	300-600	500	9	8.5·10 ⁴	25
asbestos fibers	1.7-1.95	0.8	200	200-270	700-800	18-21	1.5-2.5·10 ⁴	30
Fiber plastics: AG-4(V)	1.7-1.9	—	280	800	1200	30	35·10 ⁴	120
AG-4(S)	1.7-1.9	—	280	5000	1500	150	35·10 ⁴	120
K-4G-5	1.7-1.9	0.25	350	230	500	18	—	30
SVAM	1.9-2.0	0	200	4500	7000	500	30·10 ⁴	55

*AG-4(V) plastics contain randomly arranged fiber glass; AG-4(S) contains oriented fiber glass; modified phenolformaldehyde resin is used in both cases as binding compound.

Table 80. Physical and mechanical properties of laminated plastics

Plastics	γ, g/cm ³	Water absorption in 24 hr, %	Martens thermal stability, °C	Strength, kg/cm ²		aH, kg·cm/cm ²	E, kg/cm ²	HB, kg/mm ²
				tension	bending			
Getinaks	1.3-1.4	1.0-2.5	130-150	1300-2500	800-1500	18-20	1.0·10 ⁴	25
Textolite	1.3-1.45	0.8-1.5	120-135	1500-2500	900-1600	20-40	4.0-6.0·10 ⁴	30
Asbotextolite	1.5-1.7	2.0	250	850	1000-1200	25	1.5-2.5·10 ⁴	35-48
Glass textolite	1.6-1.85	0.5-2.0	150-200	2700-4200	1200-5300	20-300	1.6-2.0·10 ⁴	25-35
Wood veneer	1.3-1.35	5.0-18.0	140-150	600-1300	1000-2800	30-80	1.7-3.0·10 ⁴	26
Decorative plastics	1.4-1.5	0.5-1.0	120-140	900-1600	900-1800	8-15	—	25-37

The strength of laminates plastics depends on a binding agent, 1243
pressing force and strength of a filler. In many case the strength of lami-
nated plastics approaches that of the metals.

The use of thermosetting resins for laminated plastics is based on
the fact that they possess high thermal stability, have higher resistance to
load and their mechanical properties depend on temperature to a lesser
extent in comparison with thermoplastics.

A raw material of different configuration, boards and sheets from 0.2
to 100 mm in thickness are produced from laminated plastics.

Figure 80 presents physical and mechanical properties of lami-
nated plastics.

Getinakses are used primarily as electrical insulators and for
parts for electric and radio apparatus, as well as for gears, bushings,
covers, for internal bulkheads, enclosures and for furniture. Getinakses
are readily machinable by cutting, milling and other methods.

Textolites are characterized by high wear resistance which exceeds
that of copper alloys. Bearings made of textolite operate 10-20 times 1245
longer in comparison with nonferrous alloys. Textolites are used very often
for bearing inserts, noiseless gears, pulleys and for other parts subjected
to friction.

Textolites are stable in water, oil and gasoline. The only shortco-
ming of textolite is ^{their} low thermal conductivity which prevents a quick
dissipation of heat.

Glass textolites are also made on the basis of thermosetting
plastics, in which alkaline-free alumoborosilicate fibers 0.06-0.85 mm
in diameter are used as fillers.

In shipbuilding, glass textolite are used for bulkheads, enclosures,
various ship accessories, pipes for water, fuel and oil and for other pur-
poses. When combined with light fillers, they are also used in many two-
and three-layer structures.

Asbotextolite contains asbestos cloth as a filler, which is
usually impregnated with phenolformaldehyde resin. Asbotextolite is stable
at high temperatures and is resistant to friction. Because of this, it is used
for brake shoes and couplings which are subjected to heating under working
conditions.

Cellular and honeycomb plastics belong to light-weight plastics. They are distinguished by low density of order $0.10-0.01 \text{ kg/m}^3$ in comparison with other plastics. They are 5-50 times lighter than wood. Cellular plastics are used for thermal and acoustical insulation, as well as for dielectric and structural purposes. Depending on structure, this group of plastics is divided into foam, porous and honeycomb plastics. The honeycomb plastics are made from crimped vinyl plastics.

Foam plastics resembled a hardened foam consisting of many small closed cells filled with gas. This type of plastics can be prepared by adding special substances, blowing agents, into prepared compositions. Blowing agents undergo decomposition when heated and liberate a great amount of gases (NH_3 , N_2 , CO_2) which closed cell in the plastics. Foam plastics with closed cells are strong and impenetrable for water, gas and steam. Along with closed cells there are also some interconnected cells.

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Porous materials consists of interconnected pores. These plastics are usually referred as sponges. Porous plastics can be prepared by many methods, such as sintering of granulated polymers, leaching of salts (NaCl , Na_2SO_4 , etc.), foaming of a resin composition by easily diffusible gases (CO_2 , NH_2) at high temperatures, etc.

Both thermoplastics and thermosetting plastics are used for the production of foam plastics as starting materials.

Mechanical Properties of Plastics

The most important mechanical properties of plastics are the strength during tension, compression, static bending, splitting, shear, impact strength during dynamic bending, ultimate strength, etc. Mechanical properties of plastics are determined by static, dynamic and other loading methods under laboratory conditions.

GOST, OST and TU determine the type, shape and size of samples to be tested, as well as the method of taking samples and their treatment.

The simplest and the most accessible test method for the strength

of plastics is the axial tension under a static load till rupture. Depending on plastics, samples for tension are distinguished by the following six groups: I for soft and semirigid plastics; II and III for rigid plastics; IV for compressed plastics; V and VI for plastics subjected additionally to shear testing by measuring a distance between two clamped ends of samples. /246

Testing of plastics has several features which should be considered while determining their properties. For example, the strength of plastics decreases noticeably when a load is applied for a long time; and this should be considered when plastics are used for construction purposes.

Density, thermal stability, absorption of moisture, etc. must also be considered among other characteristics of plastics.

Two types of strength are revealed by a compressive testing. Namely, the ultimate strength of brittle materials which break without any visible plastic deformation; and the conditional compressive strength when the plastic deformation increases rapidly without any load increases. /247

The strength of plastics during a static bending is characterized by the ultimate strength and the sample deflection produced by a short-lasting bending load. For plastics which do not break during bending, bending stresses are determined when a deflection is equal to 1.5 times a sample thickness.

A resistance to impact loads is determined by the impact bending of notched and smooth samples for plastics which do not break during testing.

All types of laminated plastics are subjected to splitting and shear tests by a static load.

Glues

In shipbuilding, glues are used for gluing of wooden and metal parts of equipment, accessories, devices and furniture. Glued joints are distinguished by high strength and they surpass in many case mechanical joints (rivets, bolts). Application of glues in shipbuilding shortens the construction of wood ships and eliminates the use of many metal fasteners while simplifying the industrial process.

The gluing process is based on the adhesion of a glue to surfaces and hardening after application of compressive forces. Glue particles penetrate into macro- and microcracks of materials and form strong joints by cohesion forces of individual glues particles. /247

The strength of glued joints of nonmetal materials could approach and in some instances exceed the strength of the glued material.

The strength of glued metal joints (steel, aluminum) reaches 400-500 kg/cm²; they are stable against aging and can operate for a long time under all types of operating conditions.

Glues can be classified according to their origin (natural, synthetic), chemical nature and properties (organic, inorganic), strength characteristics (strong, weak), reversability (reversible, irreversible) and other features. For many years natural glues were used in shipbuilding but gradually they have been replaced by synthetic glues on the basis of polymers. Hide and casein glues are used for gluing of wood. Rosin and shellac are used in some glues but most often they are used in combination with other gluing material (for example, iditol-rosin glue). Joints produced by these glues are sufficiently strong but they are not stable against water and fungi. Their application is limited to dry places. Another negative point of these glues is the necessity to keep glued parts under pressure for a long time until the glue dries. /248

Glues on the basis of polymers possess much better properties and are used extensively in shipbuilding. With respect to the chemical nature of the principal component, these glues are grouped into (1) those prepared on the basis of polymerized polymers and (2) polycondensation. Synthetic glues on the basis of rubbers constitute a separate group.

According to physico-chemical properties, glues are divided into reversible (thermoplastic) and irreversible (thermosetting). The reversible glues can be softened or dissolved after hardening by heat and can be used again for gluing purposes. The irreversible glues change their chemical nature after hardening and can not be restored to the initial condition neither by heat or solvents.

The irreversible glues are prepared on the basis of thermosetting resins. They are used for strong and stable joints either for metals or nonmetal materials. Thermoplastic resins are used for reversible glues.

Joints produced by these glues are capable of withstanding high temperatures. Thermoplastic glues are used primarily for gluing nonmetal structures that do not carry any loads.

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Rubber-based glues are highly elastic and are used for gluing rubbers and rubbers with metals.

Universal glues are characterized by high adhesion to different materials (metals, wood, ceramics, glass, plastics). Glues which are used for gluing organic materials belong to a special group of glues.

Glues can be used in a liquid and solid state (films). In shipbuilding, liquid glues are used primarily. They contain, as a rule, some volatile base, or represent a mixture of several liquid resins.

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The strength of a glued joint depends on the glue composition, the thickness of the glue film, design of a joint and gluing conditions. The thinner the glue film, the stronger the joint, provided all other condition being equal. The glue film thickness depends on a glue viscosity which should be checked frequently during gluing. Optimal glue film thickness is considered from 0.03 to 0.15 mm.

A glued joint is characterized most often by its stability against static shearing. Operation conditions, in particularly moisture and temperature, influence the strength of glued joints. Therefore, stability of joints against water and temperature are two controlling factors with respect to the quality of joints.

Stability in water of glued joints is determined usually by placing them in water for a certain time (usually 24 hr). Stability to temperatures is established by the glue softening temperature (thermoplastic glues), or by a sharp drop in the glued joint strength (thermosetting glues).

Industry produces many types of glues and their number increase rapidly.

Table 81 presents physico-mechanical properties of some glues used in shipbuilding. Glue compositions are used on a broad scale for framing of wooden ships, for bulkheads and furniture.

Table 81. Physico-mechanical properties of glues

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Glue code	Glue composition	Gluing conditions		strength at 20°C, Operat. temp., °C		Material to be glued
		temp. °C	pressure kg/cm ²	Harden- ing time hr	kg/cm ² shear	
Structural (load-carrying)						
VLAM-B-3	Phenolformal- dehyde	15-25	2-4	12-18	90-130	Wood, textolites, PKhV-1, asbolites
K-17	Urea-formal- dehyde	15-25	2-3	24	90-130	Wood, decorative laminated plastics
VK-3 VK-4	Phenol-rubber	160-170 195-205	5-10 10-20	1,0 2,0	120-130 150-165	Steel, Al and Ti alloys, fiber glass textolites
Carbi- nol	Carbinol	18-30	0,5-5,0	24-36	90-120	Metals, diff. plastics, glass, marble, ebonite, etc.
EP-1 K-153	Epoxy polyamide Epoxythiocol	18-25 16	0,02-0,05 0,1-0,5	48 24	110-130 70-90	Metals, glass, laminated plastics, asbolites, PKhV-1
BF-2 BF-4	Resol-Butvar	150	3-20	1,0	100	Metals, fiber glass-reinf. plast., wood, plexiglass, ceramics
VK-1	Epoxy	100-150	0,2-2,0	10-1,0	100-260	Glue-welded and glue-riveted joints, carvings of steel, Ti and Al alloys
Finishing (no load-carrying)						
LK-1 LKS-T	Nitroglyptal	5,0	0,05	48	0,6	Linoleum, povinol, porolone, aspalite, metals and wood
PED-B	Epoxyperchloro- vinyl	15-35	1,0-2,0	48	1,5-2,0	Vinyl plastics, p. v. c., metals and wood
88-N	Mixture of rubber and butylphenol- formaldehyde resin	5-45	-	48	2,5	Rubber, metals, wood, concrete
Bake- lite	Phenolformaldehyde	115	-	4	-	Getinaks, textolites, glass cloth, glass
LKS	Nitroglyptal	-5 +45	0,01-0,05	1-3	0,7	Thermoinsulating material, metals, glass plastics, wood

Application of plastics in shipbuilding is determined first of all by their strength and stability against environmental factors, their industrial suitability and economy.

Fiber glass reinforced laminated plastics based on thermosetting resins are the most suitable among available plastics. Because of their high strength, stability in sea water and a comparatively simple use, fiber glass plastics are used for large size ship structures, for hulls of certain type of ships, boats, superstructures, etc.

Unsaturated polyester and epoxy resins that are cured at room temperature, or amine-aldehyde resins that require high temperatures for curing are used as binding materials in fiber glass plastics. Depending on use, reinforcements could be in the form of fibers, cloth, nonwoven matings, or rovings.

Resins for fiber glass plastics must possess high adhesive and wetting properties. By binding together individual reinforcing elements, a resin secures a uniform distribution of reinforcements and high quality of manufactured items. A resin must also possess stability to heat, water and to age slowly.

According to industrial features, thermosetting resins can be divided into two groups:

- (a) resins without solvents which harden without liberating volatile substances (polyester resins, for example, and others);
- (b) resins containing solvents in their composition (alcohol, acetone, toluene, etc.). To this group belong the majority of resins which harden at elevated temperatures. Fiber glass reinforced plastics based on these resins are cured at 150-160°C and pressure of up to 60 kg/cm² and higher. Resins that require high temperature curing are used primarily for the production of fiber-containing and laminated plastics by pressing.

Resins that harden at room temperature are best suited for the production of large size ship accessories. They do not liberate harmful volatile substances when undergoing polymerization. They are used for ship hulls in many instances. Polyester maleic acrylate (NPS-609-21m

and self-extinguishing resin (NPS-609-22m) are primarily used for this purpose. As compared with other polyester resins, they are used for the production of high strength plastics which are stable against heat and are nontoxic (lower concentration of styrene). / 252

The strength of glass plastics depends on the ratio of reinforcements and the resin, the type of the reinforcing material and production methods. The amount of resin in the plastics must be optimal, to secure a reliable binding of all fibers. Otherwise the resin and fibers would carry a load independently.

Changes in the strength of glass plastics based on polyester resin as a function of reinforcements is shown in Figure 130. It is evident in this case that a max. strength is achieved when the plastics contain 40-60 wt. % of glass fibers. With increasing fiber cloth thickness, the strength of plastics noticeably decreases because of incomplete penetration of fibers with the resin.

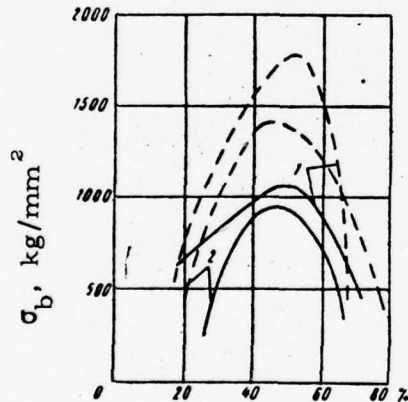


Figure 130. Strength of glass plastics as a function of glass fibers. / 253

- 1 - 200 g of glass fiber fabric per m²;
- 2 - 600 g of glass fiber fabric per m²;
- - tensile strength;
- - - - bending strength.

A combined strength of the resin and fiber glass fabrics exceeds the strength of cured resin but is below that of glass fibers. This is caused by a much higher binding force of the resin and glass fibers in comparison with tensile strength of the resin.

A strength of the fiber glass plastics decreases with decreasing or increasing concentration of glass fibers. When there is too much resin between fibers, the load is carried primarily by a resin; and when there is too little resin, not all fibers undergo impregnation and the binding force

between them weakens.

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An optimal concentration of glass fibers imparts uniform structure to plastics capable of withstanding high loads (max. strength). As a result the relationship $\epsilon_b \geq \epsilon_r$ is preserved, i. e., the binding and reinforcing materials undergo identical deformation until the compact structure of plastics deteriorates. When this relationship is disturbed, a dislocation of the plastic components takes place and the resin separates from reinforcing fibers. At this point, only the glass fibers carry the increasing load until a complete rupture of these fibers takes place. The rupture takes place usually at much higher loads in comparison with the optimal.

Table 82 presents mechanical properties of fiber glass reinforced plastics based on polyester resin and ASTT (b)-C₂O glass fabric.

Moisture influences the strength of fiber glass plastics and because of this the glass fibers are subjected to different hydrophobic treatment by hydrophobic-adhesive compounds which improve the adhesion of resins and increases the water stability of plastics (Table 83).

It is evident from this Table that plastics based on polyester and phenolformaldehyde resins suffer mostly from moisture.

Epoxy resins impart the highest strength to fiber glass plastics because of a strong adhesion to glass fibers.

Among hydrophobic-adhesive compositions used for the treatment of glass fibers, organosilicon compounds (GVS-9, GKZh-11 Soviet; and volan, garan, silane and others from foreign countries) are used most often. Silane and garan are best for the treatment of fiber glass plastics on the basis of polyester resins; and volan and garan for plastics based on phenolformaldehyde resins. Application of the hydrophobic -adhesive compounds for fiber glass plastics used in shipbuilding is compulsory because of operation conditions in sea and fresh waters.

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Long-Term Strength of Fiber Glass Reinforced Plastics

External factors (loads, moisture, temperature) decrease mechanical properties and in some instances even destroy plastics when the latter are subjected to these factors for a long time.

Table 82. Physico-mechanical properties of fiber glass plastics based on polyester resin and glass fibers ASTT(b)-C₂O

Resin type	Water absorption in 24 hr, %	Martens thermal stability, °C	Strength (kg/cm ² during)			α _l , kg·cm/cm ²	E, kg/cm ²	HB, kg/mm ²
			tension	comp.	bending			
NPS-609-21M	-	100 (Вика)	3100	3200	4300	280	1,9·10 ⁴	-
			1850	2400	2900	170	1,2·10 ⁴	
NPS-609-22M	-	-	3000	2700	3800	-	-	-
PN-1	0.5	88-100	3100	2300	3300	192	1,9·10 ⁴	20-25
			1850	1700	2200	120	1,1·10 ⁴	
PN-3	0.5	180-185	3200	2300	3800	196	1,8·10 ⁴	20-25
			1800	1800	2400	121	1,2·10 ⁴	
PN-62	-	-	3540	2700	3800	-	-	-

Note. Numerator indicates the strength with respect to base, and denominator, with respect to reinforcements

The density (γ) of fiber glass plastics of all types is 1.6 - 1.7 g/cm³.

Table 83. Effect of a preliminary treatment of glass fibers by hydrophobic substances on strength of fiber glass plastics

Treatment	Strength (kg/cm ²) of dry and wet fiber glass plastics based on								
	polyester			epoxy			phenolformaldehyde		
	dry	wet	losses %	dry	wet	losses %	dry	wet	losses %
Without treatment	4600	1900	60	5100	8700	25	3700	2100	42
Silane-136	4900	5100	0	5300	4600	26	2500	1900	24
Volan	5600	5300	6	6200	5600	10	5300	5300	0
Garan	5100	5300	0	5200	4600	12	3200	3300	0

Under static loads, fiber glass plastics can flow at room temperature. It has been established that a sample loaded with 80% of a maximum load can be destroyed in 3-5 hours. At lower loads acting for a long time their strength decreases as much as by 35% in comparison with short-term loads but no destruction takes place.

Table 84 presents strength changes of fiber glass plastics subjected to loads.

Table 84. Bending strength of fiber glass plastics subjected to short- and long-term loads

Fiber glass plastic composition	Treatment	Strength (kg/cm ²) during		Strength losses, %
		Short-term loads	Loaded for 1000 hr	
Polyester resin + glass fibers	Silane	3500-4300	2300-2800	34.4
Epoxy resin + glass fibers	Volan	4500-5200	2800-3300	37.0
Phenolformaldehyde + glass fibers	Volan	5400-5800	3300	39-43

A disruption in binding strength between glass fibers and resins due to a long-term loads leads to a decrease in overall strength of the fiber glass reinforced plastics.

A general cold flow deformation by loads acting for a certain time (t, hr) can be approximated from formula

$$\epsilon = \epsilon_0 \left[1 + \left(\frac{t}{t_0} \right)^n \right], \quad (38)$$

where ϵ_0 is the time independent deformation; t_0 is the constant (hr) which is usually assumed to be unit; n is the dimensionless constant. The exponent n depends on the plastics moisture content and amounts to 0.02 - 0.07.

The flow rate is determined with respect to time as the first

derivative as follows

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$$\epsilon' = \frac{d\epsilon}{dt} = \frac{\epsilon_0 n}{t_0} \left(\frac{t}{t_0} \right)^{n-1} \quad (39)$$

As is evident from Figure 131 the ultimate strength of the fiber glass plastics decreases and the flow rate increases with increasing temperature.

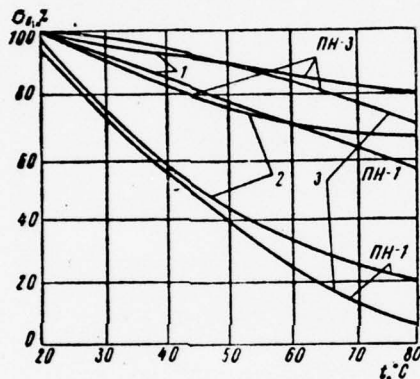


Figure 131. Properties of fiber glass reinforced plastics made of PN-1 and PN-3 resins and glass fibers ASTT(b)-C₂O as a function of temperature.

1 - tensile strength; 2 - compressive strength; 3 - bending strength.

The thermal stability of fiber glass plastics depends primarily on a type of binder. The highest thermal stability was observed in plastics based on phenolformaldehyde and especially on organosilicon resins; and the lowest among plastics based on polyester and epoxy resins.

Some fiber glass plastics are highly stable at low temperatures, in liquid nitrogen (-170°C), for example.

A long-term action of moisture decreases the strength of many fiber glass plastics. Thus, exposing the fiber glass plastics to sea water for 12 months results in 20-30% loss of their strength. The strength decreases rapidly during the first two months of exposure, then it stabilizes gradually. When exposed to moist air, the strength of fiber glass plastics decreases by 20%.

The static strength of fiber glass plastics also depends on the thickness of fiber fabrics. With increasing thickness of the fabric fibers the strength of plastics noticeably decreases, especially during compression. This is attributed to the fact that thick fibers are more twisted and therefore

lose more rapidly their stability at lower loads. On the other hand, plastics containing thick fibers exhibit higher impact strength during dynamic testing because thick fibers absorb better the impact energy.

Depending on the type of resin and reinforcing material, the impact strength of fiber glass plastics amounts to 100-300 kg·cm/cm². It reaches 400 kg·cm/cm² for some plastics, i. e., it approaches the /257 impact strength of a carbon steel.

The impact strength of fiber glass plastics based on polyester resins decreases by 20-30% at 80°C. On the other hand, it increases by 30% at - 30°C.

No fatigue limit was observed in plastics subjected to alternating loads. It has been established that the strength of plastics decreases by 25% (with respect to static bending) due to fatigue after samples are subjected to 5·10⁶ load cycles.

Use of Plastics in Fitting Ships

Ship's pipe lines and pipe systems. Use of plastics for pipelines and pipe system operating ~~at temperatures~~ at temperatures up to 100°C increased sharply in the last decade. A low thermal stability and inflammability of plastics, as well as some difficulties in assembling units and elements of pipelines prevent the use of plastics on ships on a much broader scale.

A low density polyethylene plastic is used most often on Soviet ships for pipes and fittings carrying the fresh drinking, wash and outside water; waste water, solutions of acids, alkali and other liquids in which the polyethylene is stable.

The polyethylene pipelines are used at temperatures not exceeding 50°C and up to 10 kg pressure per cm², provided the diameter of pipe fittings is from 10 to 125 mm.

The strength of polyethylene pipes is checked by internal hydraulic pressure for one hour which is calculated as follows

$$P_{\text{test}} = 2\sigma_{\text{test}} \times \frac{s_{\text{min}}}{D_{\text{out}} - s_{\text{min}}} \text{ kg/cm}^2 \quad (40)$$

where $\sigma_{\text{test}} = 70 \text{ kg/cm}^2$ is the test stress for polyethylene pipes; 1257
 s_{min} is the pipe wall thickness used in calculations (cm); D_{out} is the
average outside diameter of pipes (cm).

The hydraulic pressure (p_{test}) is determined with respect to a
conditional pressure (p_c) and the pipe conditional passage diameter, D_c .
Then the tensile strength of samples is determined which should not be
lower than 100 kg/cm^2 , as well as a relative elongation, which should not
be less than 450% when a rupture takes place.

The use of polyethylene pipes is much simpler in ^{comparison} Δ with pipes made
of other plastics (such as pipes made of thermosetting plastics) because
they are flexible, can be welded and are light. Polyethylene pipes do
not require a complex equipment for their production. 1258

As compared with steel pipes, ^{the} manufacture and assembly of poly-
ethylene pipes require only 50% of work hours. Servicing and maintenance
of polyethylene pipes is less troublesome because of their resistance to
corrosion. They do not require painting and their repair is less costly.

When planning pipelines on ships it should be kept in mind that
polyethylene pipes are thermally unstable, develop cold flow under loads
and inflammable. Therefore they should be installed away from sources
of heat, steam and hot water pipes.

A reliability of polyethylene pipes was proved in systems using
outboard water for cooling power units, in oil and fuel lines. The strength
of polyethylene pipes can be reinforced with a layer of the fiber glass
plastic made of resins that are cured at room temperature.

According to test results, the polyethylene pipes can serve
without any repairs for 30 years.

In addition to polyethylene pipes, other plastic pipes, especially
those made of fiber glass plastics are also used on ships. Pipes made of
polyester fiber glass reinforced plastics are used in Japanese shipbuilding
for outboard water, flushing and waste systems, for cooling, brine sys-
tems, oil and fuel lines. These pipes cost 35% less than the steel pipes,
and they are lighter, strong and simple to manufacture.

Lines made of polyester pipes showed their high operation
quantities on many commercial ships.

Pipelines on ships can operate at the temperature variation from

-40 to + 120°C, with only a slight deterioration in mechanical properties. At temperatures exceeding +120°C their properties deteriorate rapidly up to the point of uselessness.

Pipes made of fiber glass plastics can not be bend or welded and this presents some difficulties during assembly tasks. As a results, pipe lines are assemble of individual sections and units, with butt joints formed by a special fiber glass tape impregnated with polyester resin.

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Connecting and cut-off fittings in lines made of plastic pipes can be made either of metals or plastics. Fittings made of plastics are stronger 5-6 times in actual operation and they weigh by 40-45% less in comparison with metal fittings.

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Plastic fittings cost approximately ~~by~~ 40% less to manufacture and they do not require a complex machining and equipment for handling. Plastic fittings can be repaired under operation conditions at a much lower cost in comparison with metal fittings.

Finishing of cabins and manufacturing of various ship accessories. Plastics are used extensively for finishing of cabins on ships, manufacturing of different accessories, parts and devices. For example, vinyl boards and laminated color decorative boards are used for partitions, deckheads, various panels for passanger and service cabins, alleyways and other rooms. A surface quality of these boards vary; some of them can either absorb or reflect light, can be easily cleaned and could include different decorative designs. As opposed to the wood decorative finishing, plastic finishing does not require a special treatment, frequent repair and painting, is less flammable and less costly.

Different lights, lanterns, dome lights and many other lighting features requiring high lighting characteristics are made of semitransparent fiber glass plastics, with a colorful interweaving of glass fibers. Plexiglass is also used for this purpose.

Polyvinyl chloride and other soft plastics are used for the manufacture of materials immitating leather, silk and wood veneers. Finishing with these materials is less costly than painting.

Attractive, strong and inexpensive furniture (chairs, tables, armchairs, divans) are made of reinforced fiber glass plastics, cast

thermal plastics and foam plastics.

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Polyethylene, vinyl plastic, caprone and other plastics are used for different small items of cabin's furnishing.

Fiber glass plastics based on polyester, epoxy and other resins of cold curing, as well as thermosoftening plastics are used on ships for sanitary purposes, for shower enclosures, bath tubs, swimming pools. Lifeboats and life rafts are also made from fiber glass reinforced plastics combined with foam plastics.

Fiber glass plastics are used for the manufacture of hull fittings, screw propeller^s of different diameter and some fixtures. For example, water and gastight doors, hatch covers and stairways are made of polyester resin of cold curing.

Illuminators and other hull fixtures are made of AG-4S fiber /260 glass plastic based on modified phenolformaldehyde resin of hot curing by pressing method. This plastic possesses high strength, low setting and its expansion coefficient is close to that of the steel.

Screw propellers up to 2.5 m in diameter and higher are also made of plastics. Propeller hubs and blades of such propellers are made of fiber glass plastics by hot pressing. These propellers are 2-3 time lighter than metal, cost less and serve longer as compared with propellers made of nonferrous metals. Many passenger and freight ships, cutters and boats with outboard motors are equipped with propellers made of plastics.

Bearings for deadwood shafts are made of wood laminated plastics (laminated wood, for example). Outboard water serves as lubricant for these shafts by forming a film of water around them, which provides a viscous friction, with a low friction coefficient. At the same time it cools these bearings. They can not operate without an adequate water supply and burn fast (charring).

Rigging. Ropes made of synthetic fibers have been used for many years on ships in place of wire and hemp ropes. Caprone ropes were used first on ships because of their flexibility, low density (1.14) and high strength. They weigh two times less than steel and 6 times less than hemp ropes, while being equally strong. According to accumulated experience they satisfy the marine requirements.

A high sensitivity to sun rays, high hygroscopicity ($\sim 5\%$), /260
extensive wear upon aging and slipperiness are negative qualities of caprone ropes. A destructive effect of the sun rays can be reduced by adding the carbon black to resin ^{compounds} or dyeing the ropes into black color. However, these measures, do not provide a full protection against the sun rays.

Other synthetic fibers (Dacron, polypropylene) have better properties than caprone. They are less sensitive to the sun rays, less hygroscopic and have higher resistance to wear. It would be a good investment to produce ropes of polypropylene which is characterized by 0.92 density and 0% hygroscopicity.

Ropes made of Terylene fibers are in use on foreign ships for many years.

Safety Measures and Industrial Hygiene

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Synthetic resins used for the manufacture of ship's accessories are toxic. They liberate volatile harmful substances during processing (or parts made of them) which are harmful for skin and especially for mucuous membranes. Safety rules and industrial hygiene regulations must be followed strictly while handling many of the resins.

The basic safety rules are:

1. Workers handling resins and products made of them (manufacturing process) must pass medical examination and be provided with protective clothing and dust-retaining respirators;
2. All shops and building in which the manufacturing process takes place must be equipped with exhaust ventilation systems capable of at least ten-fols air exchange;
3. A local plenum ventilation must provide up to 3000 m^3 of clean air per 1 m^2 surface area of items being molded;
4. Each production plant must be equipped with a sanitation unit consisting of shower facilities, with hot and cold water, toilets, sinks, utility rooms, locker rooms for safety and personal clothing;
5. Special shops must be provided for molding small items, for machining operations, binder preparations and rooms for finishing works required by large moldings;

6. All rooms dealing with production of plastics must be equipped with systems eliminating pollutants and providing safe and easy cleaning of premises; /261

7. Chemicals must be stored according to specific requirements;

8. Individual hygiene and sanitation rules for everyone dealing with resins and plastic production processes must be strictly observed.

WOOD

Varieties of Wood

Wood is used on ships made of metal for decks, bulkheads, for covering of insulation, for batten ceilings, for finishing of rooms, furniture, some accessories, etc. It amounts to about 10% of the hull weight. Processing and assembly tasks of wood requires 2-5% of the total work hours spent for the construction of a ship. /262

Wood is also used for auxiliary needs, such as launching gears, keel-blocks, cribbings, scaffolds, guards, etc.

Positive qualities of wood include low weight, low thermal conductivity, high sound-absorption and easy handling. Wood is always available, cost little and many varieties are ready for use. Among shortcomings of the wood are flammability, decaying, deterioration of mechanical and physical properties due to moisture and temperature.

There are coniferous and deciduous varieties of wood. Pine, spruce, cedar, larch and fir belong to coniferous varieties. Oak, ash, beech, birch and Lignum vitae belong to deciduous trees.

Pine is the most available wood in shipbuilding. Depending on the place of growth, two types of pinewood is distinguished, mountain and white pine.

The mountain pine grows at high dry elevations and is characterized by resinous fine-grain wood which is strong and bioresistant; it has reddish or light-yellow color. The best wood is obtained from trees of about 125 years old. It is used for hulls and decks.

The white pine is used for canvas-covered decks and other auxiliary purposes because of softness, low bioresistance and swelling in water. It contains large grains and its color is white-yellowish.

Spruce is characterized by much lower mechanical and physical properties, is less stable against decaying and produces cracks when 1262 dry in comparison with pine. In shipbuilding it is used for internal decks, batten ceilings and other auxiliary needs.

Cedar grows in Ural Mountains, Siberia and Far East and is close to pine with respect to mechanical properties. Cedar wood is stable in water and it is used for hulls, decks, furniture, batten ceilings and replaces pine in many instances. The best quality wood is obtained from cedar trees of about 150 year old.

Larch exceeds all coniferous wood in respect to biostability, flammability and mechanical properties. Larch grows in northern part of the USSR. Its color is brown-yellow, with grains impregnated with resinous substances. Larch wood is suitable for shipbuilding but is used limitedly because of distances when it grows and where ships are built. 1263

Fir wood is similar to that of spruce and it is characterized by a much lower biostability, brittleness and tendencies to crack. It is used primarily for launching purposes, scaffolds, guards and other auxiliary purposes.

Oak yields heavy, strong and biostable light-brown wood. The strength of oak wood depends on the place of growth. The best quality of wood is obtained from trees grown at elevated, dry places, as opposed to moisture-laden soils. It has many and various applications in shipbuilding.

Ash grows in Caucasus and Far East; its wood is highly elastic and flexible. With respect to strength and elasticity, it exceeds the oak. In shipbuilding it is used primarily for oars, bent hull sections, furniture and cabinet works.

Beech yields pink-white, dense and strong wood which lacks biostability. It decays in 1-2 years in moist environment. However, it is preserved for a much longer time under water. Because of its attractive texture and easy handling, the beech wood is used for finishing works.

Common birch is white-yellowish in color, with such characteristics as high density, hardness and elasticity. Under moist conditions the birch wood decays rapidly. In shipbuilding it is used for cabins, furniture and as plywood panels.

Lignum vitae wood is very heavy, hard and can be preserved in water for a long time. It is used for block sheaves, stern tube and strut bearings, as well as for propeller shaft bearings. Lignum vitae grows on Antilean and Bohemian Islands. /263

Red wood, walnut, maple, Karelian birch, elm and other types of wood are also used in shipbuilding for furniture, finishing works and as plywood.

Soundproofing Materials

/306

Soundproofing materials are used for absorbing all kinds of sounds and noises produced by various mechanisms, devices, propellers, vibration of hull structures, etc.

Under the sound we understand here the propagation of mechanical oscillations in elastic media.

Soundproofing materials are used for insulation of sounds; and the vibration absorbing coatings to lower vibrations.

A human ear is capable of hearing sounds from 16-20 Hz to 18-20 kHz (1 Hz = 1 oscil. /sec).

The energy propagated by a sound wave over a surface per unit time is called the sound intensity. The hearing perception changes with changing of the sound logarithm but not the sound intensity. The sound intensity is measured in decibels as follows

$$\beta = A \log J \quad (44)$$

where J is the sound intensity.

A sound pressure of $2 \cdot 10^{-4}$ dyne/cm² which corresponds to 1000-5000 Hz is called the sound threshold in acoustical calculations.

According to the Ship's Register of the USSR the level of noise in living quarters, work rooms and engine rooms shall not exceed 40-50, 80-90 and 100 db, respectively. In reality, the noise in these rooms exceeds the allowable level in many instances.

Various materials are distinguished by different sound transmission capabilities. The sound-insulating property of a material is evaluated on the basis of the sound level differences derived from a perception on both sides of a barrier; and it is expressed in decibels (Table 92).

Table 92. Sound-insulating properties of materials

/307

Material	weight, kg/m ²	sound-insulating property, db
Three-layer plywood, 3 mm	2.3	18
Six-layer plywood, 6.4 mm	4.5	21
Steel sheets:		
0.7 mm	5.6	25
2.0 mm	15.7	33
Duraluminum, 0.5 mm	1.8	15
Cork boards, 50 mm thick	30	20
Cardboard		
5 mm	3	16
20 mm	12	20
Tarpaulin	6	6

It is evident from Table 92 that dense, nonporous material possess high sound-insulating property. A 50 mm thick cork board (30 kg/m²) has lower sound-insulating properties in comparison with the 0.7 mm steel sheet. A low sound-insulating property of porous materials is attributed to the presence of pores which propagate the sound.

Materials which absorb the sonic energy belong to ^{the} sound-absorbing materials, and those repelling the sound are called the sound-insulating materials. Materials (coatings) capable of decreasing the oscillation amplitude of a structure are classified as the damping coatings.

The sound-insulating materials can be grouped into basic and auxiliary according to their acoustic effects and the area of application.

/308

The sound-insulating properties of basic materials are high and their specific acoustic resistance exceeds that of the air. Dense and heavy materials used for hull structures and insulation boarding belong to this group of materials (Table 93).

Heat-insulating materials, deck coverings, rubber and other materials of porous structure belong to the auxiliary materials.

Table 93. Characteristics of the sound-unsulating materials used in shipbuilding

/307

Material	Density, $\text{kg/m}^3 \cdot 10^3$	Sound propagation velocity, $\text{m/sec} \cdot 10^3$	Specific acoustic resistance, $\text{kg/m}^2 \cdot 10^7$	Ultimate temperature, $^{\circ}\text{C}$
Steel	7.8	5.2	4.0	350
Titanium alloys	4.5	5.2	2.34	500
Aluminum alloys	2.8	5.1	1.3	150
Illuminator glass	2.5	5.2	1.3	-
Concrete, type 300 and 400	2.35	3.2	0.75	100
Fiber glass plastics based on polymer resins	1.7	3.5	0.59	40
Sawdust from coniferous trees	0.51	4.8	0.25	100
Laminated plastics	1.4	3.1	0.43	120
Bakelite plywood	0.8	2.0	0.18	100
Cellulose fiber sheets	1.0	1.7	0.17	60
Mineral fiber material Asbolite 609	0.9	2.0	0.16	1200

The sound-insulating materials decrease the noise in adjacent rooms to 30-40 db.

Insulating materials are characterized by the sound absorption coefficient α which is a ratio of the absorbed sonic energy to incident sonic energy:

$$\alpha = \frac{J_{\text{abs}}}{J_{\text{inc}}} \quad (45)$$

where J_{abs} and J_{inc} are absorbed and incident sound energies, respectively.

The absorption energy depends on a sound purity, type of material, its thickness, space between a material and a rigid wall, presence of films,

perforated panels, etc.

B08

Soft-fibrous and porous materials are characterized by the highest sound-absorbing properties. The sound-absorbing materials are grouped into basic and substitutes (Table 94).

Table 94. Characteristics of the sound-insulating hull materials

Material	Density, kg/m ³	Ultimate temp., °C	Sound propagation velocity in a material, m/sec.
Heat and sound-insulating material of ATM-1 type	10	-60 to +150	230
Porous polyurethane plastics which is elastic and self-extinguishing, PPU-ES type	4	70	90
Aspalite-609 made of asbestos and aluminum powder, with perforated face sides	200	600	150

The sound-absorbing structures are installed in rooms having a high level of noise (engine and pumping rooms, radio house, etc.) These structures are helpful in reducing noise level in many places on a ship.

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The heat- and sound-insulating ATM-1 material is made of staple ultrathin glass fibers impregnated with phenolformaldehyde resin. One side of this material is covered with aluminum foil or with polyethylene terephthalic film. The material is incombustible and is used for facing the bulkheads or other surfaces requiring the soundproofing.

The foam plastics PPU-ES is gas-filled material, with a uniform distribution of pores. It is incombustible and can be used in place of ATM-1. The perforated side of this material faces the surface to be soundproofed.

The following materials can be used in place of the basic sound-

proofing materials: ATIMS, VT-4, VT-4S, thermal insulating boards of 309 staple fiber glass plastics, phenol bonded semi rigid boards, polyethylene film and Vinol.

The soundproofing structures could be either resonant or porous absorbers (Figure 143). The resonant structures consist of one or several perforated rigid sheets (steel, aluminum alloys, plywood), with an air gap between them. In order to improve their sound-absorbing properties, fabric is glued on the perforated side.

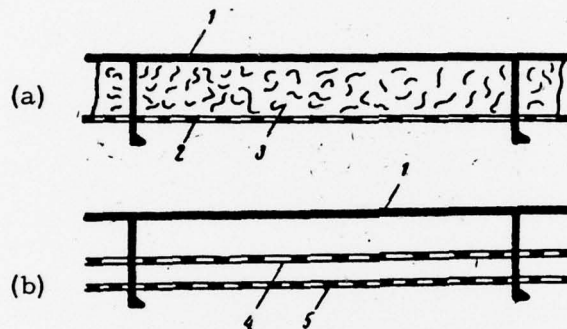


Figure 143. Types of soundproofing structures.

- (a) containing a porous absorber;
- (b) resonant.

- 1 - frame structure; 2 - perforated side;
- 3 - sound-absorbing material;
- 4 - internal perforated panel;
- 5 - external perforated panel.

Vibration-absorbing or vibration-damping coatings are very effective against sonic vibrations. The acoustic effect of these coating is based on vibration energy absorption in the course of the coating deformation. As a result the vibration amplitude of hull structures decreases, as well as the noise caused by the sonic vibration. Materials which absorb much energy during their deformation belong to a viscous-elastic group.

All vibration-absorbing coating are grouped into rigid, reinforced and soft. Tensile deformations are used in rigid coatings, and

shear deformations ~~EMR~~ in reinforced coatings. Soft coatings function on 310 account of deformations produced by waves propagating into the thickness of the viscous-elastic material (Figure 144).

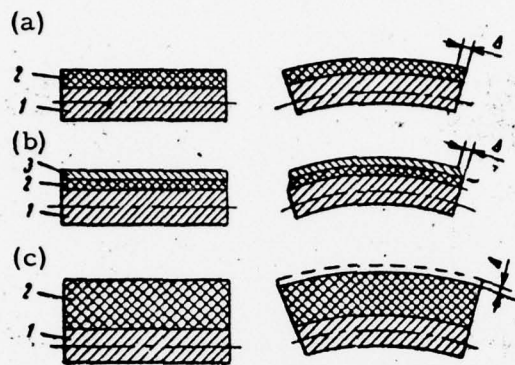


Figure 144. Structure of the vibration-absorbing coatings:

(a) rigid coatings; (b) reinforced; (c) soft.

1 - deformable board;

2 - vibration-absorbing material;

3 - spacer;

4 - deformation of the vibration-absorbing material

A material having high modulus of normal elasticity and coefficient of losses is best for rigid coatings. (The coefficient of losses determines the energy absorption in a vibrational system). High polymer plastics containing such fillers as vermiculite, mica and graphite belong to this type of materials, as well as bitumen based composition, composition Neva-3u, linoleum and felt impregnated with bitumen. If a rigid coating requires a spacer on top on it, foam plastics PKhV-1, FS-7₂ and others can be used.

Reinforced vibration-absorbing coatings should be characterized by insignificant shear modulus. Certain type of rubbers and plastics are suitable for this purpose.

Soft vibration-absorbing coatings should possess high coefficient of losses and minimal propagation velocity of compressive waves.

Some types of rubbers and rubberlike materials are characterized by / 310
these properties.

The vibration-absorbing coatings are deposited on hulls in the area of propellers, engine foundations, on structures surrounding engine rooms and in other places.

Antivibration mountings and other devices are used in addition to coatings to decrease sonic vibrations on ships.
