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# FOREIGN TECHNOLOGY DIVISION

(PART IV)

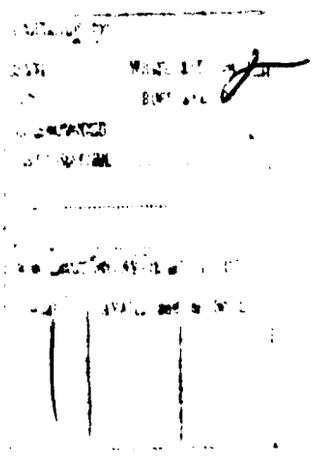
ENCYCLOPEDIA OF CONTEMPORARY ENGINEERING.
STRUCTURAL MATERIALS.

nickel thru soft magnetic materials

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# UNEDITED ROUGH DRAFT TRANSLATION

(PART FOUR OF FIVE PARTS)

ENCYCLOPEDIA OF CONTEMPORARY ENGINEERING.
STRUCTURAL MATERIALS.

English pages: 2717 - 3653

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FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.

NICKEL – Ni is a chemical element of Group VIII of the Mendeleyev Periodic System, atomic number 28, atomic weight 58.71. The most abundant isotopes are $Ni^{58}$ (67.76%) and $Ni^{60}$ (26.16%).

Nickel is widely used in various branches of engineering, primarily for the production of alloys with high strength at elevated temperatures and alloys with special physical properties. Nickel is divided into 5 grades on the basis of degree of purity.

The properties of nickel depend to a marked degree on the method of production and for resmelted nickel depend on the method or refining

TABLE 1

Chemical Composition of Nickel per GOST 849-56

| 1 Марка | 2 Содержание элементов (%) | | | | | | | | Применение 7 |
|---|---|---|---|---|---|---|---|---|---|
| | Ni+Co (не менее) 3 | в том числе Co (не более) 4 | 5 примеси (не более) Fe | Si | C | S | Cu | другие примеси 6 | |
| Н0 | 99.99 | 0.005 | 0.002 | 0.001 | 0.005 | 0.001 | 0.001 | * | 8 Для изготовления жаропрочных сплавов и сплавов с особыми физич. свойствами |
| 7a | | | | | | | | | |
| Н1 | 99.93 | 0.1 | 0.01 | 0.002 | 0.01 | 0.001 | 0.02 | ** 9 | Для изготовления ковких сплавов с особыми физич. свойствами |
| Н2 | 99.5 | 0.15 | 0.04 | 0.002 | 0.02 | 0.003 | 0.04 | *** 10 | Для изготовления высоконикелевой стали и сплавов |
| Н3 | 98.6 | 0.7 | – | – | 0.1 | 0.03 | 0.06 | – 11 | Для легирования стали |
| Н4 | 97.6 | 0.7 | – | – | 0.15 | 0.04 | 1 | – | То же 12 |

*Content of other impurities in total must not exceed 0.01%, of them the Zn, As, Mg, Al, P, Mn content must not exceed 0.001% (each), and Pb, Sn, Sb, Bl, Cd – 0.0003% (each).

**Content of Zn, As, Cd, Sn, Sb, Pb, Bl, Mg, P must not be more than 0.001% (each).

***Zn content must not be more than 0.005%.

1) Grade; 2) element content (%); 3) (no less than); 4) of that, Co (no more than); 5) impurities (no more than); 6) other impurities; 7) remarks; 7a) N; 8) for production of high-temperature alloys and alloys with special physical properties; 9) for production of forging alloys with special physical properties; 10) for production of high-nickel steel and alloys; 11) for steel alloying; 12) same.

The N0 grade nickel has the lowest carbon content. It also has a minimal amount of impurities which are harmful for the high-temperature strength of the nickel alloys (Pb, Zn, Sn, Sb, Bi, Cd and S). The N1 grade nickel has somewhat lower purity and higher content of C and Co.

TABLE 2

Properties of Pure Nickel

| 1 Свойства | Показатель свойств 2 |
|---|---|
| 3 Степень чистоты металла (%) | 99,99 |
| 4 Электродный потенциал (в) | 0,231 |
| 5 $t°_{пл}$ (°C) | 1455 |
| 6 Скрытая теплота плавления (кал/г) | 73 |
| 7 $t°_{кип}$ (°C) | 3080 |
| 8 Скрытая теплота испарения (кал/г) | 1450 |
| 9 γ (г/см³) 10 | 8,907 |
| α·10⁶ (1/°C) в интервале 20—100° | 13,3 |
| 11 ρ (мком·см) | 6,84 |
| 12 λ (кал/см·сек·°C) в интервале 0—100° | $1,428 \cdot 10^{-4}$ |
| 13 Магнитные свойства точки Кюри (°C) 14 | 360 |
| E (кг/мм²) | 22000 |
| HB (кг/мм²) | 85—70 |
| $\sigma_b$ (кг/мм²) | 28—30 |
| δ (%) | 35—40 |
| Обрабатываемость в холодном состоянии 15 | Хорошая 16 |

1) Properties; 2) property indix; 3) degree of metal purity (%); 4) electrode potential (v); 5) $t°_{pl}$ (°C); 6) latent heat of fusion (cal/g); 7) $t°_{kip}$ (°C); 8) latent heat of evaporation (cal/g); 9) γ (g/cm$^3$); 10) in range; 11) ρ (μohm/cm); 12) λ (cal/cm-sec-°C) in range; 13) magnetic properties of Curie point (°C); 14) (kg/mm$^2$); 15) cold workability; 16) good.

Nickel of the grades N2, N3, and N4 has still lower purity; nickel of these grades with the highest purity with respect to impurities is used for alloying steels (stainless and scale-resistant).

Nickel interacts energetically with gases, adsorbing them to some degree. It adsorbs hydrogen most strongly, particularly at low temperatures (−180°). Adsorption by nickel is accompanied by a thermal effect (4000-21,000 cal/mole). Carbon dioxide and ethylene are also adsorbed by nickel, while carbon monoxide dissociates with the formation of free carbon. The diffusion of gases ($H_2$, $CO_2$, CO and $O_2$) through nickel is determined by the equation: [illegible], where D is the volume of the

gas being diffused, d is the thickness of the nickel layer in mm, P is the pressure in mm Hg, T is the absolute temperature in °K, and K and b are constants, for hydrogen b = 6500; K = (1-1.9) × $10^{-2}$.

In the melting process, nickel strongly absorbs the reducing gases, which even at a low content cause brittleness of the metal during hot working. It has been established that at a temperature of 1500° 100 grams of nickel absorb up to 500 $cm^3$ of gases, of which 90% is carbon monoxide, 2.3% is carbon dioxide, 3.5% is hydrogen, and 4.2% is nitrogen. The accumulation of carbon monoxide and hydrogen causes cracking of the nickel during hot pressure working. There is also energetic absorption of oxygen, nitrogen, and hydrogen during melting of the high-temperature nickel alloys. A portion of these gases is absorbed and, being released on cooling of the metal, hinders the subsequent hot pressure working; another portion, entering into reaction with the Cr, Ti, Al, and other elements present in the high-temperature alloy, form oxides, nitrides, and carbonitrides which also have an unfavorable effect on hot pressure working and on the plastic properties of the alloys at elevated temperatures, and also on the operational stability of parts. Therefore, recently the melting of the nickel high-temperature alloys has been performed in a vacuum in high-frequency induction furnaces and in arc furnaces with consumable electrode; in many cases degassing of the metal which has been melted in a conventional furnace is performed by using vacuum during pouring. As a result of interaction with the molten metal, oxygen and nitrogen form refractory oxides which are difficult to dissolve, consisting basically of oxides of aluminum, chromium, and titanium. During the settling process these oxides envelop the crystals and are the cause of blistering and degradation of the mechanical and processing properties. In addition, nitrogen forms nitride or carbonitride refractory inclusions which reduce the plasticity

of the alloy.

Nickel produced by means of resmelting – grades NO and N1 – forges and rolls well; it is used in the form of rods, sheet, strip, wire, and tubing which are amenable to welding and brazing. Forging nickel produced from grade NO nickel is considerably softer than the N2 and N1 grades. It has less tendency to strengthening during work hardening and therefore is widely used for fabricating parts using deep drawing.

TABLE 3

Mechanical Properties of Nickel as a Function of Temperature

| Свойства 1 | 2 Темп-ра (°С) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 20 | 300 | 455 | 593 | 860 | 1000 | 1100 |
| $\sigma_b$ (кг/мм²) 3 | 49,3 | 44,8 | 30,2 | 20,6 | 9,2 | 4 | 2,5 |
| $\delta$ (%) | 26 | 31 | 20 | 16 | 11 | 11 | 11 |
| $\psi$ (%) | 72 | 67 | 31 | 25 | 18 | 15 | 24 |

1) Properties; 2) temperature (°C); 3) (kg/mm²).

TABLE 4

Mechanical Properties of Nickel at Negative Temperatures

| Свойства 1 | 2 Темп-ра (°С) | | |
|---|---|---|---|
| | +17 | −196 | −253 |
| $\sigma_b$ (кг/мм²) 3 | 45 | 63 | 79 |
| $\delta$ (%) | 35 | 46 | 48 |
| $\psi$ (%) | 77 | 89 | 69 |

1) Properties; 2) temperature (°C); 3) (kg/mm²).

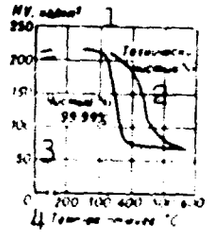



Fig. 1. Effect of annealing temperature on nickel hardness. 1) HV, kg/mm²; 2) technically pure Ni; [illegible] pure; 4) annealing temperature, °C.

Figures 1 and 2 show the variation of nickel hardness with increase of the annealing temperature and test duration. Nickel has com-

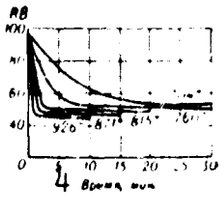


Fig. 2. Effect of temperature and aging time on nickel hardness. 1) Time, min.

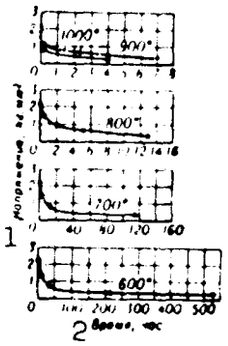


Fig. 3. Stress-rupture strength of nickel at various temperatures. 1) Stress, kg/mm$^2$; 2) time, hours.

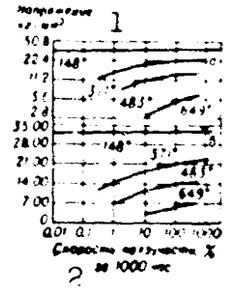


Fig. 4. Creep rate of nickel as a function of stress at various temperatures. Coordinate system: a) logarithmic; b) semilogarithmic. 1) Stress, kg/mm$^2$; 2) creep rate, % in 1000 hours.

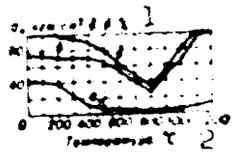


Fig. 5. Variation of plasticity and impact strength of nickel with temperature increase. 1) $a_n$, kgm/cm$^2$; $\Delta$, $\psi$; 2) temperature, °C.

paratively low mechanical properties at high temperatures, but better than those of α iron. The variation of the mechanical properties of nickel with temperature increase is shown in Table 3, and the values for negative temperatures are shown in Table 4.

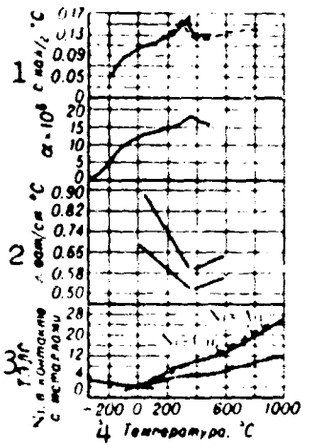



Fig. 6. Effect of temperature on the variation of physical properties of nickel. 1) c, cal/g-°C; 2) λ, w/cm-°C; 3) TEMF of Ni in contact with metals; 4) temperature, °C.

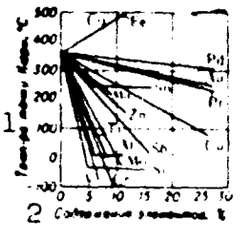



Fig. 7. Effect of alloying elements on variation of Curie point of nickel. 1) Curie point temperature, °C; 2) element content, %.

The stress-rupture strength and the creep resistance of nickel at high temperatures are shown in Figs. 3 and 4.

The impact strength of nickel varies similarly to the variation of the plasticity with a minimum at 800° (Fig. 5). Figure 6 shows the variation of the physical properties of forging nickel as a function of temperature. At a temperature of about 350° there is observed an interruption in the smooth behavior of the curves which is associated with magnetic changes. Nickel is ferromagnetic up to 340-360°, then becomes

paramagnetic; it is characterized by a low value of the electrical resistance and high temperature coefficient of electrical resistance. The effect of alloying elements on the variation of the Curie point of nickel is shown in Fig. 7. Nickel has high heat-resistance up to 1100-1150° and good thermal conductivity, which reduces the sensitivity of the material to local overheating, warping, and cracking during its use in gas turbine combustion chambers in both the pure and plated (over steel or copper) form. For example, nickel coating of gas turbine blades made from the EI388 steel which has low heat resistance made it possible to use them in jet engines with heating to 850° and has fully justified its use in operation. Nickel is also used as a heat-resistant material in analytic practice (vessels for combustion of specimens). As a result of high resistance to corrosion in numerous aggressive media (alkalis), nickel finds wide application in the fabrication of equipment for the chemical industry. The introduction of 2-4.5% manganese into nickel improves its resistance to atmospheric corrosion and corrosion at high temperatures in the presence of sulfurous gases. Manganese nickel is used primarily for the fabrication of electrodes of ignition plugs for several types of internal combustion engines, and also as a holder for incandescent filaments in electric light bulbs. The introduction of about 1.5% silicon into nickel increases its fluidity and casting properties, therefore heat-resistant cast parts are cast from silicon nickel.

References: Berkovskiy, I.Ya. and Kolokoleva, A.G., Nikelevyye splavy [Nickel Alloys], Moscow-Leningrad, 1941; Burkhardt, A., Mechanical and Technological Properties of Pure Metals, translated from German, Moscow-Leningrad, 1941; Golevin, V.A., Tsvetnyye metally [Nonferrous Metals], 1950, No. 6, page 54; Kornilof, I.I., Nikel' i yego splavy [Nickel and Its Alloys], Moscow, 1958; Betteridge, W., High-Tempera-

ture Alloys of the Nimonic Type, translated from English, Moscow, 1961; Bloom, D.S., Grant, N.J., "J. of Metals," 1951, Vol. 3, No. 11, page 1009; Woldman, N.E., Nickel and High-Nickel Alloys, "Mater. and Methods," 1946, Vol. 24, No. 6, page 1475-90; Nickel and Its Alloys, Wash., 1950; Tödt, F., Korrosion und Korrosionsschutz [Corrosion and Corrosion Protection], 2nd Ed., Berlin, 1961; Hessenbruch, W., Metalle und Legierungen für hohe Temperaturen [Metals and Alloys for High Temperatures], Vol. 1, Berlin, 1940.

F.F. Khimushin

NICKEL (ALLOY) SHEET is produced by hot rolling (hot-rolled sheet) or by hot rolling with subsequent cold rolling (cold-rolled sheet) of forged or rolled billets. Cold-rolled sheet is delivered in thickness from 0.8 to 3-3.6 mm with dimensions of 710x1420 mm. Hot-rolled sheet is made in thickness of 10-12 mm in limited sizes by agreement with the consumer. Both the hot- and cold-rolled sheets are delivered in the soft condition (after brief heating at temperatures which relieve the s strain hardening), etched and cleaned. There are more advanced methods for the production of sheet (see Steel Sheet). Sheet made from the nickel alloys differs from the analogous semimanufactures made from the iron-base alloys in higher strength at temperatures to 700° (nonaging alloys) and also in the combination of high-temperature strength with satisfactory weldability (aging alloys). For the properties of the nonaging and slightly-aging alloys see Wrought Heat-Resistant Nickel Alloys and for the aging alloys see Wrought High-Temperature Nickel Alloys.

II-101k1

## Chemical Properties, Heat Treatment and Use of Alloys for Nickel Sheet

| Марка сплава по ГОСТ 5632-61 1 | 2 Содержание элементов (%): C 3 | Si 3 | Mn 3 | Cr 3 | Ni 3 | Ti 3 | Al 3 | W 3 | Mo 3 | Nb 3 | Fe не более 4 | S не более 5 | P 5 | Прочие 5 | Вид полуфабриката 6 | Технические условия 7 | Термическая обработка 8 | Класс материала и применение 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ХН78Т (ЭИ435) 10 | 0,12 | 0,8 | 0,7 | 19—22 | осн 11 | 0,15—0,35 | не более 0,15 | — | — | — | 6 | 0,015 | 0,02 | — | Лист холоднокатаный, толщина от 0,8 до 3,6 мм 13 | ЧМТУ 11-63-62 | Закалка, нагрев при 1000°, охлаждение на воздухе 12 | Не склонный к старению сплав, детали работающие до 800—900° 14 |
| | | | | | | | | | | | | | | | Лист горячекатаный, толщина от 8,5 до 11 мм 17 | ЧМТУ 5-963-55 | | |
| ХН75МБТЮ (ЭИ602) 18 | 0,1 | 0,8 | 0,4 | 19—22 | осн 11 | 0,35—0,75 | 0,35—0,75 15 | — | 1,8—2,3 | 0,9—1,3 | 8 | 0,012 | 0,02 | — | Лист холоднокатаный, толщина от 0,8 до 3 мм 19 | ЧМТУ 6989-54 | Закалка, нагрев при 1050° с охлаждением на воздухе | Не склонный к старению сплав, детали работающие до 900° 17 |
| | | | | | | | | | | | | | | | Лист горячекатаный, толщина от 8,5 до 11 мм 20 | ЧМТУ 6829-54 | | |
| ХН60Р (ЭИ868, ВЖ98) 21 | 0,1 | 0,8 | 0,5 | 28,5—29,5 | осн | 0,3—0,7 | не более 0,5 | 13—16 | — | — | 4 | 0,013 | 0,020 | — | Лист холоднокатаный, толщина от 0,8 до 3,6 мм 22 | ЧМТУ 5459-57 | Закалка, нагрев при 1200° с охлаждением на воздухе | Не склонный к старению сплав, детали работающие до 1200° 20 |
| | | | | | | | | | | | | | | | Лист горячекатаный, толщина от 5 до 16 мм 23 | ЧМТУ 5865-57 | | |
| ХН70Ю (ЭИ652) 24 | 0,1 | 0,8 | 0,3 | 26—29 | осн | — | 2,6—3,5 | — | — | — | 1 | 0,02 | 0,02 | Барий 0,1, церий 0,03 25 | Лист холоднокатаный, толщина от 0,8 до 3 мм 26 | ЧМТУ 671-54 | Закалка, нагрев при 1200° с охлаждением на воздухе | Склонный к старению сплав, детали работающие до 1200° 27 |
| | | | | | | | | | | | 2 | | | церий 0,03 28 | Лист горячекатаный, толщина 10 мм 29 | ЧМТУ 2451-56 | | |
| ХН60ВТ (ЭИ559А) 30 | 0,1 | 0,8 | 0,3 | 15—18 | 55 31 | — | 2,35—2,75 | — | — | — | 1,5 (не более) | 0,02 | 0,02 | Барий 0,1, церий 0,03 32 | Лист холоднокатаный, толщина от 0,8 до 3 мм 33 | ЧМТУ 5-954-64 | Закалка, нагрев при 1150° с охлаждением на воздухе | Склонный к старению сплав, детали работающие до 1200° 34 |
| ХН77ТЮР (ЭИ437Б) 36 | 0,06 | 0,8 | 0,6 | 19—22 | осн | 2,35—2,75 | 0,65—0,95 | — | — | — | 6 | 0,007 | 0,015 | Бор 0,005, церий 0,03 35 | Лист холоднокатаный, толщина от 0,8 до 3 мм 38 | ЧМТУ 5-954-64 | Закалка, нагрев при 1150° с охлаждением на воздухе | Склонный к старению сплав, детали работающие до 800° 39 |
| (ЭИ894) 41 | 0,1 | 1 | 0,6 | 21—24 | осн | 0,8—1,2 | 1,8—2,3 | 4,5—5,5 | 0,8—1,2 | — | 10 | 0,03 | 0,03 | — | Лист холоднокатаный, толщина от 0,8 до 3 мм 42 | ЧМТУ 5700-60 | Закалка, нагрев при 1175° с охлаждением на воздухе, старение при 800° 8 ч 43 | Склонный к старению сплав, детали работающие до 850° 44 |
| ХН67ВМТЮ (ЭИ445Р) 45 | 0,08 | 0,8 | 0,5 | 17—20 | осн | 2,35—2,75 | 0,1—0,4 | 4—5 | 4—5 | — | 4 | 0,01 | 0,015 | Бор 0,01, церий 0,03 | Лист холоднокатаный, толщина от 0,8 до 3 мм, ширина не менее 200 мм, длина не менее 500 мм 46 | ЧМТУ ЭИ445РМ 47 | Закалка, нагрев до 1175°, охлаждение на воздухе, старение при 800° не менее 8 ч 48 | Склонный к старению сплав, детали работающие до 850° 49 |
| | | | | | | | | | | | | | | | Лист холоднокатаный, толщина от 0,8 до 3 мм 50 | ЧМТУ ЭИ445РМ | | |

1) Alloy type from GOST 5632-61; 2) content of elements (%); 3) not more than; 4) not more than; 5) balance; 6) form of mill product; 7) specification; 8) heat treatment; 9) material class and application; 10) KhN78T (EI435); 11) base; 12) not more than; 13) cold-rolled sheet, thickness from 0.8 to 3.6 mm; 14) ChMTU; 15) brief heating at 1000°, air cooling; 16) nonaging. For low load details operating at 800-900°; 17) hot-rolled sheet, thickness from 8.5 to 11 mm; 18) KhN75MBTYu (EI602); 19) cold-rolled sheet, thickness from 0.8 to 3 mm; 20) hot-rolled sheet, thickness from 8.5 to 11 mm; 21) KhN60V (EI868, VZh98); 22) cold-rolled sheet, thickness from 0.8 to 3.6 mm; 23) hot-rolled sheet, thickness from 5 to 16 mm; 24) KhN70Yu (EI652); 25) barium; 26) cold-rolled sheet, thickness from 0.8 to 3 mm; 27) slightly aging. Has high temperature resistance to 1200°. For low load details; 28) cerium; 29) hot-rolled sheet, thickness 10 mm; 30) KhNtoYu (EI559A); 31) balance; 32) barium; 33) cold-rolled sheet, thickness from 0.8 to 3 mm; 34) same; 35) cerium; 36) KhN77TYuR (EI437B); 37) boron; 38) cold-rolled sheet, thickness from 0.8 to 3 mm; 39) aging. For loaded details operating to 800°; 40) cerium; 41) (EI894); 42) cold-rolled sheet, thickness from 0.8 to 3 mm; 43) brief heating at 1175°, air cooling, aging at 800° for 8 hours; 44) aging. For loaded details operating to 850°; 45) KhN67VMTYu (EI445R); 46) cold-rolled and hot-rolled sheet, thick-

ness 3 mm, size not less than 700x1200, thickness 4 mm, size not less than 700x800 mm; 47) TsNIIChM; 48) heated at 1180°, air cooled. Aging at 850° for not less than 5 hours; 49) aging. For loaded details operating up to 900-950°; 50) hot-rolled sheet, thickness 10-25 mm, width 1000 mm, length not less than 1500 mm.

M.Ya. L'vovskiy

NICKEL (ALLOY) STRIP is produced by hot rolling and subsequent cold rolling. The rolled stock obtained from individual billets is butt welded together and cold rolled to dimension. The nickel strip is in thickness from 0.2 to 1.2 mm and width up to 400 mm.

The strip is produced in rolls, soft (after brief heating to temperatures which relieve the strain hardening), with etched surface. For the chemical composition of the nickel alloys for nickel strip, their properties, heat treatment and usage, see Nickel Sheet.

For the properties of the nonaging and slightly-aging alloys see Heat Resistant Wrought Nickel Alloys and for the aging alloys see High Strength Wrought Nickel Alloys. For the nickel alloys used for the production of nickel strip see Table.

Nickel tape (NP0, NP1, NP2, NP3 and NP4) with impurity contents from 0.02 to 1% and the NK004 and NK02 silicon-nickel tapes with respective silicon contents of 0.04% and 0.2% are produced for the vacuum-tube and other branches of industry. For the compositions and assortment, see GOST 492-52 and GOST 2170-62.

Alloys Used for the Production of Nickel Strip

| Сплав 1 | Вид полуфабриката 2 | Технич. условия 3 |
|---|---|---|
| ХН77ТЮР (ЭИ437Б), ХН60В(ЭИ868) 4 | Лента шириной 400 мм, толщиной от 0,2 до 1 мм 5 | ЧМТУ 5482-56 6 |
| ХН75МБТЮ (ЭИ602), ХН70Ю (ЭИ652) 7 | То же 8 | Изменение № 1 к ЧМТУ 5482-56 9 |
| ЭИ894 10 | Лента шириной 400 мм, толщиной от 0,2 до 1,2 мм 11 | ЧМТУ ЦНИИЧМ 515-61 12 |

1) Alloy; 2) form of mill product; 3) specification; 4) KhN77TYuR (EI437B), KhN60V (EI868); 5) strip 400 mm wide, thickness from 0.2 to 1 mm; 6) ChMTU; 7) KhN75MBTYu (EI602), KhN70Yu (EI652); 8) same; 9) amendment No. 1 to ChMTU; 10) EI894; 11) strip 400 mm wide, thickness from 0.2 to 1.2 mm; 12) TsNIIChM.

II-5411

Nickel tape (NP0, NP1, NP2, NP3 and NP4) with impurity contents from 0.02 to 1% and the NK004 and NK02 silicon-nickel tapes with respective silicon content of 0.04% and 0.2% are produced for the vacuum-tube and other branches of industry. For the compositions and assortment, see GOST 492-52 and GOST 2170-62.

M.Ya. L'vovskiy

NICKEL BARS – see High-hot-strength nickel shaping alloys.

NICKEL-BERYLLIUM ALLOYS are alloys which have high elastic and strength properties at room and elevated temperatures and relatively low electrical resistivity. The nickel-beryllium alloys are dispersion hardening as a result of the variable solubility of beryllium in nickel in the solid state. The maximal solubility of beryllium in nickel with the formation of the α-solid solution is about 2.5%; usually the nickel-beryllium alloys contain 1.9-2.5% beryllium.

The primary deficiency of the nickel-beryllium alloys is their poor pressure workability in the hot condition, which practically eliminates the possibility of obtaining sheet, strip, wire, and other mill products on an industrial scale. The technology developed in the USSR for the production and heat treatment of these alloys has made possible a sharp increase of the plasticity during hot pressure working and thereby has permitted the organization of industrial production of the nickel-beryllium alloys.

In addition to the EI996 grade binary nickel-beryllium alloy, three-component alloys of the systems Ni-Be-W (EI996B) and Ni-Be-Mo (EI996M) have been developed. The EI996, EI996B, and EI996M alloys are produced per ChMTU 614-61 and ChMTU 615-61 and are used in the form of current-carrying and structural elas ic sensitive elements of precision instruments and automatic systems.

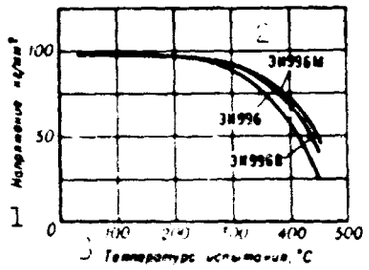
In all the nickel-beryllium alloys the strengthening NiBe phase precipitates out during aging. In the EI996B and EI996M alloys the W and Mo do not enter into the strengthening phase, but they reduce the solubility of the beryllium in the nickel. In the EI996 and EI996B al-

Physical and Mechanical Properties of the Nickel-Beryllium Alloys

| Сплав 1 | Типичные механич. свойства листового материала при 20° (состояние: закалка, 35%-ный наклеп, старение) 2 | | | | | 3 ρ (ом·мм²/м) (при 20°; не более) | 4 Температурный коэффициент электросопротивления при 20–500° (1/°C) | 5 Рекомендуемая температура эксплуатации (°C, не более) | 6 Магнитность |
|---|---|---|---|---|---|---|---|---|---|
| | σв (кг/мм²) 7 | σ0,2 | σb | δ (%) | RC | | | | |
| ЭИ996 8 | 19000–20000 | 155 | 180 | 3 | 50 | 0,35 | 0,00280 | 250 | Магнитный 9 |
| ЭИ996В | 21000–22000 | 160 | 190 | 3 | 50 | 0,26 | 0,00198 | 400 | Слабомагнитный 10 |
| ЭИ996М | 20000–21000 | 150 | 190 | 10 | 50 | 0,42 | 0,00213 | 400 | Немагнитный 11 |

1) Alloy; 2) typical mechanical properties of sheet material at 20° (condition: quenched, 35% strain hardened, aged); 3) ρ (ohm-mm²/m) (at 20°; no more than); 4) temperature coefficient of resistance at 20-500° (1/°C); 5) recommended operating temperature (°C, no more than); 6) magnetism; 7) (kg/mm²); 8) EI; 9) magnetic; 10) weakly magnetic; 11) nonmagnetic.

loys in the initial aging stage the decomposition of the solid solution takes place in two phases: with precipitation of portions of the strengthening phase and of a second solid solution which is depleted of beryllium. The EI996M alloy decomposes in a single-phase manner during




Relaxation curves in bending for the EI996 and EI996M alloys as a function of temperature. 1) Stress, kg/mm²; 2) EI; 3) test temperature, °C.

aging, which is the reason for its high heat resistance in comparison with the EI996 and EI996B alloys. Some physical and mechanical properties of the EI996, EI996B, and EI996M alloys are given in the table. The behavior of the alloys in relaxation testing of the alloys for 200 hours under bending is shown in the figure.

References: Umanskiy, Ya., et al., Kristallografiya [Crystallogra-

phy], 1957, Vol. 2, No. 4, page 503; Buynov, N.N., Podrezov, L.I., and Komarova, M.F., IAN SSSR Ser. fiz. [News of the Academy of Sciences USSR. Physics Series], 1957, Vol. 21, No. 9, page 1220; Buynov, N.N., ibid., 1959, Vol. 23, No. 5, page 648; Gerlach, W., Z. Metallkunde [Journal of Metals], 1937, Bd. 29, No. 4; Mazing, G., and Dahl, O., Beryllium-Nickel Alloys, translated from German, in book Beryllium and Its Alloys, Moscow, 1931; Kaufmann, A.R., Gordon, P., Lillie, D.W., "Trans. Amer. Soc. Metals," 1950, Vol. 42, page 785.

A.L. Shpitsberg

**NICKEL BRASS** is brass in which the primary alloying component is nickel. Addition of nickel to the copper-zinc alloys improves the mechanical properties and corrosion resistance, and also refines the grain. Nickel expands the region of the α-phase on the Cu-Zn diagram (see Brass). For example, the introduction of 2-3% Ni to the two-phase L62 brass converts it into the single-phase condition.

Mechanical Properties of LN65-5 Nickel Brass

| Состояние материала 1 | $\sigma_b$ (кг/мм²) 2 | δ (%) | Твердость по Роквеллу (шкала RF) 3 |
|---|---|---|---|
| Мягкое 4 | 38 | 65 | 66 |
| Деформированное (наклеп 50%) 5 | 67 | 4 | 110 |

1) Material condition; 2) $\sigma_b$ (kg/mm$^2$); 3) Rockwell hardness (RF scale); 4) soft; 5) wrought (50% work hardened).

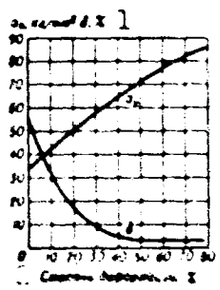



Fig. 1. Variation of mechanical properties of LN65-5 brass as a function of degree of deformation. 1) $\sigma_b$, kg/mm$^2$; δ, %; 2) degree of deformation, %.

Of industrial importance is the nickel brass LN65-5 which contains 64-67% Cu and 5-6.5% Ni, remainder Zn, total impurities (Pb, Fe, Sb, Bi, P) must not exceed 0.3%. This grade of nickel brass has high mechanical properties and resistance to erosion, is easily pressure

worked in both hot and cold conditions. The variation of the mechanical properties of nickel brass as a function of degree of deformation and temperature is shown in Figs. 1, 2, 3.

The mechanical properties of the LN65-5 brass of average chemical composition are shown in the table.

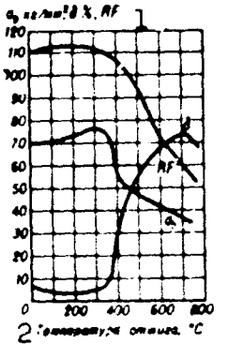


Fig. 2. Variation of mechanical properties of LN65-5 brass with annealing temperature. 1) $\sigma_b$, kg/mm$^2$; $\delta$, %, RF; 2) annealing temperature, °C.

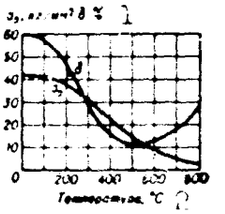


Fig. 3. Variation of mechanical properties of LN65-5 brass with temperature. 1) $\sigma_b$, kg/mm$^2$; $\delta$, %; 2) temperature, °C.

The physical properties of LN65-5 are: $\gamma$ = 8.65; $\alpha$ = 18.2·10$^{-6}$ (20°) 1/°C; c = 0.14 (20°) cal/cm-sec-°C; $\rho$ = 0.146 (20°) ohm-mm$^2$/m; E = 11,200 kg/mm$^2$; $t°_{pl}$ = 960 ; hot working performed in the range 750-850°; annealing temperature 600-650°.

The LN65-5 brass is used to fabricate condenser tubes for marine vessels, manometer tubes, screens for paper making machinery, and other articles.

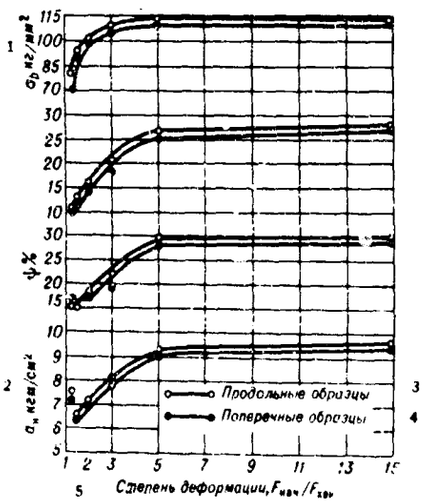
References: Smiryagin, A.P., Promyshlennyye tsvetnyye metalli i splavy [Industrial Nonferrous Metals and Alloys] 2nd edition, Moscow, 1956.

Ye.S. Shpichinetskiy

NICKEL FOIL – see Nickel strip.

NICKEL FORGINGS — semifinished products obtained by free forging of ingots or previously deformed blanks of nickel alloys.

The fundamental problem in the manufacture of forgings, other than production of parts of the required shape and dimensions, is the radical change in metal macro- and microstructure and, as a consequence, improvement in its mechanical properties, especially following heat treatment. In order to ensure adequate deformation of the cast structure and improvement of alloy mechanical properties it is necessary that the total degree of forging deformation amount to at least a 3-5-fold reduction of the ingot. The figure illustrates the change in alloy mechanical properties as a function of degree of over-all deformation.




Change in mechanical properties of nickel alloy of Ni-Cr-Al-Ti-B system as function of increased over-all deformation. 1) kg/mm$^2$; 2) kgm/cm$^2$; 3) longitudinal samples; 4) transverse samples; 5) degree of deformation, $F_{nach}/F_{kon}$.

Experimental data and practical experience indicate that the preparation of nickel forgings from an alloy based on the Ni-Cr-Al-Ti-B

system should be carried out only by drawing and axial deformation (upsetting). The forging operation (drawing) makes it possible to increase the length of the initial blank through a reduction in its cross-sectional area while a forging operation (upsetting) increases the cross-sectional area of the initial blank through a reduction in its height. Alloys based on a more complicated system such as Ni-Cr-Co-Mo-W-V-Al from open melts owing to their limited technological plasticity admit of deformation solely in the axial direction; with vacuum melting, they admit of drying and upsetting, since vacuum-melt alloys possess a fairly large reserve of plasticity. Alloys based on the given system are used with the free-forging method chiefly to manufacture parts with the shapes of bodies of revolution. Other forging operations such as, for example, bending, piercing, twisting, etc., are not used in the making of nickel forgings owing to possible failure of the material. In cases of extreme necessity, these operations may be performed only under the guidance of highly skilled specialists.

Another characteristic of nickel-forging manufacture is the need to employ a fairly low forging temperature range. While ordinary structural steels must be hot worked at 1230-850°, the range is 1200-1000° for nickel alloys. In order to prevent disturbance of continuity of the metal, which may be produced by thermal stresses due to the fairly low thermal conductivity of nickel alloys, ingots and large blanks weighing 850-1200 kg are first heated to 850-900°, and then heated to the forging temperature at an arbitrary rate. This is done in heating furnaces fueled by liquid or gas; the most stable heating regime is provided where electrical heating furnaces are employed. To produce forgings, alloys based on the Ni-Cr-Al-Ti-B system are heated to 1130-1180° and pressure worked under forging hammers (3-6 tons) or in hydraulic presses at a pressure of 1000-3000 tons, while alloys based on the Ni-Cr-

Co-Mo-W-V-Al system are heated to 1160-1200° and deformed in hydraulic presses in the axial direction with a reduction of no more than 20-35% per press stroke. Since nickel alloys have a great tendency to recrystallize, the result may be differences in grain size and degradation of mechanical properties, so that it is necessary to complete pressure working at temperatures of not below 1050-1080°.

Very little use is made of nickel forgings in ordinary machine building owing to the considerable waste of metal that occurs due to the large allowances in machining. They are most frequently used when stamping is prohibited by large size or great weight of the part.

References: Gubkin, S.I., Plasticheskaya deformatsiya metallov [Plastic Deformation of Metals], Vol. 1-3, Moscow, 1960.

G.M. Morokhovets

NICKEL-IRON-COBALT-CHROMIUM WROUGHT ALLOYS are complex alloys on the basis of a $\gamma$ solid solution with carbide or intermetallide strengthening which are used for operation at high temperatures.

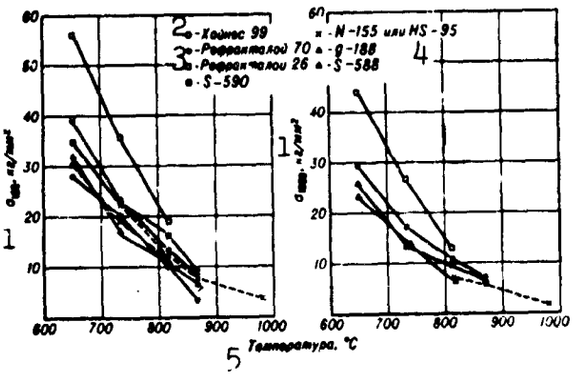



Fig. 1. Variation of stress-rupture strength after 100 and 1000 hours as a function of temperature: Haynes 99, Refractalloy 70, Refractalloy 26, S-590, N-155, HS-95, G-18B, S-588. 1) kg/mm$^2$; 2) Haynes 99; 3) Refractalloy; 4) or.

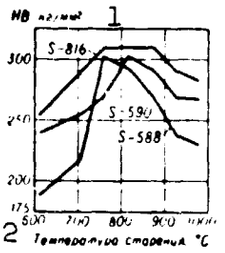



Fig. 2. Effect of 16-hour aging temperature on variation of hardness of S-588, S-590, and S-816 alloys. 1) HB, kg/mm$^2$; 2) aging temperature, °C.

The chemical composition of these alloys is presented in the table and the variation of the stress-rupture strength after 100 and 1000 hours as a function of test temperature is shown in Fig. 1. The alloys contain a considerable amount of chromium (about 20%) and additions of the carbide forming elements – Mo, W, Nb and less frequently Ti. With

regard to structure, these alloys are dispersion hardening austenite-carbide. Figure 2 shows the effect of 16-hour aging temperature on the

Chemical Composition of Nickel-Iron-Cobalt-Chromium Wrought Alloys

| Сплав 1 | 2 Содержание элементов (%) | | | | | | | | | 3 другие элементы |
|---|---|---|---|---|---|---|---|---|---|---|
| | C | Mn | Si | Cr | Ni | Co | Mo | W | Fe | |
| S-588 | 0.45 | 1.2 | 0.8 | 18.5 | 20 | — | 4 | 4 | 47 | 4Nb |
| S-590 | 0.43 | 1.25 | 0.4 | 20 | 20 | 20 | 4 | 4 | 26 | 4Nb |
| Хайнес 99 4 | 0.1 | 1.5 | 0.7 | 21 | 18 | 12 | 4 | 2.5 | — | 0.05 B |
| N-155, HS-95 5 | 0.15 | 1.5 | 0.5 | 21 | 20 | 20 | 3 | 2.5 | 30 | 1Nb, 0.15 $N_2$ |
| Рефракталой 26 | 0.05 | 0.7 | 0.7 | 18 | 37 | 26 | 3 | — | 18 | 2.8 Ti, 0.2 Al |
| Рефракталой 70 | 0.05 | 2 | 0.2 | 20 | 20 | 30 | 8 | 4 | 15 | — |
| Рефракталой 80 | 0.1 | 0.6 | 0.7 | 20 | 20 | 30 | 10 | 5 | 14 | — |
| G-18B | 0.4 | 0.8 | 1 | 13 | 13 | 10 | 2 | 2.5 | 54 | 3Nb |

1) Alloy; 2) element content (%); 3) other elements; 4) Haynes 99; 5) Refractalloy.

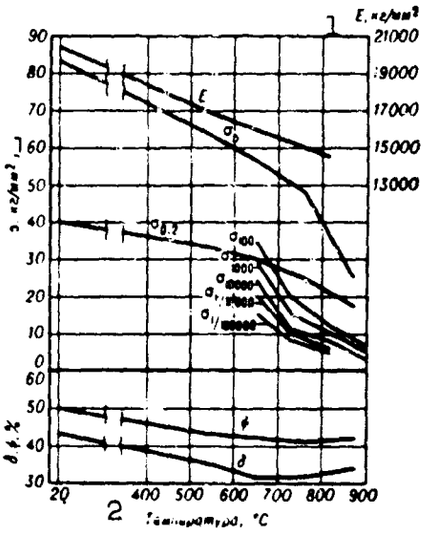



Fig. 3. Variation of mechanical properties of the N-155 alloy as a function of temperature. 1) kg/mm$^2$; 2) temperature, °C.

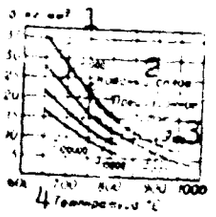



Fig. 4. Variation of stress-rupture strength of S-590 alloy as a function of temperature. 1) σ, kg/mm$^2$; 2) forged alloy; 3) precision cast; 4) temperature, °C.

variation of the hardness of the S-590 and S-588 alloys and the cobalt alloy S-816. The dispersion hardening range is widened with increase of the cobalt content in the alloy, which indicates the higher resistance to weakening of the cobalt-base alloys. The alloys are used in the thermally treated condition after a water or air quench from 1150-1200° and subsequent aging at 700-850°. The N-155 and G-18B alloys have low tendency to dispersion hardening. In order to improve the mechanical properties they are strengthened by half-hot work hardening. Figure 3 shows the variation of the mechanical properties of the N-155 alloy as a function of temperature. The characteristic feature of the nickel-iron-cobalt-chromium wrought alloys is the combination of high strength at elevated temperatures with high resistance to thermal cycling. However they are inferior to the cobalt- and nickel-base alloys with respect to strength at high temperatures.

The nickel-iron-cobalt-chromium wrought alloys have found widest application in the fabrication of gas turbine rotors and rotor blades. Figure 4 shows the variation of the stress-rupture strength of the S-590 alloy as a function of temperature.

References: Simmons, W.F., Krivobok, V.N., Mochel, N.L., Compilation of Chemical Compositions and Rupture Strengths of Super-Strength Alloys, Phil., 1958 (ASTM Special Technical Publ., No. 170); High-Temperature Alloys Under Conditions of Supersonic Flight Speeds, collection of articles translated from English, Moscow, 1962.

F.F. Khimushin

NICKEL PLATING THE ALUMINUM ALLOYS is the electrolytic coating of the surface of the aluminum alloys with a nickel layer to provide a decorative finish and also to create a sublayer for the application of other metallic coatings. It is recommended for parts intended for operation under lightly loaded conditions (GOST 3002-58). Nickel coatings on all aluminum alloys are cathodic and with a thickness up to 25 microns do not provide protection from corrosion because of the porosity. With thickness of the nickel (or nickel and chromium) layer of 50 microns, the coating may be nonporous and in this case it provides protection from corrosion. To reduce the porosity, a portion of the nickel coating may be replaced by a copper coating with mechanical polishing of both layers. Subsequent chrome plating gives good results (see Chrome Plating the Aluminum Alloys). Chemical nickel plating of the aluminum alloys is possible in which a layer of nickel containing phosphorus is deposited. Such a coating solders well.

References: Layner, V.I., Gal'vanicheskiye pokrytiya legkikh splavov [Galvanic Plating of the Light Alloys], Moscow, 1959.

N.B. Garshina

**NICKEL PLATING THE TITANIUM ALLOYS** is the application of a nickel layer to the surface of parts made from titanium alloys using galvanic or chemical methods. Galvanic nickel plating of the titanium alloys is performed in order to obtain a undercoat prior to coating with other metals (copper, silver, etc.); chemical nickel plating is performed to improve the antifriction properties.

Preparation of the surface prior to galvanic nickel plating is accomplished using the same methods as for chrome plating the titanium alloys. Etching in acid solutions and contact or electrochemical zinc plating is usually recommended. However this problem has not received adequate study and the existing methods of preparation do not give consistent results. The application of the nickel itself is accomplished in the same electrolytes and using the same conditions as for nickel plating steel. After galvanic nickel plating of the titanium alloys, annealing is performed at 250-550° for 2-4 hours to obtain good bonding of the coating with the base metal. Preparation of the surface prior to chemical nickel plating involves etching in an acid mixture or hydrosand blast treatment. The latter method is applicable for practically all titanium alloys and gives more reliable results. Chemical nickel plating is performed just as for steel and other metals at a temperature of 85-95° in aqueous solutions containing sodium (or potassium) hyposulfite, nickel salts, and other substances.

The rate of deposition of the nickel amounts to 10-20 microns per hour. The resulting dense, lustrous precipitate is a solid solution of nickel with 5-13% phosphorus, having a hardness of 300-350 HV. Subse-

quent annealing at ~400° increases the coating hardness to 600-800 HV and improves its bonding with the base metal.

References: Smolenskaya, G.N., Kudryavtsev, N.T., and Karatayev, V.M., "Metallovedeniye i termicheskaya obrabotka metallov" [Metal Sciences and Thermal Treatment of Metals], 1960, No. 11.

T.S. Anitov

NICKEL STAMPINGS. They are manufactured from previously deformed bars by reduction of the cross section by 3-5 times. The stamping of the blanks is carried out at the temperature range of 1200-980°.

Stamped pieces possess the following advantage in comparison to forged pieces: their shape and dimensions are more close to those of the finished pieces resulting in a lower expense of metal per piece and in a shorter time of cold machining.

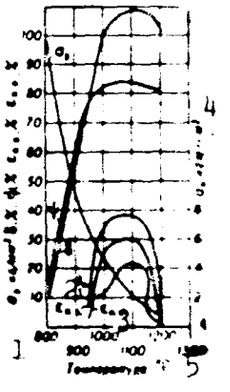


Fig. 1. Diagram of the plasticity of a refractory alloy belonging to the 3rd group. $\varepsilon_{p.c.}$ = axial deformation by pressing, in %; $\varepsilon_{p.p}$ = = plane deformation by pressing in %. 1) kg/mm$^2$; 2) $\varepsilon_{p.c.}$; 3) $\varepsilon_{p.p.}$; 4) kg/cm$^2$; 5) temperature.

Stamping causes a more favorable stressed state in the bulk of the deformed metal, increasing the technological plasticity and partially or totally excluding the local disturbances of the continuity.

The following principal parameters must be taken into account when fixing the stamping conditions: the plasticity diagram of the given alloy (Fig. 1); the curves of the deformation resistance; the characteristics of recrystallization by x-ray diffraction analysis

(Table 1); and the curves of the growth on the grains (Fig. 2).

TABLE 1

Recrystallization Temperature of an Alloy of the 3rd Group Founded by the Open and the Vacuum Method

| 1 Метод выплавки сплава | Степень деформации (%) | 3 Продолжительность отжига (мин.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 15 | | 30 | | 60 | | 240 | |
| | | $T_p^n$ | $T_p^k$ | $T_p^n$ | $T_p^k$ | $T_p^n$ | $T_p^k$ | $T_p^n$ | $T_p^k$ |
| Открытый 6 | 10 | 1150 | 1200 | 1100 | 1150 | 1050 | 1150 | 1050 | 1150 |
| Вакуумный 7 | | 1050 | 1220 | 1050 | 1200 | 1050 | 1200 | 1050 | 1150 |
| Открытый 6 | 20 | 1100 | 1150 | 1050 | 1150 | 1050 | 1150 | 1000 | 1150 |
| Вакуумный 7 | | 1050 | 1200 | 1050 | 1150 | 1000 | 1150 | 1000 | 1100 |
| Открытый 6 | 30 | 1050 | 1150 | 1050 | 1150 | 1000 | 1150 | 1000 | 1100 |
| Вакуумный 7 | | 1000 | 1150 | 1000 | 1100 | 1000 | 1100 | 950 | 1050 |

Note: $T_r^n$ = temperature at the start of recrystallization; $R_n^k$ = temperature at the end of recrystallization.

1) Method of founding the alloy; 2) degree of deformation; 3) time of annealing (min); 4) $T_r^n$; 5) $T_r^k$; 6) open; 7) in a vacuum.

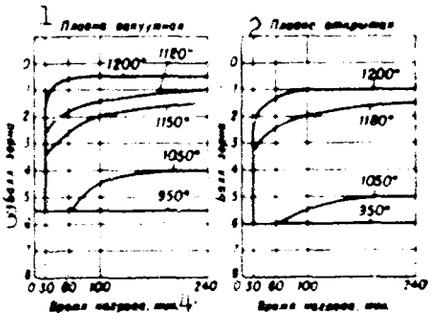



Fig. 2. Change of the grain dimensions of an alloy of the 2nd group as a function of the temperature and of the heating time. 1) Vacuum founding; 2) open founding; 3) degree of the grains; 4) heating time, min.

The stamping conditions widely used in the production of nickel-based alloys of the given chemical composition, founded by the open method, are quoted in Table 3. The deformation given in Table 3 may be increased by 15-20% in the case of the vacuum-founded alloys.

TABLE 2

Stamping Conditions of Nickel-Based Alloys

| 1 Группа сплава | 2 Система сплавов | Темп-ра обработки (°С) 3 | | Допустимая деформация (%) 4 | | 5 Тип сплава |
|---|---|---|---|---|---|---|
| | | начало 6 | конец 7 | осевая 8 | плоская 9 | |
| 1-я 10 | Ni—Cr—Al—Ti<br>Ni—Cr—Al—Ti—B | 1140<br>1180 | 1000 | 60 | 50 | ЭИ437Б 13 |
| 2-я 11 | Ni—Cr—W—MO—Al—Ti—B<br>Ni—Cr—Co—W—MO—V—Al—B | 1160<br>1190 | 1070 | 45 | 35 | ЭИ617<br>ЭИ929 14 |
| 3-я 12 | Ni—Cr—Co—W—Mo—V—Al—Ti—B<br>Ni—Cr—Co—W—Mo—Al—B—C | 1110<br>1180 | 1020 | 30 | 15—25 | ЖС6-КП 15<br>ЭП102 16 |

1) Group of the alloy; 2) system of the alloy; 3) working temperature; 4) permissible deformation; 5) type of alloy; 6) beginning; 7) end; 8) axial; 9) plane; 10) 1st; 11) 2nd; 12) 3rd; 13) EI437B; 14) EI...; 15) ZhS6-KP; 16) EP ...

In order to avoid disturbances in the continuity, small pieces (up to 5 kg) are manufactured only by static methods, i.e., on crankshaft presses with a load of 1300-4000 tons. In the case of blanks with a minimum allowance (of 0.8-1.2 mm per side), the heating of the alloys before stamping and the following heat treatment are carried out in electric heating furnaces with a protective medium, in order to prevent the loss of the refractoriness and a decrease of the structural strength of the metal. The change of the refractory endurance of an alloy of the 2nd group at a test temperature of 900° and a stress of 22 kg/mm$^2$ is listed in Table 3.

TABLE 3

Change of the Refractory Endurance of the Alloy as a Function of the Allowance and the Heating Medium

| 1 Припуск на обработку (мм на сторону) | Время до разрушения (час.) 2 | |
|---|---|---|
| | 3 нагрев в воздушной среде | нагрев в среде аргона 4 |
| Без припуска | 2—15 | 40—88 |
| 0,5 | 48—80 | 95—98 |
| 0,8 | 55—70 | 96—104 |
| 1,2 | 55—70 | 96—108 |

1) Allowance for machining (mm per side); 2) time until destruction takes place (hours); 3) heating in air medium; 4) heating in argon medium; 5) without allowance.

The reduction of the refractory endurance of nickel-based alloys after heating in air is a result of changes in the structure of the outer metal layers up to a depth of 200 microns (Fig. 3). These changes are caused by impoverishment (by 2 times) of the outer layers in the hardening elements Al, B, and Ti due to a selective diffusion which gives rise to oxidation. Therefore, the heating of small blanks with an allowance of not less than 0.8-1.2 mm is carried out in furnaces with air medium, the outer layer further being removed by cold machining.

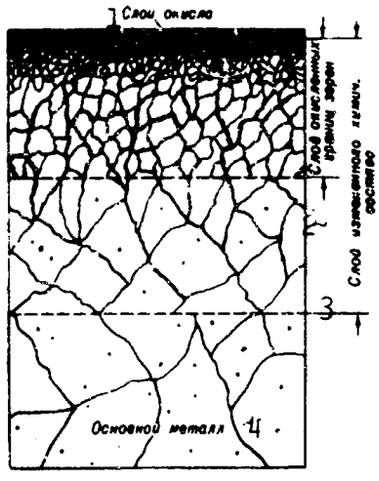



Fig. 3. Structure of the defective outer layer of refractory alloys after heating in air according to the fixed conditions (schematically). 1) Oxide layer; 2) layer of oxidized grain boundaries; 3) layer with changed chemical composition; 4) basic metal.

The heating of alloys for the production of mean- and large-size stampings (up to 1000 kg) is carried out in furnaces with air medium because these stampings possess usually greater allowances for machining (5-10 mm per one side), and the formed outer layer is removed together with the chips.

The stamping of these pieces is carried out under drop hammers with a weight of 10-25 tons of the falling part, or on hydraulic presses with a load of 3000-15,000 tons and more.

G.M. Morokhovets

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[Transliterated Symbols]

= p.o. = pressovaniye osevoye = axial deformation by pressing

= p.p. = pressovaniye ploskoye = plane deformation by pressing

= $T_r^n$ = temperatura nachala rekristallizatsii = temperature at the start of the recrystallization

= $T_r^k$ = temperaturea kontsa rekristallizatsii = temperature at the end of recrystallization

NIMONIC is a nickel high-temperature alloy for fabricating gas turbine engine parts operating at high temperatures (produced by the Mond Nickel Company of England). The chemical composition of the nimon-

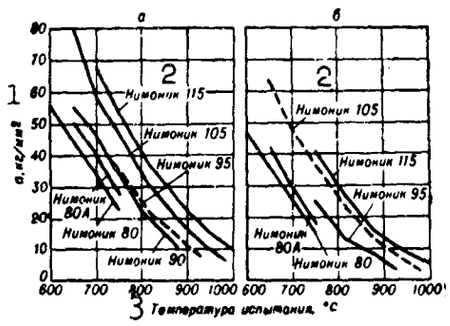



Fig. 1. Variation of 100-hour (a) and 1000-hour (b) stress-rupture strength of Nimonic alloys with temperature increase. 1) σ, kg/mm$^2$; 2) Nimonic; 3) test temperature, °C.

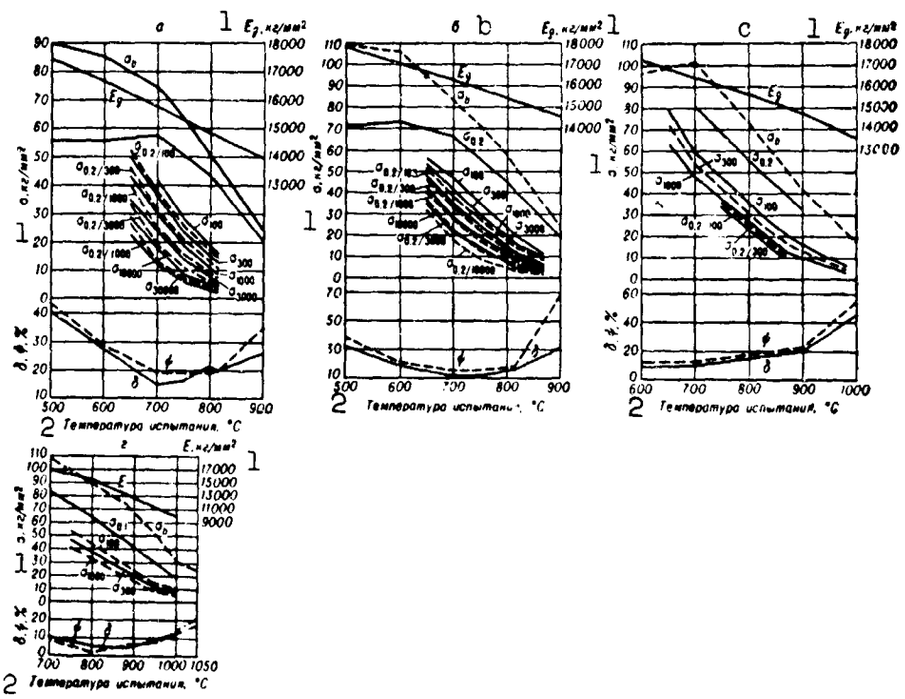



Fig. 2. Variation of mechanical properties of Nimonic alloys with temperature increase: a) 80A; b) 90; c) 105; d) 115. 1) kg/mm$^2$; 2) test temperature, °C.

ic alloys is shown in the table. The 75 alloy is used to fabricate parts which are scale resistant to 1100-1150° (combustion chamber flame tubes, exhaust stacks, nozzle guide vanes, etc.) for gas turbine engines. This alloy is one of the homogeneous, non-heat treatable group of alloys. It welds well using various forms of welding. The DS alloy

Chemical Composition of Nimonic Alloys

| Сплав 1 | Содержание элементов (%) 2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | C | Ti | Cr | Al | Si | Mn | Fe | Co | другие элементы 3 |
| 4 Нимоник DS | <0,15 | — | 17—19 | — | 2—2,5 | 0,9—1,3 | ос- 5 таль- ное | — | <0,25 Cu, 36—39 Ni |
| Нимоник 75 | 0,08—0,15 | 0,2—0,6 | 18—21 | — | <1 | <1 | <5 | — | <0,5 Cu, Ni осталь- ное 5 |
| Нимоник 80 | <0,1 | 1,8—2,7 | 18—21 | 0,5—1,8 | <1 | <1 | <5 | <2 | Ni осталь- ное |
| Нимоник 80А | <0,1 | 1,8—2,7 | 18—21 | 0,5—1,8 | <1 | <1 | <5 | <2 | Ni осталь- ное |
| Нимоник 90 | <0,1 | 1,8—3 | 18—21 | 0,8—2 | <1,5 | <1 | <5 | 15—21 | Ni осталь- ное |
| Нимоник 95 | <0,15 | 2,3—3,5 | 18—21 | 1,4—2,5 | <1 | <1 | <5 | 15—21 | <0,5 Cu, Ni осталь- ное |
| Нимоник 100 | <0,3 | 1—2 | 10—12 | 4—6 | <0,5 | — | <2 | 18—22 | 4,5—5,5 Mo, Ni ос- тальное |
| Нимоник 105 | <0,2 | 0,9—1,5 | 13,5—16 | 4,2—4,8 | — | — | <1 | 18—22 | 4,5—5,5 Mo, Ni ос- тальное |
| Нимоник 115 | <0,15 | 4 | 15 | 5 | — | — | — | 15 | 4 Mo, Ni остальное |

1) Alloy; 2) element content (%); 3) other elements; 4) Nimonic; 5) balance.

is used for parts requiring high resistance in carbonaceous media at high temperatures. It is the most economical alloy (contains about 40% Fe), and as a result of the addition of silicon has high scale resistance. The 80, 80A, 90, 95, 100, 105, 115 alloys belong to the group of alloys with high strength at high temperature with intermetallide strengthening; their high temperature strength is higher, the higher the degree of alloying (Figs. 1, 2). The 80 alloy was first used to fabricate gas turbine engine rotor blades, but it was soon replaced by the more advanced 80A alloy; at the present time this alloy serves for fabricating rotor blades of the lower-pressure engine stages. The 90 and 95 alloys have higher strength at elevated temperature as a result of the addition of 15-21% cobalt, and also the addition of aluminum and

titanium. For the same high temperature strength, the 100 and 105 alloys have lower chromium and titanium content and higher aluminum content (up to 5%). The 80 alloy is used at 650-730° with high stresses, and with moderate stresses is used up to 850°. The 90 alloy is used up to 900°, and the 100, 105, and 115 alloys at 900-1000°.

At operating temperatures the Nimonics have excellent creep and fatigue resistance characteristics and also have satisfactory resistance to scaling.

References: Betteridge, W., High-Temperature Alloys of the Nimonic Type, translated from English, Moscow, 1961; "Aircraft Prod.," 1959, Vol. 21, No. 4, page 122.

F.F. Khimushin

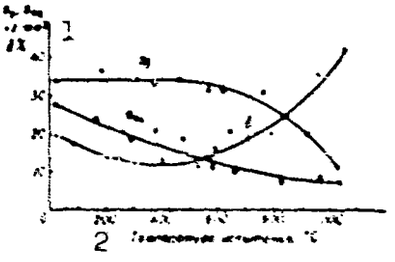
NIOBIUM – Nb is a chemical element of Group V of the Mendeleyev Periodic System, atomic number 41, atomic weight 92.906. The natural isotope is $Nb^{93}$. The most important artificial radioactive isotope $Nb^{95}$ is obtained by fission of uranium. Niobium (previously termed Columbium in the USA) is arefractory metal of a steel-gray color. The structure of the outer electron shell of the Niobium atom is: $4d^4 5s^1$. It was discovered in 1801 and was first obtained in metal form in 1907. The niobium content in the Earth's crust exceeds $2 \cdot 10^{-3}$ weight %. It is not encountered in the free form in nature; it is almost always accompanied by tantalum which isomorphically replaces niobium in minerals. The basic industrial minerals are: pyrochlore and loparite (titano-niobates of Na, Ca, and the rare earth elements), columbite (titano-niobate of Fe and Mn), and others. Deposits of niobium ores in Nigeria, Uganda, Kenya, Tanganyika, Congo, Canada, Norway are known. It is believed that its reserves (abroad) amount to 30% of the zirconium reserves and are 10 times greater than the molybdenum and tantalum reserves. The ores are usually complex, low in niobium; the $Nb_2O_5$ content in the ores is 0.05-0.5%, less often up to 2%. The ores are concentrated by gravitational and other methods. The pyrochlore ore concentrates of the USSR contain no less than 37, loparite 8, and columbite 30-60%, and also Ta and impurities of Ti, Si, Sn and others which are harmful in processing to obtain metallic niobium. Ferroniobium (40-50% Nb) and ferro-tantaloniobium for the production of special steels are obtained from the concentrates by means of alumino- and silicothermic reduction processes. The ore concentrates are treated in three stages to obtain metallic ni-

obium: preparation, separation of niobium and tantalum to obtain their pure chemical compounds, obtaining and refining the niobium. Preparation is performed by chlorination, treatment with hydrofluoric acid, smelting with alkaline or acidic fusing agents. The niobium and tantalum compounds are then converted into a solution. Potassium salts are added to the hydrofluoric acid solutions to precipitate potassium fluoro-tantalate $K_2TaF_7$, while the complex niobium fluoride ($K_2NbOF_5$) remains in solution; but it is better to separate the niobium and tantalum and purify them of the impurities by selective extraction using organic solvents (tributyl phosphate and so on) or by rectification of the higher chlorides. The most important chemical compounds of niobium which are used in producing the metal are the pentoxide $Nb_2O_5$, potassium fluoroniobate $K_2NbF_7$, and the chloride $NbCl_5$. One of the primary industrial methods of producing niobium is the carbothermic method. Sodium-thermic reduction of potassium fluoroniobate is also used, it is possible to use electrolysis of molten salts and oxides, hydrogen reduction of the chloride and other methods for obtaining niobium powder. Bars pressed from the powder or from carbothermic or sodium-thermic technical niobium are sintered in a vacuum to 2300°, cold forged, vacuum annealed at 2100-2200° to obtain dense, soft billets which are suitable for cold pressure working into rods, plates, strip, foil, wire, tubing, etc. Large blanks for extruding tubing and pressing other mill products of large dimensions are obtained by vacuum remelting sintered niobium in an arc furnace. In recent years niobium of high purity has been obtained by vacuum remelting in an electrom beam furnace at $1 \cdot 10^{-4}$-$1 \cdot 10^{-5}$ mm Hg. This method is becoming the primary industrial method for melting niobium ingots. During vacuum remelting there is evaporation of the impurities, whose vapor pressures are considerably higher than the vapor pressure of niobium. Deoxidation of niobium

takes place primarily as a result of evaporation of the lower niobium oxides, and only a portion of the oxygen may be removed in the form of carbon monoxide. The stay time of the metal in the liquid condition and the vacuum above the molten metal have a considerable effect on the niobium refining process during arc and electrom beam melting. Hot deformation of the ingots is used to produce: billets, rods, tubing blanks and other mill products. Shaped castings may be obtained from cast niobium using the method of electric arc or electron beam remelting with slag formation. Niobium monocrystals are obtained by melting without a crucible using electron beam heating. The production and usage of niobium are growing rapidly. For example, the USA in 1958 produced 12.8 metric tons of pure niobium, in 1959 - 22.5 tons, in 1961 - 114 tons (production capacity available for 300 tons), the output in 1970 is expected to be 9000 tons. According to other data, niobium production in the capitalist countries will rise to 1000 tons in two years and to 10,000 tons a year in five years. In this case the cost per kilogram of niobium will come down to 11 dollars (it will be cheaper than zirconium and molybdenum), while in 1956 niobium cost 220-275 dollars per kilogram. In addition to niobium a large amount of ferroniobium and ferrotantalum-niobium is produced. In 1955-56 60% of all the niobium used in the USA was used (in the form of ferroalloys) in the production of stainless and other steels, up to 30% was used for special alloys, and up to 10% was used in the form of the carbide, the pure metal, etc. The most promising fields of application of metallic niobium are associated with high temperatures. Niobium is one of the primary components of many high-temperature alloys and is used for fabricating jet engine and rocket parts, in chemical equipment construction, metallurgy and radioelectronics. In many cases niobium and its alloys with tantalum replace scarce tantalum. The importance of niobium for the new technology is

determined by its valuable properties.

The physical properties of niobium are: $\gamma = 8.57$ g/cm$^3$. Crystal lattice is body-centered cubic, interatomic spacing 2.85 kX, period a = = 3.294A, atomic radius 1.47 kX, $t°_{pl}$ 2500°, $t°_{kip}$ 5127°; according to the data of E.T. Wessel, with a deformation rate of $1 \cdot 10^{-3}$ sec$^{-1}$ the transition of niobium into the brittle state takes place at approximately minus 200°, and it becomes superconducting at 9.25 °K. The vapor pressure (mm Hg) and the rate of evaporation (g/cm$^2$-sec) are respectively $1 \cdot 10^{-5}$ and $1.16 \cdot 10^{-7}$ at 2194°, $1 \cdot 10^{-4}$ and $1.08 \cdot 10^{-6}$ at 2355°, $1 \cdot 10^{-3}$ and $1.06 \cdot 10^{-5}$ at 2539°. Heat of fusion is 6.4 and heat of vaporization is 166.5 kcal/g-atom (at $t°_{kip}$). c = 0.0645 cal/g-°C (at 0°). $\alpha = 7.02 \cdot 10^{-6}$ at 18° and $8.89 \cdot 10^{-6}$ at 900°. $\lambda$ is 0.125, 0.135 and 0.156 kcal/cm-sec-°C at 0°, 200°, and 600° ($K = 2.86 \cdot 10^{-5} + 0.125$), $\rho$ at 0° is $15.22 \cdot 10^{-6}$ ohm-cm (thermal coefficient at 20° $3.95 \cdot 10^{-3}$). The specific magnetic susceptibility is $+2.28 \cdot 10^{-6}$ (18°). Ionization potential is 6.77 v; secondary emission coefficient is 1.18; positive emission is 5.52 ev. Radiation coefficient is 0.37 (20°, wavelength 6500 A). Niobium is characterized by a low (4.01 ev) electron work function, low (1.15 barn) effective thermal neutron absorption section, high plasticity and retention of satisfactory strength to high temperatures (figure).




Plasticity and tensile strength of annealed niobium as a function of temperature ($\delta$ is for a specimen length of 31.8 mm). 1) $\sigma_b$, $\sigma_{pts}$, kg/mm$^2$; $\delta$, %; 2) test temperature, °C.

The comparatively large dimensions of the atomic lattice make it possible to perform considerable alloying of niobium without signifi-

cant reduction of the plasticity. The ratio of the stress which causes a permanent deformation of 1% per day at 1000° to the specific weight of niobium is equal to 0.5, i.e., it is greater than for Ti, Zr, V, Ta, Cr and W. Certain impurities (particularly H, N and O) severely degrade

TABLE 1

Mechanical Properties of Niobium in Cast and Wrought Conditions

| Состояние материала 1 | Темп-ра испытания (°C) 2 | $\sigma_b$ | $\sigma_{0,2}$ | δ | ψ | $a_н$ (кгм/см²) 4 | E (кг/мм²) 3 | Жаропрочность 5: σ (кг/мм²) | Жаропрочность 5: время до разрушения (часы) 6 |
|---|---|---|---|---|---|---|---|---|---|
| | | 3 (кг/мм²) | | (%) | | | | | |
| Литой 7 | 20° | 55 – 60 | 50 | 10 – 13 | 20 – 30 | – | – | – | – |
| | 1100 | 17 | – | 20 | – | – | – | 15 | 16 |
| | 1050 | – | – | – | – | – | – | 15 | 84 |
| Горячедефо: мированный | 20° | 60 – 70 | 60 | 20 – 25 | 25 – 35 | 37 | 1100 | – | – |
| 8 | 1000°* | 28 | – | 26 | – | – | – | 15 | 49 |
| | 1100°* | 24 | – | 30 | – | – | – | 15 | 6 |
| | 1500°* | 4 | – | – | – | – | – | – | – |
| | −70°* | – | – | – | – | 10 – 13 | – | – | – |
| | −196°* | – | – | – | – | 2 – 3 | – | – | – |
| 9 Горячедеформированный и отожженный в вакууме ($1 \cdot 10^{-4}$ мм рт. ст.) при 1600° | 20°* | 50 – 55 | 45 – 50 | 25 – 30 | 35 – 60 | 1 – 2 | 11000 | – | – |
| 10 при 1300° | 20° | 55 – 60 | – | 25 – 30 | – | – | – | – | – |
| 11 Горячедеформированный рекристаллизованный | 1100 | 18.5 | – | 37 | – | – | – | – | – |
| | 980 | – | – | – | – | – | – | 19.95 | 100 |
| 12 | 1093 | – | – | – | – | – | – | 12.95 | 100 |

*Impurity content: $O_2 - 0.05\%$, $N_2 - 0.03\%$, $H_2 - 0.002\%$, $C - 0.05\%$

**Impurity content: $O_2 - 0.001\%$, $N_2 - 0.004\%$, $H_2 - 0.002\%$, $C - 0.002\%$

1) Material condition; 2) test temperature (°C); 3) (kg/mm$^2$); 4) $a_n$ (kgm/cm$^2$); 5) high-temperature strength; 6) time to failure (hours); 7) cast; 8) hot deformed; 9) hot deformed and vacuum annealed ($1 \cdot 10^{-4}$ mm Hg); 10) at; 11) hot deformed; 12) recrystallized.

the plasticity of niobium and increase its hardness. The Brinell hardness of high-purity niobium is 45-55, while that of the technical metal is 70-120 kg/mm$^2$.

The mechanical properties of niobium also depend on the metal condition. The strength and plastic properties of cast niobium are lower than those of the wrought material. Strain hardening has effect on the strength and plasticity. With an increase of the degree of work hardening, $\sigma_b$ increases and δ decreases. In view of the high oxidizability of niobium and the capability to be saturated with gases above 200°, all tests of the mechanical properties and also heat treatment are per-

TABLE 2

Mechanical Properties of Sheet Niobium

| Состояние материала 1 | Темпра испытания (°С) 2 | $\sigma_b$ 3 (кг/мм²) | δ (%) |
|---|---|---|---|
| 4 Лист холоднокатаный (степень наклепа 80—90%)* | 20 | 70—85 | 5—8 |
| 5 Лист холоднокатаный (степень наклепа 73%)** | 300 | 56—65 | — |
| | 500 | 49 | 2—3 |
| | 600 | 53,6 | 3—4 |
| 6 Лист холоднокатаный и отожженный в вакууме при 1100°** | 200 | 47 | 11—12 |
| | 400 | 46 | 11—13 |
| | 500 | 35,1 | 9—16 |
| | 600 | 42,2 | 17—25 |
| | 800 | 31,2 | 22—24 |
| | 900 | 19,1 | 26—27 |
| | 1050 | 11,2 | 32—35 |
| 6 Лист холоднокатаный и отожженный в вакууме при 1200°*** | −196 | 76 | 9 |
| 6 Лист холоднокатаный и отожженный в вакууме при 1200°*** | 20 | 55—60 | 25—[illegible] |

*Impurity content: $O_2$—[illegible]%, $N_2$—[illegible]%, C—[illegible]%, $H_2$—[illegible]%, **
**Impurity content: $O_2$—[illegible]%, $N_2$—[illegible]%, C—[illegible]%, $H_2$—[illegible]%,
***Impurity content: $O_2$—0.06%, $N_2$—0.018%, C—[illegible]%

1) Material condition; 2) test temperature (°C); 3) $\sigma_b$, kg/mm$^2$; 4) cold-rolled sheet (degree of work hardening 80-90%)*; 5) cold-rolled sheet (degree of work hardening 73%)**; 6) sheet cold rolled and vacuum annealed at.

formed in a neutral gas medium (argon, helium) or in a vacuum.

Niobium oxidizes in air above 200° (at 150° in powder form), interacts with introgen at 400°, and with hydrogen at 250°. The limiting solubility of oxygen in niobium at 1200° is 0.52, nitrogen 0.05, carbon 0.014 weight %. Liquid metals (Na, K, Li, Bi, Hg, Pb, Sn) have practically no effect on niobium, nor do the majority of the acids and other strongly aggressive aqueous media (see Niobium Corrosion). In acid electrolytes an anodic oxide film with high dielectric characteristics is formed on niobium. Niobium does not cause inflammatory reaction on contact with living tissue. The ability of niobium to form alloys with many rare and nonferrous metals is extremely important. Niobium is easily pressure worked and machined in the cold condition. Electron beam and argon arc techniques are effective methods for welding niobium to

niobium and other metals.

References: Samsonov, G.V. and Konstantinov, V.I., Tantal i niobiy [Tantalum and Niobium], Moscow, 1959; Kolchin, O.P., Niobiy i tantal [Niobium and Tantalum], Moscow, 1959; Zakharova, G.V., et al., Niobiy i yego splavy [Niobium and Its Alloys], Leningrad, 1961; Niobiy i tantal [Niobium and Tantalum], collection of articles edited by O.P. Kolchin, Moscow, 1960; Miller, G.L., Tantalum and Niobium, London, 1959; Columbium Metallurgy, edited by D.L. Douglass and F.W. Kunz, N.Y.-London, 1960; Refractory Metals and Alloys, edited by M. Semchyshen and J.J. Harwood, N.Y.-London, 1960; Rare Metals Handbook, 2nd Edition, edited by Ch.A. Hampel, London, 1961.

O.P. Kolchin, G.V. Kurganov, L.P. Zhorova

NIOBIUM ALLOYS are alloys of niobium with Mo, W, Ti, Zr, Ta and other elements. Alloying with these elements is used to improve the

TABLE 1

Chemical Composition of Niobium Alloys

| Сплав 1 | Содержание легирующих элементов (вес. %) 2 | | | | | Вид полуфабриката 3 |
|---|---|---|---|---|---|---|
| | Mo | W | Ti | Zr | Ta | |
| 4 Высокопрочные сплавы | | | | | | |
| Ф-48 | 5 | 15 | – | 1 | – | Поковки, прутки 5 |
| Сн-74 | – | 10 | – | 5 | – | Поковки, прутки 6 |
| Пластичные и сваривающиеся сплавы средней прочности 7 | | | | | | |
| СВ-65 | – | – | 7 | 0,8 | – | Листы, прутки, трубы 8 |
| Фс-82 | – | – | – | 1 | 33 | Листы, трубы, фольга 9 |
| 10 Д-31 | 10 | – | 10 | – | – | Прутки, листы, трубы |
| ВН-2 | 3,8–5,2 | – | – | – | до 0,2% | Прутки, трубы, листы, фольга 12 |

1) Alloy; 2) alloying element content (weight %); 3) form of mill product; 4) high-strength alloys; 5) forgings, rods; 6) forgings, rods; 7) plastic and welding alloys of moderate strength; 8) sheet, rod, tubing; 9) sheet, tubing, foil; 10) D-31; 11) up to; 12) rod, tubing, sheet, foil.

TABLE 2

Physical Properties of Niobium Alloys

| Сплав 1 | Темп-ра выплавления (°С) 2 | Темп-ра испытания (°С) 3 | α·10*6 (1/°С) | λ ** (кал/см·сек·°С) 4 | c *** (кал/г·°С) 5 | ρ (мком·см) 6 | Степень черноты полного излучения **** 7 | γ (г/см³) 8 | Темп-ра рекристаллизации ***** (°С) 9 |
|---|---|---|---|---|---|---|---|---|---|
| ВН-2 | 2430 | 20 | 6,25 | 0,1 | 0,058 | 19,9 | 0,17 | 8,7 | 1250 |
| | | 1000 | 8,3 | – | 0,077 | 50 | 0,17 | – | – |
| | | 2000 | 8,84 | – | 0,09 | – | 0,21 | – | – |
| Ф-48 | 2480 | 20 | 6,46 | 0,3 | – | – | – | 9,42 | 1420 |
| | | 1100 | 7,6 | 0,42 | – | – | – | – | – |
| 10 Д-31 | 2250 | 20 | 7,79 | – | 0,074 | – | – | – | 1200 |
| Фс-82 | 2500 | 20 | – | – | – | – | – | 10,14 | 1200 |

*α was determined on 10 × 10 × 100 mm specimens in argon.

**λ was determined on 25-mm-diam specimens 40 mm long in a vacuum.

***c determined in argon.

****Determined by calorimeter method in a vacuum.

*****Degree of strain hardening 70-90%.

1) Alloy; 2) melting point (°C); 3) test temperature (°C); 4) λ** (cal/cm-sec-°C); 5) c*** (cal/g-°C); 6) ρ (μohm-cm); 7) degree of blackness of total radiation****; 8) γ (g/cm$^3$); 9) recrystallization temperature***** (°C); 10) D-31.

TABLE 3

Mechanical Properties and High-Temperature Strength of Some Niobium Alloys*

| Сплав 1 | Темп-ра испыта-ния (°С) 2 | $\sigma_в$ (кг/мм$^2$) 3 | $\delta$ (%) | $E$ (кг/мм$^2$) 3 | $\sigma_{100}$ (кг/мм$^2$) 3 |
|---|---|---|---|---|---|
| Ф-48 ** | 20 | — | — | 17500 | — |
| | 850 | 58 | — | — | 24,5 |
| | 1100 | 44,4 | — | 12650 | — |
| | 1200 | 33,6 | — | — | 11,9 |
| | 1315 | 24 | — | — | — |
| СВ-74 ** | 1200 | 31,5 | — | — | — |
| СВ-65 ** | 870 | 25 | — | — | — |
| | 1110 | 8,5 | — | — | — |
| Д-31 ** 4 | 850 | 43 | — | — | — |
| | 1100 | 24,5 | — | — | — |
| | 1315 | 14 | — | — | — |
| | 1420 | 7,7 | — | — | — |
| ВН-2, горячедеформированный пруток 5 | 20 | 65 | 20 | 11600 | — |
| | 1000 | 40 | 30 | 12320 | 20 |
| | 1100 | 30 | 40 | 12390 | 15 |
| | 1500 | 8 | — | — | — |
| ВН-2, холоднокатаный лист (степень наклепа 90%) 6 | 20 | 90 | 5 | — | — |
| | 1000 | 60 | 12 | — | — |
| | 1100 | 50 | 20 | — | 10 |
| | 1500 | 14 | 60 | — | — |

*Mechanical properties determined during tests in vacuum or in neutral gas medium (argon, helium).

**Rods.

1) Alloy; 2) test temperature (°C); 3) (kg/mm$^2$); 4) D-31; 5) BH-2, hot-deformed rod; 6) BH-2, cold-rolled sheet (degree of strain hardening 90%).

TABLE 4

Dimensions of Niobium Mill Products

| 1 Полуфабрикаты | 2 Размеры (мм) |
|---|---|
| 4 Прутки 3 | $d$ = 8—12,7 |
| Листы | Толщина 0,025—0,5 |
| Проволока 6 | $d$ = 0,025—6,25 |
| Трубы 7 | $d$ = 1,5—25 (наружный) |

1) Mill products; 2) dimensions (mm); 3) rods; 4) sheets; 5) thickness; 6) wire; 7) tubing; 8) (outside).

high-temperature strength, heat resistance, and also to alter the physical characteristics (increase the superconductivity temperature, reduce the neutron capture cross section, etc.). The chemical composition of typical niobium alloys is shown in Table 1; the physical and mechan-

ical properties of some niobium alloys are presented in Table 2 and Table 3.

Deformation of niobium alloy ingots is performed at 1000-1500° by forging, rolling, and pressing. In view of the considerable oxidizability, heating of the niobium alloys is accomplished in furnaces with neutral atmosphere or in vacuum furnaces. Heat treatment is performed in a vacuum of $1 \cdot 10^{-4}$ mm Hg.

Niobium has low heat resistance and therefore for long-term operation it is necessary to use protective coatings (see Protective Coatings for Niobium).

Niobium has low heat resistance and therefore for long-term operation it is necessary to use protective coatings (see Protective Coatings for Niobium).

Tubing made from the niobium alloys is produced with outside diameter from 0.2 mm (inside diameter 0.1 mm) to 25 mm (wall thickness 0.2 mm).

The fields of application of the niobium alloys are: nuclear power, jet engines, chemical industry (replacement for tantalum) and others.

References: Niobium and Tantalum, collection of translations (Parts 1-3), Moscow, 1954-60; Zakharova, G.V., et al., Niobiy i yego splavy [Niobium and Its Alloys], Leningrad, 1961; Jahnke, L.P., Frank, R.G., Redden, T.K., "Metal Progr.," 1960, Vol. 77, No. 6; ibid, idem., 1960, Vol. 78, No. 1.

L.P. Zhorova, G.V. Kurganov

NITRALLOY is an aluminum-bearing steel intended for the fabrication of parts to be nitrided. The most typical nitralloys which are widely used in the USSR are the 38KhMYuA and 38KhYu steels (see Nitriding Constructional Steel).

Ya.M. Potak

NITRIDABLE STRUCTURAL STEEL – steel intended for the manufacture of nitridable components with a very, wear-resistant surface layer (see also Nitridable stainless steel). Almost all alloy steel containing Al, Cr, Mo, and W is nitrided to increase its wear resistance and durability. The nitrided layer reaches its greatest hardness (HV = 900-1200 kg/mm$^2$) in aluminum-alloyed steel (see Nitralloy). After nitriding chromium-containing structural steels, such as 20Kh, 40Kh, 40KhS, 30KhGSA, or 40KhNMA, have a surface hardness HV = 500-750 kg/mm$^2$. Structural steels with an elevated chromium content (>2%) and additions of molybdenum or tungsten have a nitrided layer harder than that of ordinary alloy structural steel, but lower than that of aluminum-containing steel. Steels of types 38KhMYu and 38KhMYuA, which contain aluminum, are widely employed for nitriding. Steel of type 38KhMYuA, which is used for the most critical components, contains Mo in order to enhance its hardenability, somewhat increase the ultimate strength of its core, and prevent development of Temper brittleness of steel during nitriding. Since alloying of steel with aluminum often leads to metallurgical defects (nonmetallic inclusions, hairline cracks, and slate-type fractures), 30Kh3VA steel, which contains no aluminum, has been developed. Tables 1 and 2 show the chemical composition and mechanical characteristics of nitridable structural steels.

Figure 1 shows the influence of tempering temperature on the mechanical characteristics of quenched 38KhMYuA steel. The mechanical characteristics of 38KhMYuA and 30Kh3VA steels at elevated temperatures are shown in Fig. 2. The impact strength of all types of heat-treated steels

III-96s1

TABLE 1

Chemical Composition of Nitridable Structural Steels

| Сталь 1 | Содержание элементов (2) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | C | Si | Mn | Cr | Al | Mo | S, не более | P, не более |
| 38ХЮ 5 | 0,35—0,43 | 0,17—0,37 | 0,20—0,50 | 1,5—1,8 | 0,5—0,8 | — | 0,035 | 0,0 |
| 38ХМЮА 6 | 0,35—0,42 | 0,17—0,37 | 0,30—0,60 | 1,35—1,65 | 0,7—1,1 | 0,15—0,25 | 0,025 | 0,0 |
| 30Х3ВА 7 | 0,27—0,35 | 0,17—0,37 | 0,30—0,60 | 2,8—3,2 | — | — | 0,030 | 0,0 |
| 38ХВФЮА 8 | 0,36—0,43 | 0,17—0,37 | 0,20—0,40 | 1,5—1,8 | 0,6—0,7 | 0,1—0,2V | 0,025 | 0,0 |

1) Steel; 2) content of elements (%); 3) no more than; 4) GOST or TU; 5) 38KhYu; 6) 38KhMYuA; 7) 30Kh3VA; 8) 38KhVFYuA; 9) GOST; 10) ChMTU.

TABLE 2

Mechanical Characteristics of Nitridable Structural Steels (no less than)

| Сталь 1 | ГОСТ или ТУ 2 | Термич. обработка 3 | $\sigma_в$ (4) | $\sigma_{0,2}$ (4) | $\delta_5$ (%) | $\psi$ (%) | $a_н$ (кгм/см²) (5) | $Hв^*$ ($d_{отп}$, мм) |
|---|---|---|---|---|---|---|---|---|
| 38ХЮ 6 | ГОСТ 4543-61 10 | Закалка с 930° в масле или в теплой воде, отпуск при 640° 12 | 90 | 75 | 10 | 45 | 8 | ≥ 4,0 |
| 38ХМЮА 7 | ГОСТ 4543-61 13 | Закалка с 940° в масле или в теплой воде, отпуск при 640° | 100 | 85 | 14 | 50 | 9 | ≥ 4,0 |
| 30Х3ВА 8 | ЧМТУ 5596-56 11 14 | Закалка с 870—890° в теплой воде или в масле; отпуск при 580—620° | 100 | — | 15 | 50 | 10 | ≥ 4,0 |
| 38ХВФЮА 9 | ГОСТ 4543-61 15 | Закалка с 930° в масле или в теплой воде, отпуск при 640° | 100 | 85 | 12 | 50 | 9 | ≥ 4,0 |

*After annealing or high tempering.

1) Alloy; 2) GOST or TU; 3) heat treatment; 4) kg/mm$^2$; 5) kg-m/cm$^2$; 6) 38KhYu; 7) 38KhMYuA; 8) 30Kh3VA; 9) 38KhVFYuA; 10) GOST; 11) ChMTU; 12) quenching from 930° in oil or warm water, tempering at 630°; 13) quenching from 940° in oil or warm water, tempering at 640°; 14) quenching from 870-890° in warm water or oil, tempering at 580-620°; 15) quenching from 930° in oil or warm water, tempering at 640°.

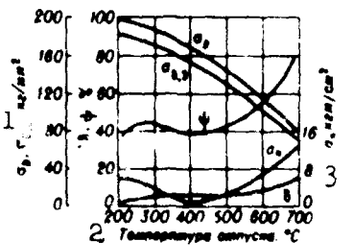



Fig. 1. Influence of tempering temperature on the mechanical characteristics of 38KhMYuA steel. 1) kg/mm$^2$; 2) tempering temperature, °C; 3) kg-m/cm$^2$.

TABLE 3

Durability of 30Kh3VA Nitridable Structural Steel

| Темп-ра (°C) 1 | Образец без надреза 2 | Образец с надрезом 3 |
|---|---|---|
| | $\sigma_{-1}$ (кг/мм²) 4 | |
| 20 | 61 | 35 |
| 200 | – | 32 |
| 400 | 50 | 28 |
| 500 | 44 | – |
| 550 | 37 | 16 |

1) Temperature (°C); 2) unnotched specimen; 3) notched specimen; 4) $kg/mm^2$.

varies only slightly as the temperature is lowered to −60°. Table 3 shows the durability of 30Kh3VA steel on alternate bending after quenching and tempering at 580°.

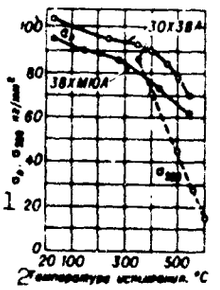



Fig. 2. Mechanical characteristics of 38KhMYuA and 30Kh3VA steels at elevated temperatures. 1) $kg/mm^2$; 2) test temperature, °C; 3) 38KhMYuA; 4) 30Kh3VA.

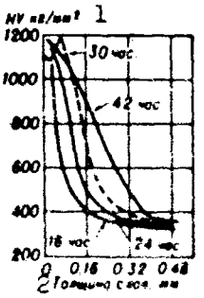



Fig. 3. Distribution of hardness through the thickness of the nitrided layer of 38KhMYuA steel (nitriding at 520°; the nitriding time is indicated on the curves). 1) $kg/mm^2$; 2) thickness of layer, mm; 3) hr.

The durability of 38KhMYuA steel at 20° is 53 $kg/mm^2$ for cylindrical (d = 8 mm) unnotched specimens and 32 $kg/mm^2$ for notched specimens;

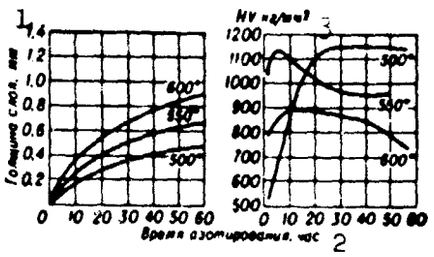



Fig. 4. Influence of nitriding temperature and time on the thickness and hardness of the nitrided layer of 38KhMYuA steel. 1) Thickness of layer, mm; 2) nitriding time, hr; 3) kg/mm$^2$.

nitriding at 500° for 48 hr increases this figure by 10 kg/mm$^2$. For all types of steel the modulus of elasticity E = 20,000 kg/mm$^2$. The modulus of elasticity varies with temperature in the same manner as for carbon steel (see Carbon structural shaping steel). Figure 3 shows the distribution of hardness through the thickness of the nitrided layer of 38KhMYuA steel.

The physical characteristics of 38KhYu and 38KhMYuA steels include: $\gamma$ = 7.65, $\alpha = 11.0 \cdot 10^{-6}$ (20–100°), $13.0 \cdot 10^{-6}$ (20–300°), and $14.5 \cdot 10^{-6}$ (20–600°)1/°C, and $\lambda$ = 0.09 (20°) cal/cm·sec·°C. Those of 30Kh3VA steel include: $\gamma$ = 7.85 and $\alpha = 12.1 \cdot 10^{-6}$(20–100°)1/°C.

The critical points of 38KhMYuA steel are $Ac_1$ = 800°, $Ac_3$ = 940°, and $Ar_1$ = 730°, while those of 30Kh3VA steel are $Ac_1$ = 730°, $Ac_3$ = 780°, and $Ar_1$ = 350°. The hot-deformation temperature for these steels is 1180–850° and their machinability is satisfactory. Heat treatment involves a preliminary stage consisting of normalization at 920–980° and high tempering at 680° and a final stage consisting of quenching in oil from 930–950° (38KhYu, 38KhMYuA) or 880–900° (30Kh3VA) and tempering at 600–700° (38KhYu, 38KhMYuA) or 580–620° (30Kh3VA). Steel of types 38KhMYuA and 30Kh3VA displays little tendency toward temper brittleness. The nitriding regimes for 38KhYu and 38KhMYuA steels are as follows: a) at 500–520° for 48–60 hr, $NH_3$ dissociation – 20–35%, nitrided-layer thickness – 0.45–0.55 mm, surface hardness HV – from 950 to 1100 kg/mm$^2$;

b) sequential nitriding: first stage at 510° for 15 hr, $NH_3$ dissociation – 20-35%; second stage at 550° for 25 hr, $NH_3$ dissociation – 40-55%, nitrided-layer thickness - 0.50-0.60 mm, surface hardness HV – from 850 to 1000 kg/mm$^2$; c) at 540° for 40 hr, cooling in running $NH_3$, nitrided-layer thickness – 0.50-0.65 mm, surface hardness HV – from 900 to 1000 kg/mm$^2$. The nitriding regime for 30Kh3VA steel is as follows: at 500-525°, $NH_3$ dissociation – 15.25% at 500° and 20-30% at 525°, nitriding time – 60-80 hr, nitrided-layer thickness – 0.35-0.55 mm, surface hardness HV – from 750 to 800 kg/mm$^2$.

Figure 4 shows the influence of nitriding temperature and time on the thickness and hardness of the nitrided layer of 38KhMYuA steel. Steel of types 38KhYu, 38KhMYuA, and 38KhVFYuA is generally not welded. When welding is necessary complete protection against oxidation or ignition of the aluminum must be provided (welding in an inert-gas atmosphere). In order to avoid welding cracks 30Kh3VA steel is welded with preliminary and subsequent heating to a temperature $\geq$200°. These alloys are used for engine and pump cylinders, gears, shafts, spindles, bushings, cams, measuring probes, and other components subject to substantial wear. Steel of type 30Kh3VA can also be employed as an unnitrided heat-resistant material for components operating at temperatures of up to 400-500°. The principal restriction on the use of nitridable structural steels is that those areas of the component with severe stress concentrators must be protected against nitriding. Those areas of the component subject to tensile and bending stresses whose magnitude approximates the yield strength of the steel as a result of concentration cannot be nitrided; nitriding of such areas permits cracking of the nitrided layer.

References: Minkevich, A.N. Khimiko-termicheskaya obrabotka stali

[Chemical-Thermal Processing of Steel], Moscow, 1950; Lakhtin, Yu.M. Fizicheskiye osnovy protsessa azotirovaniya [Physical Principles of Nitriding], Moscow, 1948.

Ya.M. Potak

NITRIDE is a compound of nitrogen with metals which is formed at high temperatures. With regard to structure and properties (see Table 1), the compounds of the metals of the transitional group (metal-like

TABLE 1

Properties of Nitrides of the Refractory Metals

| Свойства 1 | TiN | ZrN | HfN | VN | NbN | TaN | UN | BN | $Si_3N_4$ |
|---|---|---|---|---|---|---|---|---|---|
| Молекулярный вес 2 | 61.9 | 105.22 | 192.6 | 64.95 | 106.91 | 194.95 | 252.07 | 24.82 | 140.3 |
| Содержание азота (ат. %) 3 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 57.14 |
| (вес. %) 4 | 22.63 | 13.31 | 7.28 | 21.56 | 13.1 | 7.19 | 5.55 | 56.44 | 38.94 |
| $\gamma$ (г/см³) 5 | 5.44 | 7.35 | 13.84 | 6.10 | 8.41 | 15.86 | 14.32 | 2.29 | 3.19 |
| $t°_{пл}$ (°C) 6 | 2950 | 2980 | 2980 | 2050 | 2050 | 890 | 2650 | 3000 | 1900 |
| Теплота образования при температуре 298°K (ккал/моль) 7 | 80.5 | 82.2 | 88.24 | 60 | 56.8 | 60 | 68.5 | 60.7 | 179.5 |
| Энтропия образования из элементов (ккал·град·моль) 8 | 7.24 | 9.3 | 13.1 | 8.9 | 10.5 | 12.2 | 12.5 | 3.67 | 23 |
| при 20° (кал·моль·°C) 9 | 8.86 | 10.88 | — | 9.08 | 10.41 | 9.7 | — | 2.88 | 23.74 |
| $\lambda$ (кал/см·сек·°C) 10 | 0.046 | 0.049 | — | 0.027 | 0.089 | 0.021 | — | 0.036 – 0.050* | 0.041 |
| $\rho$ (мком·см) 11 | 25 | 21.1 | 33 | 85 | 78 | 128 | — | $1.3 \cdot 10^{14}$ | $10 - 10^{20}$ |
| Термич. ковфф электросопротивления (град$^{-1}$·$10^3$) 12 | +2.48 (100— 1100°) | +4.3 (20— 2560°) | — | +6.7 | — | +0.03 (20— 1410°) | — | — | — |
| $\alpha \cdot 10^6$ (1/°C) | 9.35 (25— 1100°) | 7.24 (20— 1100°) | 6.9 (20— 1100°) | 8.1 (20— 1100°) | 10.1 (20— 2700°) | 3.6 (20— 700°) | — | 7.51 (25— 1000°) | 2.75 (20— 1000°) |
| Термоэдс (мкв/°C) 13 | −7.78 | −4.78 | −2.96 | −4.6 | −2.24 | −1.6 | — | — | — |
| Работа выхода (эв) 14 | 2.92 | 2.92 | — | — | — | — | — | — | — |
| Постоянная Холла 16 | | | | | | | | | |
| $R \cdot 10^4$ (см³/кулон) | −0.67 | −1.3 | −4.2 | +0.42 | −0.52 | −3.61 | — | | — |
| $E$ (кг/мм²) 17 | 25600 | — | — | — | — | — | — | 3440— 8650 | 4700 |
| $\sigma_{-b}$ (кг/мм²) 18 | 130 | 100 | — | — | — | — | — | 24—32 | 16 |
| $RA$ | 75 | 84 | — | — | 86 | — | — | — | 99 |
| $H$ (кг/мм²) 19 | 1990 | 1520 | 1640 | 1520 | 1400 | 1060 | — | — | 3340 |

*At 300°.

1) Properties; 2) molecular weight; 3) nitrogen content (atomic %); 4) (weight %); 5) $\gamma$ (g/cm$^3$); 6) $t°_{pl}$ (°C); 7) heat of formation at a temperature of 298°K (kcal/mole); 8) entropy of formation from elements (kcal/deg-mole); 9) c at 20° (cal/mole-°C); 10) $\lambda$ (cal/cm-sec-°C); 11) $\rho$ ($\mu$ohm-cm); 12) temperature coefficient of electrical resistance (deg$^{-1} \cdot 10^3$); 13) thermoelectromotive force ($\mu$v/°C); 14) work function (ev); 15) Hall constant; 16) $R \cdot 10^4$ (cm$^3$/coulomb); 17) E (kg/mm$^2$); 18) $\sigma_{-b}$ (kg/mm$^2$); 19) H (kg/mm$^2$).

nitrides) are similar to the carbides and are interstitial phases, while the compounds of nitrogen with the nonmetals have a more complex

TABLE 2

Coefficient of Thermal Conductivity and Temperature Coefficient of Linear Expansion of Boron Nitrides

| 1 Темп-ра (°С) | λ (кал/см·сек·°С) 2 | | 1 Темп-ра (°С) | α 10⁶ (1/°С) | |
|---|---|---|---|---|---|
| | 3 параллельно направлению горячего прессования | 4 перпендикулярно направлению горячего прессования | | 3 параллельно направлению горячего прессования | 4 перпендикулярно направлению горячего прессования |
| 300 | 0,036 | 0,069 | 25—350 | 10,15 | 0,59 |
| 500 | 0,034 | 0,067 | 25—700 | 8,06 | 0,89 |
| 700 | 0,032 | 0,065 | — | — | — |
| 900 | 0,03 | 0,063 | 25—1000 | 7,51 | 0,77 |
| 1000 | 0,029 | 0,064 | — | — | — |

1) Temperature (°C); 2) λ (cal/cm-sec-°C); 3) parallel to the direction of hot extrusion; 4) perpendicular to the direction of hot extrusion.

TABLE 3

Modulus of Elasticity and Ultimate Tensile Strength of Boron Nitrides

| 1 Температура (°С) | 2 $\sigma_b$ (кг/мм²) | | 2 $E$ (кг/мм²) | |
|---|---|---|---|---|
| | 3 параллельно направлению горячего прессования | 4 перпендикулярно направлению горячего прессования | 3 параллельно направлению горячего прессования | 4 перпендикулярно направлению горячего прессования |
| 25 | 11,12 | 5,1 | 8650 | 3440 |
| 350 | 10,6 | 4,9 | 6150 | 2430 |
| 700 | 2,7 | 1,33 | 1980 | 360 |
| 1000 | 1,53 | 0,76 | 1160 | — |

1) Temperature (°C); 2) (kg/mm$^2$); 3) parallel to the direction of hot extrusion; 4) perpendicular to the direction of hot extrusion.

structure and different properties. The nitrides have several specific properties which are important for present-day technology. The nonmetallic nitrides have high thermal stability, low thermal and electrical conductivity, high chemical resistance to the action of acids and alkalis, and are refractory. The metal-like nitrides (TiN, ZrN, HfN and others) are characterized by high electrical conductivity with metallic nature of the conductivity, and also high thermal conductivity. The ma-

TABLE 4

Physical and Mechanical Properties of Silicon Nitrides

| Свойства 1 | Модификации нитридов кремния 2 | |
|---|---|---|
| | α $Si_3N_4$ | β $Si_3N_4$ |
| Содержание кремния (вес. %) 3 | 59,2 | 60,2 |
| Кристаллич. решетка 4 | Гексагональная 5 | Гексагональная |
| γ ($г/см^3$) 6 | 3,18 | 3,21 |
| H ($кг/мм^2$) 7 | 3335±120 | 3335±120 |
| $\sigma_{изг}$ ($кг/мм^2$) на образцах с пористостью 30%: 8 | | |
| при 20° 9 | 16 | 16 |
| при 1200° | 14 | 14 |
| ПА 10 | 99 | 99 |
| E ($кг/мм^2$) при: | | |
| 20° | 4700 | 4760 |
| 300° | 4860 | 4860 |
| 850° | 4760 | 4760 |
| 950° | 4720 | 4720 |
| 1000° | 4690 | 4600 |
| ρ (мком·см) при: 11 | | |
| 20° | $10^{13}$—$10^{14}$ | $10^{13}$—$10^{14}$ |
| 300° | $2 \cdot 10^5$ | $2 \cdot 10^5$ |
| 500° | $4 \cdot 10^6$ | $4 \cdot 10^6$ |
| 700° | $2{,}5 \cdot 10^7$ | $2{,}5 \cdot 10^6$ |
| 800° | $6 \cdot 10^8$ | $6 \cdot 10^7$ |
| 1000° | $1{,}5 \cdot 10^9$ | $1{,}5 \cdot 10^8$ |

1) Properties; 2) modifications of silicon nitrides; 3) silicon content (weight %); 4) crystal lattice; 5) hexagona; 6) γ ($g/cm^3$); 7) H ($kg/mm^2$); $\sigma_{izg}$ ($kg/mm^2$) on specimens with 30% porosity; 9) at; 10) E ($kg/mm^2$) at; 11) ρ (μohm-cm) at.

TABLE 5

Solubility of Some Nitrides in Concentrated Acids and Perhydrol at Room Temperature in the Course of 24 Hours and with Boiling for 2 Hours (content of undissolved residue in % after acid treatment)

| Нитрид 1 | HCl (γ = 1,19) | | $H_2SO_4$ (γ = 1,84) | | $HNO_3$ (γ = 1,4) | | $HClO_4$ (концентрированная) | | $H_2O_2$ |
|---|---|---|---|---|---|---|---|---|---|
| | холодная 3 | кипящая 4 | холодная 3 | кипящая 4 | холодная 3 | кипящая 4 | холодная 3 | кипящая 4 | кипящая 4 |
| TiN | 89 | 98 | 97 | 24 | 10 | * | 99 | * | 2 |
| ZrN | 89 | 16 | 45 | 0 | 98 | 64 | 99 | 98 | 100 |
| NbN | 100 | 99 | 100 | 0 | 99 | 100 | 98 | 100 | 16 |
| TaN | 99 | 98 | 100 | 77 | 98 | 98 | 100 | 98 | 41 |

*Precipitation of a white residue is observed.

1) Nitride; 2) concentrated; 3) cold; 4) boiling.

TABLE 6

Solubility of Nitrides in NaOH Solutions and in a Mixture of Alkali with Hydrogen Peroxide with Boiling for 2 Hours (undissolved residue in %)

| 1 Нитрид | 2 NaOH 1%-ный раствор | NaOH 10%-ный раствор | NaOH 40%-ный раствор | NaOH + $H_2O_2$ 1%-ный раствор | NaOH + $H_2O_2$ 10%-ный раствор | NaOH + $H_2O_2$ 40%-ный раствор |
|---|---|---|---|---|---|---|
| TiN | * | * | * | 9 | 16 | 43 |
| ZrN | 100 | 100 | 42 | 99 | 87 | 48 |
| NbN | 96 | 87 | 81 | 17 | 0 | 0 |
| TaN | 93 | * | * | 84 | 39 | ** |

*Partial solubility with hydrolysis.
**Solution of major portion of nitride accompanied by hydrolysis.

1) Nitride; 2) % solution.

TABLE 7

Solubility of Nitrides in Acid Mixtures with Various Additions (at room temperature for 24 hours, and at boiling temperature for 2 hours)

| Смесь кислот 1 | | TiN | ZrN | NbN | TaN |
|---|---|---|---|---|---|
| | | нерастворившаяся часть (%) 2 | | | |
| $HCl+HNO_3$ (3:1) | холодная 3 | 13 | 82 | 99 | — |
| | кипящая 4 | — | 25 | 99 | 100 |
| $HClO_4+HCl$ (1:1) | холодная | 98 | — | 98 | — |
| | кипящая | 76 | 12 | 95 | — |
| $HNO_3+H_2O_2$ (1:1) | холодная | 2 | 94 | 26 | — |
| | кипящая | 3 | 65 | 15 | — |
| $HNO_3+HF$ | нагревание 5 мин. 5 | 0 | 0 | 0 | 0 |
| $H_2C_2O_4+H_2SO_4$ (3:1) | холодная | 98 | 90 | — | — |
| | кипящая | 76 | — | — | — |
| $H_2SO_4+H_2O_2$ (2:1) | холодная | 3 | 25 | — | — |
| | кипящая | 1 | — | — | 93 |
| $H_2SO_4+HNO_3+$ $+H_2O$ (1:1) | холодная | 41 | 81 | — | — |
| | кипящая | 12 | — | — | — |
| $K_2SO_4$ (10 г) + $+H_2SO_4$ (10 мл) 6 7 | холодная | 0 | 0 | 0 | 0* |

*Sample dissolves completely in the course of 5-6 hours.

1) Mixture of acids; 2) undissolved part (%); 3) cold; 4) boiling; 5) heated for 5 minutes; 6) grams; 7) milliliters.

TABLE 8

Stability of Silicon Nitrides in Molten Metals

| Расплавленный металл 1 | Темп-ра (°С) 2 | Продолжительность контакта (часы) 3 | Результат 4 |
|---|---|---|---|
| Алюминий 5 | 800 | 950 | Не действует 6 |
| То же 7 | 1 000 | 100 | То же 7 |
| Свинец 8 | 400 | 144 | " |
| Олово 9 | 300 | 144 | " |
| Цинк 10 | 550 | 500 | " |
| Магний 11 | 750 | 20 | Слабо действует 12 |
| Медь | 1 150 | 7 | Сильно действует 13 14 |

1) Molten metal; 2) temperature (°C); 3) contact duration (hours); 4) result; 5) aluminum; 6) no reaction; 7) same; 8) lead; 9) tin; 10) zinc; 11) magnesium; 12) reacts weakly; 13) copper; 14) reacts strongly.

TABLE 9

Processing Regimes for Obtaining Nitride Powders

| Нитрид 1 | Темп-ра (°С) 2 | Продолжительность азотирования (мин.) 3 |
|---|---|---|
| TiN | 1200 | 120—240 |
| ZrN | 1200 | 60—120 |
| VN | 1200 | 240 |
| NbN | 1200 | 60—120 |
| TaN | 1200 | 60—120 |
| CrN | 900 | 60—120 |
| $Mo_2N$ | 700 | 240 |
| $Re_2N$ | 300—350 | 20—25 |

1) Nitride; 2) temperature (°C); 3) nitriding duration (min).

TABLE 10

| Нитрид 1 | Темп-ра спекания 2 (°С) | Давление при спекании 3 (кг/см²) | Продолжительность спекания 4 (мин) |
|---|---|---|---|
| TiN | 2300 | 120 | 15 |
| ZrN | 2350 | 120 | 5 |
| TaN | 2330 | 120 | 5 |
| BN | 1800 | 200 | 5 |

1) Nitride; 2) sintering temperature (°C); 3) sintering pressure ($kg/cm^2$); 4) sintering duration (min).

jority of these nitrides have a wide range of homogeneity within the limits of which their physical properties vary considerably. Thus, with decrease of the nitrogen content within the limits of the homogeneity region some of the nitrides acquire semiconductor properties (TiN, ZrN). The nitrides are less hard than the carbides and borides, have a high melting point (3000-3200°), low mechanical strength and high abrasion resistance. When heated to high temperatures in a vacuum they dissociate with the formation of metal vapors and the evolution of nitrogen.

The nonmetallic boron and silicon nitrides and the beryllium and aluminum nitrides which are similar to them in properties are insulators at ordinary temperatures, but behave as semiconductors with high thermoelectric characteristics at high temperatures. The electrical resistance of a hot-extruded specimen of boron nitride with impurities of a nonmetallic nature amounts to $17 \cdot 10^{13}$ (25°), $2.3 \cdot 10^{10}$ (500°), $3.1 \cdot 10^{4}$ (1000°), $6 \cdot 10^{2}$ (1500°) ohm-cm. In contrast with the metallic materials, the thermal conductivity and the coefficient of thermal expansion of boron nitride diminish with temperature increase. The nonmetallic nitrides decompose on melting or dissociate prior to reaching the melting point. In contrast with the metal-like nitrides, the nonmetallic nitrides have low coefficients of thermal expansion and high thermal stability. Tables 2 and 3 show the temperature dependence of some properties of boron nitride.

Of all the known nitrides, the properties of silicon nitride have been studied most thoroughly (Table 4).

Boron nitride exists in two crystalline modifications - graphite-like (αBN) and diamond-like (βBN). The first of these modifications is close to graphite in properties, while the second, cubic, modification has properties similar to diamond. The hardness of the second modifica-

tion, termed borazon, is close to the hardness of diamond, the stability on heating in air is considerably higher than that of diamond.

The metallic nitrides are resistant to acids, alkali solutions, and oxidation in the air (Tables 5-7); the nonmetallic boron and silicon nitrides are still more resistant to these aggressive media. For example, boron nitride specimens are resistant to oxidation in the air up to 60 hours at 700° and up to 10 hours at 1000°, and are resistant in chlorine up to 40 hours at 700°. Concentrated sulfuric acid does not attack boron nitride specimens at room temperature in the course of 7 days; concentrated phosphoric, hydrofluoric, nitric acids, and also carbon tetrachloride, gasoline and benzene attack it very weakly. Specimens prepared from silicon nitride do not show any marked changes in the course of 500 hours in hydrochloric, nitric, sulfuric, and phosphoric acids of any concentration; nor are they attacked by chlorine and hydrogen sulfide at 1000°, a molten mixture of sodium and potassium chlorides at 800°, a molten mixture of sodium nitrite and sodium nitrate at 350°. Specimens made from silicon nitride are stable for 115 hours in a boiling 50% solution of caustic soda, for 144 hours in molten sodium and potassium chlorides at 900°, for 100 hours in a mixture of sodium and zirconium fluorides at 800°, for 116 hours in a mixture of 3% hydrofluoric and 10% nitric acids at 70°. Titanium, boron, and silicon nitrides are quite resistant to the action of molten metals. Titanium nitride essentially does not react in the course of 40 hours with molten tin, bismuth, lead, cadmium and zinc. Silicon nitride does not interact with molten iron, brass and is also resistant with respect to attack by other molten metals (Table 8). Boron nitride is not wetted by molten steel or bronze, and is resistant to molten cryolite-alumina.

The $\sigma_b$ for boron and silicon nitrides are respectively 1.5-2.75 and 5.1-11.17 kg/mm$^2$ (lower values are obtained on specimens taken per-

pendicular to the direction of hot pressing, larger values are parallel to this direction).

$\sigma_{izg}$ for silicon nitride specimens varies little in the 20-1200° range, amounting to 15-16 kg/mm$^2$.

The metal-like nitrides are usually obtained directly by nitriding powders of the corresponding metals at 1200° (Table 9) or in certain cases by reduction of the metal oxides by carbon in a nitrogen atmosphere according to the reaction:

$$MeO + C + \frac{1}{2}N_2 \rightarrow MeN + CO.$$

The nonmetallic nitrides are obtained by similar methods, but at higher temperatures, reaching 1500° for silicon nitride and 1700° for boron nitride.

Products made from the nitrides are obtained by separate pressing and sintering or by hot pressing (Table 10) at 1800-2500°. To fabricate products from the nitrides, use is often made of the so-called activated sintering method which involves nitriding pre-pressed porous metallic or nonmetallic blanks where the blanks are pressed in metal press-forms by sleeker forming or hydrostatic pressing. To fabricate shaped products from the nitrides, use is made of the method of pressing plasticized mixtures with subsequent high-temperature sintering. All forms of sintering and heat treatment of the nitride products are performed in protective media consisting of nitrogen or dissociated ammonia.

Machining of products made from the metal-like nitrides is accomplished using the ultrasonic, anode-mechanical, and electrospark methods. Products made from the nonmetallic nitrides may be machined by the conventional methods (cutting, drilling, etc.).

The nitrides are used in various engineering fields: in the composition of refractories, as a material for abrasive disks and high-re-

sistance resistors, for detector devices, as thermal insulation for high-frequency induction furnaces, and also in metallurgy for pouring nozzles, mixers, and converters. Boron nitride is also used in the composition of dielectrics and high-temperature semiconductor materials. Borazon is an equivalent replacement for diamonds, while borazon monocrystal is a semiconductor.

Thanks to its refractory properties, silicon nitride finds application (including in the form of alloys with other nonmetallic nitrides and carbides) for the fabrication of tubing and parts of pumps for transporting and transfer of molten metals, for fabricating boats, crucibles, linings for electrolytic tanks in aluminum production, thermocouple protective tubes. Boron nitride and silicon nitride are used as components of heat-resistant and high-temperature alloys.

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K.I. Portnoy

NITRIDING OF STEEL – saturation of the surface of steel components with nitrogen; a process used to increase hardness, wear resistance, fatigue limit and corrosion resistance in the atmosphere, in water, in steam, etc. Nitriding is widely used in industry, e.g., for components working below 500° (cylinder sleeves, crankshafts and exhaust valves of piston engines; gears, shafts, liners, slidevalve elements, and other parts of fuel systems; certain components of jet engines, etc.). The nitriding process consists in heating the finish-machined component in an ammonia medium at 480-650°. At temperatures above 400°, the ammonia dissociates in the reaction $NH_3 \rightarrow 3H + N$, with formation of atomic nitrogen. The latter is absorbed by the surface of the metal and diffuses into its interior, forming various nitrogen phases in accordance with the Fe-N diagram (Fig. 1) and the process temperature. Formation of the following phases in the Fe-N system is possible: $\alpha$ – a nitrogen ferrite containing about 0.01% of nitrogen at room temperature and 0.42% at 591°; $\gamma$ – a nitrogen austenite, which exists as an equilibrium phase above the eutectoid temperature (591°); and $\gamma'$ – the nitride $Fe_4N$, an interstitial phase with a face-centered cubic lattice. At a nitrogen concentration of 2.3% and a temperature of 591°, a eutectoid forms, consisting of the $\alpha$ and $Fe_4N$ phases and reminiscent as regards structure of the pearlite of carbon steels. At nitrogen contents above 8%, the hexagonal $\varepsilon$-phase forms; the $\varepsilon$-phase persists up to the region around 11.2% N, when the nitride $Fe_2N$ appears. Nitrogen also forms nitrides with many alloying elements.

On nitrogen saturation of iron or unalloyed carbon steel, the sur-

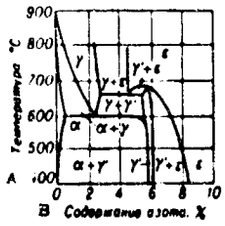



Fig. 1. Diagram of state of iron-nitrogen system. A) Temperature, °C; B) nitrogen content, %.

surface hardness rises insignificantly (by 30-50 HV) because of the low thermal stability of iron nitrides and the rapid rate of their coagulation at the temperature of the process. On saturation of steel alloyed with nitride-forming elements (Al, Ti, Cr, Mo, W, V, Nb, Mn and others), the hardness of the nitrided layer rises to 1200 HV due to the high dispersion of the nitrides precipitated and their high thermal stability. Nitriding is applied to iron and carbon, medium-alloyed (see nitriding structural steel) and high-alloyed steel, as well as cast iron. The depth of the nitrided layer depends on temperature and the duration of the nitriding process, as well as on the chemical and structural composition of the steel (Figs. 2, 3). All alloying elements reduce the depth of nitriding. This depth is also in-

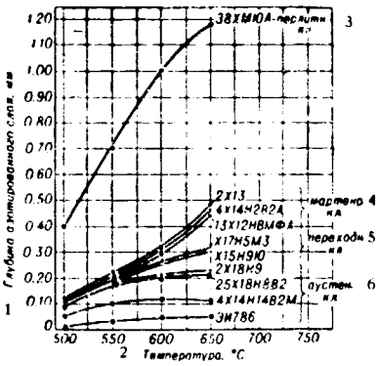



Fig. 2. Depth of nitrided layer in steel as a function of nitriding temperature. 1) Depth of nitrided layer, mm; 2) temperature, °C; 3) 38 KhMYuA – pearlite class; 4) 2Kh13, 4Kh14N2V2A, 13Kh12NVMFA – martensite class; 5) Kh17N5M3, Kh15N9Yu – transitional class; 6) 2Kh18N9 25Kh18N8V2, 4Kh14N14V2M, EI786 – austenite class.

fluenced by the structural state of the steel at the nitriding temperature. Stainless steels of the martensite class with their body-centered lattices nitride to a greater depth and austenitic steel, which has a face-centered lattice. The hardness of the nitrided layer depends chiefly on the chemical composition of the steel and the process tem-

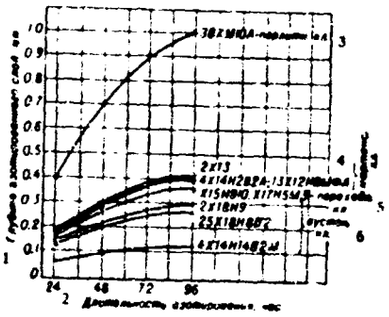


Fig. 3. Depth of nitrided steel layer as a function of nitriding time. 1) Depth of nitrided layer, mm; 2) nitriding time, hours; 3) 38KhMYuA – pearlite class; 4) 2Kh13, 4Kh14N242a-13X12NVMFA, 13Kh12NVMFA – martensite class; 5) Kh15N9Yu, Kh17N5M3 – transitional class; 6) 2Kh18N9, 25Kh18N8V2, 4Kh14N14V2M – austenite class.

perature (Fig. 4). To a lesser degree, the depth and hardness of the nitrided layer depend on the degree of dissociation of the ammonia, diminishing as this index is raised. The nitriding process is accelerated by the use of the stepped-cycle method, which consists in running the process at several different temperatures.

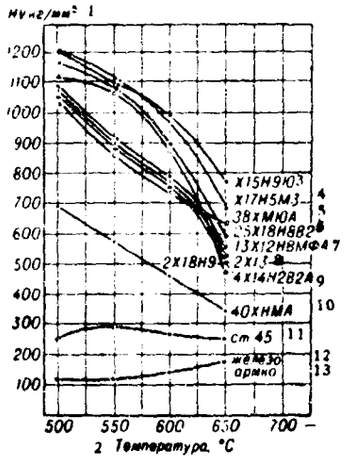


Fig. 4. Hardness of nitrided steel layer as a function of nitriding temperature. 1) HV, kg/mm$^2$; 2) temperature, °C; 3) Kh15N9Yu; 4) Kh17N5M3; 5) 38KhMYuA; 6) 25Kh18N8V2; 7) 13Kh12NVMFA; 8) 2Kh18N9; 9) 2Kh13; 10) 4Kh14N2V2A; 11) 40KhNMA; 12) steel 45; 13) Armco iron.

The wear resistance of nitrided steel is considerably greater than that of case-hardened or tempered steel. The hardness of the nitrided

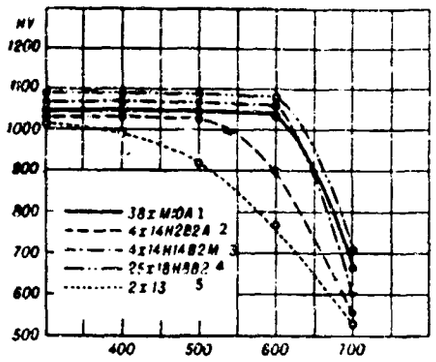



Fig. 5. Hardness of nitrided layer after repeated heating cycles. 1) 38KhMYuA; 2) 4Kh14N2V2A; 3) 4Kh14N14V2M; 4) 25Kh18N8V2; 5) 2Kh13.

Fatigue Strength of Nitrided 18KhNVA Steel

| Образец [1] | Предел выносливости (кг/мм²) [2] | |
|---|---|---|
| | [3] незотерованная | [4] азотированная |
| [5] Без надреза | 54.0 | 69.5 |
| [6] С надрезом | 23.0 | 52.0 |

1) Specimen; 2) endurance limit ($kg/mm^2$); 3) not nitrided; 4) nitrided; 5) without heating; 6) with heating.

layer does not decrease on repeated heating to 500-600° (Fig. 5), and this makes it possible to reduce wear of components operating at high temperatures. The coefficient of friction of nitrided steel, as determined on the I47 machine, drops from 0.7 at 20° to 0.1 at 600°; the weight loss due to wear is insignificant, amounting (at 560°) to 1.7 mg/$/m \cdot cm^2$ on 38KhMYuA steel and to 2 $mg/m \cdot cm^2$ on steel 25Kh18N8V2.

The fatigue strength of nitrided steel rises as a result of the appearance of compressive residual stresses in the work-hardened layer. For smooth laboratory specimens (diameter 7-10 mm), nitriding raises the fatigue limit by 30-40%, and in the presence of stress concentrators (acute notches) on the specimens, the fatigue limit is 2-3 times higher than for unnitrided specimens.

As the section of the specimen increases, the nitriding effect diminishes; nevertheless, the fatigue limit of nitrided crankshafts made from chromium-nickel-molybdenum steel is increased by 25-60%. Nitriding also results in an increase in fatigue limit under corrosive conditions. In the process of saturating the steel with nitrogen, we note a change

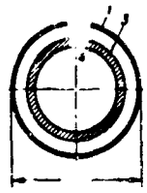


Fig. 6. Diagram showing arrangement of corrosion-resistance zones in cross section of nitrided steel. 1) Outer zone; 2) stable zone; 3) unstable zone; 4) core.

in the dimensions and deformation of components. The higher the temperature, the deeper the depth of the nitriding layer and the more complex the component shape, the greater will be the deformation. The dimensional change of components with nitriding layers of the same depth will be the greater the smaller the wall thickness of the product and the larger its diameter.

Nitrided iron and simple carbon and structural steels exhibit high resistance to corrosion in the atmosphere, mains water and steam-air media in the presence of a continuous surface layer consisting of the ε-phase. Anticorrosion nitriding is performed at 600-700° for 0.5-6 hours. Stainless steels are nitrided when the components are to possess, in addition to high wear resistance, corrosion resistance in water and moist atmospheres. Stainless steel is nitrided only after appropriate surface preparation, which consists in removal of the oxide film, which would impede the diffusion of the nitrogen. The corrosion resistance of stainless steel is lowered as a result of nitriding because of chromium impoverishment of the solid solution. To obtain a wear-resisting layer possessing optimum corrosion properties, stainless steel should be nitrided at a temperature of 550-600° and the ammonia should be dissociated to 20-40%. The nitrided layer on stainless steel has four zones with different corrosion resistances in water (Fig. 6). The first zone (depth 0.01-0.02 mm) has lower corrosion resistance; the second

zone has higher resistance. The third zone is distinguished by low corrosion resistance; it is situated between the corrosion-resistant zone and the core.

The fourth zone is the core, whose corrosion resistance is unchanged by nitriding. Under optimum nitriding conditions, the corrosion-unstable zone in martensitic and ferritic steels occupies 50-80% of the total depth of the layer. In steels of the transitional class, this zone occupies 35-45%. Austenitic steel has a minimum zone of low corrosion resistance, amounting to 20-30%. The presence of the unstable zone in the nitrided layer on stainless steel must be taken into account in fabrication of components and specification of the tolerances for final machining (grinding or polishing).

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A.G. Andreyeva

NITRIDING STAINLESS STEEL is corrosion resistant steel for the fabrication of detail parts with a nitrides surface layer of high hardness and wear resistance. In selecting a stainless steel for nitriding we must be guided by the following considerations. The martensitic and austenitic-martensitic steels have better capability for nitriding than the austenitic steels. For the same hardness ($\geq$ 800 HV) a greater depth of the nitrided layer (Table 1) can be obtained on steels of these types. Moreover, the martensitic steel has an important advantage – the hardness of the nitrided layer diminishes more uniformly from the surface to the core. Therefore, for parts requiring thermal stability to 500-600° in addition to high surface hardness and wear resistance the use of the martensitic nitriding stainless steel is preferable. If we desire higher corrosion resistance in the nitrided condition, then the austenitic nitriding stainless steel has the advantage.

TABLE 1

Nitriding Conditions and Hardness of Nitride Layer of the Nitriding Stainless Steels

| Сталь 1 | Темп-ра азотирования (°C) 2 | Продолжительность выдержки (час.) 3 | Толщина азотиров. слоя (мм) 4 | Твердость азотиров. слоя HV (кг/мм²) 5 |
|---|---|---|---|---|
| 2Х 13 (Ж2) 6 | 500<br>550<br>600 | 48<br>48<br>48 | 0,1 –0,12<br>0,24–0,28<br>0,33–0,38 | 1000–1050<br>900–950<br>780–830 |
| 13Х12НВМФА (ЭИ961) 7 | 560<br>600<br>600 | 48<br>8–16<br>24 | 0,2 –0,28<br>0,11–0,22<br>0,26–0,3 | 900–950<br>850–900<br>750–800 |
| 4Х14Н14В2М (ЭИ69) 8 | 560<br>600 | 60<br>48 | 0,09–0,11<br>0,09–0,11 | 880–930<br>750–800 |
| 25Х18Н8В2 (ЭИ946) 9 | 560<br>560<br>600 | 24<br>40<br>24 | 0,12–0,14<br>0,16–0,2<br>0,12–0,16 | 950–1100<br>900–950<br>900–950 |

1) Steel; 2) nitriding temperature (°C); 3) soak duration (hr); 4) thickness of nitride layer (mm); 5) hardness of nitride layer HV (kg/mm$^2$); 6) 2Kh13(Zh2); 7) 13Kh12NVMFA (EI961); 8) 4Kh14N14V2M (EI69); 9) 25Kh18N8V2 (EI946).

TABLE 2

Mechanical Properties of Nitriding Stainless Steels at High Temperatures

| Сталь 1 | Темп-ра (°C) 2 | σ (кг/мм²) 3 | $\sigma_{0.2}$ (кг/мм²) 3 | δ (%) | ψ (%) |
|---|---|---|---|---|---|
| 4 2Х13 (Ж2) | 300 | 63 | 51 | 10 | 68 |
| | 400 | 60 | 50 | 12 | 65 |
| | 500 | 50 | 43 | 20 | 75 |
| 5 13Х12НВМФА (ЭИ961) | 300 | 110 | 97 | 14 | 55 |
| | 400 | 105 | 87 | 14 | 56 |
| | 500 | 90 | 73 | 14 | 60 |
| | 600 | 60 | 49 | 15 | 70 |
| 6 4Х14Н14В2М (ЭИ69) | 300 | 74 | 36 | 18 | 30 |
| | 400 | 71 | 36 | 18 | 40 |
| | 500 | 65 | 34 | 17 | 42 |
| | 600 | 58 | 33 | 18 | 48 |
| 7 25Х18Н8В2 (ЭИ946) | 300 | 69 | 45 | 15 | 50 |
| | 400 | 61 | 45 | 15 | 44 |
| | 500 | 57 | 44 | 17 | 48 |
| | 600 | 51 | 37 | 16 | 50 |

1) Steel; 2) temperature (°C); 3) ($kg/mm^2$); 4) 2Kh13 (Zh2); 5) 13Kh12NVMFA (EI961; 6) 4Kh14N14V2M (EI69); 7) 25Kh18N8V2 (EI946).

TABLE 3

Physical Properties

| Сталь 1 | γ (г/см³) 2 | α·10⁶ (1/°C) | λ (кал/см·сек·°C) 3 |
|---|---|---|---|
| 4 25Х18Н8В2 (ЭИ946) | 7.98 | 15.6 (20—100°)<br>16.9 (100—200°)<br>18.6 (300—400°)<br>20 (500—600°) | 0.035 (25°)<br>0.042 (200°)<br>0.051 (400°)<br>0.06 (600°) |
| 5 4Х14Н14В2М (ЭИ69) | 8 | 17.26 (20—250°)<br>19.14 (250—500°)<br>21.67 (500—600°) | 0.038 (100°)<br>0.042 (200°)<br>0.049 (400°)<br>0.057 (600°) |

1) Steel; 2) γ ($g/cm^2$); 3) λ (cal/cm-sec-°C); 4) 25Kh18N8V2 (EI946); 5) 4Kh14N14NV2M (EI69).

Widest usage is made of the following as nitriding stainless steels: martensitic steel 2Kh13(Zh2) produced per MPTU 2362-49; martensitic steel 13Kh12NVMFA (EI961) produced per ChMTU 5949-57; austenitic steel 4Kh14N14V2M(EI69) produced per MPTU 2362-49; austenitic steel 25Kh18N8V2 (EI946) produced per ChMTU TsNIIChM 433-61 (Tables 2, 3). For chemical composition and mechanical properties at normal temperatures of the steels 2Kh13 and 13Kh12NVMFA see Martensitic Stainless

II-25N2

Steel, for steel 4Kh14N14V2M see Valve Steel. Chemical composition of the steel 25Kh18N8V2 (%) is: 0.21-0.28 C; 0.3-0.8 Si; $\leq$ 0.7 Mn; 17-19 Cr; 7.5-8.5 Ni; 2-2.5 W; $\leq$ 0.03 S; $\leq$ 0.03 P. Mechanical properties of the 25Kh18N8V2 steel are: $\sigma \geq 80$ kg/mm$^2$, $\sigma_{0.2} \geq 40$ kg/mm$^2$, $\delta_5 \geq 20\%$, $\varphi \geq 35\%$, $a_n \geq 6$ kgm/cm$^2$, HB (imprint diameter); $\geq$3.65 mm. For information on the other characteristics of the nitriding stainless steel, see Steel Nitriding. The nitriding stainless steels are used for parts subject to wear in a moist atmosphere and at temperatures to 500°.

A.G. Andreyeva

NITRIDING TITANIUM ALLOYS – nitrogen saturation of the surfaces of titanium-alloy components with the object of improving wear resistance. Titanium alloys are nitrided in nitrogen of high purity at temperatures from 850 to 950° (nitriding in ammonia is not recommended because of the significant hydrogen embrittlement of the metal). A layer consisting of titanium nitride and the solid solution of nitrogen in α-titanium forms on the surface of the component during titanium-alloy nitriding. The nitrogen content in the layer diminishes rapidly with increasing depth. The microhardness (test on Khrushchev instrument) of the layer drops from 1500 to 750–800 kg/mm$^2$. On technical titanium nitrided at a temperature of 940 ± 20° for 25–30 hours at a nitrogen supply rate of 0.25 liter/min, the layer formed is 0.06–0.08 mm deep and has a surface hardness of 850 HV (the microstructure of the nitrided layer is shown in the figure). Certain alloying elements (aluminum up to 3%, zirconium up to 3–5%) raise the rate of diffusion of nitrogen into the titanium, increasing the depth of the nitrided layer by a factor of 1.5–2; chromium inhibits the diffusion of nitrogen at all concentrations in the alloy, while other alloying elements have no noticeable influence. In titanium alloys alloyed with two or three elements, one of which is aluminum in the amount of 3–5%, many of the "neutral" elements contribute to the diffusion of nitrogen. These include tin and copper (2–3%), manganese (1–1.5%) and molybdenum (1.5–2%). Good results are also obtained on combined alloying of titanium with aluminum and zir-



Microstructure of nitrided layer on technical titanium.

conium. The formation of the nitride zone on the surfaces of components is undesirable, since it is quite brittle and impedes the diffusion of nitrogen into the interior of the metal. The nitriding temperature can be lowered considerably and a nitrided layer obtained without a nitride crust if titanium alloys are nitrided in a mixture of argon and nitrogen in the proportional 100:1 by volume or in rarefied nitrogen (1-0.1 mm Hg); here the depth of the nitrided layer increases appreciably. In certain alloys, the layer depth reaches 0.18-0.20 mm after 20 hours of nitriding in rarefied nitrogen at 940 $\pm$ 20°. Small parts such as slide-valve components, gears, bushings, pistons, levers and the like, designed to work in friction and not carrying large loads, are treated by nitriding.

References: Novikova, Ye.N., in book entitled: Titan i yego splavy [Titanium and Its Alloys], No. 3, Moscow, 1960; Smirnov, A.V., Nachinkov, A.D., "Metallovedeniye i termicheskaya obrabotka metallov [Metallography and the Heat Treatment of Metals], 1960, No. 7.

I.S. Anitov, Ye.N. Novikova

NITROCELLULOSE PLASTICS – see Plastics Based on Cellulose F ters.

NITROCELLULOSE RAYON is an artificial hydrated cellulose fiber obtained by forming from cellulose nitrate with subsequent saponification of the ester. Nitrocellulose rayon is not produced because of the production hazard (flammability of the polymers and presence of explosive solvents) and the comparatively low quality of the fiber.

L.S. Gal'braykh

NITROGENATION OF ALUMINUM ALLOYS – nitrogen treatment of aluminum alloys in the molten state (nitrogen refining) to remove gaseous and solid nonmetallic inclusions. Nitrogen is fed from the cylinder into the lower layers of the metal through a rubber hose and a quartz tube. Passing through the molten metal, the nitrogen bubbles adsorb and carry away hydrogen bubbles, as well as light solid particles, which remain floating on the surface. Heavier particles, which do not have buoyant gas bubbles, settle to the bottom of the tank. Nitrogen is bubbled through for 5-10 min, depending on the degree of contamination and the volume of the metal. Nitrogen refining can produce results only provided that the nitrogen has first been purified of oxygen and moisture. The procedure is simple, but less effective than other methods of refining aluminum alloys (see chlorination of aluminum alloys, vacuum-treatment of aluminum alloys).

The effectiveness of nitrogen refining can be increased by simultaneous use of a surface-active flux. Here, a thin layer of the flux is applied to the surface of the metal and then the nitrogen is passed through. The flux adsorbs the film of aluminum oxide on the surface of the metal and promotes more rapid separation of gases and solid inclusions. Combined use of fluxes and nitrogen increases the amounts of gases and solid inclusions eliminated from the metal by approximately 30-40%.

References: Al'tman, M.B., Izgotovleniye alyuminiyevykh splavov povyshennoy chistoty [Preparation of Aluminum Alloys of Increased Pur-

ity], Moscow, 1957; Plavka i lit'ye tsvetnykh metallov i splavov [Melting and Casting Nonferrous Metals and Alloys], edited by A.J. Murphy, translation from the English, Moscow, 1959.

M.B. Al'tman

NITRON - see Polyacrylonitrile Fiber.

NOMINAL STRESS is the ratio of the force to the original section (without account for the section change in the deformation process). It is measured in $kg/mm^2$ or $kg/cm^2$. It is widely used in elasticity theory, plasticity theory, and resistance of materials. With large deformations (plastic in the metals, elastic in the rubbers) the nominal stress becomes an imprecise characteristic. See True Stress.

Ya.B. Fridman

**NONCUMBUSTIBLE LACQUER AND PAINT COATINGS** are paints, finishes which satisfy, in contrast with the fireproof lacquer and paint coatings (see Fireproof Lacquer and Paint Coatings), only the requirement of noncombustibility of the coating, and do not have fireproofing properties.

S.I. Taubkin

NONFLAMMABLE WATER-RESISTANT FACING MATERIALS (ANAM- ANZM- ANKM- AZT- AVZH- ANChM) are fabrics made from natural or synthetic fiber with a nitrate elastic coating applied to one side in the form of a film containing an antipyrene to make the coating nonflammable. Nonflammable materials are used as a facing layer for thermal insulation of various designs and products in order to protect them from combustion, water absorption and mechanical damage. Most widely used is the light weight AZT nonflammable material with body of light Kapron fabric. For the facing layer at thermal insulation of piping, instruments and parts, use is made of the ANChM material with nonflammable nitrocellulose coating applied on cotton moleskin fabric with a fireproof impregnant. The compression of the thermal insulation during application of the nonflammable material to the piping must be minimal, since reduction of the thickness of the insulating layer decreases its thermal insulating properties. The most waterproof of the nonflammable materials is AVZM with body made from cotton canvas impregnated with a waterproofing layer which has been subjected to a waterproofing impregnation; it is used to protect the facing from moisture absorption and intense mechanical action. The basic physical and mechanical properties of the nonflammable materials for facing applications are presented in the table.

All the nonflammable facing materials of the grades mentioned with a nitrocellulose-base coating containing an antipyrene are used at temperatures from -50 to 100°. At temperatures above 100° the plasticizer separates from the coating, it becomes stiff and subject to failure from mechanical action. Bending of a nonflammable material through 180°

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## Physical and Mechanical Properties of Nonflammable Material

| 1 Марка | 2 Тканевый каркас | 3 Цвет покрытия | 4 Ширина (см) | 5 Толщина (мм) | 6 Вес 1 м² (г) | 7 Прочность на разрыв (кг/50 мм) | | 8 Удлинение при разрыве (%) | | 9 Прочность на раздир (кг) | | 10 Горючесть | 11 Водоупорность, мм водн. столба |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 12 основа | 13 уток | 12 основа | 13 уток | 12 основа | 13 уток | | |
| 14 АНАМ<br>18 АНЗМ | Перкаль 15 А85 артикула 4233 с огнезащитной пропиткой (ТУ 69-53) | 16 Алюминиевый<br>Зеленый 19 | >74.5 | 0.21 | 200±10 | >40 | >27 | 5.5 | 26.8 | 0.91 | 1.0 | Не горит и не тлеет 17 | 900—1000 |
| 20 АНКМ | | Кремовый 21 | >73.5 | 0.21 | 235±15 | — | — | — | — | — | — | — | — |
| 22 АНЧМ | Молескин артикула 396 23с огнезащитной пропиткой (ТУ 30499-48) | Коричневый 24 | 70.0 | 0.59 | 350—385 | 38 | 50 | 4.5 | 26.0 | 1.5 | 2.5 | Не горит 25 | — |
| 26 АЗТ | 27 Капроновая ткань артикула 1916 (ТУ 68-53) | Зеленый 19 | 85.0 | 0.14 | 110—125 | 41 | 32 | 17—35 | 19—38 | 0.98 | 1.0 | 28 Вне пламени горелки плавится, по удалении источника огня не горит | 450—550 |
| 29 АВЗМ | 30 Хл.-бум. башмачная палатка артикула 832, подвергнутая водоупорной пропитке (ТУ 69-53) | Зеленый 19 | >81.5 | 0.71 | 600±15 | 100 | 90 | 15.0 | 14.0 | 5.0 | 4.3 | Горит медленно, тлеет 31 | Свыше 1000 32 |

1) Type; 2) fabric body; 3) coating color; 4) width (cm); 5) thickness (mm); 6) weight per $m^2$ (g); 7) breaking strength (kg/50 mm); 8) breaking elongation (%); 9) tear strength (kg); 10) combustibiltiy; 11) water resistance, mm $H_2O$; 12) warp; 13) fill; 14) ANAM; 15) percale A85 grade 4233 with fireproof impregnation (TU 69-53); 16) aluminum; 17) does not burn or smolder; 18) ANZM; 19) green; 20) ANKM; 21) cream; 22) ANChM; 23) moleskin grade 396 with fireproof impregnation (TU 30499-48); 24) brown; 25) does not burn; 26) AZT; 27) Kapron fabric grade 1516 (TU 68-53); 28) melts beyond burner flame, does not burn when source of fire is removed; 29) AVZM; 30) cotton footwear canvas grade 832 subjected to waterproof impregnation (TU 69-53); 31) burns slowly, smolders; 32) over.

at -50° does not affect its physical and mechanical properties. Attachment of the nonflammable material to the thermal insulation is accomplished by stitching along the insulation contour or by bonding.

L.A. Yaseneva

NONFOULING PAINTS are complex compositions used for the prevention of fouling by marine organisms of ship hulls, hydro-technical structures, instruments and other objects and products used in sea water. The composition of the nonfouling paints includes the film-forming materials, solvents, pigments, and also specially added poisonous substances or toxins. The pigments and toxins are dispersed in the medium of the film-forming materials (using ball mills).

The action of the nonfouling paints is based on the leaching of the toxic materials by the sea water. In the layer of sea water adjacent to the surface painted with the nonfouling paints there is created a high concentration of the toxic substances and the larvae of the marine organisms which enter this layer die from poisoning. Thus, the effectiveness of the nonfouling paint is associated not only with the absolute content of the toxic substances in the composition, but primarily with the rate of transfer of these substances from the painted surface into the sea water. However, too high a rate of leaching of the toxins can lead to rapid loss of toxicity as a result of depletion of the poisonous substances from the painted surface. The nonfouling paints are divided into three types: 1) paints based on film-forming agents which are not soluble in sea water; 2) paints containing in their composition film-forming agents which are soluble in sea water; 3) plastic or mastic paints. The paints of the 1st type are prepared on the basis of very strong and waterproof film-forming agents, for example, from the copolymers of vinyl chloride, and contain up to 50% toxic substances. The paints of the 2nd type contain the basic film-forming

substance (condensation and polymerization resins, bitumens and so on) and also colophony, which has definite solubility in sea water. The paints of this type contain about 30-50% toxic substances. With dissolution of the colophony in the sea water there are formed pores in the coating film, through which the toxic substances are continously leached out. The paints of the 3rd type contain the usual toxic substances and are prepared on the basis of film-forming agents which have relatively low melting points (wax, colophony, bitumens, etc.). The paints of this type are used without organic solvents. Prior to use they are heated to the melting point and are applied in a thick layer in the hot form (thickness to several mm) on the surface being protected. Compounds of copper, mercury and arsenic are basically used as the toxic substances in the non-fouling paints. The most widely used toxin is cuprous oxide, which has a solubility in sea water of 5.4 mkg/ml with a pH equal to 8.1, which provides for a long-term transfer of the toxin into the sea water in a concentration which is lethal for the fouling organisms. This solubility of cuprous oxide in sea water is achieved after an incubation period which may last as long as three months, depending on the surrounding temperature and the pH of the sea water. During this time severe fouling can develop on surfaces coated with paints containing only a single toxin (cuprous oxide). Therefore, toxins with high solubility (mercuric oxide, certain organic compounds of arsenic, etc.) which begin to be released from the painted surface immediately after immersion in the sea water are added to the composition of the nonfouling paints. As a rule, mixtures of toxins are used in the non-fouling paints, as these give the greatest practical effect. A useful addition to the nonfouling paints has been found to be zinc oxide, which has some toxicity and, in addition, accelerates the leaching out of the cuprous oxide. Soviet industry produces nonfouling paints under

the NIVK label in various colors: NIVK-2 and 2V are green; NIVK-2A and 2G are brown. The protective properties of these paints are limited to 6-9 months. Industry also produces the grades KhV-53, KhS-79, KR-24 and KR-29 which protect against fouling for 1.5-2 years. The nonfouling paints are applied only over a tough anticorrosive coating. With contact of the nonfouling paint with the substrate metal there may occur severe corrosion as the result of the formation of galvanic pairs. The use of nonfouling paints is the most effective and reliable method of combating fouling. The nonfouling paints play a particularly important role when they are used on ships which operate in warm and tropical waters in which the most varied forms of growth organisms live. In the absence of a reliable nonfouling coating the underwater portion of the ships is covered rapidly with a layer several centimeters thick and the growth density is more than 5 $kg/m^2$. This fouling makes a sharp reduction in the operational performance of the ships; headway speed is lost, fuel consumption goes up, periods between drydocking are shortened, etc.

References: Marine Fouling and its Prevention, transl. from Eng., ed. by V.N. Nikitin and N.I. Tarasov, M., 1957; Ragg M., Protection of Ships from Fouling and Corrosion, transl. from Ger., ed. by Ye.V. Iskr', L., 1960.

A.M. Frosm

**NONMAGNETIC CAST IRON** – is a high-alloy cast iron with an austenitic base of the structure characterized by minimum values of: magnetic permeability, watt losses, and distortion of the magnetic field. Non-magnetic cast iron with a ferritic structure base (aluminum-alloy cast iron) is also used. Depending on the chemical composition, the nonmagnetic cast iron can be subdivided into: manganese, manganese-nickel, nickel-manganese, manganese-copper-aluminum, nickel, and aluminum alloy cast iron.

Nonmagnetic cast iron is used for parts of oil-filled switches, for collectors of rotors and stators, for inner flywheels, windings and bar holders of electrical machines; for parts of welding transformers; for parts of electric magnetos and magnetic separators, and also for various parts of electrical machines, apparatuses and devices. The chemical composition and the properties of nonmagnetic cast iron are listed in Tables 1-2 on page 45.

TABLE 1

Chemical Composition of Nonmagnetic Cast Iron

| Чугун 1 | Сечение отливки (мм) 2 | Содержание элементов (%) 3 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | C | Si | Mn | P | S, не более 4 | Ni | Cu | Al |
| Марганцовистый 5 | 5–10 | 3,5–3,9 | 2,5–3,2 | 7,5–8,5 | 0,3–0,7 | 0,07 | – | 1,5–2,8 | 0,1–0,7 |
| | 12–20 | 3,4–3,8 | 2,4–3,0 | 8,0–9,5 | 0,3–0,7 | 0,07 | – | 1,5–2,8 | 0,1–0,7 |
| | 20–40 | 3,4–3,8 | 2,4–2,8 | 9,0–10,5 | 0,3–0,7 | 0,07 | – | 1,5–2,8 | 0,1–0,7 |
| | Более 40 | 3,2–3,6 | 2,3–2,7 | 10,5–12,5 | 0,3–0,7 | 0,07 | – | 1,5–2,8 | 0,1–0,7 |
| Марганцовоникелевый 6 | – | 3,5 | 2,0–2,2 | 8–9 | 0,3–0,7 | 0,07 | 4,5 | – | – |
| То же 7 | – | 3 | 2,3–2,5 | 8–9 | 0,3–0,7 | 0,07 | 4,5–5,0 | – | – |
| Никельмарганцовистый 8 | – | 2,7–3,5 | 2,0–3,2 | 5–6 | 0,3–0,7 | 0,07 | ~10 | – | – |
| Марганцовомедноалюминиевый 9 | – | 2,8–3,7 | 3,5–4,5 | 7–16 | 0,3–0,7 | 0,07 | – | ~5 | 4,5 |
| Никелевый 10 | – | 2,5–3 | 1,5–3 | 0,5–1,2 | до 0,3 | до 0,08 | 14–17, 1,5–2,5 Cr | 6–8,5 | – |
| Алюминиевый 11 | – | 1–2 | до 5 | до 1,5 | – | – | – | ~1 | 20–34 |

1) Cast iron; 2) diameter of the casting; 3) percentage of elements; 4) not more than; 5) manganese; 6) manganese-nickel; 7) the same; 8) nickel-manganese; 9) manganese-copper-aluminum; 10) nickel; 11) aluminum; 12) more than; 13) up to.

TABLE 2

Electrical and Magnetic Properties of Nonmagnetic Cast Iron

| Чугун 1 | $\mu_{макс}$ (гс/э) 2 | ρ (микроом·см) 3 |
|---|---|---|
| Марганцовистый 4 | 1,1–2,5 | 130–160 |
| Марганцовоникелевый 5 | 1,1–2,5 | 120–185 |
| Никельмарганцовистый 6 | 1,1–2,5 | 120–185 |
| Марганцовомедноалюминиевый 7 | 1,1–3,0 | 150–200 |
| Никелевый 8 | 1,02–1,08 | 100–110 |
| Алюминиевый 9 | 1,005–1,008 | 150–200 |

1) Cast iron; 2) $\mu_{maks}$ (gauss/oersted); 3) ρ (microohms·cm); 4) manganese; 5) manganese-nickel; 6) nickel-manganese; 7) manganese-copper-aluminum; 8) nickel; 9) aluminum.

References: Levi, L I., Elektrotekhnicheskoye chugunnoye lit'ye [Cast Iron for Electrical Enginerring] in the book: Spravochnik po mashinostroitel'nym materialam [Handbook on Machine-Building Materials], Vol. 3, Moscow, 1959; Girshovich, N.G., Sostav i svoystva chuguna [Composition and Properties of Cast Iron], in the book: Spravochnik po chugunnomu lit'yu [Handbook on Iron Casting], 2nd Edition, Moscow-Leningrad; 1960; Grilliat, J. and Poirot, R., "Fonderie," 19[illegible], No. 17[illegible], pages 449-460.

A.A. Simkin

NONMAGNETIC MATERIALS are para- and diamagnetic materials with magnetic permeability $\mu \leq 1.5$. Particularly wide usage is made of nonmagnetic steels and rrons, and also alloys of copper and aluminum, less frequent usage is made of polymer materials, which are often not sufficiently strong and thermally stable. The nonferrous alloys are easily machined and pressure worked, have adequate corrosion resistance. but their mechanical properties are not always satisfactory. Because of their low electrical resistance they have high eddy-current power losses. The bronzes are relatively expensive and scarce. The brasses are often magnetic due to iron impurities. In machine construction, instrument and equipment construction, use is made of the nonmagnetic steels and irons with austenitic structure, which are sufficiently strong and are stainless with high Ni content or the addition of 14-18% Cr.

The austenitic structure and paramagnetism of steel and iron are achieved by the introduction of Ni and Mn separately or together. At normal operating temperatures the resulting austenite is very stable. With extended heating above 500-600° the austenite decomposes in connection with carbidization, facilitating the $\gamma \rightarrow \alpha$-transformation during severe cooling and deformation. The N24Kh2(1) (see table) steel is completely nonmagnetic with water quench from 600°. Its deficiencies a are: increase of the magnetic permeability at negative temperatures and during strain hardening as a result of martensitic transformation, and also its expense resulting from the high nickel content; it is used infrequently. The primary wat to reduce the costs of the nonmagnetic

steels is partial or complete replacement of the nickel by manganese. These steels frequently have more stable austenite. The purely manganese steels are infrequently used because of the difficulty of machining and high brittleness. More often use is made of the more complex-alloyed austenitic steels produced in the form of sheet, wire and strip, most of which after tempering or normalization may be subjected to cold rolling or drawing. Materials 2-6 (see table) are recommended for parts requiring high mechanical strength. Materials 1 and 7-9 have the highest corrosion resistance. The dispersion hardening K40NKhM (8) alloys or the EI702 (9) alloy are recommended for nonmagnetic elastic elements which require high elastic properties in corrosive media at normal and elevated temperatures. For parts of complex configuration requiring high strength, use may be made of the cheaper nonmagnetic irons, whose electrical resistance (1.4-2.0 ohm-$mm^2$/m), as a rule, is higher than that of the nonmagnetic steels and nonferrous alloys. Most widely used are the nickel-manganese irons (10) which machine well and are characterized by low hardness over a wide range of casting thicknesses (HB 130-180). Replacement of the nickel by Mn reduce the cost of the iron. But with high manganese content the carbides precipitate out, the hardness increases and machining becomes difficult. Therefore, along with the increase of the Mn content there is an increase of the amount of Si to aid graphitizing, i.e., softening the iron and improving the casting properties. In thick castings slow cooling may lead to decomposition of the austenite. Therefore with increase of wall thickness the Mn content is increased and the amount of Si is reduced. Recently the nonmagnetic irons have been modified with Mg, which increases their strength by about a factor of 1.5. In connection with the refining action Mg and Mn, these irons are annealed at a temperature of about 950°. The nonmagnetic materials are used to fabricate inserts and

II-20N2

flanges, shrouds, tension bolts, nonmagnetic springs, compass housings, parts for periscopes and instruments for submarines, metallic distribution panels, bimetallic thermometers, etc.

Composition, Properties and Application of Some Nonmagnetic Steels and Irons

| № п.п | Марка по ГОСТ | Содержание (%) | | | | | Термич. и мех. обработка* | Магнитная пр. при напр. поля H = 1000 э (гс/э) | Уд. электр. сопр. (ом·мм²/м) | Предел текуч. (кг/мм²) | Предел прочн. (кг/мм²) | Относ. удлинение (%) | Применение |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | Mn | Ni | Cr | прочие | | | | | | | |
| 1 | Н24Х2 | 0.2–0.3 | 0.5–1.3 | 23–25 | 2–3 | – | | | | | | | |
| 2 | 30Г18Х | 0.25–0.35 | 18–19 | – | 1 | – | | | | | | | |
| 3 | 30Г18СД | 0.35–0.50 | 17.5–21.5 | – | – | 1.0–1.5 Si<br>1.0–1.5 Cu | | | | | | | |
| 4 | ЭИ629 | 0.15–0.25 | 6.0–7.0 | 10.0–13.0 | 11.0–15.0 | – | | | | | | | – |
| 5 | ЭИ269 | 0.5–0.6 | 4.0–5.5 | 18.5–21.5 | 0.25 | – | | | | | | | |
| 6 | 6ЧН8Г9Х4В | 0.55–0.65 | 7.5–8.6 | 8–9 | 3.8–4.2 | 0.5–0.7 V | | | | | | | – |
| 7 | 2Х18Н9Т | 0.14–0.26 | 0.3–0.7 | 10–11 | 17–19 | <1.0 Ti | | | | | | | |
| 8 | Н40НХМ | 0.07–0.12 | 2.0 | 35 | 20 | 3.0–3.5 Mo | | | | | | | |
| 9 | ЭИ702 (36НХТ) | ≤0.05 | 0.8–1.3 | 34.5–36.5 | 11.5–13 | <1.1 Ti<br><1.1 Al | | | | | | | |
| 10 | никель | 2.6–3.2 | 5–7.5 | 9–12 | До 1.1 P | 2.5–3.5 Si | – | 1.03 | 1.40 | 130–180 | В соответствии с требованиями ГОСТ | | – |
| 11 | марганцевые чугуны | 3.2 | 7.5 | 15 | – | 3.2 | – | 1.08 | 1.40 | 130–170 | | | – |
| 12 | | 3.5 | 8–9 | 4–5 | – | 2.2 | – | 1.5 | | 150–160 | СЧ12-28 | – | – |
| 13 | | 3.4–3.9 | 6.8–7.5 | – | – | 2.6–3.1 | – | 1.5 | 1.5–2 | 120–200 | СЧ15-32 | – | – |
| 14 | марганцевые не магнитные чугуны | 3.4–3.9 | 8.1–9.5 | – | 1.5–2 Cu | 2.6–3.0 | – | 1.5 | 1.5–2 | 120–200 | СЧ15-32 | – | – |
| 15 | | 3.4–3.9 | 10–12 | – | 0.4–0.6 Al | 2.4–2.8 | – | 1.5 | 1.5–2 | 120–200 | СЧ15-32 | – | – |
| 16 | | 2.4–2.8 | 10 | – | 1–1.5 Cu<br>2 Al | 1.0–1.5 | – | 1.5 | 1.5–2 | 120–200 | СЧ15-32 | – | – |
| 17 | кремнистый | 1–2 | ≤1.5 | – | 3.5–4.5<br>2.5 Al | ≤5 | – | 1.005–1.008 | 1.8–2.0 | – | – | – | – |
| 18 | Mn–Cu–Al | 2.8–3.7 | 7–16 | – | ≤3 Cu<br>≤3.5 Al | 3.5–4.5 | – | 1.01–1.0 | 1.5–2 | – | – | – | – |

*Works well with C ≤ 0.25–0.3; also used in cold-deformed form. Strain hardening increases magnetic permeability.

**Magnetic permeability is not increased with strain hardening, corrosion resistance is lower than for 25% nickel steel. Retains ductility at negative temperatures to -180°.

1) No in sequence; 2) GOST grade; 3) content (%); 4) thermal and mechanical treatment*; 5) magnetic permeability with H 1000 oersted (gauss/oersted); 6) resistivity, ohm-mm²/m; 8) ultimate tensile strength, kg/mm2; 9) percent elongation at failure, %; 10) application; 11) N24Kh2; 12) tempering at 600-800° or normalization; 13) compass housings, periscope parts, machinery and equipment chassis*; 14) 30G18Kh;

15) forged condition; quenched from 1000°; same + cold deformation to 18%; 16 where required for high mechanical properties: shafts, windings for electrical machines**; 17)50G18SD; 18) normalization from 850° + cold drawing to 60% reduction; 19) wire and strip for windings and springs; 20) EI429; 21) normalization + cold rolling (drawing); 22) EI269; 23) normalization or quenching from 1000° + cold drawing; 24) primarily wire; 25) 6CN8G9Kh4V; 26) 2Kh18N9T; 27) normalization or quench from 1100° + cold drawing; 28) parts with high corrosion resistance; 28') K40NKhM; 29) quench from 1100° + cold drawing + tempering at 350-500°: 30) winding springs for clockwork mechanisms, core supports, elastic elements operating in agressive media at normal and elevated temperatures; 31) EI702 (36NKhT); 32) quench from 960-980° + tempering at 650-670° for 204 hours; 33) elastic sensitive elements and other parts operating in nitric acid and certain other aggressive media at normal and elevated temperatures; 34) parts with wall thickness; 35) nickel-; 36) to; 37) in accordance with GOST requirements; 38) manganese irons; 39) SCh; 40 manganese nonmagnetic irons; 41) aluminum.

References: Zaymovskiy A.S. and Chudnovskaya L.A., Magnitnyye materialy (Magnetic Materials), 3rd edition, Moscow-Leningrad, 1957 (Metally i splavy v elektrotekhnike, t. 1) (Metals and Alloys in Electrical Engineering, Vol. 1); Spravochnik po mashinostroitel'nym materialam (Handbook on Machine Construction Materials), Moscow, 1959, Vol. 1, pages 778-782; Vol. 3, pages 354-358; Pretsizionnyye splavy (Precision Alloys), Moscow, 1959 (collection of works of the Central Scientific Research Institute for Ferrous Metals, No. 22); Dovgalevskiy Ya.M., Chuguny s osobymi svoystvami (Irons with Special Properties), Moscow, 1957.

Sh.Ya. Korovskiy

NONMETALLIC INCLUSIONS IN ALUMINUM ALLOYS are internal defects of cast and wrought mill products associated with the contamination of the metal by oxides and gases (primarily hydrogen). In the wrought mill products the solid nonmetallic inclusions are by convention divided into oxide films (OF) and slag inclusions (SI). Superficially they are differentiated by the color, shape and dimensions of the inclusions.

The oxide films (OF) are inclusions of oxides of the base and alloying metals which lead to the appearance of internal defects in wrought mill products in the form of lines on macrosections and raised of differing extent, and which have a color from gray-yellow to dark-yellow in the fracture. In the cast material the OF do not have any obvious orientation and are comparatively rarely detected in inspection of macrosections and fractures of castings. After deformation the oxide films are arranged in the direction of flow of the metal and amy cause the formation of local discontinuities in the metal (delaminations) which sometimes show up during mechanical working of parts. With increase of directed deformation of the metal, the magnitude of the discontinuities in the metal resulting from the presence of OF increases, which is associated with breaking up (fractionation) and formation of delaminations in the locations of the films in the course of deformation. The OF do not reduce the mechanical properties of the mill products along and across the fiber. However the properties are markedly reduced through the thickness of the mill products (along the normal to the film). OF may reduce the fatigue strength of the metal; for example, in specimens of the D16 alloy OF reduce the fatigue characteristics of

the material by 20-30%. The most probable dimensions of the OF are in the range of 0.3-1.5 $mm^2$, in individual very rare cases the area of the OF may reach tens of $mm^2$. The admissibility of OF is determined by the magnitude and nature of the working stresses and is established by full scale tests of the parts. OF are not permitted on the surfaces of finished articles operating under conditions of transient loads. Recognition of defects on surfaces of parts is aided by anodizing. In production conditions monitoring for the presence of OF is accomplished by selective study of individual mill products from a lot with regard to macrostructure and fracture in the film plane and by ultrasonic defectscopy. The ability to detect OF by ultrasonic testing depends on the size and nature of the defect, and also on the configuration of the mill products or parts (see Ultrasonic Defectoscopy).

The OF have differing composition, structure, and color depending on the chemical composition of the alloy. In aluminum alloys with magnesium content to 1% the OF consist basically of $Al_2O_3$, with magnesium content of more than 1.5% the OF consists of MgO and complex oxides of the spinel type ($mAl_2O_3 \cdot nMgO$). Introduction of beryllium into the aluminum alloys leads to change of the OF composition as a result of the formation of beryllium oxides mentioned above varies in the range of 3.65-4.05 $g/cm^3$, therefore the OF precipitate in the liquid metal. However the presence of adsorbed gas on the surfaces of the oxide films hinders their precipitation during the metal settling process. The primary source of metal contamination by OF is oxidation of the metal during melting in reverberatory furnaces as a result of the marked increase of metal surface area (formation of a large number of drops) as it is melted. Another way for the OF to occur is associated with open pouring of liquid metal which is accompanied by fracture of the surface OF and their increase in the solidifying metal.

The primary factors in the technology for producing metal with low OF contamination involve the use of electrical distributing furnaces (mixers), covered pouring of the liquid metal in all operations (through pipes), refining with chlorine or fluxes, vacuum treatment (see Vacuum Processing of Aluminum Alloys), settling after refining, use of raised tap holes and continuous filtering during pouring of the metal from the mixer into the crystallizer.

Slag inclusions (SI) are particles of products of the interaction of the molten metal with the lining and atmosphere of the furnace, and with fluxes IS are present in the mill products and parts in compct form. The major portion of the SI is brittle and breaks up during metal deformation. With unfavorable location of the SI in the metal, they may serve as foci for fatigue cracks. Inspection of the metal for SI is accomplished by studying the macrostructure of cast ingots and wrought mill products and by ultrasonic defectoscopy. Just as for the OF, the amount of SI allowed is determined by the magnitude and nature of the working stresses in the parts and is established by full scale tests of the parts in question. Modern inspection methods make it possible to detect inclusions with diametral dimensions of more than 0.8-1.0 mm in parts. To reduce metal contamination it is advisable during preparation of the alloys to use a lining made from refractory materials which do not interact with the molten metal.

Delaminations are local discontinuities in wrought products made from the aluminum alloys. Delaminations are caused by the presence in the metal of oxide films with gases adsorbed on their surfaces. Another cause of delaminations are the local fractures of the metal caused by severe and nonuniform deformation. The most probable sizes for these defects are in the range from 1 to 20 $mm^2$, in individual rare cases the area of the delaminations may reach hundreds of $mm^2$. As a rule, delami-

nations have an elongated form in the direction of metal flow during deformation. Inspection methods used are similar to those for the OF.

References: Metallurgicheskiye osnovy lit'ya legkikh splavov (metallurgical Fundamentals of Casting Light Alloys), collection of articles, Moscow, 1957; Alyuminiyevyye splavy (Aluminum Alloys), collection of articles. Moscow, 1955; Dobatkin V.I., Slitki Aluuminiyevykh splavov (Aluminum Alloy Ingots), Sverdlovsk, 1960.

V.A. Zasypkin, A.Ye. Semenov

**NONMETALLIC INCLUSIONS IN STEEL** are inclusions which are observed in the structure of solidified steel and which are primarily oxide, sulfuric, and nitride compounds with the elements present in the metal, or with elements present in the composition of the form with which the liquid metal is in contact.

Nonmetallic inclusions in steel, being generally quite brittle and weak, may reduce the mechanical properties of the steel. Large inclusions sometimes serve as a focus for the formation of cracks, particularly with operation of parts under conditions of repeated stresses or in the case of high thermal and structural stresses. Nonmetallic inclusions in steel also lead to nonuniform separation of the structural components. Studies of recent years have shown that the scaly structure in steel fracture, leading to severe anisotropy of properties, is associated with considerable contamination of the metal with nonmetallic inclusions. These inclusions destroy the continuity and act as stress concentrators. The harmful effect is particularly marked with repeated heating and cooling, when the inclusions become foci for the generation of cracks. On the basis of the conditions for the occurrence and the presence of nonmetallic inclusions in steel, they are divided into four groups: 1) products of deoxidation of the liquid metal (manganous oxide, alumina, titanium oxide, and with poor deoxidation – ferrous oxide, chromium oxides, etc.). These oxides may be found in complex compounds, both among themselves and with the slag-forming materials: 2) particles of refractory materials as a result of the liquid metal eroding the furnace lining, troughs, ladles, headers, etc.; 3) par-

ticles of slag ($mFeO \cdot nSiO_2$ or $mFeO \cdot nCaO$ and others) and sulfur compounds (FeS, MnS), picked up by the liquid metal during pouring from the furnace; 4) products of the reactions taking place with diffusion of various gases in the metal (aluminum or titanium nitrides).

The effect of nonmetallic inclusions in steel on the variation of the mechanical and other properties depends primarily on the melting point and the capability of the grains of the basic metal for wetting, and also on the over-all amount of nonmetallic inclusions and their properties. If the nonmetallic inclusions do not wet the grains of the base metal or are refractory in nature, then they have a rounded form and are most often located within the grains; they cause only slight deterioration of the steel mechanical properties. However, if the nonmetallic inclusions in steel are low melting and at the same time have the capability of wetting the grains of the base metal, then prior to solidification they will flow along the grain boundaries and will form brittle film which separate the grains; in this case there will be considerable deterioration of the mechanical properties of the steel. The nonmetallic inclusions in steel which are concentrated in the outer layers of a part, where the maximal bending and torsional stresses act, are more critical than those found in the deeper zones. Particularly harmful are the nonmetallic inclusions in steel in the case of the action of external forces across the fibers; reduction of the strength (particularly fatigue strength) along the fibers is noted only in the presence of extremely brittle inclusions. In the production of certain grades of quality and high-quality steels, the amount of nonmetallic inclusions in the steel is covered by specifications; for this purpose there is a standard five-number scale consisting of a set of characteristic structures observed under the microscope on unetched slides with 100-fold enlargement.

Determination of the amount of nonmetallic inclusions in steel is made on longitudinal sections which are prepared on specimens equal to a circle or 1/4 circle for blanks of thickness greater than 50 mm, and equal to 1/2 circle for blanks of thickness less than 50 mm. Specimen length in the direction of the fiber is usually 10-12 mm.

The evaluation is made by comparing the worst location on the section with a reference rating scale which is made up for the different forms of inclusions: silicates, oxides, sulfides, etc. The steel melt is characteized either by the highest rating from several specimens, or by the arithmetic mean of several specimens, each of which is evaluated by the highest maximal rating number.

For several grades of steel, ball bearing, for example, purity with respect to nonmetallic inclusions in the steel is one of the primary factors determining the operational life of the products; in this case special more rigid standards are used.

The methods of combating nonmetallic inclusions in steel are defined by creating conditions which reduce the possibility of the occurrence of the inclusions in the metal. Thus, good deoxidation, complete melting of the additives, and adequate time of the metal in the furnace reduce the amount of nonmetallic inclusions of the first group, careful preparation of the furnace, ladle, and headers and good quality refractories reduce the amount of inclusions of the second group. Adequate fluidity of the metal and slag and proper slag composition improve the metal purity with regard to the inclusions of the third group. Adequate time of the metal in the furnace and in the ladle prior to pouring is one of the methods of reducing the amount of inclusions of the fourth group. Particularly effective is vacuum treatment of the liquid metal before pouring.

I.N. Kidin, M.L. Bernshteyn

NONSPARKING – see Arc-Resistance.

NONWOVEN MATERIALS are textile materials made from natural, artificial, and synthetic fibers which are produced without the use of the spinning and weaving processes. The production of the nonwoven materials is accomplished by: stitching fibrous fabric with yarn (the knit-stitch method); sizing fibrous fabric with binding materials (adhesive method); felting the fibrous mass. The fibers are arranged in the fabric: in the transverse direction with respect to the length of the fabric; criss-cross (in the lower and upper layers of the fabric the fibers are arranged in the transverse direction, and in the middle layer they are in the longitudinal direction); randomly. The technological cycle for the production of the nonwoven materials is shortened from 11-12 to 4-5 steps. In fabrication of the nonwoven materials by the knit-stitch method the machinery productivity is increased by 10-12 times, and in the adhesive method it is increased by 60-70 times in comparison with the production of fabric on weaving looms. The labor expenditure is reduced by a factor of from 3 to 10, and the output per unit floor area increases by a factor of 3-4. The nonwoven materials are used for thermal and sound insulation and in the garment industry.

I.A. Sheftel'

NORMALIZATION OF STEEL is a heat treatment process involving heating the steel to 30-50° above the upper critical point $A_{c_3}$, hold at this temperature, and air cooling. Normalization of steel is performed to reduce the grain size which grows with overheating during the time of hot mechanical working, cementation, or welding. Normalization leads to improvement of the mechanical properties, primarily the impact strength. Normalization at a temperature 100-150° above $A_{c_3}$ is sometimes used to correct severely overheated steel (see Overheating of Steel). Normalization of low-carbon and medium-carbon unalloyed and low-alloy constructional steel is also performed to improve the mechanical workability. In many cases normalization of steel is a preparatory operation readying the structure for subsequent quenching. The medium-alloy and high-alloy constructional steels, and also martensitic stainless steel, which have been heated above the critical range and air cooled are subjected in this case to partial or full tempering. Many high-alloy constructional steels and all the martensitic stainless steels are subjected to full tempering during normalization.

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

Ya.M. Potak

NORMAL STRESS is the ratio of the force component acting perpendicular to a given section to the area of this section. It is measured in $kg/mm^2$ or $kg/cm^2$; depending on the sign, we differentiate compressive and tensile normal stresses. The latter play a decisive role in the processes of brittle fracture. If only normal stresses act on the areas (without tangential stresses) then the three-dimensional (triaxial) stress state may be characterized by three quantities, for example, in a cylindrical bar by the axial, circumferential and radial stresses.

Ya.B. Fridman

NOTCH is a sharp variation of the cross section of a body being deformed which causes concentration (nonuniformity) of the deformations and stresses near the "peak" of the notch. The majority of cracks begin near notches. Examples of notches are: bolt threads, openings, chamfers, keyways, initial cracks, scratches, etc. The presence of a notch can alter sharply the mechanical characteristics of a body (see Notch Sensitivity, Stress Concentrator).

Ya.B. Fridman

NOTCH SENSITIVITY – is the effect of a notch on the strength and other mechanical properties of a material. It is usually evaluated on the basis of the relative change of the mechanical properties of notched specimens in comparison with those of nonnotched ones. The notch sensitivity manifests itself differently under impact, short-time, static long-time, and alternating loads (see Fatigue). Notch sensitivity with regard to strength, deformation and energy are distinguished. Notches generally exert a harmful effect because they tend to reduce strength, plasticity and toughness. An absence of notch sensitivity is also possible, e.g., the notched specimen of a plastic material usually has a higher strength than that of a smooth specimen having the same minimum cross section, when the plastic material is submitted to a static stretching. The type of the load (stretching, bending, skewing stretch, etc.) has a higher effect on the properties of notched than of smooth specimens, and influences, therefore the notch sensitivity. In practice, a large part of units and constructions have notches, and therefore, a reduction of the notch sensitivity is a primary method in obtaining objects with a high strength. Such a reduction is attainable in the case of impact and static loads by the formation of softened zones (by a local high-frequency tempering, etc.) near to the vertices of the notches, and by generation of residual compressive stresses on the surface (by cold hardening, nitridizing, carburizing, etc., of the surface) in the case of alternating loads. The notch sensitivity may also be reduced by construction measures, for example, by application of relieving notches (see Relieving notch), by increasing the radius of

the curvature in the vertex of the notch, etc.

Ya.B. Fridman

NOVOLAC – see Phenol Plastics.

NYLON 6 is a synthetic heterochain fiber of the kapron type. It is obtained from polyamide – a product of caprolactam polymerization. It is produced in the USA, England in the form of ordinary and high-strength filamentary thread, staple fiber, monofiber, bristle; it is termed kapron in the USSR, silon in Czechoslovakia, perlon in East and West Germany, stilon in Poland, etkalon in Holland.

For details of properties and uses see Kapron and Polyamide Fiber.

Physicochemical and Mechanical Properties of Nylon 6

| Свойства 1 | Филаментная нить 2 | | Штапельное волокно 3 |
|---|---|---|---|
| | обычная 4 | высокопрочная 5 | |
| 6 Влагосодержание (%): | | | |
| 8 при стандартных условиях 7 | 4–5 | 4–5 | 4–5 |
| при 95% относит. влажности | 6,5–8,5 | 6,5–8,5 | 6,5–8,5 |
| Разрывная длина (км) 9 | 41–52 | 61–77 | 34–50 |
| 10 Потери прочности (%): | | | |
| 11 в мокром состоянии | 8,6–4,4 | 20,6–12,8 | – |
| 13 в петле 12 | 15,6–6,9 | 18,6 | – |
| в узле | 15,6–8,6 | 29–10,3 | – |
| 15 Временное сопротивление разрыву (кг/мм²) 14 | 41–52 | 77–88 | 30–56 |
| Удлинение (%): | | | |
| в сухом состоянии 16 | 24–40 | 16–18 | 37–50 |
| в мокром состоянии 17 | 28–42 | 19–24 | 42–46 |
| Упругое восстановление (%) 18 | 100 | 92–94 | 92–94 |
| Модуль упругости (кг/мм²) 19 | 230–240 | 490–500 | 175–205 |

1) Property; 2) filament; 3) staple fiber; 4) ordinary; 5) high-strength; 6) moisture content (%); 7) under std. conditions; 8) at 95% relative humidity; 9) breaking length; 10) strength loss (%); 11) in wet state; 12) in loop; 13) in knot; 14) short-term tensile strength ($kg/mm^2$; 15) elongation (%); 16) dry; 17) wet; 18) elastic recovery (%); 19) elastic modulus ($kg/mm^2$).

E.M. Ayzenshteyn

NYLON 66 is a synthetic heterochain fiber which is the product of polycondensation of AG salt (hexamethylenediamine and adipic acid). It is produced in the USA, England, Italy, France, in the USSR (anid), in East and West Germany (perlon T) in the form of filamentary thread, staple fiber, monofiber of various thickness. It is produced in the form of fiber which is shiny or dull and may be tinted various colors. Properties of nylon 66 are: specific weight 1.14, moisture content (at standard conditions) 4.5 percent, at 95% relative humidity 8%; surface heat of wetting $7.6 \cdot 10^{-4}$ cal/cm$^2$; softening temperature 235°; $t_{pl}$ 250°; zero-strength temperature 240°; initial plastic flow temperature 220°; cold resistance -70°; optimal temperature for fixation using dry heat 225°, saturated steam 130°, water 98°; maximal temperature for ironing 180°, processing 128°, washing 60-90°; heat content 0.4 cal/g-°C; thermal conductivity $6.6 \cdot 10^{-4}$ cal/sec-°C; coefficient of linear expansion (per 1°) $4.9 \cdot 10^{-5}$; initial temperature for cracking 60°. Resistance to thermal aging (at 100° for 7 days): relative breaking strength 95%; elongation 110%; at 200° for 2 hour figures are respectively 27% and 54%. Resistance to thermal and sunlight aging of matte fiber is lower than for shiny fiber (with introduction of 5% matte material the breaking strength is reduced by 50%). Dielectric permeability at 60 and $10^6$ Hz is respectively 4.1 and 3.4: tangent of dielectric loss angle under these conditions is 0.014 and 0.04; volume resistivity $4.5 \cdot 10^{13}$ ohm-cm; electrical strength 15.6 kv/mm; strength is lost with temperature increase (65 km at 40° and 48 km at 120°), destruction of the fiber takes place at 200° – reduction of the breaking load by 80% after 2 hours –

at 100° the destruction is slight (3% after 2 hours, about 4% after 20 hours). It is noncombustible, melts in a flame. After irradiation by ultraviolet rays with wavelength less than 300 Å for 24 hours, 23% of the strength and 25% of the elongation are lost. Resistance to sunlight increase with introduction of magnesium, chromium and other salts into the fiber. It is stable in concentrated and hot alkali solutions; does not dissolve in carbon tetrachloride, acetone, benzene, dichlorethane and other organic solvents; decomposes in 5-percent HCl with boiling; dissolves, partially decomposing, in cold concentrated solutions of HCl, $H_2SO_4$, $HNO_3$; dissolves in m-cresol and in other compounds of the phenol type, and also in concentrated formic acid; attacked by hypochlorite and peroxide, bleached by sodium chlorite; is colored well using acidic, basic and scetate pigments, less well by the azo- and vat dyes. It is resistant to the action of microorganisms, fungus and moths; breaking length of the filamentary fiber is: ordinary 41-53 km, high-strength 65-80 km, staple 36-60 km (numbers in parentheses for the following characteristics correspond respectively to ordinary and high-strength filamentary fiber and then to the staple fiber); strength loss (in %): in wet condition 13-12 (13-14, 13-15), looped 15-14 (15-17, 17-18), knotted 15-14 (15-17, 17-18); breaking stress 47-60 kg/mm$^2$ (70-90, 41-70); elongation: under normal conditions 32-26% (28-16, 42-16), in the wet condition37-30% (32-18, 46-18); elasticity (at 8-10% elongation) for all forms of the fibers is 100%, modulus of elasticity is 185 kg/mm$^2$ 360, 100-400), initial modulus (1%) is 4 kg/mm$^2$ (8, 2). Nylon 66 has a circular cross section and smooth surface, is characterized by high resistance ot wear, therefore is often used together with cotton, wool, viscose, staple fiber, etc. In the moist condition the wear resistance diminishes by a factor of 2-2.5. Nylon 66 is more thermally stable than kapron, but is marked by lower colorability and lower re-

sistance to repeated deformation. Areas of application. Engineering uses: filamentary thread for tire cord, filter fabric, typewriter ribbons, cables, electrical insulation materials, parachute shroud lines, etc.; monofiber and bristle for milling sieves, superflexible sleeves, fish netting, paint brushes, etc.; staple fiber for filter fabrics, sp special work clothing, tents, sails, etc.

References: Floyd D.E., Polyamides, translated from English, Moscow, 1960; Klare G., Chemistry and Technology of Polyamide Fibers, translated from German, Moscow, 1956; Synthetic Polymer Fiber, edited by R. Hill, translated from English, Moscow, 1957.

Ye.M. Ayzenshteyn

NYLON 610 is a synthetic heterochain fiber. It is obtained from polyamide – a product of polycondensation of hexamethylene diamine and sebacic acid. The melting point of nylon 610 (215°) and the moisture absorption at standard conditions (1.6%) are lower than for nylon 66. The stiffness indices and the other mechanical properties under atmospheric conditions are higher than those of nylon 66. Specific weight is 1.09, flow temperature 203°, coefficient of linear thermal expansion 0.19 kcal/m-hr-°C, specific heat 0.4 cal/g-°C, electrical strength in short-time testing is 16.8 kg/mm, electrical resistivity $4.5 \cdot 10^{13}$ o ohm-cm. For properties of nylon 610 see Polyamide Fiber. Nylon 610 is produced in the form of coarse grades of monofiber and bristle, from which brushes, tennis racquet strings, etc. are fabricated.

Reference: Synthetic Polymer Fiber, edited by R. Hill, translated from English, Moscow, 1957.

Ye.M. Ayzenshteyn

OBSIDIAN – see Volcanic glass.

OIL- AND GASOLINE-RESISTANT RUBBER – rubber cable of functioning in various oils, fuels, lubricants, and hydrolic fluids. This material is produced in soft, moderately hard, and hard variants. Soft oil- and gasoline-resistant rubbers have good frost resistance and are used in the manufacture of linings which will function at low compression, flexible piping, diaphragms, and containers; depending on the working pressure and design characteristics, moderately hard and hard rubbers of this type are used to produce valves, gaskets, packing rings, and cups. The higher the working-medium pressure and temperature and the speed at which the rubber moves across the contact surface, the harder and more supportive should be the rubber used. Table 1 shows the physical and mechanical characteristics of oil- and gasoline-resistant rubbers.

TABLE 1

Physical and Mechanical Characteristics of Oil- and Gasoline-Resistant Rubbers

| 1 Тип резины | 2 Предел прочности при разрыве (кг/см²) | 3 Относительное удлинение (%) | 4 Остаточное удлинение (%) | 5 Твердость по ТМ-2 | 6 Условно-равновесный модуль (кг/см²) | 7 Коэфф. старения по прочности при 70° в теч. 144 час. | 8 Температура хрупкости (°С) |
|---|---|---|---|---|---|---|---|
| Мягкие 9 | 120÷40 | 250÷600 | 0÷40 | 35÷60 | 10÷35 | 0,6÷0,7 | −30÷−50 |
| Средней твердости 10 | 160÷40 | 200÷350 | 0÷40 | 55÷75 | 35÷60 | 0,6÷0,8 | −20÷−30 |
| Твердые 11 | 200÷40 | 120÷300 | 0÷30 | 60÷90 | 80÷180 | 0,6÷0,8 | −20÷−50 |

1) Type of rubber; 2) ultimate tensile strength ($kg/cm^2$); 3) relative elongation (%); 4) residual elongation (%); 5) hardness in TM-2 apparatus; 6) short-term equilibrium modulus ($kg/cm^2$); 7) strength coefficient of aging over 144 hr at 170°; 8) embrittlement temperature (°C); 9) soft; 10) moderately hard; 11) hard.

The physical and mechanical properties of an oil- and gasoline-resistant rubber do not, however, determine its resistance to specific aggressive media. The resistance of such a rubber to a given medium is evaluated from its distension (the change in the weight or volume of the specimen or component) and the change in its physical and mechanical characteristics on exposure to the medium at the maximum working temperature. The maximum change in physical and mechanical characteristics and the maximum distension are achieved comparatively rapidly (within three days at 50°) and an equilibrium state sets in, further changes being observed only as a result of "aging," which takes place at a rate that is comparable to that of "aging" in air and depends on the ambient temperature, the formula of the rubber, and the chemical composition of the medium. Distension of an oil- and gasoline-resistant rubber by up to 15% by weight has no material effect on its physical and mechanical characteristics, but further distension causes the rubber to soften, reduces its hardness and short-term equilibrium modulus, and causes its tensile strength and relative elongation to drop markedly. A rubber distended by more than 60% is virtually unusable. Table 2 shows the maximum permissible distension for various rubbers in the most commonly employed media.

A rubber component decreases or increases substantially in volume on distension and in designing support areas for such components it is necessary to take into account the possible change in volume, especially when working with sliding packing components in units with limited frictional forces. Highly distensible rubbers can be employed for packing stationary joints with closed bearing areas; the gap between touching components should be minimal, in order to keep the rubber from flowing into it.

Articles of oil- and gasoline-resistant rubber operate at temper-

atures –40 and +130° (–50 and +200° in some cases). The service life of a component decreases as the temperature rises. Thus, oil- and gasoline-resistant rubbers may retain their elasticity and usefulness in a working medium for 6-10 years at temperatures between –40 and +30°, while at 200° even the most thermostable rubbers lose their elasticity within 2 or 3 days. An increase in the heat resistance of an oil- and gasoline-resistant rubber usually leads to a decrease in its frost resistance. As a result, in each individual case the rubber to be used should be selected on the basis of the requisite operational-temperature range and the design characteristics, purpose, and function of the component.

TABLE 2

Distension of Oil- and Gasoline-Resistant Rubbers in Various Media

| 1 Среда | 2 Температура (°С) | 3 Продолжительность набухания (час.) | 4 Набухание резин (вес. %) на основе каучуков | | |
|---|---|---|---|---|---|
| | | | 5 хлоропренового | 6 нитрильного | 7 фторсодержащего |
| 8 Бензин «Галоша» | 20 | 24 | – | от +10 до –10 | – |
| 9 Бензин «Галоша» + 5% бензола | 20 | 24 | от +20 до +30 | от +10 до –10 | – |
| 10 Бензин «Галоша» + 25% бензола | 20 | 24 | от +40 до +60 | от +30 до –10 | – |
| 11 Керосин тракторный | 20 | 24 | от +10 до +20 | от +5 до –5 | – |
| 12 Масло АМГ-10 | 70 | 24 | от +15 до +5 | от +20 до –13 | – |
| 13 Масло МС | 130 | 24 | от +8 до –15 | от +10 до –30 | – |
| 14 Масло МК | 70 | 24 | – | от –6 до +10 | – |
| 15 Масло ЛМИЗ 36/1 | 200 | 24 | – | – | от +10 до –15 |
| 16 Топливо Т-1 | 20 | 24 | от +20 до +10 | от +5 до –6 | – |

1) Medium; 2) temperature (°C); 3) distension time (hr); 4) distension (% by weight) of rubbers based on the following gum rubbers; 5) chloroprene; 6) nitrile; 7) fluorine-containing; 8) "Galosh" gasoline; 9) "Galosh" gasoline + 5% benzene; 10) "Galosh" gasoline + 25% benzene; 11) tractor kerosene; 12) AMG-10 oil; 13) MS oil; 14) MK oil; 15) LMIZ 36/1 oil; 16) T-1 fuel; 17) from; 18) to.

Oil- and gasoline-resistant rubbers are based on chloroprene, butadienenitrile (SKN-18, SKN-26, SKN-40), and fluorine-containing (SKF, etc.) gums. Chloroprene rubbers are less heat- and oil-resistant, but have better technological characteristics, are easily extruded, calendered, and molded, and can be readily cemented. These characteristics

are especially important in the production of thin-walled articles by cementing.

Rubbers based on butadienenitrile gums are the most widely used. Fluorine-containing rubbers are the least frost-resistant, have lower technological characteristics, and are employed only when increased thermostability is required (for components which must function at 150-200°).

Antiaging agents are added to oil- and gasoline-resistant rubber primarily to facilitate retention of properties during storage in air before exposure to the intended medium. During exposure the antioxident is gradually washed out and the rubber is protected from aging only by the inhibitors in the fuel or oil in question. As a result of the leaching out of antiaging agents, antifreezes, and softeners and their replacement by the fuel or oil a rubber component extracted from the working medium and air-dried becomes brittle, fragile, and susceptible to aging after the fuel or oil has evaporated. In order to prolong the storage and service lives of components fabricated from oil- and gasoline-resistant rubbers it is consequently necessary to try to keep them in continuous contact with the working medium.

L.I. Bichevskaya

OLIGOMERS – see Polymers.

OPOKA (geological) – a hard, highly porous rock consisting primarily of fine (approximately 10 μ) particles of hydrated silica (opal) with an admixture of sand, clay particles, etc. The Moos hardness of light varieties is 3-4, while that of dark varieties ranges up to 5.0; this rock has a bulk weight of 1.04-1.82 $g/cm^3$ and a specific gravity of 2.30-2.55. It is similar in characteristics, composition, and applications to Diatomite and Tripolite, from which it differs in its lower content of silica-armored organisms, its lower silica-particle hydration, its nonwetability in water, and its higher hardness.

P.P. Smolin

OPTICAL DEFECTOSCOPY – a nondestructive method for checking materials and components by optical means that permit detection of defects not visible to the unaided eye. Various optical devices are used, including the MBS-1 and MBS-2 binocular microscopes, the MIM-8 horizontal microscope, the MIM-7 vertical microscope, metallographic microscopes, instruments of the RVP-457 type, inspection cystoscopes of the Ts-13 type (for inspecting the inner surfaces of tubes and holes), etc.

S.I. Kalashnikov

OPTICAL DENSITY – a dimensionless quantity characterizing the extent to which light passing through a layer of material is absorbed. It equals the logarithm to the base ten of the ratio of the intensity of the incident light to the intensity of the transmitted light:

$$D = \lg I_0/I.$$

The concept of optical density is closely related to that of the Light-absorption coefficient $\alpha$. The optical density of a layer of a homogeneous (nondiffusing) substance equals:

$$D = 0{,}434 \cdot \alpha\, l - \lg[(1-R_1)(1-R_2)],$$

where $l$ is the thickness of the layer and $R_1$ and $R_2$ are the reflection coefficients at its boundaries.

L.S. Priss

OPTICAL STRESS COEFFICIENT – a constant relating the difference in the refraction coefficients of tangent and normal rays to the stresses applied to a transparent model. This quantity depends on the characteristics of the material, the wavelength of the light, and the temperature.

This factor is used in the optical-polarization method for determination of mechanical stresses in machine components.

References: Shchegolevskaya, N.A. et al., Raznomodul'nyye opticheski aktivnyye materialy dlya polyarizatsionno-opticheskogo metoda issledovaniya napryazheniy [Optically Active Materials of Varying Modulus for Investigation of Stresses by the Optical-Polarization Method], Izv. Vysshikh uchebnykh zavedeniy. Mashinostroyeniye [News of Higher Educational Institutions, Machine Building], 1958, No. 3-4, page 72.

V.V. Korolev

**ORGANIC GLASS** – a polymer of the methyl ester of methacrylic acid. This material exhibits high transparency with respect to visible and ultraviolet rays, good moldability, high strength, and good dielectric characteristics and oil-, gasoline-, and water-resistance. It is readily machined and glued. It is produced in transparent colorless, transparent colored, and opaque forms (using fillers in the latter case). Organic glass of types SOL (plasticized polymethyl methacrylate) and ST-1 (unplasticized) are produced commercially.

TABLE 1

Optical Characteristics of Organic Glass

| Марка 1 | Оптич. коэффициент напряжения 2 | Оптические искажения (мин): 3 — двоение изображения 4 | 3 — абсолютное оптич. искажение 5 | 6 Светорассеяние (стильбы): исходного стекла 7 | 6 Светорассеяние (стильбы): после испытания на абразивостойкость 8 |
|---|---|---|---|---|---|
| СОЛ 9 | 2.0—2.5 | 2—3 | 3—9 | $0.40 \cdot 10^{-4}$ | $13.5 \cdot 10^{-4}$ |
| СТ-1 10 | 2.0 | 2—3 | 3—9 | $0.25 \cdot 10^{-4}$ | $10.3 \cdot 10^{-4}$ |

1) Type; 2) optical stress coefficient; 3) optical distortion (min); 4) displacement of image; 5) absolute optical distortion; 6) light-scattering (stilbs/phot); 7) initial glass; 8) after testing for abrasion-resistance; 9) SOL; 10) ST-1.

Tables 1, 2, and 4 show the optical characteristics of organic glass.

With respect to chemical structure SOL and ST-1 are high linear polymers, while with respect to structural characteristics they are amorphous polymers with unoriented and oriented structures. Organic glass can be vitreous, highly elastic, or viscous, depending on temperature. It softens on heating and hardens on cooling. In the vitreous

TABLE 2

Index of Refraction of Organic Glass

| Марка 1 | Показатель преломления при температуре (°С) 2 | | | | |
|---|---|---|---|---|---|
| | 21 | 45 | 60 | 75 | 85 |
| СОЛ 3 | 1.492 | 1.488 | 1.486 | 1.483 | 1.481 |
| СТ-1 4 | 1.489 | 1.486 | 1.484 | 1.482 | 1.481 |

1) Type; 2) index of refraction at temperature of (°C); 3) SOL; 4) ST-1.

TABLE 3

Temperature Regions of Various States of Organic Glass

| Марка 1 | Температурные границы состояния (°С) 2 | | |
|---|---|---|---|
| | стеклообразного 3 | высокоэластического 4 | вязкотекучего 5 |
| СОЛ 6 | До 90 | 105—150 | ~175 |
| СТ-1 7 | До 110 | 120—170 | ~185 |

1) Type; 2) temperature limits of state (°C); 3) vitreous; 4) highly elastic; 5) viscous; 6) SOL; 7) ST-1.

state organic glass has the characteristics of a solid (only slight elastic deformation occurs under stress). At elevated temperatures it passes into the highly elastic state: large reversible deformations take place under the action of small forces. After the load is removed deformation disappears at certain temperatures. When the temperature is further raised organic glass passes into the viscous state. When subjected to small forces in this state the polymer undergoes both reversible deformation and irreversible plastic deformation. Figure 1 shows the compressive deformation of SOL and ST-1 as a function of temperature. The specimens were compressed under a stress of 0.5 $kg/cm^2$ for 1 min.

Table 3 shows the temperature regions occupied by the vitreous, highly elastic, and viscous states of organic glass.

Table 5 presents data on the bulk weight, resistance to surface cracking, and distension resistance of organic glass in organic solvents.

ST-1 is more resistant to surface cracking during artificial aging than SOL. Figure 2 shows curves representing the relaxation of stresses in these materials at different temperatures. The softening temperature of SOL is 90-95°, while that of ST-1 is 110-120°.

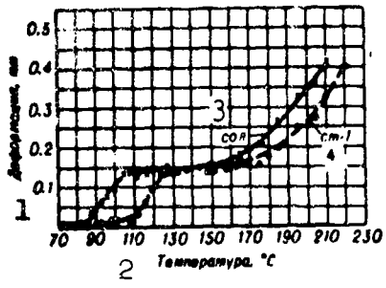



Fig. 1. Compressive deformation of organic glass as a function of temperature. 1) Deformation, mm; 2) temperature, °C; 3) SOL; 4) ST-1.

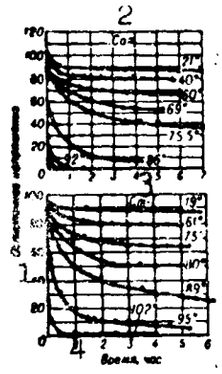



Fig. 2. Curves showing the relaxation of stresses in organic glasses (initial stress – 100 kg/cm$^2$). 1) Residual stress; 2) SOL; 3) ST-1; 4) time, hr.

TABLE 4

Spectral Transmissivity of Organic Glass

| 1 Марка | 2 Области спектра | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 ультрафиолетовая | | 4 видимая | | | | | 5 инфракрасная | | | | | | | | | | |
| | 6 длина волн (мкм) | | | | | | | | | | | | | | | | | |
| | 300 | 320 | 340 | 360 | 380 | 400 | 750 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2200 | 2400 | 2600 | 2800 | 3000 |
| | 7 коэффициент светопропускания (%) | | | | | | | | | | | | | | | | | | |
| 8 СОЛ | 11 | 53 | 76 | 86 | 88 | 89 | 92 | 90 | 90 | 61 | 60 | 70 | 45 | 49 | 7 | 0 | 2 | 12 | 0 |
| 9 СТ-1 | 0 | 0 | 11 | 85 | 89 | 90 | 80 | 92 | 92 | 90 | 80 | 59 | 42 | 49 | 5 | 1 | 8 | 20 | 0 |

1) Type; 2) spectral region; 3) ultraviolet; 4) visible; 5) infrared; 6) wavelength (m μ); 7) pass coefficient (%); 8) SOL; 9) ST-1.

TABLE 5

Characteristics of Organic Glass

| 1 Марка | 2 Объемный вес ($г/см^3$) | 3 Стойкость к поверхностному растрескиванию в условиях искусственного старения * в течение 400 час. (серебрится через час) | 4 Набухание в растворителях за 7 суток (привес, %) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 5 в этиловом спирте | 6 в ацетоне | 7 в дихлорэтане | 8 в дистиллированной воде | 9 в масле | 10 в бензине |
| СОЛ 11 | 1,18 | 50 | 1,35 | 13 Растворяется | | 0,4 | 0 | 0 |
| СТ-1 12 | 1,18 | 70 | 1,15 | 14 То же | | 0,4 | 0 | 0 |

* Ultraviolet light, relative humidity – 90%, temperature – 20°.

1) Type; 2) bulk weight ($g/cm^3$); 3) resistance to surface cracking during artificial aging* for 400 hr (silvering for 1 hr); 4) distension in solvents over 7 days (gain in weight, %); 5) ethyl alcohol; 6) acetone; 7) dichloroethane; 8) distilled water; 9) oil; 10) gasoline; 11) SOL; 12) ST-1; 13) dissolves; 14) the same.

TABLE 6

Thermal Coefficient of Linear Expansion of Organic Glass

| Марка 1 | 2 Коэффициент линейного термич. расширения $\alpha \cdot 10^6$ при температуре (°С) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | –40 | –20 | 0 | 20 | 40 | 60 | 80 | 100 |
| 3 СОЛ | 64 | 63 | 66 | 71 | 86 | 96 | 125 | – |
| 4 СТ-1 | – | – | – | 77 | 82 | 86 | 93 | 111 |

1) Type; 2) coefficient of linear expansion $\alpha \cdot 10^6$ at temperature of (°С); 3) SOL; 4) ST-1.

TABLE 7

Thermophysical Characteristics of Organic Glass

| 1 Марка | 2 Теплопроводность (ккал/м·час·град) | | | | Температуропроводность $a \cdot 10^4$ ($м^2$/час) | | | | 4 Теплоемкость (ккал/кг·град) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 температура (°С) | | | | | | | | | | | |
| | 20 | 50 | 100 | 120 | 20 | 50 | 100 | 120 | 20 | 50 | 100 | 120 |
| СОЛ 6 | – | 0,164 | 0,152 | – | – | 3,82 | 3,00 | – | – | 0,36 | 0,42 | – |
| СТ-1 7 | 0,156 | 0,155 | 0,144 | 0,142 | 3,2 | 3,1 | 2,6 | 2,5 | 0,41 | 0,42 | 0,47 | 0,48 |

1) Type; 2) thermal conductivity (kcal/m·hr·degree); 3) temperature conductivity $\alpha \cdot 10^4$ ($m^2$/hr); 4) heat capacity (kcal/kg·degree); 5) temperature (°С); 6) SOL; 7) ST-1.

TABLE 8

Physicomechanical Characteristics of Organic Glass

| Свойства (1) | СОЛ (2) | | | | СТ-1 (3) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | температура (°С) (4) | | | | | | | | |
| | −60 | 20 | 60 | 80 | −60 | 20 | 60 | 80 | 100 |
| Предел прочности (кг/см²): (5) | | | | | | | | | |
| при растяжении (6) | 1 120 | 710 | 410 | 150* | 1135 | 780 | 510 | 380 | 120* |
| при сжатии (7) | 55 000 | 29 000 | 18 000 | 14 000 | — | 32 100 | 23 750 | 21 750 | 12 900 |
| при изгибе (8) | — | 990 | 735 | 530 | — | 1180 | 885* | 610* | 305* |
| Относительное удлинение (%) (9) | 1,6 | 3,6 | 21,0 | 60* | 2,2 | 4,0 | 6,0 | 30,7 | 60* |
| Удельная ударная вязкость (кг·см/см²) (10) | 14,5 | 13,0 | 14,2 | 15,4 | 14,9 | 13,8 | 14,9 | 15,5 | 18,2 |
| Твердость по Бриннеллю (кг/мм²) (11) | — | 21,5 | — | — | — | 23,7 | — | — | — |

* Specimens did not fracture.

1) Characteristic; 2) SOL; 3) ST-1; 4) temperature (°C); 5) ultimate strength (kg/cm$^2$); 6) on extension; 7) on compression; 8) on bending; 9) relative elongation (%); 10) impact strength (kg·cm/cm$^2$); 11) Brinell hardness (kg/mm$^2$).

TABLE 9

Technological Regimes for Treatment of Organic Glass

| Марка (1) | Температура разогрева в процессе ориентации (°С) (2) | Формование (3) | | | Сварка (8) | | | Применяемые клеи при: (11) | |
|---|---|---|---|---|---|---|---|---|---|
| | | температура разогрева (°С) (4) | | Температура отжига (°С) (7) | темп-ра разогрева (°С) | время выдержки (мин) (9) | давление (кг/см²) (10) | склеивании (12) | протектировании (13) |
| | | перед формованием (5) | конец формования (6) | | | | | | |
| СОЛ (14) | 115—120 | 115—150 | 105 | 75±5 | 140—300 | 1—15 | 5—10 | В-31-Ф9 (16) | Казеиновый (18) |
| СТ-1 (15) | 125—130 | 130—160 | 115 | 90±5 | 180—300 | 1—15 | 3—40 | ПУ-2 (17) | Желатиновый, мездровый (19) |

1) Type; 2) heating temperature during orientation (°C); 3) molding; 4) heating temperature (°C); 5) before molding; 6) end of molding; 7) annealing temperature (°C); 8) welding; 9) holding time (min); 10) pressure (kg/cm$^2$); 11) glues used for; 12) gluing; 13) protection; 14) SOL; 15) ST-1; 16) V-31-F9; 17) PU-2; 18) casein; 19) gelatin, hide.

Table 6 presents data on the thermal coefficient of linear expansion of SOL and ST-1.

Table 7 shows the thermophysical characteristics of organic glass.

The physicomechanical characteristics of organic glass are shown in Table 8.

Table 9 shows the technological processing regimes for organic

II-4,-6

glass.

Organic glass is widely used for the windows of airplanes, helicopters, automobiles, trolleys, and buses and in construction and illumination engineering.

M.M. Gudinov

ORGANIC GLASS (heat-resistant type 2-55 and thermostabilized type T2-55) – copolymers based on methyl methacrylate with various additives. Type 2-55 is a copolymer with a linear structure based on methyl methacrylate and with a photostabilizing component added. Type T2-55 is a copolymer whose distinguishing structural feature is the presence of infrequent macromolecular linkage and which has thermostabilizing and photostabilizing components added. The partial cross-linkage in T2-55 glass makes it more thermostable than type 2-55, although it has the same basic physicomechanical characteristics as the latter.

Table 1 shows the temperature regions occupied by the various states of types 2-55 and T2-55 organic glasses.

In the vitreous region both type 2-55 and type T2-55 are rigid isotropic materials capable of withstanding rather high loads without material deformation. The strength of these glasses drops as the temperature rises, although remaining sufficiently high at temperatures up to the vitrification point, 130°, and they can be used for long-term operation in this temperature region. The behavior of type 2-55 organic glass in the highly elastic state is similar to that of SOL and ST-1 glasses in this state. A distinctive feature of the thermostabilized organic glass T2-55 is its limited deformability in this temperature region, since T2-55 exhibits lower tensile elongation in the highly elastic state than nonthermostabilized organic glass. As type 2-55 glass passes into the viscous-deformation temperature region it begins to break down and fabrication of load-bearing components in this temperature zone is consequently undesirable. As a result of its partially

cross-linked structure type T2-55 glass has a considerably higher breakdown temperature than type 2-55 and can be used over a very broad temperature range.

TABLE 1

Temperature Regions Occupied by Various States of Types 2-55 and T2-55 Organic Glass (°C)

| Марка 1 | Стеклообразное 2 | Стеклование 3 | Высокоэластич. 4 | Начало резкого увеличения потери летучих 5 | Вязкотекучее 6 | Начало резкого падения прочности 7 |
|---|---|---|---|---|---|---|
| 2-55 | До 130 8 | 130—140 | 145—200 | 190—200 | 200 | — |
| T2-55 | До 130 | 130—140 | 145—300 | 230 | >300 | 240 |

1) Type; 2) vitreous; 3) vitrification; 4) highly elastic; 5) beginning of sharp increase in loss of volatile components; 6) viscous; 7) beginning of sharp drop in strength; 8) up to.

TABLE 2

Physicomechanical Characteristics of Organic Glass

| Свойства 1 | 2-55 | | | | | T2-55 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 температура (°C) | | | | | | | | | |
| | —60 | 20 | 60 | 80 | 100 | —60 | 20 | 60 | 80 | 100 |
| 3 Предел прочности при растяжении (кг/см²) | 1225 | 925 | 635 | 520 | 365 | 1220 | 1000 | 730 | 580 | 370 |
| 4 Относительное удлинение (%) | 2,0 | 2,8 | 4,0 | 4,8 | 11,0 | 2,1 | 3,3 | 4,2 | 4,5 | 21,2 |
| 5 Уд. ударная вязкость (кг·см/см²) | 15,7 | 14,8 | 15,3 | 15,6 | 15,9 | 13,2 | 15,0 | 16,5 | 8,2 | 17,1 |
| 6 Предел прочности при изгибе (кг/см²) | — | 1210 | 975 | 810 | 585 | 1325 | 1200 | 1100 | 980 | 720 |
| 7 Упругость (кг/см²) | — | 41600 | 29300 | 25300 | 20500 | — | 40800 | 30100 | 25200 | 19100 |
| 8 Коэффициент Пуассона | — | 0,40 | — | — | — | — | 0,33 | — | — | — |

1) Characteristic; 2) temperature (°C); 3) ultimate tensile strength (kg/cm²); 4) relative elongation (%); 5) impact strength (kg·cm/cm²); 6) ultimate bending strength (kg/cm²); 7) elasticity (kg/cm²); 8) Poisson's ratio.

Tables 2-5 show the physicomechanical, optical, thermophysical, and physicochemical characteristics of organic glass.

The temperature range within which types 2-55 and T2-55 organic glass are processed to produce window components and are subjected to orientation lies in the high-elasticity region. These glasses are molded at 145-190° and oriented at 145-150°. They are glued with PU-2 and

TABLE 3

Spectral Transmissivity of Organic Glass

| 1 Марка | Коэфф. преломления 2 | 3 области спектра: 4 ультрафиолетовая, 5 видимая, 6 инфракрасная; 7 длина волны (мμ); 8 коэфф. светопропускания (%) | | | | | | | | | | | | | | 9 Оптический коэффициент напряжения, брюстеры | 10 Светостойкость (снижение светопропускания в результате облучения кварцевой лампой ПРК-2 в течение 50 час) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 300 | 320 | 340 | 360 | 380 | 400 | 750 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | | |
| 2-55 | 1,496 | 0 | 0 | 0 | 67 | 85 | 88 | 90 | 89 | 88 | 82 | 50 | 40 | 25 | 20 | —2 | |
| T2-55 | 1,4978 | 0 | 0 | 0 | 45 | 74 | 80 | 90 | 89 | 90 | 80 | 60 | 49 | 33 | 21 | 1,2—1,6 | |

1) Type; 2) index of refraction; 3) spectral region; 4) ultraviolet; 5) visible; 6) infrared; 7) wavelength (m μ); 8) pass coefficient (%); 9) optical stress coefficient, brewsters; 10) photostability, % (decrease in phototransparency during irradiation with a PRK-2 quartz bulb for 50 hr).

TABLE 4

Thermophysical Characteristics of Organic Glass

| Марка 1 | Термический коэффициент линейного расширения α·10⁶ (1/°C) при темп-ре (°C) 2 | | | | Теплопроводность (ккал/м·час·°C) при темп-ре (°C) 3 | | Теплоемкость (*ккал/кг град*) при темп-ре (°C) 4 | | Температуропроводность α·10⁴ (м²/час) при темп-ре (°C) 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 60 | 80 | 100 | 20 | 50 | 20 | 50 | 20 | 50 |
| 2-55 | 69 | 69 | 73 | 84 | 0,18 | 0,18 | 0,43 | 0,43 | 3,4 | 3,4 |
| T2-55 | 75,6 | 75,6 | 75,6 | 94,5 | 0,156 | 0,156 | 0,416 | 0,436 | — | — |

1) Type; 2) thermal coefficient of linear expansion $\alpha \cdot 10^6$ (1/°C) at temperature of (°C); 3) thermal conductivity (kcal/m·hr·°C) at temperature of (°C); 4) heat capacity (kcal/kg·degree) at temperature of (°C); 5) temperature conductivity $\alpha \cdot 10^4$ ($m^2$/hr) at temperature of (°C).

TABLE 5

Physicochemical Characteristics of Organic Glass

| Марка 1 | Уд. в. 2 | 3 Стойкость к поверхностному растрескиванию: 4 в дибутилфталате (неотожженного стекла) | в условиях искусственного старения * 5 | 6 Набухание за 7 суток (привес, %) в: 7 этиловом спирте | ацетоне 8 | 9 дихлорэтане | дистиллированной воде 10 | 11 масле | 12 бензине |
|---|---|---|---|---|---|---|---|---|---|
| 2-55 | 1,18 | >50 час. 13 | Серебрится через 70 час. 14 | 12,6 | растворяется 15 | 4,5 | 1,97 | 0 | 0,05 |
| T2-55 | 1,2 | >50 час. | >100 час. | 2,26 | 3,62 | 0,16 | 1,8 | — | — |

* Ultraviolet light, relative humidity – 90%, temperature – 20°.

1) Type; 2) specific gravity; 3) resistance to surface cracking; 4) in dibutylphthalate (unannealed glass); 5) during artificial aging; 6) distention over 7 days (gain in weight, %) in; 7) ethyl alcohol; 8) acetone; 9) dichloroethane; 10) distilled water; 11) oil; 12) gasoline; 13) hr; 14) silvered after 70 hr; 15) dissolves.

[illegible] glues. Type [illegible] is fused at [illegible] min at a pressure of 5-10 kg/cm$^2$. Type T2-5 is [illegible] under a pressure of 10-40 kg/cm$^2$. These glasses can be cut, sawn, drilled, milled, etc. In fastening window components of type 2-55 unoriented glass to metal frames special strips are used to insure tight fastening. Window components of type T2-55 organic glass must be fastened loosely to their frames. Rigid sealing (with and without bolts) can also be employed for fastening oriented-glass components. The temperature range over which heat-resistant and thermostabilized glasses can be used is considerably broader than that for SOL glass. Glass of the SOL type can function for prolonged periods under stresses of 100 kg/cm$^2$ at temperatures of from -60 to +60°. Type ST-1 organic glass can function for long periods under these conditions at temperatures of from -60 to +80°, while types 2-55 and T2-55 can operate at temperatures of from -60 to +100°. When there is a temperature gradient through the thickness of the glass type 2-55 can function at temperatures of from -60 to +160° and type T2-55 at temperatures of up to 240-300°, depending on the temperature, the operational time, and the thickness of the material.

Ye.S. Osikina

ORGANIC TRIPLEX – usually three-layered organic glass with an intermediate elastic interlayer, consisting of a polyvinylbutyrol film (GOST 9438-60) or its heat-resistant versions. It is made from the SOL, ST-1 and 2-55 organic glasses. The relationship between the thickness of organic glass and film layers depends on the requirements put to the glazing.

Sealed aircraft cabins are glazed with organic triplex with a thickness from 10 mm; here the thickness of the elastic transparent interlayer comprises 2-4 mm. The thickness of the organic glass layers in organic triplex can be symmetrical and unsymmetrical.

TABLE 1

Physicomechanical Indicators of Organic Triplex

| 1 Свойства | 2 Марка | | | |
|---|---|---|---|---|
| | ОТ-16 | 3 ОТ-СТ-1 | ОТ-2-55 | ОТ-200 |
| 4 Удельный вес | 1.16 | 1.16 | 1.16 | 1.20 |
| Предел прочности (кг/см²): 5 | | | | |
| 6 при растяжении | 625 | 675 | 790 | 760 |
| 7 при изгибе | 930 | 970 | 1420 | 1499 |
| 8 при сдвиге | 100 | 100 | 250 | 96 |
| 9 Модуль нормальной упругости при растяжении (кг/см²) | 25 900 | 25 800 | 3800 | 3800 |
| 10 Твердость по Бринеллю (кг/мм²) | 22 | 21 | – | – |
| Относительное удлинение при разрыве (%) 11 | 3.0 | 4.0 | 3.0 | 2.0 |
| 12 Коэффициент линейного расширения $\alpha \cdot 1/°C$ | $6-9 \cdot 10^{-5}$ | $8.7 \cdot 10^{-5}$ | $5-7 \cdot 10^{-5}$ | $6-7 \cdot 10^{-5}$ |
| 13 Коэффициент теплопроводности (ккал/м·час·°C) | 0.12–0.18 | 0.12–0.18 | 0.19 | 0.18 |
| 14 Удельная ударная вязкость (кг·см/см²) | 16.0 | 16.0 | 18.0 | 37.9 |
| 15 Стрела прогиба (мм) | 5.0 | 6.0 | – | – |

1) Properties; 2) brand; 3) OT-ST-1; 4) specific gravity; 5) ultimate strength ($kg/cm^2$); 6) in tension; 7) in flexture; 8) in shear; 9) standard tensile modulus of elasticity ($kg/cm^2$); 10) Brinell hardness ($kg/mm^2$); 11) relative elongation at break (%); 12) linear expansion coefficient $\alpha \cdot °C^{-1}$; 13) thermal conductivity coefficient (kcal/m-hour-°C); 14) specific impact ductility ($kg-cm/cm^2$) 15) deflection (mm).

Glazing from organic triplex: reduces the sensitivity to stress

raisers by approximately a factor of two; power and thermal loads are taken up by different layers of the organic triplex (as a power layer it is expedient to use oriented organic glass from heat-resistant forms of polymethylmetacrylate, while as the external layer, the surface of which is subjected to high temperatures, it is advantageous to use non-

TABLE 2

Optical Properties of Organic Triplex

| 1 Марка | 2 Светопрозрачность (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | для видимой части спектра 3 | для ультрафиолетовой части спектра с длиной 4 волны (мкм): | | | | | |
| | | 300 | 310 | 320 | 330 | 340 | 350 |
| ОТ-16 | 89 | 5 | 5 | 9 | 18 | 26 | 47 |
| ОТ-СТ-1 5 | 89 | 0 | 0 | 0 | 0 | 7,9 | 20,9 |
| ОТ-2-55 | 88 | 0 | 1,2 | 1,2 | 1,2 | 1,2 | 2,0 |
| ОТ-200 | 86 | 0 | 1,2 | 1,2 | 1,2 | 1,2 | 2,0 |

1) Brand; 2) translucence; 3) for the visible spectral region; 4) for the ultraviolet spectral region with a wavelength (micromicrons); 5) OT-ST-1.

oriented heat-resistant organic glass, if possible silicate glass); it eliminates the danger of instantaneous loss of airtightness in the cabin due to impact loads, since the elastic interlayer, being capable of large residual elongations, aids in the repairing of the hole thus formed by drawing it together; for example, when organic triplex glazing is broken, the pressure drop in a sealed cabin under certain conditions requires 15-20 minutes, while glazing from a monolithic organic glass produces a pressure drop under the same breakage conditions in 20 secs; it makes it possible to combat fogging up and icing by installing electrical heating elements between the organic glass layers.

Prolonged storing of organic triplex sheets is permitted in premises with a relative air humidity not exceeding 20%.

The physicomechanical indicators of organic triplex are given in Table 1, and the optical indicators are given in Table 2.

References: "Aircraft Prod.," Vol. 16, No. 2, pages 62-69, 1954;

"Mod. Plast.," Vol. 30, No. 4, pages 111-114, 1952; "Mech. Engng," Vol. 79, No. 2, page 175, 1957; "Plastics," Vol. 25, No. 277, page 464, 1960.

Z.I. Mikheyeva

Manu-
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No.

2848 ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = All-Union State Standard

ORIENTED GLASS PLASTIC (SVAM, AG-4s) – a plastic reinforced with parallel fibers, threads, or filaments. It is a structural and electrical-insulating material, whose specific characteristics are determined by the method by which it is produced and processed and the properties of its initial components (fiberglass and polymer binders). Oriented glass plastic is characterized by a combination of high strength and low specific gravity, marked anisotropy of physicomechanical characteristics (which makes it possible to reinforce the material of a structure in a given direction in conformity with the stress distribution in its components), resistance to aggressive media, rot resistance, nonmagnetizability, high dielectric characteristics, and low thermal conductivity. Its elevated physicomechanical characteristics are due to effective utilization of the strength of the fine glass fibers which it contains. This is achieved by rigid orientation and tensioning of the fibers in a polymer binder, absence of intertwining, which causes additional stresses and reduces strength, especially on compression, partial or complete avoidance of textile processing, which reduces the strength of the fibers themselves, and the use of polymer binders, which ensure joint working of the fiber system to the point of fracture. Glass fibers with a diameter of more than 10-12 μ (which cannot be employed in the production of glass cloth because of their low flexibility) can be used in oriented glass plastic. Aluminoborosilicate fibers are generally used in the manufacture of this material, with calcium-sodium and other fibers being employed. The optimum glass content of oriented glass plastic is 78-85% (by weight). The choice of binders is di -

tated by the required strength, rigidity, heat resistance, moisture resistance, dielectric characteristics, etc., as well as by technological and economic considerations. The extent to which the strength of the fibers and the characteristics of the material are utilized depends on the elastic and nonelastic characteristics of the binders, their cohesive strength and adhesion to glass, and their wettability, which governs the uniformity with which the film is distributed over the fiber surface. Compositions based on epoxy, epoxy-phenolic, polyester, butyrophenolic phenol-formaldehyde, silicoorganic, polyamide, and other resins are widely used in oriented glass plastic. In order to increase its adhesion and moisture resistance the surface of the fibers is treated with various sizers, which form stable bonds between the polymers and the glass, or appropriate active additives are introduced directly into the binder. When commercial threads or filaments carrying lubricants, which generally reduce adhesion, are used it is necessary to remove the fubricant (by chemical, thermochemical, or other methods) before applying the binder or sizer.

Binder-coated threads and filaments and sheets and strips with parallel or intersecting fibers are used in the production of oriented glass plastic and oriented-glass-plastic products. Such products can be fabricated by winding, broaching, pressing, and template forming. Oriented glass plastic is used for high-strength structural elements, facing (including sandwich panels and sheathing), aircraft structural components, cylindrical and shaped articles for various purposes, tanks, beams, and machine-building components. The high specific strength of this material makes it promising for use in aircraft and rocket building. As a result of its high dielectric characteristics, oriented glass plastic can be employed in electronics and radio engineering, particularly in the form of foil sheets and sheets for patching printed cir-

cuits. Thin sheets (15-20 μ) of electrical insulating glass with an intersecting structure are used as between-turn, slot, and interlayer insulation and permit a substantial reduction in the size and weight of various computer, radio, and electronic equipment. For a detailed description of the physical and mechanical characteristics of oriented glass plastic see Glass plastics.

References: Burov, A.K. et al., Issledovaniye vozmozhnosti polucheniya vysokoprochnykh anizotropnykh materialov na osnove tonkikh steklyannykh volokon [Investigation of the Possibility of Producing high-strength anisotropic materials based on fine glass fibers], Zhurnal tekh. fiz. [Journal of Technical Physics], 1945, Vol. 15, No. 7, page 407; Burov, A.K., Andreyevskaya, G.D., Sinteticheskiye volokonistyye anizotropnyye struktury [Synthetic Fibrous Anisotropic Structures], Moscow, 1952; Kiselev, B.A., Stekloplastiki [Glass Plastics], Moscow, 1961; Gulyayev, A.S., Novyy steklovoloknistyy pressmaterial AG-4 i yego izgotovleniye [The New Fiberglass Press-Material AG-4 and its Manufacture], Moscow, 1959.

E.S. Zelenskiy

ORIENTED ORGANIC GLASS – a material obtained by planular multiaxial extension or compression of organic glass heated to a temperature above its softening point (in the high-elasticity region), with subsequent fixation of the deformed state by cooling. Oriented organic glass has higher physicomechanical characteristics than unoriented glass, these depending principally on the degree of extension ($\varepsilon_{pr}$) and the extension temperature ($T_v$). When the volume of material remains unaltered the degree of extension is determined from the formula:

$$\varepsilon_{np} = \left( \sqrt{\frac{H_1}{H_2}} - 1 \right) \cdot 100,$$

where $H_1$ and $H_2$ are the initial and final thicknesses of the glass and the optimum value of $T_v$ is 10-15° above the softening temperature of the glass ($T_r$). Organic glass is a uniformly strong material in the plane of the sheet, but has different characteristics (Table 1) in the direction perpendicular to this plane (through the thickness of the sheet). Organic glass sheets are manufactured on special equipment insuring uniform planular extension. Orientating of organic glass materially reduces its brittleness and increases its impact strength, tensile elongation, and radius of curvature during static bending. The degree of extension at which the material exhibits its optimum characteristics is recommended for glass to be used for aircraft windows.

Table 2 shows the basic characteristics of various types of oriented organic glass. Oriented glasses have material advantages over unoriented glasses with respect to resistance to surface cracking (Table 3), long-term strength (Table 4), and sensitivity to stress concentra-

TABLE 1

Characteristics of Type SOL Oriented Organic Glass ($\varepsilon_{pr}$ = 62%) During Tensile Testing as a Function of Specimen-Cutting Direction

| Направление вырезки образцов 1 | Темп-ра испытания (°С) 2 | Предел прочности при растяжении (кг/см²) 3 | Относительное удлинение при разрыве (%) 4 |
|---|---|---|---|
| По плоскости листа (в любом направлении) 5 | 20 | 825 | 14.8 |
| | 60 | 585 | 34 |
| | 80 | 400 | 41.1 |
| В направлении толщины материала . .6 . . . | 20 | 300 | 4.3 |
| | 60 | 235 | 4.4 |
| | 80 | 215 | 4.7 |

1) Specimen-cutting direction; 2) test temperature (°C); 3) ultimate tensile strength (kg/cm$^2$); 4) relative tensile elongation (%); 5) along plane of sheet (in any direction); 6) through thickness of material.

tors (Table 5). Oriented organic glass has a substantially higher strength under cyclic tensile loads than unoriented glass. When oriented glass not supported at its perimeter is heated to a temperature above $T_r$ relaxation processes (shrinkage) take place, bringing the glass to a state corresponding to that of unoriented glass. The linear dimensions of oriented glass are stable at temperatures 15-20° below $T_r$. On complete heating oriented and unoriented organic glasses have the same maximum working temperatures, 60° for SOL glass, 80° for ST-1 glass, and 100° for 2-55 glass. Oriented glasses are molded by methods similar to those used for unoriented glasses; in essence, this technique consists in preliminary bending at temperatures below $T_r$ and fixation of the molds in dyes at temperatures above $T_t$ (approximately equal to $T_v$), with shrinkage of the material prevented by rigid fastening of the preliminarily bent blank along its entire perimeter. The best method for producing window components based on organic glass is one that provides for combined extension and molding of the glass, the so-called "composite technique." In comparison with similar components of unoriented glass window components of oriented glass have a static strength 1.5-2 times higher, better localization of damage under impact

TABLE 2

Principal Mechanical Characteristics of Types SOL, ST-1, and 2-55 Organic Glass ($\varepsilon_{pr}$ = 50%)

| Показатели 1 | 2 сол | | | | 3 СТ-1 | | | | | 2-55 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 температура (°С) | | | | | | | | | | | | | | |
| | −60 | 20 | 60 | 80 | −60 | 20 | 60 | 80 | 100 | −60 | 20 | 60 | 80 | 100 | 120 |
| 5 Предел прочности при растяжении (кг/см²) | 1410 | 775 | 430 | 205 | 1440 | 830 | 500 | 340* | 185* | 1415 | 1080 | 706 | 535 | 335 | 160 |
| 6 Относительное удлинение (%) | 3,3 | 23,2 | 31,0 | 43,7 | 3,9 | 20,0 | 27,0 | 60* | 60* | 3,4 | 12,9 | 13,3 | 17,6 | 51,0 | 60* |
| 7 Модуль упругости (кг/см²) | — | 30 600 | 19 200 | 11 400 | — | 30 900 | 20 800 | 16 200 | 7300 | — | 39 800 | 28 250 | 23 900 | 15 300 | 8300 |
| 8 Предел прочности при статическом изгибе (кг/см²) | 1540 | 1195* | 690* | 395* | 1835 | 1010* | 565* | 425 | 235* | 1945 | 1550 | 1075 | 745* | 535* | 350* |
| 9 Удельная ударная вязкость (кг·см/см²) | 25,8 | 25,5 | 29,8 | 36,8 | 31,4 | 33,3 | 39,9 | 49,9 | 200* | 30,5 | 32,0 | 33,1 | 36,2 | 38,7 | 200* |
| 10 Твердость по Бринеллю (кг/мм²) | — | 21,1 | — | — | — | 23,7 | — | — | — | — | 23,7 | — | — | — | |

*Specimens did not fracture.

1) Characteristic; 2) SOL; 3) ST-1; 4) temperature (°C); 5) ultimate tensile strength ($kg/cm^2$); 6) relative elongation (%); 7) modulus of elasticity ($kg/cm^2$); 8) ultimate strength on static bending ($kg/cm^2$); 9) impact strength ($kg \cdot cm/cm^2$); 10) Brinell hardness ($kg/mm^2$).

TABLE 3

Resistance of Organic Glass to Surface Cracking Under a Stress of 100 kg/cm$^2$ (Material Oriented to 50%)

| Марка стекла 1 | Состояние стекла 2 | Темп-ра испытания (°С) 3 | Время появления первых микротрещин серебра (мин) 4 |
|---|---|---|---|
| СОЛ 5 | Неориентированное 7 | 60 | 18,5 |
| | Ориентированное 8 | 60 | > 685 |
| СТ-1 6 | Неориентированное | 60 | 98 |
| | | 80 | 3,5 |
| | Ориентированное | 60 | > 660 |
| | | 80 | 24 |
| | Неориентированное | 80 | 19,8 |
| | | 100 | 3,5 |
| | Ориентированное | 80 | – |
| | | 100 | 55,6 |

1) Type of glass; 2) condition of glass; 3) test temperature (°C); 4) time required for first microcracks to appear in "silvering" (min); 5) SOL; 6) ST-1; 7) unoriented; 8) oriented.

TABLE 4

Long-Term Strength (in hr) of Type ST-1 Organic Glass in the Oriented ($\varepsilon_{pr}$ = 50%) and Unoriented States (Test Temperature – 80°)

| Состояние стекла 1 | 2 Напряжение (кг/см$^2$) | | | |
|---|---|---|---|---|
| | 100 | 126 | 150 | 175 |
| 3 Неориентированное | 9 | 6,3 | 2 | 1,75 |
| 4 Ориентированное | >1000 | >1000 | >1000 | >1000 |

1) State of glass; 2) stress (kg/cm$^2$); 3) unoriented; 4) oriented.

TABLE 5

Sensitivity of Oriented Organic Glass to Stress Concentrators (Holes With a Ratio $d/\ell$ = 0.2)

| 1 Марка и степень вытяжки, % | 2 Предел прочности при растяжении (кг/см$^2$) | | 5 Снижение прочности (%) | 6 Коэффициент чувствительности к концентраторам напряжения |
|---|---|---|---|---|
| | гладких образцов 3 | образцов с отверстиями 4 | | |
| 7 СОЛ | | | | |
| $\varepsilon_{пр}$ = 0 | 770 | 433 | 44 | 0,5 |
| $\varepsilon_{пр}$ = 50 | 890 | 780 | 13 | 0,09 |
| 8 СТ-1 | | | | |
| $\varepsilon_{пр}$ = 0 | 795 | 450,3 | 44 | 0,51 |
| $\varepsilon_{пр}$ = 50 | 845 | 865 | 0 | 0 |
| $\varepsilon_{пр}$ = 0 | 860 | 533 | 39 | 0,4 |
| $\varepsilon_{пр}$ = 50 | 1152 | 1055 | 9 | 0,06 |

1) Type and degree of extension, %; 2) ultimate tensile strength (kg/cm$^2$); 3) smooth specimens; 4) specimens with holes; 5) decrease in strength (%); 6) coefficient of sensitivity to stress concentrators; 7) SOL; 8) ST-1.

loads, and higher long-term strength under static loads. These characteristics, in conjunction with the higher resista . of oriented glass to atmospheric conditions, materially increase operational reserves and reliability.

B.V. Perov

ORLON – see Polyacrylonitrile fiber and Modified polyacrylonitrile fiber.

OSMIUM, Os – a chemical element in group VIII of the Mendeleevian periodic system; it has an atomic number of 76 and an atomic weight of 190.2. Natural osmium consists of 7 stable isotopes: $Os^{184}$ (0.018%), $Os^{186}$ (1.582%), $Os^{187}$ (1.64%), $Os^{188}$ (13.27%), $Os^{189}$ (16.14%), $Os^{190}$ (26.38%), and $Os^{192}$ (40.97%). A number of radioactive isotopes with mass numbers of from 182 to 195 have been produced artificially. Osmium is a metal of the platinum family and has a concentration of $5 \cdot 10^{-6}$% by weight in the earth's crust. It has a density of 22.48 g/cm$^3$ and a $t^{\circ}_{pl}$ of approximately 3045°. It is distinguished by high oxidizability, forming the volatile oxide $OsO_4$. Among the valuable characteristics of osmium are its high melting point and its ability to accelerate certain chemical reactions. See Precious metals.

O.Ye. Zvyagintsev

OVERAGING OF ALUMINUM ALLOYS - see [illegible] aluminum alloys.

OVERHEATING OF STEEL – formation of a coarse-grained and sometimes coarsely acicular structure in steel as a result of extremely severe heating. The heating time and temperature are the decisive factors governing the extent of austenite-grain growth. Pure iron and ferritic stainless steel are the materials most susceptible to overheating. Increasing the carbon content of steel to the eutectoid point reduces its tendency toward overheating, while the presence of low-solubility carbides prevents this process altogether. Inherently fine-grained steel has a lesser tendency toward overheating below a certain temperature, but when heated to substantially above this point its tendency toward overheating is greater than that of coarse-grained steel. Overheated coarse-grained steel has a reduced viscosity and a high susceptibility to brittle fracture. Overheating often causes machine components to fracture. Prequenching heating of overheated steel reduces its grain size. However, the complex of small grains formed during repeated heat treatment sometimes retains the texture of the coarse austenite grains, which leads to development of so-called naphthalinic fracture. In order to break down the coarse-grained texture of overheated steel it must be subjected to intermediate annealing or normalization before quenching. In order to correct substantial overheating the normalization or annealing temperature should be rather high, above Chernov's point B (100-150° above $Ac_3$). This causes recrystallization of the austenite grains, which have undergone some cold-working as a result of the phase transformations.

Severe overheating sometimes causes lithoidal fracture, which

takes the form of intercrystalline brittle fracture in coarse-grained steel. Fracture of this type appears on heating to very high temperatures (1250-1350°). It cannot be eliminated by repeated heat treatment (with the exception of prolonged Homogenization of steel at high temperatures). Blanks and finished components exhibiting lithoidal fracture are therefore generally rejected in order to eliminate the possibility of their undergoing brittle fracture during operation.

References: Mes'kin, V.S., Osnovy legirovaniya stali [Principles of the Alloying of Steel], Moscow, 1959; Sadovskiy, V.D., Malyshev, K.A., Sazonov, B.G., Fazovyye i strukturnyye prevrashcheniya pri nagreva stali [Phase and Structural Transformations in Steel on Heating], Sverdlovsk-Moscow, 1954; Braun, M.P., Priroda izloma peregretoy stali [Character of Fracture in Overheated Steel], Kiyev, 1954.

Ya.M. Potak

OXIDATION OF ALUMINUM ALLOYS – the chemical treatment of aluminum alloys in solutions that set up protective surface films. With respect to controlling the process to give the film desirable characteristics the technical feasibility of oxidation is limited in comparison with anodizing (see Anodizing of aluminum alloys). The protective characteristics of films obtained by chemical oxidation are lower than those of films obtained by anodizing; the films themselves are considerably thinner, have a lower corrosion resistance, and, being soft, cannot function under abrasion and wear. The principal advantages of films produced by chemical oxidation are their cheapness and simplicity. Such films provide a good base for painting. They can also be employed to provide long-term corrosion protection for aluminum components, particularly those which cannot be protected by anodic oxidation or painting (e.g., the inner surface of long curved tubes of small diameter). In chemical oxidation a thin passive film is formed on the surface of the component, protecting it against corrosion. The composition of the film depends on the composition of the solution in which oxidation is carried out. Thus, for example, when aluminum components are treated in pure boiling water for 1-4 hr so-called nonporous bomite ($Al_2O_3 \cdot 1\text{-}5H_2O$) films 0.3-0.5 μ thick are formed on the aluminum surface; these films do not increase in thickness on further treatment in boiling water. In order to obtain thicker films with better protective properties it is necessary to utilize solutions that cause slight dissolution of the existing coating (pores) and thus promote penetration of the oxidizing solution to the surface of the metal. Weakly acidic or weakly alkaline

TABLE 1

Composition of Solutions No. 1 to No. 5 (g/liter) for Oxidation of Aluminum Alloys

| Компоненты 1 | 2 Номер раствора | | |
|---|---|---|---|
| | 6 | 7 | 8 |
| 3 Однозамещенный фосфорнокислый натрий $NaH_2PO_4$ | 31.8 | 66.5 | 31.8 |
| 4 Фтористый алюминий $AlF_3$ | — | — | 5 |
| 5 Бифторид натрия $NaHF_2$ | — | 4.2 | — |
| Бихромат калия $K_2Cr_2O_7$ 6 | 10.6 | 14.7 | 10.6 |
| 7 Серная кислота $H_2SO_4$ . 8 | — | 4.8 | — |
| Соляная кислота HCl . 8 | 4.8 | — | 4.6 |
| Фтористый натрий NaF . 9 | 5 | — | — |

1) Component; 2) solution number; 3) phosphoric acid $H_3PO_4$; 4) chromic anhydride $CrO_3$; 5) sodium fluoride NaF; 6) hydrofluoric acid (40%).

TABLE 2

Composition of Solutions No. 6 to No. 8 (g/liter) for Oxidation of Aluminum Alloys

| Компоненты 1 | 2 Номер раствора | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Фосфорная кислота $H_3PO_4$ . 3 . . . | 50—80 | 40—50 | 64 | 12 | 24 |
| Хромовый ангидрид $CrO_3$ . . . 4 . . . | 7—8 | 8—10 | 10 | 3.6 | 6.8 |
| Фтористый натрий NaF . 5 . . . | — | 4—5 | 5 | 3.1 | 5 |
| Фтористоводородная кислота (40%-ная) 6 | 4—5 | — | — | — | — |

1) Component; 2) solution number; 3) monosubstituted sodium phosphate $NaH_2PO_4$; 4) aluminum fluoride $AlF_3$; 5) sodium bifluoride $NaHF_2$; 6) potassium bichromate $K_2Cr_2O_7$; 7) sulfuric acid $H_2SO_4$; 8) hydrochloric acid HCl; 9) sodium fluoride NaF.

solutions with passivating components are used for this purpose. Strongly acidic and strongly alkaline solutions without passivating components etch the aluminum rather than forming films. There are many solutions for chemical oxidation of aluminum and its alloys, but only a few of them are used commercially. The oldest technique for chemical oxidation and one that is still rather widely used is treatment in a hot alkaline solution with the following composition: 40-50 g/liter sodium carbonate $Na_2CO_3$, 10-15 g/liter sodium chromate $Na_2CrO_4$, and 2-2.5 g/liter sodium hydroxide NaOH. The solution is used at a temperature of 80-100° and the oxidation time ranges from 3 to 20 min, depending on the extent to which the solution is depleted. In order to neutralize any residue of the alkalis and to provide additional passivation the metal is treated in a 2% solution of chromic anhydride ($CrO_3$) at room temperature for 10-15 sec. The passive film formed varies in color from

dark yellow to brown, depending on the chemical composition of the alloy. Oxidation in acid solutions is a more advanced technique. A typical solution contains chromic anhydride $CrO_3$ (3-3.5 g/liter) and sodium fluorosilicate $Na_2SiF_6$ (3-3.5 g/liter). This solution is used at a temperature of 13-25° and the oxidation time is 8-10 min. The passive film formed ranges from light yellow to light brown in color, depending on the chemical composition of the alloy. Oxidation in solutions containing phosphates, chromates, and fluorine compounds has recently come into wide use (see Tables 1 and 2). This oxidation technique is called the alodine method in the USA and the alochrome method in England.

Solutions Nos. 1 and 2 are rather widely used in the Soviet Union for corrosion protection of aluminum alloys.

References: Bernik, S., Pinner, R., Khimicheskaya i elektroliticheskaya obrabotka alyuminiya i yego splavov [Chemical and Electrolytic Treatment of Aluminum and Its Alloys], Leningrad, 1960; Shreyder, A.V., Oksidirovaniye alyuminiya i yego splavov [Oxidation of Aluminum and Its Alloys], Moscow, 1960.

N.A. Makarov

OXIDATION OF MAGNESIUM ALLOYS – the chemical treatment of magnesium alloys in solutions that set up protective surface films. This process is generally carried out by immersing the component in the solution, but individual sections can be coated by flooding them with solution or by swabbing the areas to be oxidized with a cotton or gauze pad wetted in the solution (local oxidation). The basic purpose of these films is to protect magnesium alloys against corrosion and to increase the adhesion of paints to the metal. Oxidation in solutions containing chromium salts is widely employed in industry. The oxidation methods most widely used under modern industrial conditions are shown in the table. The thickness of oxychromate (produced by methods Nos. 1, 1a, 3, 3a, and 5) and fluorochromate (produced by methods Nos. 2 and 4) films does not exceed 3 μ. The color of the film produced depends on the composition of the solution and the alloy, the pretreatment of the surface, etc., varying from golden yellow to black. Such films protect magnesium alloys from corrosion during production and shipment, but do not provide corrosion protection under atmospheric conditions. In the latter case a combination of an oxide film and a coat of paint furnishes reliable protection; oxide films are good bases, increasing the adhesion of paints to the metal and improving their protective characteristics. Selection of an oxidation method depends on the composition of the alloy, its condition, and the purpose for which the component in question is intended. Method No. 1 is used for oxidizing cast components and semifinished products that have no dimensional tolerances of precision class 1 or 2; methods Nos. 1a and 3a are used for oxidizing

deformed semifinished products. Cast and deformed components with dimensional tolerances of precision classes 1 and 2 are oxidized by method No. 3. Methods Nos. 2 and 4 are recommended for oxidation of components which must function under rigid operational conditions, since the protective characteristics of the films formed are quite high. Components manufactured to precision classes 1 and 2 can be oxidized by these methods. Oxidation of assembled units containing steel, brass, bronze, zinc-plated, or cadmium-plated components is permissible. All standard magnesium alloys can be oxidized, with the exception of Mg-Mn alloys, on which high-quality films cannot be formed. Method No. 5 is a general-purpose technique for oxidizing all commercial casting and shaping alloys.

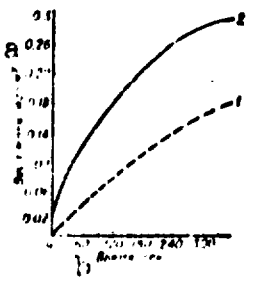


Figure. Growth of chromate film on magnesium alloys with time, usmethod No. 1: 1) ML5 alloy; 2) MA8 alloy. a) Weight of film, mg/cm$^2$; b) time, sec.

Additional treatment of films obtained by methods Nos. 1, 3, and 5 in 4-5% $K_2Cr_2O_7$ at 60-80° for 15 min usually increases their protective characteristics. In essence, oxidation in solutions containing chromic acid or its salts (passivators) and acids or salts with acid hydrolysis products (activators) consists in production of insoluble compounds on the metallic surface by the oxidation-reduction reaction:

$$Cr_2O_7^{2-} + 3Mg + 14H^+ \rightarrow 2Cr^{3+} + 3Mg^{2+} + 7H_2O$$

The accumulation of magnesium ions and trivalent chromium ions in the metal-solution boundary layer and the shift in pH in the alkaline direction lead to formation of low-solubility compounds of trivalent and hexavalent chromium and magnesium, of which the film consists. The increase in film thickness is a parabolic function of time (Figure). The film-formation rate is determined by the concentration ratio of the film-forming agent and the ac-

II-11,0-3

Methods for Chemical Oxidation of Magnesium ...

| 1 Метод и состав раствора | 2 Содержание компонентов в растворе | 3 Режим работы: 4 температура раствора (°С) | 3 Режим работы: 5 время обработки (мин) |
|---|---|---|---|
| 6 Метод № 1 | 18 | | |
| 7 Двухромовокислый калий | 40—50 г/л | 70—80 | До 2 |
| 8 Азотная кислота (уд. в. 1,4) | 65—85 мл/л [19] | | |
| 9 Хлористый аммоний | 0,75—1,25 г/л | | |
| Метод № 1а | | | |
| 7 Двухромовокислый калий | 15—20 г/л | 70—80 | До 2 |
| 8 Азотная кислота (уд. в. 1,4) | 15—25 мл/л | | |
| 9 Хлористый аммоний | 0,75—1,25 г/л | | |
| Метод № 2 | | | |
| 10 Предварительная обработка в фтористоводородной кислоте | 150—200 г/л | 15—30 | 5—10 |
| 11 Двухромовокислый натрий | 30—25 г/л | 100 | 45 |
| 12 Сернокислый аммоний | 30—25 г/л | | |
| 13 Аммиак (25%-ный) | 6—4 мл/л | | |
| Метод № 3 | | | |
| 7 Двухромовокислый калий | 140—160 г/л | 65—80 | 0,5—1,5 |
| 14 Уксусная кислота (60%-ная) | 10—20 мл/л | | |
| 15 Хромовый ангидрид | 1—3 г/л | | |
| 12 Сернокислый аммоний | 2—4 г/л | | |
| Метод № 3а | | | |
| 7 Двухромовокислый калий | 80—100 г/л | 65—75 | До 2 |
| 14 Уксусная кислота (60%-ная) | 5—15 мл/л | | |
| 15 Хромовый ангидрид | 3—4 г/л | | |
| 12 Сернокислый аммоний | 3—4 г/л | | |
| Метод № 4 | | | |
| 16 Предварительная обработка во фтористом натрии или калии | 35—50 г/л | 15—30 | 10—12 |
| 7 Двухромовокислый калий | 100—150 г/л | 90—100 | 40—60 |
| Метод № 5 | | | |
| 7 Двухромовокислый калий | 30—50 г/л | 15—30 | 5—15 |
| 17 Алюмокалиевые квасцы | 8—12 г/л | | |
| 14 Уксусная кислота (60%-ная) | 5—8 мл/л | | |

1) Method and solution composition; 2) content of components; 3) working regime; 4) solution temperature (°C); 5) treatment time (min); 6) method; 7) potassium dichromate; 8) nitric acid (specific gravity 1.4); 9) ammonium chloride; 10) preliminary treatment in hydrofluoric acid; 11) sodium dichromate; 12) ammonium sulfate; 13) ammonia (25%); 14) acetic acid (60%); 15) chromic anhydride; 16) preliminary treatment in sodium or potassium fluoride; 17) alumopotassium alum; 18) g/liter; 19) ml/liter.

tivator and by the ...lution temperature. The protective properties of the film depend on the composition of the solution, the oxidation regime, and the composition of the alloy. Such films are relatively resistant to prolonged heating only at temperatures of up to 120° or, when conjoined with paints, of up to 200°. The fatigue strength of the alloy is not reduced by the presence of a surface film. Thin hydroxide films have poor protective and adhesive characteristics. Thick hydroxide films, which are produced in autoclaves, have satisfactory protec-

tive properties but are highly brittle. Another chemical protection method is phosphating. This process can be carried out in hot solutions, such as one containing 27-32 g/liter Mazhef's mixture and 0.3 g/liter NaF, at 96-98° for 30-40 min or in cold solutions, such as one containing 60 g/liter Mazhef's mixture and 25 g/liter $Zn(NO_3)_2$. The film formed consists of insoluble diphosphates and triphosphates of the cations contained in the solution and of magnesium.

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M.A. Timonova

OXIDATION OF TITANIUM ALLOYS – saturation of the surface of titanium alloys with oxygen at elevated temperatures (thermal oxidation of titanium alloys). This produces a surface oxide film and a layer consisting of a solid solution of oxygen in titanium (the so-called alphirated layer).

The basic purpose of oxidation is to increase the antifriction characteristics of titanium alloys. Before oxidation the friction surface is water-sand-blasted and then degreased with gasoline. At this point the components are heated to 700-800° in electric muffle or chamber furnaces with free movement of air and held at this temperature for from 1 to 12 hr, depending on the type of alloy. They are then furnace-cooled at a rate of no less than 100° per hour to 300°; final cooling takes place in air. After oxidation the components are degreased with gasoline, a glue-based lacquer of the BF2 type is applied to the friction surface, and they are heated at 140-160° to permit polymerization of the lacquer (the latter operation is not obligatory). Oxidized titanium and titanium alloys will have fully satisfactory antifriction characteristics if they display a favorable combination of a hard (HV 1200), compact surface oxide film tenths of a micron thick, good adhesion of this film to an alphirated layer 10-30 μ thick, and an ability to withstand lubrication. Oxidized components function well in friction pairs with identical materials, steel, and nonferrous alloys under loads of up to 100 kg/cm$^2$ and sliding speeds of up to 0.5 m/sec with continuous lubrication (the type of lubricant is not important). Under these conditions the coefficient of friction amounts to 0.06-0.07.

I.S. Anitov

**OXIDE CERAMICS** – are ceramic materials obtained by sintering of the powdered oxides of aluminum, beryllium, magnesium, calcium, zirconium, cerium, thorium, uranium, etc. Objects made from oxide ceramics are used as refractories for the lining of high-temperature furnaces, of crucibles for metal smelting, for structural parts of machines, apparatus, as moderators and fuel elements in nuclear reactors. as cutting tools, etc.

Aluminum oxide (corundum). The specific weight of corundum single crystals is 3.992. The mechanical properties of sintered corundum are high, but the data dealing with them are contradictory which may be explained by the unlikeness of the investigated specimens and of the methods of determination. The ultimate compression strength is 50-500 kg/mm$^2$ (depending on the weight by volume and the structure of the specimens.) The ultimate compression strength as a function of the temperature is given in Table 1.

TABLE 1

| Темп-ра (°С) 1 | 2 Предел прочности при сжатии (кг/мм$^2$) | Темп-ра (°С) 1 | Предел прочности при сжатии (кг/мм$^2$) 2 |
|---|---|---|---|
| 20 | 300–500 | 1100 | 60 |
| 400 | 150 | 1200 | 50 |
| 800 | 140 | 1400 | 25 |
| 800 | 130 | 1500 | 10 |
| 1000 | 90 | 1600 | 5 |

1) Temperature (°C); 2) ultimate compression strength (kg/cm$^2$).

The ultimate bending strength is 12-55 kg/mm$^2$. The tensile strength depends on the temperature (Table 2).

The modulus of elasticity as a function of temperature is given in

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Table 3.

TABLE 2

| 1 Темп-ра (°C) | 2 Предел прочности при разрыве (кг/мм²) | 1 Темп-ра (°C) | 2 Предел прочности при разрыве (кг/мм²) |
|---|---|---|---|
| 20 | 26.5 | 1210 | 13.0 |
| 300 | 25.6 | 1310 | 4.5 |
| 805 | 24.0 | 1400 | 3.0 |
| 1050 | 23.8 | 1460 | 1.1 |
| 1130 | 22.1 | | |

1) Temperature (°C); 2) ultimate tensile strength ($kg/mm^2$).

The melting point of corundum is 2050°, the temperature limit for the application of products made from sintered corundum is 1950°; the

TABLE 3

| 1 Темп-ра (°C) | 2 Модуль упругости $E \cdot 10^{-6}$ ($кг/см^2$) | 1 Темп-ра (°C) | 2 Модуль упругости $E \cdot 10^{-6}$ ($кг/см^2$) |
|---|---|---|---|
| 20 | 3.82 | 1000 | 3.22 |
| 200 | 3.80 | 1200 | 2.75 |
| 400 | 3.70 | 1400 | 2.05 |
| 600 | 3.60 | 1500 | 1.5 |
| 800 | 3.45 | | |

1) Temperature (°C); 2) modulus of elasticity, $E \cdot 10^{-6}$ ($kg/cm^2$).

deformation under a load of 2 $kg/cm^2$ begins at 1900°.

The mean specific heat is given in Table 4.

TABLE 4

| 1 Температурный интервал | 2 Удельная теплоемкость (кал/г·°C) | 1 Температурный интервал | 2 Удельная теплоемкость (кал/г·°C) |
|---|---|---|---|
| 100—200 | 0.2070 | 1000—1100 | 0.2540 |
| 300—400 | 0.2250 | 1100—1200 | 0.2645 |
| 500—600 | 0.2395 | 1300—1400 | 0.2705 |
| 600—700 | 0.2500 | 1400—1500 | 0.2755 |
| | | 1500—1700 | 0.2800 |

1) Temperature range; 2) specific heat (cal/g·°C).

With regard to the heat conductivity, the sintered corundum is more near to the metals than to the usual ceramic materials: 0.072 at 100°, 0.031 at 400°, and 0.015 cal/cm·sec·°C at 1000°. The mean coefficient of the linear thermal expansion is equal to $88 \cdot 10^{-7}$ in the tem-

perature range from 30 to 1000°. The heat endurance of the sintered corundum is low, the specimen becomes destroyed after 3-8 thermal shocks with a temperature drop from 850 to 20° (water). The specific electric resistance as a function of the temperature is given in Table 5.

TABLE 5

| 1 Темп-ра (°С) | 2 Удельное электрич. сопротивление (ом·см) | 1 Темп-ра (°С) | 2 Удельное электрич. сопротивление (ом·см) |
|---|---|---|---|
| 14 | $1 \cdot 10^{14}$ | 300 | $3 \cdot 10^{12}$ |
| 100 | $2 \cdot 10^{13}$ | 800 | $3.5 \cdot 10^{7}$ |
| 200 | $4 \cdot 10^{11}$ | | |

1) Temperature (°C); 2) specific electric resistance (ohm·cm).

Sintered corundum is characterized by a high chemical stability: not one chemical reagent, including alkalis and hydrofluoric acid, affect corundum at room temperature. Corundum crucibles show almost no corrosion when molten alkalis and peroxides are heated in them for a long time; aluminum and its alloys with other metals, alkali and earth alkali metals, silicon, tin, iron, etc., may be melted in them without fear of corrosion. Sintered corundum known under different names (Sinterkorund, Alundum, Corundise, Aluminoxide, Monofrax, Microlit, Thermocorund, etc.) is used for refractories, crucibles, protection tubes of pyrometers, and for insulators, spinnerets, gages, cutters, etc.

Beryllium oxide. Specific gravity 3.02; melting point 2570±30°; Mohs hardness 9; microhardness 1520 kg/mm$^2$. The ultimate compression and tensile strength of sintered beryllium oxide as a function of the temperature are given in Table 6.

The modulus of elasticity E is given in Table 7 for diverse temperatures.

The mean specific heat is given in Table 8.

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Beryllium oxide is characterized by a high volatility when heated (Table 9).

TABLE 6

| 1 Темп-ра (°С) | 2 Предел прочности при сжатии (кг/мм²) | 1 Темп-ра (°С) | 3 Предел прочности при разрыве (кг/мм²) |
|---|---|---|---|
| 20 | 210 | 24 | 10.5 |
| 100 | 100 | 400 | 10.5 |
| 1000 | 60 | 800 | 9.5 |
| | | 1000 | 7.4 |
| | | 1200 | 2.8 |

1) Temperature (°C); 2) ultimate compression strength ($kg/mm^2$); 3) ultimate tensile strength ($kg/mm^2$).

TABLE 7

| 1 Темп-ра (°С) | Модуль 2 упругости $E \cdot 10^{-6}$ (кг/см²) | 1 Темп-ра (°С) | Модуль 2 упругости $E \cdot 10^{-6}$ (кг/см²) |
|---|---|---|---|
| 25 | 2.72 | 1000 | 2.65 |
| 400 | 2.72 | 1100 | 1.95 |
| 800 | 2.72 | 1200 | 0.7 |

1) Temperature (°C); 2) modulus of elasticity, $E \cdot 10^{-6}$ ($kg/cm^2$).

TABLE 8

| 1 Темп-ра (°С) | Средняя 2 удельная теплоемкость (кал/г·°С) | 1 Темп-ра (°С) | Средняя 2 удельная теплоемкость (кал/г·°С) |
|---|---|---|---|
| 100 | 0.299 | 600 | 0.461 |
| 200 | 0.351 | 800 | 0.487 |
| 400 | 0.421 | 960 | 0.497 |

1) Temperature (°C); 2) mean specific heat (cal/g·°C).

TABLE 9

| 1 Продолжительность выдержки (мин.) | Летучесть бериллиевых образцов (г/см²), 2 обжигаемых в среде окиси углерода при темп-ре: | | |
|---|---|---|---|
| | 1600° | 1790° | 1800° |
| 10 | 0.09 | 0.11 | 0.17–0.21 |
| 20 | 0.12–0.13 | 0.13 | 0.20–0.25 |
| 30 | 0.14 | 0.15 | 0.27–0.28 |
| 40 | 0.13 | 0.16–0.18 | 0.25–0.34 |

1) Holding time (min); 2) volatility ($g/cm^2$) of beryllia specimens fired in carbon monoxide at a temperature of.

The volatility increases beginning with 100°, if water vapor is present in the gas medium. The heat conductivity of beryllia approaches to that of lead; it is equal to 0.500 at 100°, 0.211 at 400°, and 0.0462 cal/cm·sec·°C at 1000°.

The mean linear thermal expansion coefficient α of sintered beryllia is given as a function of the temperature in the Table 10.

TABLE 10

| 1 Температурный интервал (°C) | Средний линейный коэфф. теплового расширения 2 α·10 | Температурный интервал (°C) 1 | Средний линейный коэфф. теплового расширения α·10⁷ 2 |
|---|---|---|---|
| 20—50 | 50 | 20—400 | 72 |
| 20—100 | 54 | 20—600 | 77 |
| 20—200 | 60 | 20—800 | 84 |
| | | 20—1000 | 89 |

1) Temperature range (°C); 2) mean linear thermal expansion coefficient, $\alpha \cdot 10^7$.

The elctric conductivity of specimens from sintered beryllia is equal to $6 \cdot 10^{-9}$ at 660°, and $1 \cdot 10^{-7}$ $ohm^{-1} \cdot cm^{-1}$ at 1000°.

The heat endurance of products made from beryllia is higher than that of products made from other oxides. The number of heating-quenching cycles is given in Table 11. The heated specimens are blown on with compressed air for 1 min. The cycles are repeated until the specimen is destroyed.

TABLE 11

| 1 Материал образца | 1400° | 1500° | 1600° | 1700° |
|---|---|---|---|---|
| | 2 количество теплосмен | | | |
| 3 Окись магния | 6 Не выдерживает | | | |
| 4 Окись бериллия | 12 | — | 5 | 4 |
| 5 Окись алюминия | 4 | 8 | 2 | 1 |

1) Material of the specimen; 2) number of thermal shocks; 3) magnesia; 4) beryllia; 5) alumina; 6) does not stand.

Creep phenomena are observable at high temperatures in objects made from beryllia. This effect occurs even at 1000-1050° under a load of 6.65 kg/cm$^2$. Beryllia is highly toxic; the air must not contain more than 0.01 microgram/m$^3$ beryllia. Beryllia belongs to the weakly basic refractories, with regard to its chemical properties. Alkalis and alkali carbonates can be melted in beryllia crucibles, and molten lead oxides and borates can be kept in them for a long time; the crucibles resist up to 1600° the effect of lime-phosphate slags. Beryllia decomposes in contact with acid substances. Products from sintered beryllia do not react with hydrogen peroxide, hydrogen, nitrogen, carbon dioxide, sulfur dioxide, sulfur, bromine, iodine, and ammonia. Beryllia reacts readily with fluorine and fluorides. Sintered beryllia is used as a refractory for crucibles, and for machine parts, engines and nuclear reactors (neutron moderator).

Magnesium oxide: Specific gravity 3.58; melting point 2800±13°; Mohs hardness 6; ultimate strengths; compression strength 140 at 20°, 150 at 400°, and 115 kg/mm$^2$ at 1000°; tensile strength: 9.8 at 20°, 10.7 at 400°, 11.3 at 600°, 10 at 800°, 5.6 at 1200°, and 4.2 kg/mm$^2$ at 1300°. The mean specific heat is given in Table 12.

TABLE 12

| 1 Темп-ра (°C) | 2 Средняя удельная теплоемкость (кал/г·°C) | 1 Темп-ра (°C) | 2 Средняя удельная теплоемкость (кал/г·°C) |
|---|---|---|---|
| 100 | 0.233 | 1100 | 0.282 |
| 300 | 0.247 | 1300 | 0.287 |
| 500 | 0.259 | 1500 | 0.291 |
| 700 | 0.269 | 1700 | 0.293 |
| 900 | 0.276 | 1800 | 0.294 |

1) Temperature (°C); 2) mean specific heat (cal/g·°C).

The heat conductivity of magnesia specimens with a porosity of 2.3-8.1% is quoted in Table 13 as a function of the temperature.

The mean linear coefficient of thermal expansion is quoted in Table 14.

TABLE 13

| 1 Темп-ра (°C) | 2 Теплопроводность (кал/см сек °C) | 1 Темп-ра (°C) | 2 Теплопроводность (кал/см сек °C) |
|---|---|---|---|
| 200 | 0,0845 | 1000 | 0,0160 |
| 400 | 0,0377 | 1200 | 0,0140 |
| 600 | 0,0263 | 1400 | 0,0138 |
| 800 | 0,0194 | 1600 | 0,0157 |
| | | 1800 | 0,0216 |

1) Temperature (°C); 2) heat conductivity (cal/cm·sec·°C).

TABLE 14

| 1 Темп-ра (°C) | 2 Средний линейный коэфф. теплового расширения $\alpha \cdot 10^7$ | 1 Темп-ра (°C) | 2 Средний линейный коэфф. теплового расширения $\alpha \cdot 10^7$ |
|---|---|---|---|
| 300 | 120 | 1100 | 141 |
| 500 | 126 | 1300 | 145 |
| 700 | 132 | 1500 | 150 |
| 900 | 137 | 1700 | 156 |
| | | 1800 | 160 |

1) Temperature (°C); 2) mean linear coefficient of thermal expansion, $\alpha \cdot 10^7$.

The temperature also affects the specific electric resistance $\rho$ (Table 15).

TABLE 15

| 1 Темп-ра (°C) | 2 Удельное электрич. сопротивление $\rho \cdot 10^3$ (ом см) | 1 Темп-ра (°C) | 2 Удельное электрич. сопротивление $\rho \cdot 10^3$ (ом см) |
|---|---|---|---|
| 950 | 120 | 1200 | 30 |
| 1000 | 95 | 1300 | 9,0 |
| 1100 | 82 | 1400 | 3,0 |
| | | 1500 | 1,1 |

1) Temperature (°C); 2) specific electric resistance, $\rho \cdot 10^3$ (ohm·cm).

Magnesia is stable to alkalis, it is easily destroyed by acids. Iron, zinc, tin, copper, and aluminum can be melted in magnesia crucibles. Besides crucibles, linings for high-temperature furnaces are made

from magnesia.

Calcium oxide. Specific gravity 3.08-3.35; melting point 2570±10°; Mohs hardness 6; mean specific heat 0.172 at 190°, 0.181 at 375-400°, and 0.193 cal/g at 590-680°.

The heat conductivity of calcium oxide specimens with 8.75% porosity is quoted in Table 16 as a function of the temperature.

TABLE 16

| 1 Темп-ра (°C) | Теплопроводность (кал/см сек·°C) 2 | 1 Темп-ра (°C) | Теплопроводность (кал/см сек·°C) 2 |
|---|---|---|---|
| 100 | 0.0333 | 600 | 0.0181 |
| 200 | 0.0242 | 800 | 0.0174 |
| 400 | 0.0200 | 1000 | 0.0170 |

1) Temperature (°C); 2) heat conductivity (cal/cm·sec·°C).

The mean coefficient of linear thermal expansion is equal to $138 \cdot 10^{-7}$ in the temperature range from 0 to 1700°. The specific electric resistance is $70 \cdot 10^6$ at 763°; $104 \cdot 10^3$ at 1235°; 2045 at 1370°, and 91 ohm·cm at 1460°. The hydration of CaO in moist air is the main disadvantage of the products made from calcium oxide. Calcium oxide crucibles resist the action of melted calcium phosphates, they are used for smelting of platinum and other metals of this group.

Zirconium dioxide. Specific gravity 5.6; melting point 2700±20°; Mohs hardness 7. The ultimate compression and tensile strengths of sintered zirconia are quoted in Table 17 as a function of the temperature.

TABLE 17

| 1 Темп-ра (°C) | 2 Предел прочности при сжатии спеченной стабилизированной $ZrO_2$ (кг/мм²) | 1 Темп-ра (°C) | 3 Предел прочности при разрыве спеченной при 1900° $ZrO_2$ (кг/мм²) |
|---|---|---|---|
| 20 | 210 | 20 | 14.8 |
| 500 | 160 | 885 | 11.2 |
| 1000 | 120 | 1030 | 9.3 |
| 1200 | 80 | 1170 | 8.8 |
| 1400 | 13 | 1280 | 8.4 |
| 1500 | 2 | 1540 | 1.3 |

1) Temperature (°C); 2) ultimate compression strength of sintered and stabilized $ZrO_2$ kg/mm²; 3) ultimate tensile strength of $ZrO_2$ sintered at 1900° (kg/mm²).

The modulus of elasticity also depends on the temperature (Table 18).

TABLE 18

| 1 Темп-ра (°С) | 2 Модуль упругости $E \cdot 10^{-6}$ (кг/см²) | 1 Темп-ра (°С) | 2 Модуль упругости $E \cdot 10^{-6}$ (кг/см²) |
|---|---|---|---|
| 20 | 1.72 | 850 | 1.16 |
| 300 | 1.38 | 1050 | 1.16 |
| 485 | 1.30 | 1225 | 1.07 |
| 570 | 1.18 | 1360 | 0.96 |

1) Temperature (°C); 2) modulus of elasticity, $E \cdot 10^{-6}$ ($kg/cm^2$).

The specific heat is 0.120 at 20°; 0.137 at 500°; 0.157 at 1000°; and 0.175 cal/g·°C at 1400°. The heat conductivity is 0.0038 at 100°, and 0.0045 cal/cm·sec·°C at 400°. The coefficient of the linear thermal expansion is equal to $100 \cdot 10^{-7}$ in the range of 30-1000°. The heat endurance of products from $ZrO_2$ depends on the degree of the stabilization of the latter. The specific electric resistance of sintered $ZrO_2$ is $10^4$ ohm·cm at 1000°, and 6-7 ohm·cm at 1700°. The high electric conductivity permits to use rods of $ZrO_2$ as heaters in high-temperature furnaces. $ZrO_2$ is resistant to diverse reducing agents at low temperature. Potassium, sodium, aluminum, iron, glass and silicates can be melted in $ZrO_2$ crucibles. Solutions of alkali hydroxides, carbonates and acids (apart from concentrated $H_2SO_4$ and HF) do not affect $ZrO_2$. Sintered $ZrO_2$ is used for the lining of furnaces, as crucibles for melting of quartz glass, platinum, and alloys, as insulator, etc.

Thorium dioxide. Specific gravity 9.69; melting point 3050±20°; Mohs hardness 6.5. The ultimate compression strength at different temperatures is quoted in Table 19.

The ultimate tensile strength is 10 $kg/mm^2$ at 20°. The modulus of elasticity is $1.40 \cdot 10^4$ at 20°, and $1.1 \cdot 10^4$ $kg/mm^2$ at 1000°. The heat conductivity is 0.025 at 100°, 0.014 at 500°, and 0.008 cal/cm·sec·°C

at 1000°. The coefficient of linear thermal expansion is equal to $90 \cdot 10^{-7}$ in the range 25-100°. Crucibles from sintered $ThO_2$ are practica-

TABLE 19

| 1 Темп-ра (°С) | 2 Предел прочности при сжатии (кг/мм²) | 1 Темп-ра (°С) | 2 Предел прочности при сжатии (кг/мм²) |
|---|---|---|---|
| 20 | 150 | 1000 | 36 |
| 400 | 110 | 1200 | 20 |
| 600 | 60 | 1400 | 5 |
| 800 | 50 | 1500 | 1 |

1) Temperature (°C); 2) ultimate compression strength ($kg/mm^2$).

ble up to 2700° in an oxidizing atmosphere or in vacuum; they are used for smelting platinum, rhenium, and for raffination of radium. Sintered $ThO_2$ is stable to basic slags, but it is destroyed by $SiO_2$; at high temperature, $ThO_2$ becomes reduced by carbon. Objects made from sintered $ThO_2$ are used in nuclear reactors. During storage, thorium compounds gradually emit radioactive gases injurious to health, therefore, appropriate precautionary measures must be kept.

Uranium dioxide. Specific gravity 10.97; melting point 2878±22°; Mohs hardness 3.5; the heat conductivity of the sintered $UO_2$ is 0.0234 at 100°, 0.0105 at 600°, and 0.00815 cal/cm·sec·°C at 1000°. The specific electric conductivity ($ohm^{-1} \cdot cm^{-1} \cdot 10^{-3}$) is: 9.3 at 22°; 14.0 at 40°; 20.5 at 60°; 37.2 at 96°, 73 at 155°; 126 at 223°, and 235 at 327°. Sintered $UO_2$ is used as a structural material in nuclear reactors, for crucibles, pyrometer tubes, etc. Objects made from $UO_2$ are practicable only in neutral and reducing media, because heated $UO_2$ becomes transformed in $U_3O_8$ in oxidative media. Protecting gloves and gas masks must be used when operating with $UO_2$.

Cerium dioxide. Specific gravity 7.3; melting point 2750°; Mohs hardness 6; mean specific heat 0.0918 cal/g·°C at 25°. The coefficient of linear expansion is $86 \cdot 10^{-1}$ in the range 100-500°. The specific

electric resistance is $2.2 \cdot 10^3$ at 800°, and $1.9 \cdot 10$ ohm·cm at 1200°.

References: Tresvyatskiy S.G., Cherepanov A.M., Vysokoorneupornyye materialy i izdeliya iz okislov [High-Refractory Materials and Products from Oxides], Moscow, 1957; Pavlushkin N.M. Spechennyykorund [Sintered Corundum], Moscow, 1961; Poluboyarinov D.N., Balkevich V.L., Popil'skiy R.Ya., Vysokoglinozemistyye keramicheskiye i ogneupornyye materialy [High-Alumina Ceramic and Refractory Materials], Moscow, 1960.

N.M. Pavlushkin

OXIDE MAGNETS - see Oxifers.

OXIDE SCALE IN ALUMINUM ALLOYS - see nonmetallic inclusions in aluminum alloys.

OXYFERS (Ferrites) – nonmetallic magnetic materials manufactured by powder metallurgy. They are solid solutions of ferric oxide $Fe_2O_3$ and oxides of divalent metals (Ni, Mn, Zn, Mg, Cu, etc.). The majority of oxyfers have a complex cubic lattic of the spinel ($MgO-Al_2O_3$) type and they are all semiconductors. The high electrical resistance (~$10^1$-$10^8$ ohm·cm) and magnetic characteristics of oxyfers make them valuable radio-engineering materials. Binary oxyfers, which consist of the ter-

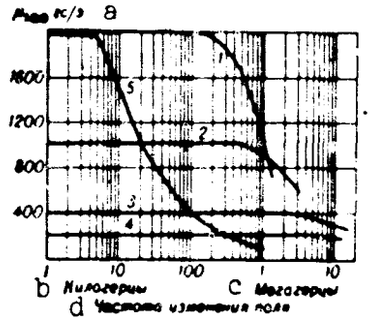



Figure. Permeability efficiency as a function of field-variation frequency for certain nickel-zinc oxyfers and low-nickel 50NKhS permalloy: 1) Oxyfer 2000; 2) oxyfer 1000; 3) oxyfer 400; 4) oxyfer 200; 5) 50NKhS permalloy 0.1 mm thick. a) $\mu_{eff}$, cps/oersted; b) kilocycles; c) megacycles; d) field-variation frequency.

nary oxide system $Me_I O-Me_{II} O-Fe_2O_3$, are of technical importance. Binary nickel-zinc and manganese-zinc oxyfers are widely used as soft magnetic materials (in transmission, radio, radar, and television equipment). By way of illustration, the figure shows effective permeability $\mu_{eff}$ as a function of field-variation frequency for a number of nickel-zinc oxyfers in comparison with low-nickel 50NKhS permalloy. It can be seen from this figure that, even for oxyfers with extremely high permeabilities, the critical frequency band within which there is a sharp drop

in permeability (and a rapid increase in losses) is displaced to the vicinity of 100 kc-1 mc, while for permalloy this band lies within the range 10-100 kc. Low-permeability oxyfers (RCh-50, RCh-12) are used at frequencies of up to tens of mc. Oxyfers based on $MgO-MnO-Fe_2O_3$ with a rectangular hysteresis loop have been developed; they are used in magnetic amplifiers and as memory elements in computers. Oxyfers of type I-5, which have a high magnetic induction, are used in high-power high-frequency equipment. Ferrites based on $MeO-BaO-Fe_2O_3$, which have a hexagonal lattice and a low permeability, are used at frequencies of up to 500 Mc. Copper-nickel oxyfers, which are distinguished by a narrow absorption band, are intended for use in the three-centimeter range ($10^4$ mc. Hexagonal barium oxyfers have been used as a basis for development of permanent magnets with a number of advantages over metal magnets (low specific gravity, high electrical resistance, etc.). Isotropic oxide magnets have characteristics equivalent to those of alnico magnets. Thus, ferroksdur (14% BaO and 86% $Fe_2O_3$) has a residual induction $B_r$ = = 2000 gausses, a coercive force $H_c$ = 1500 oersteds, and a magnetic energy $(BH)_{maks} = 0.8 \cdot 10^6$ gauss·oersted. Pressing in a magnetic field makes it possible to produce anisotropic magnets with characteristics equivalent to those of cobalt-containing alnico magnets. Barium oxide magnets are widely used for acoustic converters, magnetic-focusing devices, rotors and stators for low-power electric motors, etc.

References: Sholts, N.N. and Piskarev, K.A., Oksidnyye magnitnyye materialy [Oxide Magnetic Materials]. Moscow, 1958 (Mosk. dom. nauch.-tekhn. propagandy im. F.E. Dzerzhinskogo. Peredovoy opyt proizvodstva. Ser. radiopriborostroyeniye [Moscow House of Scientific-Technical Information imeni F.E. Dzerzhinskiy. Advanced Production Experience. Radio-Instrument Building Series], No. 6); Zaymovskiy, A.C. and Chudnovskaya, L.A., Magnitnyye materialy [Magnetic Materials], 3rd Edi-

tion, Moscow-Leningrad, 1957; Smolenskiy, G.A. and Gurevich, A.G., in collection: Poluprovodniki v nauke i tekhnike [Semiconductors in Science and Technology], Vol. 2, Moscow-Leningrad, 1958, pages 349-424.

B.G. Livshits and A.A. Yudin

OZONE RESISTANCE OF POLYMERS – the ability of polymers to withstand the action of atmospheric ozone. This characteristic is especially important for rubber components that must function under tension or are subject to alternating deformation. Ozone reacts with the surface of many polymers to form a brittle film that fractures under the action of tensile stresses. This phenomenon is then repeated with the exposed layer, etc. As a result, the component is covered with numerous fine cracks, which make it unsuitable for further use. The ozone resistance of polymers is determined to a considerable extent by the presence of polar substitutes. A negligible concentration of ozone in the atmosphere is sufficient to affect the characteristics of a polymer. The air near the earth's surface contains $10^{-6}$% ozone, but this content may vary materially with the time of year, the latitude, and the condition of the atmosphere. Ozone is activated by solar radiation (see Atmosphere resistance). The ozone resistance of polymers can be increased by use of protective substances, such as waxes, or by addition of antiozonants, such as pyrrole derivatives, the nickel salt of dithiocarbamic acid, etc. However, these substances are not always sufficiently effective. Certain rubbers, such as those based on polychloroprene, have an elevated ozone resistance, so that they can be employed as protective films on the surface of more sensitive materials. Chlorsulfopolyethylene, silicone rubbers, and fluoridated polymers also have high ozone resistance.

References: Kuz'minskiy, A.S., Lezhnev, N.N., Zuyev, Yu.S., Okisleniye kauchukov i rezin [Oxidation of Gums and Rubbers], Moscow, 1957;

II-7,0-2

Buist, J.M., Aging and Weathering of Rubber, Cambridge, 1956.

N.N. Lezhnev

PACKING CARDBOARD – is a material for the preparation of packings, tightly separating one working part of a machine from another or from the environmental medium. It secures a tight connection even of not accurately parallel planes (due to a nonuniform compression of the packing in the diverse points). Packing cardboard is compressible, highly elastic, snows an insignificant linear deformation when moistened and dried; it absorbs lubricating oil, fuel oil, and water in a low degree and does not cause corrosion of the joint surfaces, it is not destroyed by action of the sealed medium and when the joint is separated; it does not peel off when the packings are prepared. Packing cardboard loses the elasticity when heated above 130-150° and becomes brittle. Packing cardboard is deliverable in the following grades: grade A (impregnated) from sulfate cellulose, rags and gluing substances; it is used in gasoline pipelines, gasoline engines of motorcars, refrigerators, and other machines; 2) grade B from sulfate cellulose, without gluing substances; the specificial properties are obtained by an appropriate selection of the components and the conditions of the production; it is used for packings in petrolcum pipelines, diesel engines, tractors, etc. Packing cardboard is delivered in the color of the natural fiber. Production of colored grade A packing-cardboard is permitted when asked by the commissioner. The surface of the packing-cardboard must be smooth, without warps, folds, wrinkles, bubbles, nonfibrous inclusions and squeezed spots. Packings for the fuel supply and the lubrication system of aircrafts are made from packing-cardboard of the grades VIANIB and VIAKAD. These grades of packing-cardboard are made by tan-

ning and impregnation of the cardboard basis with gelatine-glycerol mixtures and castor oil; they are characterized by a high mechanical strength (temporary tensile strength 240 kg/cm$^2$ in transversal direction), a high density (volume weight 1.0-1.5 g/cm$^3$), a good resistance to oil, gasoline and kerosene, and a limited linear deformation.

The physicomechanical properties of packing cardboard are listed in the Table

TABLE

Physicomechanical Properties of Packing Cardboard

| 1 Показатели | Марка А 2 | | Марка Б 3 | |
|---|---|---|---|---|
| | толщина (мм) 4 | | | |
| | 0.2—0.8 | 1.0—1.5 | 0.30—0.50 | 0.8—2.5 |
| 5 Объемный вес (в г/см³) | 0.80 | 0.85 | 0.80 | 0.85 |
| 6 Впитываемость за 6 час (%, не более) при полном погружении в: | | | | |
| 7 воду | 60 | 60 | 150 | 120 |
| 8 бензин (галолин) | 35 | 30 | — | — |
| масло (автол) 9 | 35 | 30 | — | — |
| 10 Предел прочности при растяжении (в кг/мм², не менее): | | | | |
| 11 в поперечном направлении | 1.0 | 1.0 | 2.0 | 1.5 |
| 12 в среднем по двум направлениям | 2.0 | 2.0 | 4.0 | 2.5 |
| Линейная деформация после 13 выдерживания образца в гигростате в течение 24 час, (%, не более): | | | | |
| 11 в поперечном направлении | 1.0 | 1.0 | 1.0 | 1.0 |
| 12 в среднем по двум направлениям | 0.65 | 0.65 | — | — |
| 14 Сжимаемость при нагрузке 40 кг/см² (%, не менее) | 28 | 25 | — | — |
| 15 Упругая деформация картона после снятия нагрузки (%, не менее) | 85 | 85 | — | — |
| 16 Влажность (%) | 12 | 12 | 10 | 10 |

1) Indices; 2) grade A; 3) grade B; 4) thickness (in mm); 5) weight by volume (g/cm3); 6) acility to soak in within 6 hrs (%, not more than) when completely immersed into; 7) water; 8) benzine (gasoline); 9) oil (autol); 10) ultimate tensile strength (kg/mm$^2$, not less than); 11) in longitudinal direction; 12) as an average of two directions; 13) linear deformation after holding the specimen in a hydrostate for 24 hrs (%, not more than); 14) compressibility under a load of 40 kg/cm$^2$ (%, not less than); 15) elastic deformation of the cardboard after removal of the load (%, not less than); 16) moisture content (%).

It is delivered according to GOST 9347-60.

S. Sh. Ryvlin

PAINTS (enamels) are varnish and paint materials consisting of a film-forming and thinly dispersed pigment, sometimes with the addition of mineral fillers. The paints in which the film-forming material is linseed oil are termed oil paints; the paints containing lacquer are termed enamels. The properties of the paints (enamels) depend on the form of the film-forming material, the nature and the quantity of the pigment. The pigments give color to the paint film or enamel film, improve the sunlight and atmospheric stability, reduce moisture penetration and moisture-swelling, increases the temperature resistance, contribute anticorrosion properties, reflect light and thermal rays, increase the blackness coefficient. As pigments (50-100 parts by weight to the film-forming material) use is made of powders of aluminum, bronze, stainless steel, zinc, titanium oxides (white color), iron (yellow, brown, black and red colors), chromium (green color), cadmium salt (yellow and red colors), strontium (yellow color) and others. Use is also made of organic pigments which are not water-soluble, phthalecyanate, madder lake, azo dyes and others. In order to improve the operational qualities of the paints and enamels and to reduce their cost, [illegible] are added 25-100 parts by weight (of the film-forming material) of filler (asbestite, kaolin, talc and others). Mica is introduced to improve the thermal resistance. The degrees of dispersion of the pigment has an important effect on the quality of the paint and the coating film; the finely dispersed pigments and fillers are less prone to sedimentation, have better covering power, give coatings with better atmospheric stability.

The paints and enamels are divided into two groups depending on the film-forming material: the bituminous group contains bitumens or asphalts and also drying oils; the fillers are asbestite and mica, the pigment is aluminum powder which sharply increases the atmospheric resistance; moisture resistant coatings with good dielectric characteristics are formed. The oil group uses natural or thickened linseed oil as the film-forming material. The coatings using natural linseed oil have satisfactory atmospheric resistance (of the order of 2-3 years depending on the nature of the pigment in the paint composition). The best anticorrosive properties are achieved with the use of oil primers containing red lead or lead chromate. The absence of luster, poor spreading, and also shortage of vegetable oils limit the use of the oil paints. The enamel paints are oil paints using a base of natural resin, colophony, rosin ester, modified vegetable oils. They are used primarily for painting items which are located indoors. They have high luster, good spreading, moderate moisture resistance, are hard. The alkyd paints use a base of glyptal or pentaphthalic resins, modified vegetable oils. The enamels prepared from "thin" resins (containing little oil) have low atmospheric resistance and are used for painting items located indoors. The enamels prepared from "heavy" resins are atmospheric resistant, have excellent luster, are hard, water-resistant, are resistant to the action of lubricating oils and petroleum fuels. They are used for painting railway cars, buses, instruments, and also as [illegible] insulating coatings. The phenol-oil paints use a base of phenolformaldehyde resin mixed with oils. The hot-drying coatings have excellent hardness, water resistance, luster, are suitable for use in a humid tropical climate. The alkyd-melamine-formaldehyde and alkyd-urea-formaldehyde or synthetic enamels have high sunlight resistance, hardness, are resistant to the action of oils, gasoline, water, alcohol.

They are used for painting autos, instruments and machinery. In the cellulose-ester-base lacquers, cellulose esters serve as the film-forming agent. The nitrocellulose enamels dry rapidly, have good luster and atmospheric resistance, are used for painting furniture, instruments and machinery; the drawback is the high flammability of the film. The ethyl-cellulose enamels have better atmospheric resistance and considerably less combustibility of the film, are used in aircraft construction. The epoxies are based on epoxy resins. The epoxy enamels, as a result of the interaction of the epoxy resin with the hardeners (polyamides, organic acids, and others) which contain mobile hydrogen which reacts with the epoxy groups, harden at room temperature; improved properties are obtained with heating to 100-150°. The films of the epoxy enamels are water-, oil- and gasoline-resistant; they are resistant to hot concentrated alkalies and weak acids; they are hard, have excellent adhesion, high elasticity. They are used as chemical-, water- and thermal-resistant coatings for instruments and machinery. The acryl paints use acryl resins as the base. They are fast-drying, have high sunlight- and atmospheric-resistance. They are used in the aircraft industry instrumentation. The vinyls are based on the polymerizing perchlorvinyl resins or the copolymers of polyvinyl chloride with vinylidene chloride or polyvinyl acetate. They are fast-drying and have high chemical, frost and water resistance. The perchlorvinyl enamels are atmospheric (to 5-8 years) and chemicall resistant; they are used as anticorrosive and protective coatings for items made from the ferrous and nonferrous alloys (in conjunction with suitable primers), wood and plastics used in any conditions, particularly tropical. Long-term heating of the coating above 90-100° is not permitted. The enamel film is noncombustible and relatively resistant to the action of molds and fungi. The silicones are based on the silicone resins, sometimes in combination with

the epoxy, alkyd or acryl resins. They have satisfactory atmospheric and water resistance. They are used primarily as thermally resistant coatings for items made from steel, aluminum and magnesium alloys and the plastics, can withstand long-term heating to 400-550° and short-term heating to 700-800° without essential degradation of the film properties. The coatings are dried at 180-200°.

References: Lyubimov B.V., Spetsial'nyye lakokrasochnyye pokrytiya v mashinostroyenii [Special paint-Type Coatings in Machine Construction], M.-L., 1959; Organic Protection Coatings, transl. from Eng., M.-L., 1959; Drinberg A.Ya., Gurevich Ye.S., Tikhomirov A V., Tekhnologiya nemetallicheskikh pokrytiy [Technology of Normetallic Coatings], L., 1957.

V.V. Chebotarevskiy

PALLADIUM, Pd – a chemical element in group VIII of the Mendeleyevian periodic system having an atomic number of 46 and an atomic weight of 106.4. There are six stable isotopes: $Pd^{102}$ (0.96%), $Pd^{104}$ (10.97%), $Pd^{105}$ (22.23%), $Pd^{106}$ (27.33%), $Pd^{108}$ (26.71%), and $Pd^{110}$ (11.81%). Fission of U, Th, and Pu produces radioactive isotopes of Pd, the most important of which is $Pd^{109}$. Palladium belongs to the platinum family of metals; the Pd content of the earth's crust is $1 \cdot 10^{-6}$% by weight. The density of this metal ($g/cm^3$) is 12.02 at 20° and 11.0 at 1550°, its $t^{\circ}_{pl}$ is 1552°, and its $t^{\circ}_{kip}$ is ~3980°. Palladium is similar in properties to silver, but is higher-melting and is not tarnished by hydrogen sulfide. It is used as a catalyst, as a component of many technical, dental, and jewelry alloys, and in corrosion-resistant coatings. See Precious metals.

O.Ye. Zvyagintsev

PAPER FOR FACING ELECTRICAL STEEL – a thin paper manufactured from sulfated unbleached cellulose. It is produced in rolls 76 ± 2 cm wide, as well as in other formats (GOST 1201-52), and has smooth-cut edges. The table shows the technical specifications of this paper.

An important special feature of electrical-steel-facing paper is its low acidity, which is measured by determining the quantity of 0.01-normal NaOH necessary to neutralize an aqueous extract of 1 g of paper.

| Показатели 1 | Нормы 2 |
|---|---|
| Вес 1 м² (г) 3 | 20±2 |
| Толщина (мк) 4 | 33±2 |
| Лоск гладкой стороны бумаги (град., не менее) 5 | 10 |
| 6 Разрывное усилие полоски сухой бумаги шириной 15 мм в продольном направлении (кг, не менее) | 0.6 |
| 7 Время разрыва полоски бумаги шириной 15 мм, смоченной с гладкой стороны крахмальным клейстером, под действием груза 132 г (сек.) | 7 |
| 8 Кислотность (мл) | 2 |

1) Index; 2) normal; 3) weight of 1 $m^2$ (g); 4) thickness (μ); 5) luster of smooth side (degrees, no less than); 6) tensile strength of strip 15 mm wide, in longitudinal direction, (kg, no less than); 7) tearing time of strip 15 mm wide with smooth side wetted with starch sizing, under 132-g load (sec); 8) acidity (ml).

This material has a uniform fiber distribution and sufficiently close sheaths to ensure low porosity and the required mechanical strength when wet or dry, as well as the necessary permeability to air. When glued to a sheet of steel it should not form blisters, wrinkles, or folds; it should not have lumps, spots, tears, punctures, or holes. Defects within the roll (scarcely noticeable folds or wrinkles and small spots or punctures) are permissible if they are not detected during inspection. The weight of sheets with such defects should not exceed 2% of the sample weight. This paper is intended for facing sheets of elec-

trical steel to provide insulation and corrosion protection.

Z.I. Gruzdeva

PARACHUTE FABRICS – are used for making parachute canopies. The main requirements put to parachute fabrics, which are a low weight, high strength and satisfactory air permeability, are ensured by using high-number threads and creating a high density which is the same for the warp and weft. The plain weave is most frequently used in making parachute fabrics. To increase the strength with a moderate weight the carcass structure is used. Parachutes are made from silk, cotton and capron fabrics.

The characterization of parachute fabrics is given in the table below.

Characterization of Parachute Fabrics

| 1 Наименование ткани | 2 Артикул | 3 Ширина (см) | 4 Максимальный вес 1 м² (г) | 5 Число нитей на 10 см: основа | 5 Число нитей на 10 см: уток | 6 Минимальная разрывная нагрузка полоски шириной 50 мм (кг): основа | 6 Минимальная разрывная нагрузка полоски шириной 50 мм (кг): уток | 7 Минимальное разрывное удлинение (%): основа | 7 Минимальное разрывное удлинение (%): уток | 8 Воздухопроницаемость* (л/м² сек) | 9 ГОСТ, ТУ, ВТУ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 Эксцельсиор | 1053 1070 | 74/94 | 22 | 480—510 | 450—490 | 16 | 19 | 8 | 10 | — 13 | ГОСТ 2581—54 |
| 14 Газ-шифон | 1510 | 110 | 28 | 370—390 | 360—400 | 13 | 13 | 21 | 25 | — | ГОСТ 1[illegible]—49 |
| 15 Каркасное полотно «К» | 1057 | 106,5 | 56 | — | — | 30,6 | 32,5 | 11 | 12 | 950—1200—4[illegible] | ГОСТ 1[illegible]—42 |
| 16 Полотно техническое капроновое каркасное | 1521/14179 | 99—102 | 56 | — | — | 50 | 48 | 23 | 23 | 900—1800 | ТУ № МГ 422—59 |
| 19 Перкаль Б2 | 1791 | 111 | 61 | 424—440 | 480—520 | — | — | — | — | 380—700 | ГОСТ 1102—43 |
| " Б1 | 1791 | 89 | 65 | 424—440 | 480—520 | 26 | 26 | 5 | 8 | | |
| 21 Полотно техническое капроновое | 1520 | 87 | 116 | — | — | 115 | 100 | 26 | 26 | 95—350 23 | ТУ МГ 4[illegible]—59 |
| АСТ-28 23 | 1903 | 86 | 200 | 248—258 | 225—245 | 75 | 75 | 10—18 | 11—19 | — | ГОСТ 11[illegible]—43 |
| Полотно техническое капроновое 21 | 152[illegible]/20999[illegible] | 86 | 180 | — | — | 200 | 200 | 22 | 22 | — 24 | ВТУ МГ 579—[illegible] |

*The GOST does not contain a definition of air permeability.

1) Fabric designation; 2) type; 3) width (cm); 4) maximum weight of 1 $m^2$ (g); 5) thread count per 10 cm; 6) minimum rupture load of a 50 mm wide strip (kg); 7) minimum elongation at break (%); 8) air permeability* (liters/$m^2$·sec); 9) GOST, TU, VTU; 10) warp; 11) weft; 12) excelsior; 13) GOST; 14) chiffon gauze; 15) "K" carcass linen; 16) commercial linen; 17) capron carcass; 18) TU No. MG 422-59; 19) B2 percale; 20) B1; 21) commercial capron linen; 22) TU MG 420-59; 23) AST-28; 24) VTU MG 579-60.

Natural silk parachute fabrics – excelsior (type 1093 and 1070), chiffon gauze (type 1510) and "K" carcass linen (type 1057) ensure rapid opening of the parachute in the air. A shortcoming of these fabrics is the high cost and the relatively rapid aging due to atmospheric effects. Excelsior and carcass linen which are made for use in parachutes go through scouring, while chiffon gauze is used in the unfinished state. The fabrics are produced in cuts (80 m long), folded into folds of one meter and rolled onto wood poles in accordance with GOST 1637-42. The type 1791 B2 and type 1791 B1 cotton percales belong to the light parachute fabrics group. Cotton fabrics ensure good opening, stability on descent, sufficient descent velocity and landing smoothness of the parachute canopy. A shortcoming of these fabrics is their high weight. Unfinished cotton fabrics after desizing are produced in the form of cuts folded into folds of one meter and packed in bales.

Capron fabrics have a high strength and low weight. These fabrics are scoured and finished without dressing. They are packed similar to fabrics from natural silk.

Silk and capron parachute fabrics, in accordance to GOST 1637-42, are in addition tested for air permeability, which determines the magnitude of the impact load at the instant the parachute opens as well as its descent velocity before landing.

A new characteristic of parachute fabric strength is the rupture energy upon air extrusion on the "Shopper-Dalena" system instrument, supplemented by a diagramming device.

References: Gavrilov, A.M. and Konstantinov, A.S., Tekstil'nyye materialy v samoletostroyenii [Textile Materials in Aircraft Construction], Moscow, 1940; Spravochnik po mashinostroitel'nym materialam [Handbook of Machine-Building Materials], Vol. 4, Moscow, 1960; Ukazatel' gosudarstvennykh standartov [Index of State Standards], Moscow,

1964; Potapova, L.V., Otsenka razryvnoy prochnosti tkaney metodom prodavlivaniya vozdukhom [Estimating the Tensile Strength of Fabrics by the Air Extrusion Method], "Izv. vysshikh uchebnykh zavedeniy. Tekhnologiya tekstil'noy promyshlennosti" [News of Higher Institutions of Learning. Technology of the Textile Industry], No. 5, 1959.

L.V. Potapova

| Manuscript Page No. | [Transliterated Symbols] |
|---|---|
| 2898 | ГОСТ = GOST = Gosudarstvenny obshchesoyuznyy standart = All-Union State Standard |
| 2898 | ТУ = TU = tekhnicheskiye usloviya = technical specifications |
| 2898 | ВТУ = VTU = Vsesoyuznyye tekhnicheskiye usloviya = All-Union technical specifications |

PARAMAGNETIC CRYSTALS FOR QUANTUM AMPLIFIERS AND GENERATORS - crystals having a positive magnetic permeability, which generally rises as the temperature drops. The paramagnetism of such crystals is due to their content of paramagnetic ions, such as $Cr^{3+}$, $Fe^{3+}$, $Cd^{3+}$, $Nd^{3+}$, and $Pr^{3+}$.

The magnetic moment of these ions with respect to an external magnetic field can lie only in rigidly defined directions characterized by different ion energies. Thus, when the orientation of the magnetic moment is changed energy ($\Delta E$) is absorbed or radiated in the form of electromagnetic oscillations with a frequency $\nu = \Delta E/h$ ($h = 6.62 \cdot 10^{-27}$ erg·sec and is Planck's constant). The radiation of energy by such ions, which occurs under definite conditions (induced radiation), is utilized in paramagnetic quantum amplifiers and generators operating in the ultrahigh-frequency and optical ranges. Such generators and amplifiers are extremely stable and have a very low inherent-noise level. The paramagnetic crystals most widely used for this purpose are monocrystals of ruby, $Al_2O_3 \cdot Cr^{3+}$ (i.e., corundum with an admixture of chromium); $TiO_2 \cdot Fe^{3+}$, $CaWO_4 \cdot Cr^{3+}$, $CaWO_4 \cdot Ho^{3+}$, etc., are also employed.

References: Kvantovyye paramagnitnyye usiliteli [Paramagnetic Quantum Amplifiers], collection of articles translated from English, Moscow, 1961.

M.M. Gorshkov

PARONIT – a sheet packing material manufactured by rolling a mass consisting of asbestos, powdered ingredients, and rubber. It is produced in sheets and in the form of gaskets. Asbestos-product plants manufacture the following types of paronit.

Paronit (GOST 481-58), a sheet material ranging from 300 × 400 to 1200 × 1700 mm in size and from 0.4 to 6.0 mm in thickness. It has a specific gravity of 1.5-2.0 and a thermal conductivity of 0.422-0.445 kcal/m·hr·degree; the breakdown strengths of sheets 0.52, 1.0, 1.5, and 2.0 mm thick are 3.55, 2.3, 1.6, and 1.2 kv/mm respectively. The mean shrinkage of sheets 0.6-2.0 mm thick under a pressure of 600 $kg/cm^2$ is 18-23%. It is used in the form of packings in joints intended to function in water and steam at a pressure of 50 $kg/cm^2$ and a temperature of 450°, in petroleum and heavy and light petroleum products at temperatures of 200-400° and pressures of 70-40 $kg/cm^2$, and in liquid and gaseous oxygen at a pressure of 2.5 $kg/cm^2$ and temperatures of from -62 to -182°. Paronit sheets 1.0, 1.5, and 2.0 mm thick should not fracture or crack when bent by 180° around cylinders 12.24 and 42 mm in diameter. Paronit packings should insure complete hermetic sealing at a steam pressure of 100 $kg/cm^2$ and a temperature of 450°.

UV-10 paronit (TUMKhP 1369-50R) is used in the form of packings for aircraft-engine joints intended to operate in kerosene and oil. It has a specific gravity of 2.0 and a thickness of from 0.4 to 2.5 mm and is produced in sheets 550 × 550 mm in size and in the form of ready-made packings. Tensile testing should yield the indices shown in the table.

| Условия испытания 1 | Прочность на разрыв (кг/см², не менее) 2 | | Увеличение веса 5 (%) |
|---|---|---|---|
| | в продольном направлении 3 | в поперечном направлении 4 | |
| При температуре [illegible] без предварительного набухания 6 | 320 | 120 | – |
| После выдерживания в керосине в течение 24 час. при температуре 15–20° 7 | 180 | 70 | 16 – 26 |
| После выдерживания в масле МК в течение 24 час. при температуре 150° 8 | 280 | 100 | 23 |

1) Test conditions; 2) tensile strength (kg/cm$^2$, no less than); 3) in longitudinal direction; 4) in transverse direction; 5) increase in weight (%); 6) at 15-20° without preliminary distension; 7) after soaking in kerosene for 24 hr at 15-20°; 8) after soaking in MK oil for 24 hr at 150°.

Bend-testing indices should be the same as those given for paronit by GOST 481-58. A specimen of UV-10 paronit clamped between two aluminum, duralumin, or steel plates should not cause corrosion and should peal away when the plates are separated.

Type ECh paronit (electrolizer) is intended for sealing electrolizers of type "FV" and for electrical insulation of electrolizer cells. It is produced in sheets 2.3 m long, no more than 1300 mm wide, and 1.0-7.5 mm thick and in the form of ready-made packings. Its gain in weight after soaking in 30% KOH for 24 hr at 90° should not exceed 20% and its residual shrinkage after compression at 600 kg/cm$^2$ should be no more than 10%; its electrical resistance should be no less than $10^7$ ohms per running meter for a specimen 1 mm$^2$ in cross-section. This material has a specific gravity of 2.0; a specimen 300 × 20 × 2 mm in size should not crack when bent through 180° around a cylinder 42 mm in diameter.

Type 56 paronit (TUMKhPT773 Lit. A) is used in the manufacture of packings intended to seal joints in components operating in ethyl alcohol, L1 oil, air, water vapor, steam gas (63% steam and 37% free oxy-

gen), and liquid oxygen. It is produced in sheets 500 x 500, 1000 x x 950, and 1200 x 700 mm in size and from 0.5 to 2.5 mm thick. This material has a specific gravity of 1.6-1.9; its bending indices are the same as those given for paronit by GOST 481-58. Packings of type 56 paronit should insure complete hermetic sealing of systems at component-joint sites under the conditions shown in the table.

| Среда 1 | Давление (кг/см²) 2 | Темп-ра (°С) 3 |
|---|---|---|
| 4 Водяной пар и парогаз | 8 До 75 | 9 До 450 |
| 5 Этиловый спирт | До 50 | От +60 до −50 |
| 6 Масло Л1 (ТУ 333-52) | До 50 | От +50 до −50 |
| Воздух 7 | До 55 | От +40 до −50 |

1) Medium; 2) pressure (kg/cm$^2$); 3) temperature (°C); 4) water vapor and steam; 5) ethyl alcohol; 6) L1 oil (TU333-52); 7) air; 8) up to; 9) from.

Specimens of type 56 paronit clamped between two plates of aluminum, aluminum alloys, steel, or brass should not cause corrosion. The guaranteed storage life of this material is 6 years.

Graphitized type 56 paronit has essentially the same characteristics as type 56 paronit. The surface of the former is supplementally coated with a smooth layer of graphite and vulcanized, which gives it greater mechanical strength. It is produced in sheets 550 x 550 mm in size and from 0.5 to 2.0 mm thick. Graphitized type 56 paronit should be able to withstand a pressure of 75 kg/cm$^2$ at 450° in steam or steam gas and at 50° in ethyl alcohol.

Ferronite is a sheet packing material with a metallic reinforcing grid obtained by rolling a raw asbestos-rubber mass. It is used in the form of packings in aviation-engine building for sealing joints in components intended to operate in gasoline, kerosene, mineral oil, and the combustion products of these substances. Ferronite should be able to withstand a working pressure of 75 kg/cm$^2$ in such media. It is produced in sheets no larger than 1500 x 1000 mm and from 0.8 to 1.2 mm thick.

It has a specific gravity of 2.7. This material is elastic and should not fracture or crack when strips are bent through 180° around a cylinder 24 mm in diameter.

Type 56 ferronite is a sheet packing material with a metallic reinforcing grid manufactured by rolling a raw asbestos-rubber mass. It is used in the production of packings intended to function in steam and steam gas. This material is supplied in the form of sheets 550 × 550 mm in size and 1.5 and 2 mm thick. Its specific gravity is 2-2.5. Type 56 ferronite should not fracture or crack when bent through 180° around a cylinder 42 mm in diameter; it should not separate, peel away from its metallic reinforcing grid, or corrode aluminum, aluminum alloys, steel, or brass. The guaranteed storage life of this material is 5 years.

Type 9-38-56 paronit is used in the form of packings of varying size and shape for sealing joints in metallic surfaces intended to function in gasoline, TS-1, T-1, and TR fuels, MK-8, TsNIL36/1, and other oils, and similar fuels and oils at temperatures of up to 200°. It is produced in sheets 500 × 500 and 600 × 500 mm in size and from 0.4 to 2.5 mm thick and has a specific gravity of 1.5-2.0. Before exposure to working media its ultimate tensile strength in the transverse direction at 18-20° should be no less than 150 kg/cm$^2$, while after exposure to working media for 24 hr at 200° this index should be no less than 100 kg/cm$^2$. Specimens of type 9-38-56 paronit soaked in fuels or oils for 24 hr at 200° may exhibit a weight gain of 5-18%; this material retains its elasticity and does not corrode D16 duralumin (plated or unplated) or other metals. It has a guaranteed storage life of 2 years.

S.I. Chernyshev

**PASS COEFFICIENT** – the ratio of the radiant energy passing through a body to that incident on it: $d = E_{prosh}/E_{pad}$. The pass coefficient depends on the thickness, chemical composition, and physical state of the body, and on density as well for gases.

G.A. Zhorov

PATENTING OF STEEL – a type of heat treatment carried out as an intermediate operation during the drawing of carbon steel in order to increase its plasticity. Cold deformation causes steel to become stronger and less plastic, which hampers subsequent drawing; heat treatment (patenting) must consequently be employed to restore the plasticity of steel after a certain reduction in area has been achieved. Patenting consists in isothermal quenching (see Quenching of steel) from 800-900° in baths with a medium temperature of 500-650° (depending on the type of steel). Patenting gives steel a structure consisting of highly dispersed sorbite and a small amount of troosite, this being favorable for subsequent cold deformation. Patenting followed by cold-working (by further passes through the die) insured production of wire with a very high strength ($\sigma_b$ = 300-450 kg/mm$^2$) and elasticity and sufficient reserve plasticity. Patenting must be conducted in such fashion as to keep the drawing process continuous; on leaving the die the wire is consequently passed through tubes mounted in a furnace heated to the quenching temperature of the steel. After heating the wire is drawn through a lead bath, removed, cooled, wound on drums, and drawn through the next die. The length of the furnace and the bath, the distance from the bath to the winding drum, and the rate at which the wire travels are calculated in such fashion that the wire can be heated to the requisite temperature, the transformations during isothermal quenching can go to completion, and the wire can be cooled in air.

M.L. Bernshteyn

PAVINOL – a decorative-apparel fabric of natural or artificial fiber with an elastic polyvinyl chloride coating applied to one side. Depending on its purpose, we can distinguish haberdashery pavinol, which is a leather substitute, and aviation pavinol. Haberdashery pavinol is based on cotton cloth of the byaz' or moleskin type. Aviation pavinol is based on fiberglass or cotton cloth impregnated with a fire-retardant substance. Pavinol is give a decorative appearance by addition of mineral or organic pigments to the coating and application of an embossed pattern to its surface. This material has a higher resistance to repeated wear than cloth, leather, or leatherette. Pavinol is fastened mechanically or by gluing.

Depending on its decorative pattern, coating, and cloth base, haberdashery pavinol is produced in railroad-car, screen, and automobile types, which are used for the inside trim of automobile cabs and railroad passenger cars, as a movie-screen material, etc. Aviation pavinol is used for facing the ceiling and walls of passenger-aircraft cabins. We can distinguish aviation pavinols of type PA, which is based on type AP fiberglass cloth, and type PA-1, which is based on A-85 percale cotton cloth impregnated with a fire-retardant substance.

Surface dirt on pavinols is easily removed with a soap solution in gasoline.

The table shows the basic physicomechanical characteristics of pavinols.

L.Ya. Yaseneva

PEARLITIC CAST IRON – is a cast iron with an eutectic (0.7-0.9%) content of combined carbon corresponding to an entirely pearlitic metal base of the cast iron, ferrite and structurally free carbides being absent. The pearlitic structure consists of alternating cementite and ferrite lamellae of various degrees of dispersity depending on the chemical composition of the cast iron and on its cooling rate when passing the critical $A_{r_1}$ point.

Gray iron, high-strength magnesium-alloy iron, and malleable (non-alloy and low-alloy) iron may have a pearlitic structure. Iron castings with a pearlitic structure possess an increased strength, which is higher the greater the degree of dispersity of the pearlite (on the condition that the graphite precipitations be equal in dimension, shape and distribution), and an increased wear resistance (see Gray iron, Malleable iron, Magnesium-ally iron, Wear-resistant iron, Antifriction iron, Friction iron, Cast iron for piston rings). The pearlitic base of the structure is obtained during the casting process of the object or after the heat treatment of white or mottled iron, or also of gray or high-strength (magnesium-alloy) iron with a ferrite-pearlitic or pearlite-cementitic structure (see Heat treatment of cast iron).

III-1-ch1

Classification of the Metal Base of Cast Iron with Regard to to the Dispersity of the Pearlite (GOST 3443-57)

| 1 Балл | 2 Обозначение | 3 Межпластинчатое расстояние (мк) | 4 Характеристика перлита |
|---|---|---|---|
| 1 | Пд 0,2 | <0,3 | 6 Весьма тонкопластинчатый (сорбитообразный) |
| 2 | Пд 0,5 | 0,3—0,8 | Тонкопластинчатый 7 |
| 3 | Пд 1,0 | 0,8—1,3 | Мелкопластинчатый 8 |
| 4 | Пд 1,4 | 1,3—1,6 | Среднепластинчатый 9 |
| 5 | Пд 1,6 | >1,6 | Крупнопластинчатый 10 |

1) Degree; 2) designation; 3) interlamellar distance (microns); 4) characteristics of the pearlite; 5) Pd...; 6) highly thin-lamellar (sorbite like); 7) thin-lamellar; 8) fine-lamellar; 9) medium-lamellar; 10) coarse-lamellar.

A.A. Simkin

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[Transliterated Symbols]

2910 Пд = Pd = perlita dispersiya = dispersion of the pearlite

PEELING STRENGTH – a characteristic of the strength of adhesion between a flexible film of adhesive (usually a polymer) and a solid base of metal, glass, etc. The index of peeling strength is the work required to separate 1 $cm^2$ of the glued surface or the force (GOST 411-41) applied per unit specimen width, which depends materially on the peeling rate, increasing with the latter. Variations in temperature affect primarily the type of separation. As the temperature rises the internal stresses produced in the film during gluing may be partially eliminated as a result of the fact that the film usually has a higher coefficient of thermal expansion than the base and partially neutralized by the increase in the rate of the relaxation processes taking place in the film. This raises the adhesion strength and a mixed type of fracture is observed in place of adhesive fracture. If the temperature is further increased fracture becomes cohesive, since the strength of polymers drops sharply, falling below their adhesion strength, as temperature rises.

G.M. Bartenev

PEGMATITES – rocks occurring in veins, lenses, and pockets and characterized by gigantic mineral constituents, an unusual structure and texture, a high content of volatile components (water, fluorine, boron, etc.), and a diverse, complex mineral composition.

Pegmatites are classified by: 1) mineral composition (quartz-feldspar, muscovite, cryolite, tourmaline, beryl, spodumene, eudialite, disthene, etc.); 2) chemical composition (sodium-lithium, boron-fluorine, fluorine-beryllium, niobium-tantalum with rare elements, etc.); 3) commercial use (ceramics, glass, rare metals, mica, piezoquartz, emerald, etc.). The applications of pegmatites are based on their mineral composition, structure, and textural and geochemical characteristics.

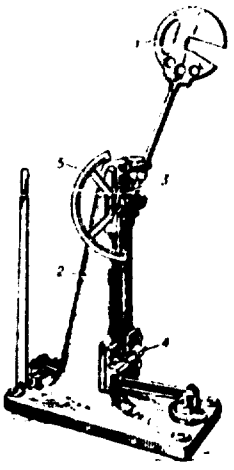
Pegmatites are used to produce potassium feldspar for electrical insulation, sodium feldspar for glass manufacture, mica for the electronics industry, and gems (emerald, phenacite, chrysoberyl, tourmaline, and amethyst).

References: Fersman, A.Ye., Pegmatity [Pegmatites], Vol. 1, 3rd Edition, Moscow-Leningrad, 1940; Vlasov, K.A., Teksturno-paragenetich-eskaya klassifikatsiya granitnykh pegmatitov [Textural-paragenetic classification of granitic pegmatites], IAN SSSR, Ser. geol. [News of the Academy of Sciences USSR, Geological Series], 1952, No. 2; Magidovich, V.I., Polevoshpatovoye syr'ye, yego zameniteli i vozmozhnyye novyye istochniki v SSSR [Feldspar Raw Materials, Their Substitutes, and Possible New Sources in the USSR], Tr. In-ta geol. rudnykh mestorozhdeniy, petrografii, mineralog. i geokhimii AN SSSR [Transactions of the

Institute of Ore-Deposit [illegible]logy, Petrography, Mineralogy, and Geochemistry of the Academy of Sciences USSR], 1961, No. 48.

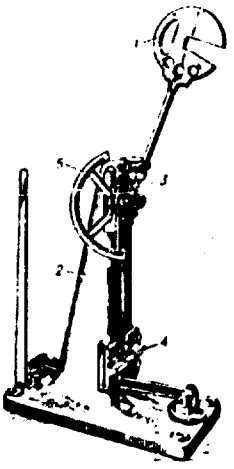
V.I. Magidovich

PENDULUM IMPACT TESTER is a testing machine for determining the properties of materials under conditions of dynamic application of loads, i.e., at high deformation rates. In testing using impact testers, most often a determination is made of the impact strength in bending of notched specimens (GOST 9454-60) and sometimes the determination is made in impact tension. The working element of the impact tester (figure) is a massive pendulum with knife which rotates freely in bearings mounted on the frame. The pendulum is raised to the initial position (usually manually) and retained by a catch or ratchet device. The specimen is mounted on supports, after which the pendulum is released and breaks the specimen as it falls. Measurement of the initial and final angles of thependulum (on a scale) permits determining the work expended on fracture of the specimen. Pendulum impact testers have been built with work capacity from 0.4 to 250 kgm. Impact testers with energy capacity of 15 and 30 kgm (types MK-15 and MK-30) are produced in the USSR.



Pendulum impact tester: 1) pendulum; 2) frame; 3) latching device; 4) specimen support; 5) scale.

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Pendulum impact tester: 1) pendulum; 2) frame; 3) latching device; 4) specimen support; 5) scale.

II-59M1

Reference: Avdeyev B.A., Tekhnika opredeleniya mekhanicheskikh sovystv materialov (Technique for Determing Mechanical Properties of Materials), 3rd edition, M., 1958.

I.V. Kudrayvtsev, D.M. Shur

PENTAPLAST – a high-molecular simple polyester obtained from the chlorinated product of pentaerythritol. It has good mechanical and dielectric characteristics and a higher thermostability than ordinary thermal plastics. With respect to chemical stability it occupies a position intermediate between fluorine-containing plastics and vinyl chloride and styrene polymers; it is resistant to hydrolysis in weakly acid and alkaline media and capable of maintaining predetermined dimensions under severe operational conditions. Pentaplast is readily converted to finished products with standard equipment by pressure-casting (at a material temperature of 190-240°), extrusion (at an extrusion-head temperature of 220-240°), or pressing (at a pressform temperature of 170-210° and a pressure of 150 kg/cm$^2$). The characteristics of this material include: specific gravity – 1.4, ultimate bending strength – 500-700 kg/cm$^2$, ultimate tensile strength of film – 360-370 kg/cm$^2$, impact strength – 35-40 kg·cm/cm$^2$, Vik's thermostability – 160-170°, Brinell hardness – 7-9 kg/mm$^2$, tensile elongation of film – 55%, water absorption over 24 hr at 20° – 0.02%, deep electrical resistance – $4 \cdot 10^{16}$ ohm·cm, tangent of dielectric-loss angle at $10^6$ cps – $11 \cdot 10^{-3}$, dielectric constant at $10^6$ cps – 2.8, and breakdown voltage – 23 kv/mm. Pentaplast is used in the manufacture of corrosion-resistant chemical equipment (tubing, valves, fittings, pumps, flexible hoses, and various types of tanks). Its low coefficient of thermal expansion and high wear resistance make it possible to use this material in the production of components for precision instruments and mechanisms.

References: KhP, 1961, No. 3, page 26; ZhPKh, 1961, vol. 34, No. 2.

N.P. Gashnikova

PERLITE – a structural constituent of steel, a mixture of Ferrite and Cementite. Depending on the character of the phases, we can distinguish granular perlite, in which the cementite is globular in form, and laminar perlite, in which the phases have the form of elongated plates. Whether perlite with a granular or laminar structure is obtained in steel of a given composition is determined by the heat-treatment regime. Perlite is usually found in steel subjected to annealing, normalization, or high tempering. Thus, this phase is produced by decomposition of austenite (during cooling) or martensite (during heating). A continuous perlitic structure is formed (by a eutectoid reaction, see Steel) in ordinary annealed carbon steel with a carbon content of approximately 0.83%; a perlitic structure and grains of ferrite occur at a lower carbon content, while perlite and cementite particles are observed at a higher content. The structure of the perlite present determines whether products of structural and machine-building steels have sufficient strength, plasticity, and viscosity.

M.L. Bernshteyn

PERLITE – a hydrogen-containing volcanic glass exhibiting characteristic concentric spherical cleavage. When subjected to impact stresses this material breaks into small spheres, or "pearls." The technical definition of perlite includes all varieties of volcanic glass with an $H_2O$ content of 1-6% and the ability to form pumice swell) when baked at 900-1250°. In industry perlite is used principally in the distended state. This property is characteristic of perlite with an acid composition, i.e., containing 68-74% $SiO_2$. The remainder of the description given herein pertains to this variety. Perlite can be white, gray, brown, or green in color, depending on the character of the secondary changes that it has undergone, its porosity, and its content of crystalline phases with a particle size <1 μ. Its index of refraction (n) is 1.486-1.506, depending on its $SiO_2$ and $H_2O$ contents. Increasing the concentrations of these components causes a rise in n.

| Показатели 1 | 2 Перлит | | |
|---|---|---|---|
| | 3 массивный | 4 пористый | 5 вспученный (искусственная пемза) |
| 6 Уд. вес . . . . . 7. . . . . | 2,344–2,394 | 2,3–2,38 | 2,243–2,302 |
| Объемный вес (г/см³) 8. . . . . | 2,3 | 1,2–1,8 | 0,2–0,63 |
| Пористость истинная (%) . . . . . | 1,89–3,93 | 15–50 | 71,91–82 |
| Пористость эффективная (%) 9. . . . . | 1,90–3,92 | 10–40 | 52,08–62,7 |
| Количество открытых пор по отношению к общей пористости (%) 10 | 100 | – | 72–82 |

1) Characteristic; 2) perlite; 3) massive; 4) porous; 5) distended (artificial pumice); 6) specific gravity; 7) bulk weight (g/cm³); 8) true porosity (%); 9) effective porosity (%); 10) number of open pores with respect to total porosity (%).

Certain of the physical characteristics of perlite vary in accordance with its textural characteristics (massive, porous, etc.) (see

Table).

The viscosity of perlite is $10^{11}$ poises at 800° and $10^{8}$ poises at 1100°; its specific electrical resistance is $10^{10}$ ohm·cm. The mechanical strength of distended perlite ranges from 3-4 to 60-100 kg/cm$^2$, increasing with its bulk weight. The thermal conductivity of perlite is 0.136 kcal/m·degree·hr at temperatures of from -10° to +10°, 0.16 kcal/m·degree·hr at 20-40°, and 0.02-0.09 kcal/m·degree·hr at 180°. Its sound-absorption coefficient is 0.4-0.85 at 400-1100 cps and 0.2-0.4 at 100-800 cps. Untreated perlite is employed in the cement industry as a hydraulic concrete additive. It makes finished products light-weight and gives them good sound-insulating, heat-insulating, and refractory characteristics. Distended perlite is nonhygroscopic and chemically inert. As a result of its ability to retain its heat-insulating characteristics at temperatures of from -200° to +100° it is used in the construction of refrigerated ships and refrigerator units, for insulating liquid-gas tanks, in the form of vacuum-powdered insulation, for sheating steam pipes and boilers, etc. (especially when mixed with diatomite, asbestos, bentonite, clay, MgO, phenolic resins, bauxite, etc.). Distended perlite is used in the chemical industry for filters and as a filler, in agriculture as a carrier for microfertilizers and various poisons, in the petroleum industry for flushing and cementing deep wells, as an additive to the clay mortar in petroleum drilling, for cementing drill holes, as an adsorbant, etc.

References: Petrov, V.P., Nasedkin, V.V., Tr. in-ta geologii rudnykh mestorozhd., petrografii, mineralogii i geokhimii [Transactions of Ore-Deposit Geology, Petrography, Mineralogy, and Geochemistry], 1961, No. 48; Zhukov, A.V., Bayvel', I.Ya., Soloninko, I.S., Vspuchennyy perlit [Distended Perlite], Kiyev, 1960; Kashkay, M.A., Mamedov, A.I., Perlity, obsidiany, pekhshteyny i ikh mineralogo-petrograficheskiye i

fiziko-khimicheskiye osobennosti [Perlites, Obsidians, Pechsteins, and Their Mineralogical-Petrographic Characteristics], Baku, 1961; Otis, L.M., Foley, J.M., Perlite, in book: Minerals Yearbook, 1958, Vol. 1, Washington, 1959.

V.V. Nasedkin

PERLON – a synthetic heterochain fiber of the caprone type, a polymerization product of caprolactam. It is produced in the German Democratic Republic and the Federal Republic of Germany in the form of an ordinary high-strength thread, staple fiber, monofilament, and bristle and under the names of caprone (USSR), rylon (USA), silon (Czechoslovakia), stilon (Poland), and encalon (Holland). For its characteristics and applications see Capron and Polyamide fiber.

E.M. Ayzenshteyn

PERLON V – a synthetic heterochain fiber of polyurethane (the polycondensation product of hexamethylene diazocyanate and tetramethylene glycol). It is produced in the Federal Republic of Germany and the German Democratic Republic on an experimental-industrial scale in the form of monofilament and bristle. For details on the characteristics and applications of this material see Polyurethane fiber.

E.M. Ayzenshteyn

PERMALLOY - see High-permeability soft magnetic alloys.

PERMALON – see Polyvinylidene chloride fiber.

PERMENDUR – see Magnetic materials with high magnetic saturation.

PERMINVAR – see Magnetic materials with an elevated permeability constant.

PEROVSKITE – a mineral, calcium titanate ($CaTiO_3$), having the composition 59% $TiO_2$ and 41% CaO; in natural crystals the $TiO_2$ content varies from 58.7 to 59.4% and the CaO content from 36.8 to 41.5%. Small impurities of FeO, MnO, and MgO are also present. Perovskite containing $Nb_2O_5$, $Ta_2O_5$, and $Ce_2O_2$ (0.1-5.6%) is called knopite. This mineral is grayish-black, reddish-brown, orange-yellow, or light yellow in color. Its luster is adamantine or, less frequently, metallic. Perovskite has a Mohs hardness of 5.5-6. It exhibits clear cubic cleavage, has a specific gravity of 3.95-4.05, and displays rhombic syngony. When it is heated the structure of perovskite is altered in the direction of greater symmetry, but at 900° it remains rhombic. This mineral is optically biaxial: $N_m$ = 2.34-2.31 and $N_g - N_p$ = 0.017. It has the lattice parameters a = 5.3670 A, b = 7.6438 A, c = 5.4439 A, and z = 4. Monocrystals of perovskite exhibit a weak piezoelectric effect. The dielectric permeability of a monocrystal is 5.3, while that of the polycrystalline aggregate is $\geq$120. A slight admixture of $NaNbO_3$ (2.5%) causes an increase in dielectric characteristics. The dielectric permeability of this mineral rises from 160 to 900 over the temperature interval from -200° to +300°. Its melting point is 1970°.

Perovskite is most widely used in ferroceramics, being the principal component of one type of titanium ceramic. A capacitor ceramic produced from perovskite (95% $CaTiO_3$ + 5% kaolin) has a dielectric permeability of 78, a tg $\delta$ of $8.8 \cdot 10^{-4}$, and a deep resistance of $12 \cdot 10^{11}$ ohm·cm. This mineral is most frequently employed as an additive to ceramic mixtures whose principal component is barium titanate (artificial).

Addition of perovskite raises the Curie point and increases the residual polarization of the fired mass. Perovskite is used in the manufacture of high-temperature electromechanical converters, electroacoustical emitters and pickups, capacitors, and piezo elements of various types and sizes and for producing ultrastable special enamels in the paint industry. The chemically pure mineral, which is obtained by artificial means, is employed in electroceramics.

References: Bonshtedt, E.M., Perovskit [Perovskite], Moscow-Leningrad, 1935; Rasynkov, R.Ye., Vinogradov, V.V., IAN SSSR, Ser. fiz. [News of the Academy of Sciences USSR. Physics Series], 1957, Vol. 21, No. 3; Skanavi, G.I., ZhETF, 1947, Vol. 17, No. 5; Freydenfel'd, E.Zh. and Apsitis, A.A., ZhPKh, 1957, Vol. 30, No. 9.

V.V. Nasedkin

PETZE V – a synthetic fiber produced by extrusion in the form of thread and bristle in the German Democratic Republic; see Polyvinyl chloride fiber.

Z.Z. Zazulina

PHASE TRANSITIONS – are physical transformations in which the substance changes from one phase into another. One or several parts of a system (in termodynamic equilibrium), which do not differ from each other wit regard to the chemical composition and the physical properties, but which are delimited from the other parts (phases) of the system by interfaces, are termed phases.

All transformations known in nature may be subdivided into three principal groups: transformations of phases, substances, and elements. In contrast to the chemical and nuclear transformations (reactions) in which the composition and the structure of the molecules or atomic nuclei are changed, i.e., the one substance or element passes over into another, the phase transition is a transformation in which the structure, the nature of the intermolecular relationships or the composition (concentration) of systems containing a great number of particles is changed.

Almost all phase transitions are connected to a certain degree with disordering processes, because the various phases differ in the degree and way the atoms and molecules are ordered. Three types of phase transitions are discernible depending on the degree of orderliness and the position of the particles within the phases: 1) transition from one ordered phase into another ordered one; 2) transition from an ordered phase into a disordered one, and 3) transition from one disordered phase into another disordered one. Examples of phase transitions in one- and two-components are listed in the Tables 1 and 2.

TABLE 1

Examples of Phase Transitions from an Ordered Phase into a Disordered Phase

| Число компонент в системе 1 | 2 Характерное свойство, изменяющееся при переходе | 3 Упорядоченная фаза | 4 Разупорядоченная фаза |
|---|---|---|---|
| 6 | Структура 7 | Кристалл 8 | Жидкость 9 Газ |
| 6 | Структура | Жидкость | |
| 10 | Намагниченность 11 | Ферромагнетик 12 | Парамагнетик |
| 13 | Поляризация 14 | Сегнетоэлектрик | 15 Диэлектрик |
| 16 | Электропроводность | 17 Сверхпроводник | 18 Проводник |
| 5 Одна 19 | Вязкость (гелия) | 20 Сверхтекучая жидкость | 21 Вязкая жидкость |
| 22 | Ориентация цепных молекул | 23 Ориентированное кристаллич. состояние | 24 Неориентированное аморфное состояние |
| 26 | Структура твердых сплавов типа замещения | 27 Сверхструктура | Структура |
| 25 Две 28 | Структура эвтектических сплавов | 29 Твердая эвтектика | Жидкая эвтектика 30 |

1) Number of components in the system; 2) the characteristic property which becomes changed due to the transition; 3) ordered phase; 4) disordered phase; 5) one; 6) structure; 7) crystal; 8) fluid; 9) gas; 10) magnetization; 11) ferromagnetic; 12) paramagnetic; 13) polarization; 14) seignettoelectric; 15) dielectric; 16) electrical conductivity; 17) superconductor; 18) conductor; 19) viscosity (of helium); 20) superfluid; 21) viscous fluid; 22) orientation of the chain molecules; 23) oriented crystal state; 24) nonoriented amorphous state; 25) two; 26) structure of solid substitution alloys; 27) superstructure; 28) structure of eutectic alloys; 29) solid eutectic; 30) liquid eutectic.

The phase transition may be caused by a change of the temperature, the concentration, or of one of the external parameters: the hydrostatic-type pressure, the mechanical stress, or the intensity of the so-called generalized forces, i.e., the electric, magnetic or gravitational fields, etc. A discontinuous or a continuous transfer occurs in this case, depending on the nature and the state of the system. Corresponding to this fact, the phase transitions are subdivided into transitions of the 1st and of the 2nd order. The phase transitions of the 1st order are characterized by discontinuities of the state functions (the

energy, entropy, volume, magnetic moment, electric polarization, etc., of the system), i.e., of the generalized coordinates. In the case of the phase transitions of 2nd order, the state functions change continyously, but their derivatives (specific heat, coefficient of thermal expansion, compressibility, etc.) change discontinuously.

TABLE 2

Examples of Phase Transitions from one Ordered Phase into Another Ordered (Disordered) Phase

| Число компонент в системе 1 | Характерное свойство, изменяющееся при переходе 2 | 3 Фаза I | 4 Фаза II |
|---|---|---|---|
| Одна 5 | 6 Структура | Кристаллич. модификация α 7 | Кристаллич. модификация β 8 |
| | Ориентация цепных молекул 9 | Поперечно-ориентированное кристаллич. состояние 10 | Продольно-ориентированное кристаллич. состояние 11 |
| Две 12 | 13 Состав твердых растворов типа замещения | Твердый раствор α компоненте *B* 14 | Твердый раствор β компоненте *A* 15 |
| | Состав жидких расслаивающихся растворов 16 | Раствор компоненты *A* в компоненте *B* (разупорядоченная фаза) 17 | Раствор компоненты *B* в компоненте *A* (разупорядоченная фаза) 18 |

1) Number of components in the system; 2) the characteristic property which is changed due to the transition; 3) phase I; 4) phase II; 5) one; 6) structure; 7) crystal modification α; 8) crystal modification β; 9) orientation of the chain molecules; 10) transversely oriented crystalline state; 11) longitudinally oriented crystalline state; 12) two; 13) composition of solid substitution solutions; 14) solid α solution of the component A in the component B; 15) solid β solution of the component B in the component A; 16) composition of liquid demixing solutions; 17) solution of the component A in the component B (the disordered phase); 18) solution of the component B in the component A (the disordered phase).

Among the examples quoted in the Tables 1 and 2, the transition from one type of crystal lattice to another, melting and crystallization, crystallization of polymers under deformation, are typical phase transitions of the 1st order; the transition of helium into the super-

fluid state, of a ferromagnetic into a paramagnetic, the disordering processes of alloys at high temperatures, etc., are phase transitions of the 2nd order. The transitions in seignettoelectrics are phase transitions of the 2nd order which are similar to those of the 1st order. Phase transitions of both the 1st and the 2nd order are observable in many cases depending on the state of the system and the environmental conditions, when ordered and disordered phases are present. The following systems belong to such types: a fluid-gas system, in which both types of phase transitions are observable under different external pressures on the specific heat vs. temperature curves; demixing solutions with an upper and a lower critical temperature; superconducting metals in which phase transitions of the 1st and 2nd order become observable by change of the external magnetic field, etc.

References: Semenchenko, V.K., "Zhurnal fizicheskoy khimii" [Journal of Physical Chemistry], 1947, Vol. 1, No. 12, page 1461; 1951, Vol. 25, No. 1, page 121; Semenchenko, V.K., Skripov, V.P., ibid., No. 3, page 362; Bartenev, G.M., Remizova, A.A., ibid., 1957, Vol. 31, No. 11, page 2534; Landau, L.D., Lifshits, Ye.M., Staticheskaya fizika [Statistical Physics], Moscow – Leningrad, 1951 (Tereticheskaya fizika [Theoretical Physics], part 4).

G.M. Bartenev

PHENOL FORMALDEHYDE ADHESIVE – is a compound containing the condensation products of phenols and aldehydes. The phenol formaldehyde adhesives are subdivided into 2 groups: 1) nonmodified, and 2) modified by polymer materials. The nonmodified phenol formaldehyde adhesives (VIAM B-3; VIAM F-9; TsNIIMOD-1, TsNIIPS-2, etc.) are compounds of resols and acid catalysts (curing agents), (Petrov's catalyst, HCl, etc.). They cure at normal temperature and, to accelerate the bonding, at higher temperatures. The curing process depends upon the temperature at which the bonding is performed: the holding time is 3-5 hours at 16-30°, and 1.5-2 hours at 60-70°. Solvents (acetone, ethanol, etc) are added to the compound in order to stabilize the product. The hydrolyzing effect on the wood cellulose and other materials which results in an accelerated aging, is a common disadvantage of these adhesives; they are used to bond wood, wood-pulp plastics, plywood, foamed plastics and other porous materials; they are prepared by mixing the resin with the catalyst at the place of application; the working life of the adhesive is 2.5-4 hours. The adhesive consumption is 160-250 $g/m^2$ when applied on one surface only, and 250-340 $g/m^2$ when applied on both surfaces. The shearing strength of the joints of wood (ash or oak) or of wood-pulp plastics (delta wood material) is not less than 130 $kg/cm^2$; the adhesive joints are waterproof. During the bonding process the rooms and workshops must be well ventilated and the appropriate rules of accident prevention must be strictly observed.

Phenol formaldehyde adhesives modified by rubbers and polyacetals. These are compounds of resol resin and acrylonitrile rubbers with addi-

tions of vulcanizing agents, fillers, etc. They are heat resistant up to 250-300°; the strength of the adhesive joint is high also in the case of nonuniform peel. These adhesives are used to bond metals, plastics and other nonporous materials stressed structures. The VK-32--200 adhesive has a high frotproofness, shakeproofness, elasticity and a strength of to 30 kg/cm$^2$ at 20° in the case of a nonuniform peel. The strength of the joint is hardly affected by exposure to a temperature of 200° for 300 hours, and to a temperature of 300° for 20-30 hrs; the adhesive resists oils, liquid fuels, water and tropical climates. The adhesive is delivered in the form of a film which makes application convenient. Two layers of adhesive (150-250 g/m$^2$ for each layer) are applied to the surfaces to be joined; the objects are kept exposed for 20 minutes at 20° and for 30 minutes at 60° after the second layer has been applied, thereupon the joint is mated and pressed at 6-20 kg/cm$^2$ and 180° for 1-2 hours. The VK-32-250 adhesive has a higher strength at 250° than the VK-32-200 adhesive. The VK 32-2 adhesive is used to bond glass-fiber heat-insulations on metals; it has a high heat resistance.

Phenol polyvinyl acetal adhesives. The properties of these adhesives depend on the ratio of the components: the higher the proportion of the phenol formaldehyde resin, the higher the heat resistance and the lower the elasticity of the adhesive joints.

The BF adhesives are alcoholic solutions of phenol formaldehyde resin and polyvinyl butyral. The BF-2 adhesive is the most used, it provides a solid strength and is suitable for the bonding of metals and nonmetallic materials; the joints are heatproof up to 60°. The VS-10T and VS-350 adhesives contain the higher heat-resistant polyvinyl acetal and small additions of siliconorganic compounds; they are stable to 300--350°. The bonding conditions for the BF-2 are: temperature 140-160°; holding time 0.5-1.0 hrs; pressure from 2 to 5-10 kg/cm$^2$. For VS-10

they are: temperature 180°; holding time 2 hrs; pressure 0.6-2.0 kg/cm$^2$. The joints bonded by BF-2 are more elastic than those bonded by VS-10T; the peel strength at 20° is 28 and 11 kg/cm$^2$, respectively. The shearing endurance of metal joints bonded by BF-2 is 26 kg/cm$^2$ at $6 \cdot 10^6$ cycles; the joint with VS-10T withstand $1.8 \cdot 10^7$ cycles at a stress of 65/kg$^2$, and $1 \cdot 10^5$ cycles at 40 kg/cm$^2$ and 300°; the long-life shearing strength for metal joints bonded by BF-2 is 62 kg/cm$^2$ at 20° (in a 2000 hour test) and 13 kg/cm$^2$ at 60° (in a 300 hour test). Both adhesives are heat-resistant, oil- and gasoline-proof, and have sufficient resistance to the effect of water and humidity. The adhesives are deliverable in the form of films.

D.A. Kardashev

PHENOL-FORMALDEHYDE FOAMS – compositions based on phenol-formaldehyde resins of the lacquer type (type FF foam) and the products of their combination with SKN-40 nitrile rubber (type FK foam). The nitrile-rubber content of the initial mixture affects the elasticity, mechanical strength, and heat resistance of FK foam. The table shows the physicomechanical characteristics of phenol-formaldehyde foams.

Physicomechanical Characteristics of Types FF and FK Phenol-Formaldehyde Foams

| Показатели 1 | ФФ 2 | ФК-20 3 | ФК-40 4 | ФК-20 А 20 5 | ФК-20 СТ 6 |
|---|---|---|---|---|---|
| 7 Объемный вес (г/см³) | 0.2 | 0.2 | 0.2 | 0.2 | 0.4—0.5 |
| 8 Предел прочности при сжатии (кг/см²) | 40.0 | 30.0 | — | 23.0 | 200—280 |
| 9 Предел прочности при растяжении (кг/см²) | 11.9 | 20.0 | 7.8 | 15.3 | 100 |
| 10 Относительное удлинение при растяжении (%) | — | 6—8 | 12—14 | 2.0 | — |
| 11 Удельная ударная вязкость (кг·см/см²) | 18 0.2 | 0.8 | 2.2 | 0.74 | 7.0 |
| 12 Линейная усадка за 24 часа (%, не более) | 0.6 (при 150°) | 1.0 (при 130°) | 1.0 (при 80°) | 2.0 (при 200°) | 1.0 (при 130°) |
| 13 Водопоглощение за 24 часа (кг/м²) | 0.3 | 0.3 | 0.5 | 0.09 | 1.15 |
| 14 Коэффициент теплопроводности (ккал/м час °С) | 19 0.052 | 0.052 | 0.052 | 0.061 | 21 — |
| 15 Горючесть | После выне сения из пламени гаснет | 20 Горит | Горит | Горит | Горит при поджигании с обожженных торцов |
| 16 Коэффициент линейного расширения (1/°С) | $35 \cdot 10^{-6}$ | $36 \cdot 10^{-6}$ | $78 \cdot 10^{-6}$ | $41 \cdot 10^{-6}$ | $23 \cdot 10^{-6}$ |
| 17 Линейная усадка в процессе изготовления (%) | 0.5—0.7 | 0.7—1.0 | 1.0—1.5 | 0.8 | 0.7—1.0 |

1) Characteristic; 2) FF; 3) FK-20; 4) FK-40; 5) FK-20-A-20; 6) FK-20-ST; 7) bulk weight ($g/cm^3$); 8) ultimate compressive strength ($kg/cm^2$); 9) ultimate tensile strength ($kg/cm^2$); 10) relative tensile elongation (%); 11) impact strength ($kg \cdot cm/cm^2$); 12) linear shrinkage over 24 hr (%, no more than); 13) water absorption over 24 hr ($kg/m^2$); 14) coefficient of thermal conductivity ($kcal/m \cdot hr \cdot °C$); 15) combustibility; 16) coefficient of linear expansion ($1/°C$); 17) linear shrinkage during manufacture (%); 18) at; 19) extinguished after removal from flame; 20) burns; 21) burns when ignited at freshly exposed faces.

When the temperature is raised to 150° the strength of phenol-formaldehyde foams decreases by 20-30% from its level at 20°, while at 200° it drops by 50-60%. Prolonged heating at temperatures above 150° in air causes carbonization and gradual decomposition of foams. When heated under conditions that exclude direct contact with air phenol-formaldehyde foams retain their shape and some reserve strength. Type FK-20-A-20 foam is the most heat-resistant. When used as a filler in sandwich structures it can withstand prolonged heating at 200-250° and brief heating (up to 3 hr) at 300°. The strength of type FF foam at negative temperatures (down to -60°) is the same as its strength at 20°. Type FK foam with an increased nitrile-rubber content becomes more rigid at negative temperatures. The electrical-insulating characteristics of phenol-formaldehyde foams deteriorate on heating. These materials are inert with respect to corrosion of steel and aluminum and magnesium alloys. All phenol-formaldehyde foams have good heat-insulating characteristics.

Phenol-formaldehyde foams are produced in the following variants: types FF and FK-20 in slabs no less than 450 x 260 x 45 mm in size, with cut and uncut faces; extruded semifinished products of types FK-20-A-20 and FK-40 in the form of solid and hollow cords for production of foam slabs or fillers with a bulk weight of 0.12-0.20 (hollow) or 0.22-0.30 (solid) g/cm$^3$ for FK-20 and 0.20-0.28 (hollow) or 0.32-0.40 (solid) g/cm$^3$ for FK-20-A-20 and FK-40; rolled semifinished products of these same types in the form of sheets or films less than 7 mm thick, which are folded into flat bundles. The comparatively heavy, high-strength phenol-formaldehyde foam FK-20-ST, which is reinforced with glass cloth, is used in the production of articles formerly manufactured from aluminum alloys and other materials. The physicomechanical characteristics of FK-20-ST are shown in the table. Types FF and FK-20-

A-20 foam are employed as load-bearing fillers for laminated structures intended to operate at elevated temperatures for prolonged periods and in the manufacture of buoyant and nonsubmersible devices. Type FK-20 is used as a load-bearing filler for laminated structures intended to operate at elevated temperatures and in the production of radio components, while type FK-40 is employed as a load-bearing and damping filler and in the manufacture of shaped products.

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V.A. Popov

PHENOL FORMALDEHYDE PRODUCTS – are resins obtained by polycondensation of phenols and aldehydes. The resins for technical purposes, obtained by reaction of phenols with formaldehyde or furfural, are subdivided into two groups: the novolak resins (novolaks), and the resol resins (resols). The novolaks are hard, brittle and transparent resins with a color from light-amber (phenol formaldehyde resins) to black (phenol furfural resins). The curing of the novolaks, i.e., the transformation into the infusible and insoluble state, is carried out by heating with urotropine. The novolak resins of the grade 18 (phenol formaldehyde), 17 (phenol-xylenol formaldehyde), and 118 (phenol-cresol-furfural formaldehyde) have a drop point of 95-105° according to Ubbelohde; the content of free phenol does not surpass 9%; the viscosity of a 50% alcohol solution is equal to 70-130 centipoises according to Ostwald; they are used for the preparation of novolak molding powders. The PB and PK-104 binders (powdered bakelite) are finely pulverized mixtures (sieve residue 0.05-2% maximal) of a novolak resin (with a drop point higher than 105° according to Ubbelohde, and containing not more than 5.5% of free phenol) with urotropine (7.4%); they are used as a binder for abrasive discs and sand molds; the temporary tensile strength is 80-180 kg/cm$^2$ when containing abrasive grains, and 20-40 kg/cm$^2$ when containing sand. Iditol, and alcoholic solution of novolak resin (content of free phenol 0.1-3.0%; softening point 92-97° according to Krämer-Sarnow), is used for the manufacture of varnishes, mastics, foundation cements, etc.

PFN-12, a material for atomized coating, is a mixture of a novolak

resin, modified by polyvinyl acetate, with urotropine and a mineral filler; it is used instead of a lead-tin solder to face-up the seams and to even the surfaces of automobile hoods and cabins; it is recommended for the coating of metals; the strength of the adhesion to the metal is not less than 100 kg/cm$^2$; the impact strength is 50 kg/cm$^2$; the heat resistance is 120-140°; TPF-37, a similar material, is heat resistant up to 180-200°.

The resol resins are applied in diverse fields. The methods of application depend on the purpose; curing of resol resins either in the cold by addition of acid catalysts, or at high temperatures is the general feature. Four types of resol resins are available: solid, liquid, water-emulgated, and varnish resins. The solid resol resins 211 and 214 are phenol-aniline formaldehyde resins with a drop point of not less than 75° according to Ubbelohde, a curing (gelatinization) rate of 50-120 sec at 150 ± 2°, and a free phenol content of not more than 6%; they are used for the production of electric insulating ammonia-free pressing powders. Liquid resol resins (phenol-base and cresol-base) are used for the impregnation of asbestos and cellulose fibers in the production of fibrous faolite, of certain brake materials, etc. Liquid bakelite (ball viscosity 10-300 sec, polymerization rate 60-240 sec at 150 ± 2°, free phenol content 10-20%) is used as a wetting agent in the production of abrasive discs; the resin No. 30 is used for dies and for master patterns.

Water-emulgated resins. These are: 1) phenol alcohols, the primary products of the condensation of phenols with formaldehyde (sodium hydroxide used as a catalyst; dry residue not less than 50%, free phenol content not more than 9%; diluted with water in a 1:3 ratio; shelf life 2 months); they are used as binders in the production of slag- and glass-wool, for water-repellent impregnation of sawdust, etc. 2) Phenol re-

sin of the B grade (dry residue not less than 70%, free phenol content not more than 2%, viscosity of 150-450 centipoises according to Ostwald; acetone used as a stabilizer, shelf life 6 months) is used as a binder in the manufacture of slag- and glass-wool, and of plates and shells from them; further, in the production of plates from wood shavings and wood fibers, as an adhesive for plywood, asbestos cement, and other nonmetallic materials, and also for the production of cold-curing adhesives for wood. 3) SP-2 phenol-base resins: TsMIIMOD-1, VIAMF-9 (free phenol content not more than 3%, dry residue not less than 50%), VIAM-B (free phenol content not more than 21%, dry residue not less than 80%), and also the B resin are used for cold-curing adhesives for wood. Petroleum sulfoacids, Petroff's contact, are added as a curing agent in an amount of 18-30% of the weight of resin. The shelf life of these resins is 4-6 months. 4) Resins made from commercial xylenols and over-all phenols, shales and brown coal (S-1, NIIFS-35, etc.) are used as a binder for wood shavings and wood fiber plates in a quantity of 5-7 and 5-15%, respectively, of the wood weight. The resins have a viscosity of 15-50° according to Ford-Engler, and contain 4-9% of free phenol.

Varnish resins are alcoholic solutions of resol resins. Bakelite varnish (50-70% dry residue; not more than 14% free phenol; polymerization rate 50-115 sec at 150 ± 2° on a heating plate; shelf life 6 months in a tight package) is used to impregnate and to cover wood, metals, and nonmetallic materials. Bakelite varnish coatings resist solutions of acids and organic solvents; they do not withstand alkalis and oxidizers. The limit temperature for the application of coatings is 120-130°. The adhesion between the varnish and the metal is increased by addition of fillers (graphite, andesite meal, kaolin, etc.), in an amount of 40%. Mirror enamel is an alcoholic solution of resol resin

modified by polyvinyl acetal (not less than 20% dry residue, 6-10° viscosity according to Ford-Engler, shelf life 6 months in tight package) and is used for coating of mirrors with silver amalgam. The SKS and SBS varnishes are used for hot adhesive-bonding of the veneers in the production of indurated plywood. Bakelization, i.e., curing of the coatings at 140-160°, is necessary when resol varnish resins are used. The curing must be carried out stepwise, raising gradually the temperature and keeping it for a long time at 60-80° due to the water, formaldehyde and other volatile products which originate during the curing reaction and which may hinder the formation of a tight and lustrous film. An example of the curing conditions is given in the article Faolite.

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M.S. Krol'

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[Transliterated Symbols]

2941 ПБ = PB = pul'verbakelit = bakelite powder

2943 ЦНИИМОД = TsNIIMOD = Tsentral'nyy nauchno-issledovatel'skiy institut mekhanicheskov obrabotki drevesiny = Central Scientific Research Institute for the Mechanical Processing of Wood

2943 ВИАМ = VIAM = Vsesoyuznyy nauchno-issledovatel'skiy institut aviatsionnykh materialov = All-Union Scientific Research Institute for Aviation Materials

PHENOLIC PRESS-POWDERS – compositions of phenolic resins (of the lacquer or resol type) or modified phenolic resins, mineral (quartz dust, kaolin, ground mica, feldspar, microasbestos, etc.) and organic (sawdust, ground coke, graphite) fillers, hardeners (urotropin, lime, etc.), binders (oleic acid, stearin, stearates), dyes (nigrosine, ruby lac, etc.), and accelerators. The resins are modified with polyamides,

TABLE 1

Principal Applications and Compositions of Phenolic Press-Powders

| Type, Color and Working Temperature | Application | Composition |
|---|---|---|
| K-18-2, K-15-2, K-17-2; K-20-2, K-118-2, K-119-2; Monoliths 1, 2, 3, 5, 7, 8, 10; Color – black, red, brown, green, and mixtures of these colors; from –60 to +60° | I. General-purpose<br>Unstressed reinforced and unreinforced components for general engineering applications (housings for radio receivers and transmitters, control-wheel knobs, household electrical appliances, etc.) entailing operation under atmospheric conditions and components in decorative colors. Ammonia may be liberated under operational conditions. Not recommended for components of low-power and radio equipment touching contacts. The dielectric characteristics of these materials are lowered in a humid atmosphere. Impact strength – 5-6.5 kg·cm/$/cm^2$, ultimate bending strength – no less than 600 $kg/cm^2$, modulus of elasticity – $70\text{-}90 \cdot 10^3$ $kg/cm^2$, tensile elongation – 0.2-0.8%, thermal conductivity – 0.18-0.20 kcal/m·hr·°C, heat capacity – 0.33-0.35 kcal/kg·°C, Martens thermostability – less than 125°, ultimate compressive strength – 1600-2000 $kg/cm^2$ | Lacquer resin, urotropin, sawdust |

| | | |
|---|---|---|
| FKP-1, FKPM-10; black; | II. High-impact-strength | |
| | Components for general engineering applications with an increased resistance to impact loads. Impact strength – 9-15 kg·cm/cm$^2$, ultimate bending strength – no less than 500 kg/cm$^2$, Martens thermostability – no less than 125° | Lacquer resin modified with gum rubber, sawdust (FKP-1) or mineral (FKPM-10) filler |
| FKPM-15T, Fkpm-15; black; up to 150-200° | For principal applications see group VII | |
| | III. Electrical-insulating | |
| a) K-21-22, K-220-21, K-211-2; from light to dark brown; b) K-18-42, black; K-214-43, natural green | Low-stress reirforced and unreinforced components for electronic applications, bulb sockets, automobile ignition components intended to operate in gasoline and oil). In addition, phenoloxazolidine materials have stable dielectric characteristics at elevated humidities and high plasticity during processing, the latter making it possible to produce highly reinforced components<br>OFP-6 is an ammonia-free phenolic press powder; for additional applications see group V. Its impact strength is no less than 4.5 kg·cm/cm$^2$<br>Bending strength – no less than 550 kg/cm$^2$, modulus of elasticity – 63-88·10$^3$ kg/cm$^2$ for subgroup a) tensile elongation – 0.67-0.77%, thermal conductivity – 0.18-0.20 kcal/m·hr·°C, heat capacity – 0.35 kcal/kg·°C, Martens thermostability – no less than 120° | a) Resol resin, sawdust; b) Phenolic resins, sawdust, and mineral fillers; c) Phenoloxazolidine resins, organic and mineral fillers |
| c) OFPM-296; OFP-6, natural yellow; FKPM-10 FKPM-15, and FKPM-15T; from –60 to +100° | For principal applications to groups II<br>For principal applications see group VII | |

| | | |
|---|---|---|
| | IV. High-frequency | |
| K-211-3, K-211-4, K-211-34; natural green; from -60 to +100° | Unstressed and lightly reinforced components intended to function in the presence of high-frequency currents and in high-humidity atmospheres; K-211-34 is specifically used for pressing mica capacitors and radio insulators. Impact strength - no less than 3.5 kg·cm/cm$^2$, bending strength - no less than 550 kg/cm$^2$, Martens thermostability - no less than 150° | Aniline-phenol-formaldehyde resin, mineral filler |
| K-114-35, up to 100°; V-4-70, up to 170°; natural green | Phenolic press-powders modified with polyamide used in the manufacture of highly stressed and highly reinforced components to high-precision specifications. This group is more water-resistant than other phenolic press-powders (24-hr water absorption - 0.015%); it has an impact strength of no less than 5 kg·cm/cm$^2$ and its mechanical and dielectric characteristics are stable in humid atmospheres. The Martens thermostability of type K-114-35 is no less than 120°, while that of type V-4-70 is no less than 140° | Phenolic resin modified with polyamide, mineral filler |
| | V. Ammonia-free | |
| K-214-2, brown, from -60° to +100° | Unstressed and lightly stressed reinforced and unreinforced components of low-power and radio equipment which do not corrode touching brass or silver contacts. Impact strength - no less than 4.5 kg·cm/cm$^2$, bending strength - no less than 600 kg/cm$^2$, Martens thermostability - no less than 125° | Aniline-phenol-formaldehyde resin, sawdust |
| OFP-6 | For principal applications see group III | |
| FKPM-15 | For principle applications see group VII | |
| | VI. Electrical control (high-hot-strength) | |
| K-18-53, dark violet; K-18-56; K-17-56, black; K-119-56, black | Electrical control components for technical and household applications (switches, sockets, housings for distribution boxes, etc.). Schramm hot strength - no less than 4, impact strength - 3-3.5 kg·cm/cm$^2$, bending strength - no less than 400-450 kg/cm$^2$, Martens thermostability - 145° | Lacquer resin, urotropin, microasbestos, sawdust |

| | | |
|---|---|---|
| | VII. Moisture- and chemical-resistant electrical insulating | |
| FKPM-15, FKPM-15T, black, up to 125° | Highly reinforced components with complex shapes for electronic applications, resistant to impact loads and water. Components of FKPM-15 can be reinforced with silver. Impact strength – 7-9 kg·cm/cm$^2$, bending strength – 450-570 kg/cm$^2$, water absorption – 0.2-0.4 g/dm$^2$ | Phenol-formaldehyde resin modified with gum rubber, mineral filter |
| | VIII. Moisture- and chemical-resistant | |
| K-17-23, K-18-23 (phenolite 1), black; K-17-36, K-18-36 (phenolite 4), natural yellow and colored (green, red) | Materials with increased water resistance (24 hr water resistance – no more than 0.3%) and resistant to 75% sulfuric, 40° hydrochloric, and 75% phosphoric acids at 70°, 50% acetic acid and 3% DDT at 35°, at salt solutions, hydrofluoric and salicylic acids, mercury and mercury vapor, 5% calcium hypochlorite, solvents (gasoline, white spirits, turpentine, fatty acids, and mineral oils at 20°; they are unstable in oxidizing and alkaline media. They are intended for components requiring high water and acid resistance (caps and stoppers for storage battery tanks, components for artificial-fiber manufacturing machinery, sanitary products, and radio components) and are pressed at a temperature of 150-170°. Phenolite 1 can be pressed into shapes. Impact strength – no less than 4.5 kg·cm/cm$^2$, bending strength – no less than 550 kg/cm$^2$, thermal conductivitity – 0.25 kcal/m·hr·°C for phenolite 1 | Lacquer resin modified with polyvinyl chloride, mineral and organic fillers |
| K-17-81, K-18-81 (decorosite), black; K-17-82, K-18-82 (antifrik), black up to 125° | Same as phenolites 1 and 4. Resistant in weakly alkaline media and with increased mechanical strength and antifriction characteristics. Used for washing-machine components and antifriction products (bearing components). Impact strength – no less than 6 kg·cm/cm$^2$, short-term bending resistance – no less than 600 kg/cm$^2$, coefficient of friction – 0.06-0.15 for antifrik | Lacquer resin modified with polyvinyl chloride, vibration-pulverized coke (decorosite) or graphite (antifrik) |

| | IX. Special-purpose | |
|---|---|---|
| Monoliths 4 and 6, black | X-ray apparatus components. Specific gravity – 2.25-2.6, impact strength – no less than 3.5 kg·cm/$cm^2$, Martens thermostability – no less than 105° | Lacquer resin, urotropin, barite |
| K-104-205, black | Semiconductive powder for components of medical electrical equipment. Impact strength – no less than 3.5 kg·cm/$cm^2$, bending strength – no less than 500 kg/$cm^2$, Martens thermostability – no less than 120° | Lacquer resin, graphite, urotropin, sawdust. |

polyvinylchloride, gum rubber, etc. The guaranteed storage life of phenolic press-powders is 6-8 months in a dry room at a temperature of no higher than 25°. These materials are made into finished products of varying weight and shape (Table 1) by direct hot pressing or casting molding at temperatures of 160-200° and pressing pressures of 150-1300 kg/$cm^2$. Certain phenolic press-powders (K-18-2, phenolit 1) can be subjected to hot shaping extrusion to produce tubes, rods, angle brackets, etc. Metal reinforcing wires are easily inserted into the press-powders during the production process. Components of phenolic press-powders do not corrode and do not cause reinforcing wires embedded in them to corrode; the ammonia liberated by certain press-powders operating in hermetically sealed enclosures reacts with silver reinforcing wire. Phenolic press-powders are thermostable, do not age, can function over a wide temperature range, and are resistant to organic solvents, gasoline, and oils; they are unstable in alkalies and oxyidizing agents. The dielectric and mechanical characteristics of these materials usually decrease with rising temperature and humidity. Types K-18-22, K-18-53, K-114-35, K-211-3, K-211-34, K-18-36, and FKPM-15T are resistant to tropical temperatures, high humidity, fungi, and molds. Articles pressed from phenolic press-powders generally do not require machining, except for removal of burrs. When holes must be drilled this

TABLE 2

Dielectric Characteristics of Phenolic Press-Powders

| 1 Назначение и марки | 2 Удельное объемное электрическое сопротивление (ом·см, не менее) | 4 Удельное поверхностное электрическое сопротивление (ом, не менее) | 6 Электрич. прочность (кв/мм, не менее) | 8 Тангенс угла диэлектрич. потерь: при частоте тока 50 гц | при частоте тока $10^6$ гц | 11 Диэлектрич. постоянная: при частоте тока 50 гц | при частоте тока $10^6$ гц |
|---|---|---|---|---|---|---|---|
| 12 Общего назначения | | | | | | | |
| 13 К-17-2; К-20-2; К-118-2; К-119-2 монолиты 7, 8, 10 | $1 \cdot 10^{11}$ | $1 \cdot 10^{12}$ | 11 | 0.1—0.7 | — | 32<br>6—10 (до 30) | — |
| 14 К-18-2; монолиты 1, 3, 5 | $1 \cdot 10^{11}$ | $1 \cdot 10^{12}$ | 12 | " | — | — | — |
| 15 Ударопрочные | | | | | | | |
| 16 ФКП-1, ФКПМ-10 | $1 \cdot 10^{11}$ | $1 \cdot 10^{11}$ | 10 | 0.02—0.03 | — | 7.5—9 | — |
| 17 Электроизоляционные | | | | | | | |
| К-21-22 | $5 \cdot 10^{12}$ | $5 \cdot 10^{13}$ | 15 | 0.07—0.11 | 0.04 | 7.5—9.6 | 5.5—5.7 |
| К-220-21 | $5 \cdot 10^{12}$ | $5 \cdot 10^{13}$ | 13 | 0.09—0.12 | 0.03—0.04 | 7.5—9.6 | 4.9—5.1 |
| К-211-2 | $5 \cdot 10^{12}$ | $5 \cdot 10^{14}$ | 13 | 0.012—0.08 | 0.03—0.04 | 7.5—9.6 | 4.8—4.9 |
| 18 ОФПМ-296 | $1 \cdot 10^{14}$ | $1 \cdot 10^{13}$ | 14 | — | — | — | — |
| 19 ОФП-6 | $1 \cdot 10^{13}$ | $1 \cdot 10^{13}$ | 14 | — | — | — | — |
| К-18-42 | $5 \cdot 10^{12}$ | $1 \cdot 10^{13}$ | 15 | 0.03—0.04 | 0.02 | 8.6—9.0 | 5.2 |
| К-214-43 | $1 \cdot 10^{13}$ | $5 \cdot 10^{13}$ | 15 | 0.014—0.03 | 0.03 | 8.6—9.1 | 6.5 |
| 20 Высокочастотные | | | | | | | |
| К-211-3; К-211-4 | $1 \cdot 10^{13}$ | $1 \cdot 10^{14}$ | 15 | 0.015 | 0.01 | 7.0 | 6.0 |
| К-211-34 | " | " | " | 0.013—0.02 | 0.01—0.03 | 8.0 | 5.5—6.0 |
| К-111-35 | $1 \cdot 10^{13}$ | $1 \cdot 10^{14}$ | 16 | 0.015—0.03 | 0.01 | 6—8 | 5.0 |
| 21 В-4-70 | $1 \cdot 10^{14}$ | $1 \cdot 10^{14}$ | 17 | 0.02—0.03 | 0.008—0.01 | 6—7.5 | 4.5—5.1 |
| 22 Безаммиачный К-214-2 | $5 \cdot 10^{12}$ | $1 \cdot 10^{13}$ | 13.5 | 0.03—0.08 | 0.03—0.06 | 10.2—10.8 | 5—6 |
| 23 Электроустановочные (жаростойкие) | | | | | | | |
| К-18-53 | $1 \cdot 10^{9}$ | $1 \cdot 10^{10}$ | 11 | 0.25—0.31 | 0.08—0.09 | 50—81 | 6.0—6.4 |
| К-18-56; К-17-56 | " | " | " | 0.2—0.24 | 0.08—0.1 | 24—40 | 6.2—6.3 |
| 24 Электроизоляционные влагохимстойкие | | | | | | | |
| 25 ФКПМ-15 | $1 \cdot 10^{12}$ | $1 \cdot 10^{13}$ | 13 | 0.05—0.07 | 0.08—0.09 | 6—7.5 | — |
| 26 ФКПМ-15 Т | $1 \cdot 10^{11}$ | $1 \cdot 10^{13}$ | 13 | 0.03—0.07 | — | 6—7.5 | — |
| 27 Влагохимстойкие | | | | | | | |
| 28 К-18-23; К-17-23 (фенолит 1) | $1 \cdot 10^{12}$ | $1 \cdot 10^{13}$ | 14—17 | 0.026—0.041 | — | 4.9—6.9 | — |
| 29 К-18-36 (фенолит 4); К-17-36 | $1 \cdot 10^{12}$ | $1 \cdot 10^{13}$ | 14—17 | 0.01—0.03 | — | 4.5—8.0 | — |
| 30 Специального назначения | | | | | | | |
| 31 Монолиты 4 и 6 | 33 — | — | 8 | — | — | — | — |
| К-104-205 | Общее сопротивление не более $1 \cdot 10^5$ ом | | | — | — | — | — |

1) Application and type; 2) deep resistance; 3) ohm·cm, no less than; 4) skin resistance; 5) ohms, no less than; 6) electric strength; 7) kv/mm, no less than; 8) tangent of angle of dielectric loss; 9) at frequency of; 10) cps; 11) dielectric constant; 12) general-purpose; 13) K-17-2, K-20-2, K-118-2, K-119-2, monoliths 7, 8, 10; 14) K-18-2, monoliths 1, 3, 5; 15) high-impact-strength; 16) FKP-1, FKPM-10; 17) electrical-insulating; 18) OFPM-296; 19) OFp-6; 20) high-frequency; 21) V-4-70; 22) ammonia-free; 23) electrical control (high-hot-strength); 24) moisture- and chemical-resistant electrical-insulating; 25) FKTM-15; 26) FKTM-15T; 27) moisture- and chemical-resistant; 28) K-18-23, K-17-23 (phenolite 1); 29) K-18-36 (phenolite 4), K-17-36; 30) special-purpose; 31) monoliths 4 and 6; 32) up to; 33) total resistance no more than $1 \cdot 10^5$ ohms.

TABLE 3

Processing Regimes for Phenolic Press-Powders

| 1 Марки | 2 Текучесть по Раушигу (мм) | 3 Расчетная усадка (%) | 4 Удельное давление прессования: 5 компрессионного (кг/см²) | 6 литьевого (кг/см²) | 8 Температура прессования (°С) | 9 Время выдержки в форме после предварительного подогрева в генераторе ТВЧ (мин на 1 мм толщины изделия) |
|---|---|---|---|---|---|---|
| 10 К-17-2; К-18-2; К-20-2; монолиты 1, 2, 3, 5, 7, 9, 10 К-119-2 | 90—180 | 0.6—1.0 | 150—650 | 800—800 | 16 Черных 170—200 17 Цветных 170—180 | 0.08—0.4 |
| К-21-22; К-220-21; К-211-2 | 90—180 | 0.6—1.0 | 150—600 | 650—1300 | 180—200 | 0.1—0.7 |
| К-211-3; К-211-4; К-211-24 | 90—190 | 0.3—0.7 | • | • | • | • |
| К-214-2 | 90—190 | 0.6—1.0 | • | • | • | • |
| К-214-43 | 150—180 | 0.6—1.0 | 150—600 | 800—1300 | 180—210 | Не более 1.0 18 |
| К-116-35 | 100—190 | 0.4—0.7 | 300—600 | 1000—1300 | 155—165 | 1.2—1.6 |
| 11 ОФПМ-296 | 90—180 | 0.6—0.8 | 300±50 | 500—1000 | 175—180 | Не более 1.0 |
| 12 ФКП-1; ФКПМ-10 ФКПМ-15; ФКПМ-15 Т | 80—180 50—180 | 0.6—1.0 0.6—1.0 | 300±50 | 500—1000 | 165—175 | 19 Не менее 1—1.5 20 Предварительный подогрев обязателен |
| 13 К-17-23; К-18-23 (фенолит 1) | 90—180 | 0.6—1.0 | 300±50 | 500—1000 | 160—170 | 0.7—0.9 |
| 14 К-17-36; К-18-36 (фенолит 4) | 90—180 | 0.6—1.0 | 300±50 | 500—1000 | 150—170 | 0.35—0.45 |
| К-18-53 | 90—190 | 0.7—0.8 | 300—500 | — | 165—180 | 0.3—0.5 |
| К-18-56 | 90—200 | 0.7 | 200—400 | — | 175—200 | 0.15—0.40 |
| 15 Монолиты 4 и 6 | 120—200 | 0.8 | 300±50 | 500—1000 | 160—180 | 1.5—2.5 |

1) Type; 2) Rauschig flowability; 3) calculated shrinkage; 4) pressing pressure; 5) compression; 6) casting molding; 7) kg/cm$^2$; 8) pressing temperature (°C); 9) holding time after preheating in high-frequency generator (min per mm of product thickness); 10) K-17-2, K-18-2, K-20-2, monoliths 1, 2, 3, 5, 7, 9, and 10, K-119-2; 11) OFPM-296; 12) FKP-1, FKPM-10, FKPM-15, FKPM-15T; 13) K-17-23, K-18-23 (phenolite 1); 14) K-17-36, K-18-36 (phenolite 4); 15) monoliths 4 and 6; 16) black; 17) colored; 18) no more than; 19) no less than; 20) preliminary heating obligatory.

operation is carried out on ordinary drill presses. External or internal threads and relief patterns are formed on phenolic-press-powder products during pressing.

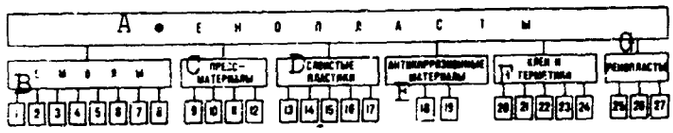
Table 2 shows the dielectric characteristics of phenolic press-powders, while Table 3 shows the processing regimes employed.

References: Petrov, G.S., Levin, A.N., Termoreaktivnyye smoly i plasticheskiye massy [Thermoreactive Resins and Plastics], Moscow, 1959; Plastmassy v mashinostroyenii [Plastics in Machine Building], collection of articles, Moscow, 1959.

PHENOLITES 1-4 – see Phenol molding powders.

PHENOL PLASTICS – are phenol-aldehyde resin-base plastics. The phenol plastics may be subdivided into 6 general groups: resins, molding materials, sandwich plastics, adhesives, anticorrosive materials, and foamed plastics. The classification of the phenol plastics is quoted in the diagram. About 200 grades of phenol plastics are available in the USSR. Thermosetting regins are obtained with a surplus of formaldehyde and an alkaline catalyst, and thermoplastic resins result with a surplus of phenol and an acid catalyst. Thermosetting resins, when in the initial, fusible and soluble state, are termed resols (resins in the A-stage). The macromolecules of the resol become complicated when heated, after long storage, or under the action of acids; the resin becomes more viscous, it loses its solubility in organic solvents, but may still swell in them, heating causes only softening but not melting; in this state, the resin is termed resitol (or resin in the B-stage). Under subsequent heating, the macromolecules of the resin become cross-linked forming a rigid spatial structure, infusible, and insoluble in organic solvents, the so-called resite (resin in the C-stage). Resite has a specific gravity of 1.14-1.30, and a specific resilience of 2.5-10 $kg \cdot cm^2$. Resites are resistant to aqueous and weakly acid media, gasoline, oils and organic solvents; they become degradated in alkaline media, a degradation occurs also when heated for a long time with phenol. Resite possesses high dielectric properties. Being transformed from resol into resite, the resin becomes cured, and mechanically, thermally and chemically stable. With a surplus of phenol in an acid medium, hard and brittle thermoplastic resins, novolaks, are form-

ed, a polymer-homologous mixture of branched molecules with an irregular structure. In order to obtain heat resistant and stable commercial products, which do not melt at high temperatures, the novolaks are transformed into resites, i.e., a three-dimensional structure is imparted to them. A supplementary quantity of formaldehyde must be added to transform novolaks into resites. In practice, the powderlike crystalline compound of formaldehyde with ammonia, hexamethylene tetramine (urotropine), is added. Urotropine decomposes when heated, and the products of its decomposition cure (cross-link) the chains of the novolak into a resite. Resins of a regular structure (ortho-novolaks), i.e., resins with only linear, nonbranched molecules, having a higher curing rate and better physicomechanical properties, are obtained by using zinc acetate or chloride and certain other compounds as catalysts.




Resins: 1) Ion-exchange resins, cationites, resins for demineralization of water and extraction of metals; 2) cast resites and resin No. 30 for dies and models; 3) materials for atomized coating; 4) impregnated graphites; 5) binders for plates from wood shapings and wood fibers; glass-wood and slag-wool, glass-felt; 7) resins for paint and varnish coatings on wood or metal; 8) resins used as binders for molding materials and sandwhich plastics. Pressing materials: 9) asbestos-fiber plastics, fiber plastics, glass-fiber plastics; 10) pressing powders for general technical purposes (materials for electric insulation, for high-frequency, engineering materials resistant to moisture and chemical reagents, etc.); 11) pressing materials with a crumbled filler; 12) friction materials. Sandwich plastics: 13) asbestos-textolites; 14) Pertinax; 15) indurated plywood; 16) glass-textolites; 17) textolites. Anticorrosive materials: 18) antegmites; 19) faolites. Adhesives and cements: 20) Cold- and hot-curing cements, resistant to fuels up to 200°; 21) adhesives for binding of fluoroplast, capron and other polymers; 22) adhesives for binding of rubbers and of rubbers with metals; 23) universal adhesives of the BF type; 24) cold- and hot-curing adhesives for wood and plywood. Foamed plastics: 25) rigid foamed plastics (with a weight by volume of 50 kg/m3 and more); 26) micro-bubbles to inhibit the evaporation on the surface of petroleum products; 27) honeycomb structures. A) Phenol plastics; B) resins; C) molding materials; D) sandwich plastics; E) anticorrosive materials; F) adhesives and cements; G) foamed plastics.

The plasticity, fusibility and solubility of the novolaks and resols are utilized in the production of phenol plastics. Various fillers (powderlike or fibrous materials, paper, fabrics, wood veneers, etc.) are impregnated with novolak or resol resins, and parts of devices and machines, pipes, sheets and plates are formed from the semifinished products. The material becomes dense and cured into resite during the molding process at temperatures about 140-200° and a pressure of 100-1200 $kg/cm^2$. In some cases, the curing is carried out in ovens at a temperature of 200° (bakelization process) or in the cold in the presence of acid catalysts. The properties of the phenol-aldehyde plastics depend on the resin (the binder) and the filler (the type of the filler, its quantity, dispersity and orientation in the products). The use of resins prepared from crystalline phenol yields plastics with a high mechanical strength and heat resistance; cresol and aniline-phenol resins give plastics with the best dielectric properties. Phenol plastics with asbestos as a filler possess an increased heat resistance, a low heat conductivity, and high friction properties. Addition of graphite increases the heat conductivity and significantly reduces the friction coefficient of the material. Phenol plastics with mineral fillers are quite resistant to radiation. The most durable phenol plastics are obtained by using glass fiber and certain synthetic fibers.

Phenol resins are easily compatible with rubber, polyvinyl acetals, polyamides, etc., forming block copolymers and graft copolymers. The combined-resin-base phenol-aldehyde plastics do not lose their thermosetting capacity and obtain additive properties characteristic of the polymer materials. Polyvinyl chloride, for example, possesses a good chemical stability but a very low heat resistance. Pressing materials made using phenol resins combined with polyvinyl chloride retain the heat resistance characteristic of phenol resins, and gain the chemical

stability characteristic of the polyvinyl chloride. Combination with rubbers allows the production of impact-resistant materials, adhesives and cements; combination with polyvinyl acetal results in adhesives with a good adhesion to metals and to nonmetallic materials, etc.

Diversely shaped objects are easily obtainable from phenol plastics. The objects may be easily reinforced by metal during production, and do not require an additional machining after being taken out from the mold. Objects may be manufactured from sandwich plastics by machining on machines used for the tooling of metals.

The modified-resins-bade varnishes, binders, cements, cold- and hot-curing adhesives manifest a good adhesion, resistance to atmospheric phenomena and to heat.

The good mechanical and dielectric properties, the thermosetting property and the heat resistance of phenol plastics, the capability to work a long time at high temperatures and under diverse climatic conditions, including the polar and the torrid zone, the practically total absence of a change of the properties caused by aging, secure the wide application of phenol plastics in instrument manufacture, radio-electronics, construction of chemical, petrochemical and textile machines, in aviation and automobile industries and in other branches of the national economy.

The properties of materials based on phenol resins are quoted in the following articles: Asbestos Friction Materials, Asbestos-fiber Plastic, Asbestos Plastic, Antegmite, Fiber Plastic, Pertinax, Wooden Sandwich Plastics, Lignofol, Phenol-formaldehyde Adhesive, Foamed Phenol-formaldehyde Plastic, Pressing Materials with a Crumbled Filler, Phenol Molding Powders, Faolite, Phenol Formaldehyde Products.

References: Barg, E.I., Tekhnologiya sinteticheskikh plasticheskikh mass [Technology of Synthetic Plastics], Leningrad, 1954; Losev, I.P.,

Trostyanskaya, Ye.B., Khimiya sinteticheskikh polimerov [Chemistry of Synthetic Polymers], 2nd Edition, Moscow, 1964; Kargin, V.A., Slonimskiy, G.L., Kratkiye ocherki po fizikokhimii polimerov [Short Essays on the Physical Chemistry of Polymers], Moscow, 1960.

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PHENYL SILOXANE RUBBER – is the product of the joint condensation of methyl dichlorosilane and methyl phenyl dichlorosilane. It possesses an increased compatibility with organic materials. It is used for the production of rubbers with an elevated frostproofness and resistance to radiation effects. Phenyl siloxane rubbers maintain their elastic properties up to –80° when they contain 5 mole-% phenyl groups, and up to –110° containing 10 mole-% of them. Introduction of phenyl groups into the rubber in a quantity higher than 10 mole-% reduces gradually the frostproofness of the polymers, and with a content of 22 mole-% the brittleness point of the polymer is higher than that of the common dimethyl siloxane rubber (Table 1).

TABLE 1

Frostproofness and Brittleness Point of Rubbers From Dimethyl Siloxane Rubber (KD) and Phenyl Siloxane Rubber Containing 6 Mole-% Phenyl Groups

| 1 Каучук | 2 Коэф. морозостойкости при | | | | | | 3 Температура хрупкости (°С) |
|---|---|---|---|---|---|---|---|
| | –55° | –60° | –65° | –75° | –85° | –90° | |
| 4 КД | 0.65 | 0.06 | 0.0 | – | – | – | –68 |
| 5 К.ф. | 0.89 | 0.85 | 0.85 | 0.89 | 0.65 | 0.59 | –74 |

1) Rubber; 2) coefficient of frostproofness at; 3) brittleness point (°C); 4) KD; 5) phenyl siloxane rubber.

The rubber becomes nonburning when more than 22 mole-% phenyl groups are introduced. Taking the degree of cross-linking of the filled dimethyl siloxane rubber after irradiation with $3 \cdot 10^{-7}$ roentgen equal

to 100%, the degree of cross-linking amounts 25% at a content of 7.5 mole-% phenyl groups, and 13% at a content of 30 mole-%, hence, the polyphenyl siloxane rubber is resistant to radiation.

The dielectric characteristics of phenyl siloxane rubbers and dimethyl siloxane rubbers are given in Table 2.

TABLE 2

Dielectric Characteristics of Phenyl Siloxane and Dimethyl Siloxane (KD) Rubbers

| Условия испытания 1 | Тангенс угла диэлектрич. потерь 2 | | Диэлектрическая постоянная 3 | | Удельное объемное сопротивление (ом·см) 4 | | Пробивная прочность (кв/мм) 5 | |
|---|---|---|---|---|---|---|---|---|
| | КД 6 | К. Ф 7 | КД 6 | К. Ф. 7 | КД 6 | К. Ф. 7 | КД 6 | К. Ф. 7 |
| а До увлажнения . . . . | — | 0.0007 | — | 2.9 | — | $4.8 \cdot 10^{15}$ | — | — |
| 9 После пребывания в воде в течение 7 суток . . | 0.0018 | 0.0010 | 2.0 | 3.0 | $1 \cdot 10^{}$ | $4.7 \cdot 10^{15}$ | 16.8 | 16.5 |

1) Test conditions; 2) tangent of the loss angle; 3) dielectric constant; 4) specific volume resistance (ohm·cm); 5) breakdown voltage (kv/mm); 6) KD; 7) phenyl siloxane rubber; 8) before wetting; 9) after being kept in water for 7 days.

The introduction of phenyl groups into the rubber reduces somewhat the resistance of the phenyl siloxane rubbers to diverse aggressive media (Table 3).

The formulae, the preparation and the technique for stocks of phenyl siloxane rubbers are the same as for dimethyl siloxane rubber stocks. The phenyl siloxane rubbers have the same disadvantages as the dimethyl siloxane rubbers: degradation when operating at a temperature of 180° and higher; increased tendency to accumulate residual deformations. These disadvantages are removable by introducing additional vinyl groups. Such rubbers have found application in practice abroad. Thus, the rubber Dr-54, produced by the British firm I.C.I., is a methyl vinyl phenyl siloxane rubber. This rubber possesses high technical

characteristics.

Phenyl siloxane rubbers are used in shipbuilding, in the cable and

TABLE 3

Swelling of Vulcanized Dimethyl Siloxane (KD) and Phenyl Siloxane Rubbers in Diverse Media (% by Weight) During 24 Hours

| Среда [1] | Темп-ра (°С) [2] | [3] КД | [4] К. ф. |
|---|---|---|---|
| **Кислоты** [5] | | | |
| [6] Серная 75%-ная | 20 | 1.6 | 1.2 |
| [7] Азотная концентрированная | 20 | 27.7 | 31.4 |
| **Основания** [8] | | [19] | |
| [9] Едкий натр 20%-ный | 100 | не набухает | |
| [10] Аммиак концентрированный | 20 | 5.0 | 5.8 |
| [11] Перекись водорода 30%-ная | 20 | 0.6 | 1.0 |
| **Растворители** [12] | | | |
| [13] Бензол | 20 | 127 | 179 |
| [14] Анилин | 120 | 42 | 71.0 |
| [15] Дифенил | 50 | 24 | 40 |
| [16] Дибутилфталат | 65 | 40 | 89 |
| [17] Дихлорэтан | 20 | 42 | 71.9 |
| [18] Ацетон | 20 | 17 | 15 |

1) Medium; 2) temperature (°C); 3) KD; 4) phenyl siloxane rubber; 5) acids; 6) 75% sulfuric acid; 7) concentrated nitric acid; 8) bases; 9) 20% sodium hydroxide; 10) concentrated ammonia; 11) 30% hydrogen peroxide; 12) solvents; 13) benzene; 14) aniline; 15) diphenyl; 16) dibutyl phthalate; 17) dichloroethane; 18) acetone; 19) does not swell.

aviation industry, and in other industrial branches.

F.A. Galil-ogly

PHLOGOPITE – is a low-iron magnesia-alumina mica belonging to the biotite subgroup, with the composition $KMg_3[Si_3AlO_{10}][F, OH]_2$. The crystalline structure of the phlogopite, similar to that of all micas, is characterized by aluminum-oxygen tetrahedrons (with the ratio Al: :Si = 1:3). This fact involves a residual negative charge between the three-layer sheets, which is compensated by the monovalent $K^+$ ion. In contrary to other micas, in the case of phlogopite an Mg ion is situated on all places of the six-fold coordination between two aluminum-oxygen layers within the laminated sheets. Phlogopite crystallizes in the monoclinic system. The crystals are discoid (pseudohexagonal), short-prismatic, sometimes truncated-pyramidal; they are frequently coarse with distinctly expressed (parallel) hatching on the side faces. The structure is laminar. A so-called percussion figure similar to a six-rayed star occurs after the impact of a blunt needle on the cleavage plane; an indentation figure (a six-rayed star with direction of the rays perpendicular to the edges) occurs when a dull-pointed rod is impressed. Phlogopite is easily cleavable into elastic and flexible thin laminae; the thin phlogopite laminae are colorless with a greenish-gray tint; 0.3-0.4 mm thick laminae have a yellowish-brown or greenish brown color with a silvery or golden tint, they may be also reddish-brown or black; phlogopite does not give a streak; the appearance is glassy, and nacreous and almost metallic on the cleavage planes. The density is 2.78-2.85; the hardness is 2.5-2.7; the melting points is 1270-1330°; the mineral is fusible only with difficulty. It becomes decomposed in acids, especially in sulfuric acid; alkalis barely attack

it. The specific heat is 0.206 cal/degree; the heat conductivity (perpendicular to the cleavage planes) is 0.0010-0.0016 cal/cm·sec·°C. The heat resistance is 700-1000°. The compression strength (of 4 × 4 cm laminae) is 2050-2650 kg/cm$^2$; the index of flexibility (maximum thickness of phlogopite bent around a cylinder with a diameter of 4 mm) is 8-11 μ; the wearability is equal to that of copper. The hygroscopicity (after 48 hrs) is about 0.25%; the water absorption (after 48 hrs) is 1.5-5.2%. Phologopite possesses a high electric strength which amounts to 117-145 kv/mm in the direction perpendicular to the cleavage planes for 0.025 thick laminae (test with cylindrical electrodes in oil); the specific volume resistance is $10^{13}$-$10^{14}$ ohm·cm in this direction, and $10^{8}$-$10^{9}$ ohm·cm in the parallel direction; the specific surface resistance is $10^{10}$-$10^{11}$ ohm·cm. The dielectric losses of phlogopite are 0.006-0.093 at a frequency of 50 cps, and 0.002-0.01 at a frequency of 1000 kcps. The electrical characteristics mentioned above concern a phlogopite not attacked by hydration processes and not containing mineral inclusions which considerably impair the dielectric properties of the phlogopite.

More than 90% of the phlogopite is used for electric insulation, about 10% for the manufacture of sight holes of oil burners, valves of gas masks, heat insulating plates, etc. Phlogopite is used in the following forms: 1) as mica scale for the manufacture of heat resistant material and commutator micanites, and, like muscovite, for the production of molding, flexible, and packing micanites, of mica foil and mica tapes for the electric insulation of turbo-generators and other high-voltage engines, of electrical motors, etc.; 2) as lamellae for the production of certain grades of capacitor mica which must meet high-requirements with respect to the dielectric losses; 3) as cut mica (rectangular plates) for shielding of aircraft sparkplugs and for diverse

electrical insulating packings; 4) as sockets for aircraft sparkplugs, for electrical and thermal insulation, etc., and 5) as scale for filling ruberoid, for the manufacture of diverse heat insulating objects, etc.

References: Betekhtin, A.G., Kurs mineralogii [Course of Mineralogy], 3rd Edition, Moscow, 1961; Volkov, K.I., and Zagibalov, P.N., Tekhnologiya slyudy [Technology of Mica], Moscow, 1958; Trebovaniya promyshlennosti k kachestvu syr'ya [Requirements of Industry to the Qualities of Ray Materials], a handbock for geologists, No. 23; Lashev, Ye.K., Markov, P.N., Suloyev, A.I., Slyuda [Mica], Moscow-Leningrad, 1947; Winchell, A.N. and Winchell, G., Opticheskaya mineralogiya [Optical Mineralogy], translated from English [2nd Edition], Moscow, 1953.

N.N. Zubarev

PHOSPHOR CAST IRON – is a cast iron with a phosphorus content higher than 0.3% (up to 1.5%). A phosphorus content within the indicated limits, improves the flowability of the cast iron and, under certain friction conditions, the wear resistance.

TABLE 1

Effect of Phosphorus on the Mechanical Properties of Cast Iron Modified by Magnesium and Cerium (3.0-3.2% C; 2.0-2.25% Si, 0.1% Mn, 0.02% S)

| 1 Содержание фосфора (%) | $\sigma_b$ | $\sigma_{изг}$ 2 | Стрела прогиба f (мм) 4 |
|---|---|---|---|
| | 3 ($кг/мм^2$) | | |
| 0 | 41 | 106 | 71.7 |
| 0.25 | — | 106 | 41.0 |
| 0.50 | — | 105 | 19.0 |
| 0.80 | 115.8 | 104 | 15.2 |
| 1.00 | 42.8 | 104 | 11.8 |
| 1.50 | 45.0 | 100 | 9.0 |

1) Phosphorus content; 2) $\sigma_{izg}$; 3) ($kg/mm^2$); 4) depth of curvature.

When the phosphorus content is increased, hard inclusions of phosphite eutectic are formed in the structure of the cast iron: in gray cast iron, a binary phosphite eutectic with HB = 400 $kg/mm^2$ which decreases the plasticity, somewhat increases the strength (up to 0.8-% P) and does not almost affect the endurance limit of the cast iron (Table 1); in white iron, a ternary phosphite eutectic is formed with HB = 600 $kg/mm^2$. The inclusions of the phosphite eutectic remain in the form of fine globuli after tempering.

Phosphor cast iron is used for precision castings as: large size castings in general machine building, thin-walled wear-resistant castings of a medium mechanical strength, castings which are not submitted

to mechanical tests and artistic casting (Table 2). Phosphor cast iron is also used for engine piston rings (see Cast iron for piston rings),

TABLE 2

Chemical Properties and Application of Phosphor Cast Iron

| Назначение отливок | Марка по ГОСТ 1412—54 | Толщина стенок отливки (мм) | Содержание элементов (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | C | Si | Mn | P | S, не более |
| Конструкционное | СЧ 00 | до 10 | 3,2—3,8 | 2,4—2,7 | | | |
| То же | СЧ 12-28 | 10—20 | 3,2—3,8 | 2,3—2,6 | | | 0,15 |
| » | | 20—30 | 3,1—3,6 | 2,2—2,5 | | | |
| » | СЧ 15-32 | до 20 | 3,2—3,6 | 2,0—2,6 | 0,5—0,8 | 0,65 | 0,15 |
| » | | 20—30 | 3,1—3,5 | 2,0—2,3 | | | |
| » | СЧ 21-40 | до 20 | 3,2—3,4 | 2,0—2,3 | | | 0,14 |
| » | | 20—30 | 3,1—3,4 | 1,9—2,2 | | | |
| Ванны | СЧ 21-40 | — | 3,5—3,9 | 1,8—2,1 | 0,5—0,8 | 0,3—0,5 | 0,10 |
| Радиаторы | — | — | 3,4—3,8 | 2,2—2,6 | 0,9—1,2 | 0,4—0,6 | 0,10 |
| Трубы канализационные | — | — | 3,4—3,8 | 2,6—2,8 | 0,5—0,8 | 0,5—0,8 | 0,12 |
| Трубы, отливаемые центробежным способом | СЧ 18-36 | — | 3,2—3,4 | 1,8—2,2 | 0,6—0,9 | 0,5—0,7 | 0,10 |
| Художественное литье | — | — | 3,2—4,0 | 2,0—2,5 | 0,6—0,9 | 0,5—1,2 | 0,08 |

1) Purpose of the casting; 2) grade according to GOST 1412-54; 3) wall-thickness of the casting (mm); 4) percentage of elements; 5) not more than; 6) structural; 7) SCh; 8) up to; 9) the same; 10) baths; 11) radiators; 12) sewage pipes; 13) pipes produced by centrifugal casting; 14) artistic casting.

for wear-resistant castings working at flood lubrication, low specific pressure and low speed (see Antifriction cast iron), for molds used in the pressure die-casting of zinc and aluminum alloys (1.5% P), etc.

References: Girshovich, N.G., Sostav i svoystva chuguna [Composition and Properties of Cast Iron], in the book: Spravochnik po chugunnomu lit'yu [Handbook on Iron Casting], 2nd Edition, Moscow-Leningrad, 1960; Riley, R.V., "Brit. Foundryman," 1960, Vol. 53, No. 12, 549-555.

A.A. Simkin

PHOTOGRAPHIC METHOD OF GAMMA-RAY EXAMINATION consists in the transillumination by gamma-rays of the object to be tested resulting in a gamma-photograph on photographic material (x-ray film) which represents the internal macroscopic structure of the object. The relative positions of the radiation source, the object, and the x-ray film are similar to that used in radio-materiology. During the transillumination, the radiation source is usually placed in the container of the gamma-ray examination equipment, which protects the attendants from the radiation effect; the film is placed in a light-tight casette made from a material which is transparent for gamma radiation (black paper, oil-cloth, aluminum foil, etc.). Having placed the container and the casette in the required position, the source is switched on for a certain time (the exposure time) and the film is then treated photographically in the usual manner. The gamma rays which have passed through the various sections of the object, become attenuated to a different degree depending on the thickness, the composition, and the density of the material. The attenuation is stronger in the more thick and dense sections; therefore, the negative representation of these sections is more light on the gamma picture. All representations on the gamma picture are obtained in conical projection because one endeavors to keep the linear dimensions of the radiation source as small as possible in comparison with the dimensions of the pattern and the distance between the source and the film. Most of the flaws occurring in practice are of a hollow type (blisters, gas bubbles, cracks, nonfusions in welded joints); therefore, the negative representations of these flaws on the

gamma patterns have the appearance of spots or lines darker than the representations of the flawless sections. The testing of the quality of the transilluminated object is carried out by examination of the gamma pattern in passing light. The dimension of the flaw in the direction of the rays (the "ray" dimension) involves a corresponding degree of blackening of the flaw representation, hence, the geometrical dimensions of the found flaw may be judged by the size of its representation and the difference between the blackening of the flaw and the flawless section.

The sensitivity of the photographic method of gamma-ray examination is characterized by the minimum ray dimension which is detectable by transillumination. The absolute value of this dimension is a measure of the "absolute sensitivity" of the method at given conditions of transillumination, and the relative value, expressed as a percentage of the transilluminated object, is the measure of the "relative" or percentual sensitivity. The main factors which lower the real sensitivity (besides the scattered radiation) are: blurred edges of the flaw representation, a great distance between the flaw and the film, and a different thickness of the tested object in the same pattern. In most of the cases, the real relative sensitivity is 1.5-2.5% within the usual thickness range.

The photographic method of gamma-ray examination is one of the most reliable and widespread methods of flaw detection in welded joints, making apparent nonfusions, porosity, unsound spots, blisters, and in some cases also cracks. Butt joints are transilluminated in the direction perpendicular to the plane of the sheets, the radiation source and the middle of the casette must be in the center of the joint. Overlapping joints are transilluminated either perpendicularly to the plane of the sheets or at an angle of 30-45°. The transillumination may be

carried out twice, in both directions, to increase the reliability. Corner joints and T-connections are treated in the same manner. Three possibilities of placement of the source and the film relative to the joint are possible in the transillumination of the welded joints of pipelines, tanks, and similar objects: 1) transillumination from within; 2) transillumination from the outside through one wall, and 3) through both walls. The first method gives the best results, the third variant the poorest ones, being, however, frequently the only one possible (in the testing of ring joints in pipelines with a small diameter).

The photographic method of gamma-ray examination makes it possible to test cast objects without a previous preparation of the surface. Shrinkage cavities, blow holes, slag inclusions, friable structures, etc., are discoverable by transillumination. Cracks are discoverable only in certain cases, therefore, the transillumination is combined with the magnetic luminescence or color methods in doubtful cases. The above described method to test cast objects is especially efficient at the primary stages of their machining because it makes it possible to reject the imperfect pieces in time. The transillumination of small, simply shaped cast objects is carried out by one exposure, great and complicated objects are transilluminated in parts.

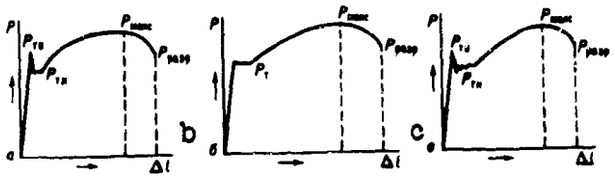
The application of the photographic method of gamma-examination is efficient also when the regularity of the arrangement of internal parts, inaccessible to a visual test, must be controlled during the assembly of objects and aggregates. This method makes it possible also to detect flaws in internal parts occured during the service. Generally, the flaws in complicated units and aggregates with considerable changes in thickness are more clearly detectable by means of gamma-irradiation than by x-ray irradiation.

The advantages of the photographic method of gamma examination and also of x-ray materiology and xerography in comparison with other methods of flaw detection are: a sufficient sensitivity and the possibility to test objects made from many materials and different in shape and dimensions, including objects with a nonmachined surface; an easily interpretable gamma-photogram which gives continuous representation of the internal macrostructure of the tested object; the simplicity of the device which does not require high skill of the attendants; the possibility of a test under field conditions, in the shop, on the assembly stage, etc. A low productivity, the difficulties in the testing of heated and moved parts, and also a difficult automatization of the test process belong to the disadvantages of this method.

References: see the article Gamma-ray examination.

L.K. Tatochenko

PHYSICAL YIELD STRENGTH – the stress at which, despite increasing deformation, the dynamometer needle of the test machine first comes to a stop or reverses. This characteristic is designated by the symbol $\sigma_t$. Technical-grade iron, soft steel, and certain types of bronze exhibit a physical yield strength. In this case the extension diagram has the form shown in Figs a, b and c. A decrease in load from the val-




ue $P_{tv}$ in the deformation diagram (Fig. a) indicates an upper yield strength, in contrast the the lower yield strength, which corresponds to the least load $P_{tn}$ at which the material begins to flow (Figs a and c). The upper ($\sigma_{tv}$) and lower ($\sigma_{tn}$) tensile yield strengths are calculated from the formulas $\sigma_{tv} = P_{tv}/F_0$ and $\sigma_{tn} = P_{tn}/F_0$, where $F_0$ is the initial cross-sectional area of the specimen in $mm^2$. The upper physical yield strength depends to an especially large extent on the test conditions (specimen shape, test rate, and design of test machine).

According to current concepts, the existence of a physical yield strength is due to small quantities of impurities dissolved in the solid solution (carbon and nitrogen in iron), whose atoms concentrate around the dislocations, influencing their displacement under stress.

S.I. Kishkin-Ratner

LIMIT OF ELASTICITY – the stress below which plastic (residual) deformation does not occur. Because of the difficulty of reliable determination of this characteristic the arbitrary elastic limit is used in engineering, being defined as the stress (in kg/mm$^2$ or kg/cm$^2$) at which the residual deformation reaches a definite predetermined value. In accordance with GOST 1497-61, in determining the arbitrary elastic limit the residual-elongation tolerance is selected as 0.05% of the initial specimen lengths; this is sometimes reduced to 0.01-0.003%. The tolerance is indicated in the subscript to the letter designating the elastic limit, e.g., $\sigma_{0.05}$, $\sigma_{0.01}$, etc. The elastic limit for extension, compression, warping, and bending are determined from the formulas:

$$\sigma_{0,05\ р} = P_{0,05}/F_0; \quad \sigma_{0,05\ сж} = P_{0,05\ сж}/F_0;$$
$$\sigma_{0,05\ см} = P_{0,05\ см}/da; \quad \sigma_{0,05\ изг} = M_{0,05\ изг}/W,$$

where $P_{0.05}$ (in kg) and $M_{0.05}$ (in kg-cm or kg-mm) are respectively the load and the bending moment at which the residual elongation reaches 0.05%, $F_0$ is the cross-sectional area of the specimen during tensile or compressive testing (in mm$^2$ or cm$^2$), $\underline{d}$ is the aperture diameter (in mm or cm), and W is the moment of specimen resistance during bending (in mm$^3$ or cm$^3$). The 0.05% residual-elongation tolerance corresponds to a 0.07% residual-shear tolerance. The tortional elastic limit is determined from the formula

$$\tau_{0,075кр} = M_{0,075\ кр}/W,$$

where $M_{0.075kr}$ is the torsional moment in kg-cm or kg-mm at which the residual shear $\gamma = 0.075\%$ ($\gamma = \theta r/\ell$, where $\theta$ is the twist angle per unit specimen length in radians, $\underline{r}$ is the radius of the rod to be twist-

ed in mm or cm, and $\ell$ is the working length of the rod in mm or cm).

S.I. Kishkin-Ratner

PIEZOELECTRIC CERAMICS – see Ceramic radio-engineering materials.

PIEZOELECTRIC MATERIALS – a group of crystalline electrical-insulating substances whose crystal cells lack a center of symmetry. As a result, when they are deformed their particles (ions or polar groups) are displaced asymmetrically, which causes polarization and development of surface charges (the direct piezoeffect); when an electric field is applied to such bodies, they are deformed in conformity to the magnitude of the applied field (the inverse piezoeffect).

Piezoelectric materials are thus electromechanical transformers that permit direct conversion of mechanical energy to electrical energy and vice versa. The piezoeffect was first investigated in quartz crystals by the Curie brothers in 1880.

Ferroelectric materials (which see) deform on polarization and also exhibit a piezoeffect. All ferroelectrics are piezoelectric in the ferroelectric region, although the converse does not hold.

At small deformations the charges produce at the surface of such materials are proportional to the applied mechanical stress. The proportionality coefficient relating stress and charge (polarization) is called the piezomodulus. It depends to a large extent on the crystallographic orientation of the forces acting and of the surfaces at which the piezoeffect is being studied. The piezomodulus is consequently designated by subscripts indicating these directions:

$$q_{ik} = d_{ik} X_i,$$

where $q_{ik}$ is the charge produced at the surface perpendicular to the crystallographic direction $\underline{k}$ under the influence of the stress-vector component in the direction $i$-$X_i$ and $d_{ik}$ is the piezomodulus, i.e., the

charge produced at the surface perpendicular to the crystallographic direction k under the action of a unit stress in this direction.

When a not overly large potential difference is applied to a piezoelectric plate a deformation proportional to the field voltage E is produced:

$$\frac{\Delta l}{l} = \lambda_{ik} E,$$

where $\lambda_{ik}$ is the piezoelectric constant.

Materials with high piezomoduli and low dielectric and mechanical losses are good piezoelectrics. They are used for stabilizing the carrier frequencies of radio transmitters, for high-selectivity filters, ultrasound generators, sound pickups, and pressure-measuring devices (especially in rapidly varying processes), as time standards, etc.

Natural or artificially cut piezoquartz is one of the principal piezoelectric materials. This mineral has a Moos hardness of ~7, a tangent of dielectric-loss angle tg $\delta \approx 2 \cdot 0^{-4}$, and piezomodului $d_{11} = -d_{12} = 6.8 \cdot 10^{-8}$ and $d_{14} = -1.8 \cdot 10^{-8}$SGSE. The piezomodulus $d_{11}$ decreases and $d_{14}$ increases as the temperature rises. There may consequently be sections of a plate whose piezocapacity depends little on temperature over the given ranges t and f. Piezoquartz is widely used for stabilizing and filtering radio signals, generating ultrasound, and measuring mechanical quantities (piezometry). Rochelle salt is characterized by three independent piezomoduli:

$$d_{14} = 2{,}4 \cdot 10^{-5}; \quad d_{25} = -1{,}6 \cdot 10^{-6}; \quad d_{36} = 3{,}5 \cdot 10^{-7} \text{ CGCE},$$

and two Curie currents at +22.5° and −15°. Rochelle salt is soft and unstable at low (<35%) and high (>85%) humidities. The dielectric losses of Rochelle salt are considerably larger than those of quartz. It is used principally as a sensing element in phonograph pickups and in sound-reproducing equipment. It has an anomalously high piezomodulus

over the temperature range −20 – +30°, which is associated with its ferroelectric properties. As a result of its markedly higher moisture resistance and more stable piezomodulus ammonium dihydrophosphate ($d_{36} = 1.5 \cdot 10^{-6}$, $d_{14} = 5 \cdot 10^{-8}$ CGSE) is used as the radiative element in sonar equipment, where it has replaced Rochelle salt, as well as in phonograph pickups, piezomicrophones, and other electromechanical converters. Potassium tartrate and the ethylene diamine salt of tartaric acid are of relatively good quality, have a high piezosensitivity, and are replacing quartz in communications filters. Piezoceramics, which are plates of polarized ferroceramic materials, are becoming quite important.

References: Tyul'panov, A.A., P'yezoelektricheskiye materialy [Piezoelectric Materials], in book: Spravochnik po elektrotekhnicheskim materialam [Handbook of Electronic Materials], Vol. 2, Moscow-Leningrad, 1960; Shubnikov, A.V. et al., Issledovaniye p'yezoelectricheskikh tekstur [Investigation of Piezoelectric Structures], Moscow-Leningrad, 1955; Mezon, U., P'yezoelektricheskiye kristally i ikh primeneniya v ul'traakustike [Piezoelectric Crystals and Their Application in Ultraacoustics], translated from English, Moscow, 1952; Kedi, U., P'yezoelektrichestvo i yego prakticheskiye primeneniya [Piezoelectricity and Its Practical Applications], translated from English, Moscow, 1949; Serova, I.A., Sluchevskiy, V.S., Strelets, P L., Proizvodstvo keramicheskikh p'yezoelementov [Production of Ceramic Piezoelements], Leningrad, 1959.

Sh.Ya. Korovskiy

PIEZOQUARTZ METHOD – a technique for measuring forces from the electric charge produced on elastic deformation of a given specimen of cut quartz crystals. In view of the very small deformability of quartz this method has a very low inertia and is consequently widely employed for measuring impact forces, pressure, acceleration, and vibration. The piezoelectric charges are recorded on the paper strip or screen of a recording instrument. The inverse piezoeffect, in which elastic deformation occurs when an electric field is applied, is also utilized in the piezoquartz method.

Ya.B. Fridman

PIG IRON (foundry iron) – is a pig iron containing those alloying constituents which are present in the iron ore in the form of oxides

Chemical Composition of Pig Iron

| Чугун 1 | Технические условия 2 | Марка чугуна 3 | Содержание элементов (%) 4 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | S, не более | Mn, группа 5 | | P, не более | Si, не более, категория | | Cr, класс | | | Ni |
| | | | | | 1-я 7 | 2-я 8 | | 1-я 10 | 2-я | A | Б | В | |
| Хромоникелевый калийсиликовый доменный 12 | ЧМТУ 5-[illegible]-55 | ДХЧ-1<br>ДХЧ-2<br>ДХЧ-3<br>ДХЧ-4<br>ДХЧ-5<br>ДХЧ-6 | — | 0,16 и более 33<br>0,26—0,75<br>0,76—1,25<br>1,26—1,75<br>любые пределы, согласно ГОСТ 4381—55 | не более 0,80 | 0,21—0,60 | 0,5 | 0,03<br>0,04<br>0,05<br>0,05<br>0,05<br>0,06 | 0,04<br>0,04<br>0,05<br>0,05<br>0,05<br>0,05 | 2,20—2,70<br>2,20—2,70<br>2,20—2,70<br>2,20—2,70<br>не более 3,5<br>То же | 2,71—3,20<br>2,71—3,20<br>2,71—3,20<br>2,71—3,20<br>3,5<br>3,5 | —<br>—<br>—<br>—<br>—<br>— | 1,0<br>1,0<br>1,0<br>1,0<br>1,0<br>до 0,99<br>не менее 0,5 |
| Хромоникелевый типа халлеровского доменный 13 | ЧМТУ 3433-53 | ХЧ-1<br>ХЧ-2<br>ХЧ-3<br>ХЧ-4 | — | 2,76 и более<br>2,26—2,75<br>1,76—2,25<br>1,25—1,75 | не более 1,0 | — | 0,5 | 0,03<br>0,03<br>0,04<br>0,04 | —<br>—<br>—<br>— | 1,61—2,20 | 2,21—2,80 | 2,81—3,20 | 0,6—1,0 |
| Хромоникелевый из восточно-кимперсайских руд (доменный) 14 | То же | ХНК-2<br>ХНК-3<br>ХНК-4<br>ХНК-5 | — | 2,26 и более<br>1,76—2,25<br>1,26—1,75<br>0,76—1,25 | не более 1,0 | — | 0,5 | 0,03<br>0,03<br>0,04<br>0,045 | —<br>—<br>—<br>— | 0,8—1,2 | 1,21—1,6 | — | 0,6—1,0 |
| То же, древесноугольный 15 | То же | ХНД-2<br>ХНД-3<br>ХНД-4<br>ХНД-5 | — | 2,26 и более<br>1,76—2,25<br>1,26—1,75<br>0,76—1,25 | не более 1,0 | — | 0,5 | 0,03<br>0,03<br>0,04<br>0,04 | —<br>—<br>—<br>— | 0,8—1,0 | 1,01—1,60 | — | 0,6—1,0 |
| Бокситовый титановый 16 | ТУ-1948 | БЛТ-1<br>БЛТ-2<br>БЛТ-3 | — | 1,76—2,25<br>1,26—1,75<br>0,76—1,25 | 0,4—1,0 | — | 0,5 | 0,03<br>0,04<br>0,04 | —<br>—<br>— | до 0,5 | до 0,5 | до 0,5 | Ti 0,6—1,0 |
| Бокситовый титано-медистый 17 | То же | БТМЦ-1<br>БТМЦ-2<br>БТМЦ-3 | — | 1,76—2,25<br>1,26—1,75<br>0,76—1,25 | 0,4—1,0 | — | 0,5 | 0,03<br>0,04<br>0,04 | —<br>—<br>— | до 0,5 | до 0,5 | до 0,5 | Ti 0,6—1,0<br>Cu 2,0 |
| Хромоникелевый калийный древесноугольный 18 | ТУ-[illegible] | ВЦЛ-1<br>ВЦЛ-2 | — | 0,81—1,3<br>0,3—0,8 | не более 1,0 | — | 0,5 | [illegible] | — | до 1,0 | до 1,0 | до 1,0 | не менее 0,2 |
| Рафинированный ХМК 19 | [illegible]<br>ЦНИИЧМ 17-56<br>[illegible] | [illegible]<br>ХМК-2<br>ХМК-3 | 2,2—2,9<br>2,81—3,80<br>[illegible] | до 1,0 [illegible]<br>1,26—1,75<br>не менее 1,5 | до 0,6<br>до 0,6<br>до 0,6 | — | 0,5<br>0,5<br>0,5 | 0,03<br>0,03<br>0,03 | —<br>—<br>— | [illegible]<br>до 1,75<br>1,76—2,20 | [illegible]<br>до 1,75<br>1,76—2,20 | 0,1—0,75<br>до 1,75<br>1,76—2,20 | 1 не менее 1,0<br>не менее 0,5 |

1) Pig iron; 2) technical specifications; 3) pig iron grade; 4) percentage of elements; 5) group; 6) 1st; 7) 2nd; 8) not more than; 9) not less than; 10) category; 11) class; 12) Khalilovo chrome-nickel, coke smelted; 13) chrome-nickel of the Khalilovo type, coke-smelted; 14) chrome-nickel iron from the East-Kimpersoy ores (coke); 15) the same, charcoal-smelted; 16) beauite-titanium; 17) bauxite-titanium-copper; 18) chrome-nickel cast iron for rollers, charcoal-smelted; 19) refined OKhMK; 20) ChMTU; 21) the same; 22) TU-..; 23) TsNIIChM; 24) LKhCh; 25) KhCh; 26) KhNK; 27) KhND; 28) BLTZ; 29) BTML; 30) VTL; 31) LKhCh R; 32) and more; 33) up to.

and which were reduced during the iron-melting in the blast furnace. The content of alloying constituents in pig iron depends on the content of the corresponding oxides in the ore of the given deposit and the method of melting the pig iron in blast furnaces. The chemical composition of the most widely used grades of pig iron is quoted in the Table. Pig iron is added to the metal charge for shaped castings with a medium and an increased strength. The chrome-nickel pig iron from the Khalilovo, East Kimpersoy, and other deposits are used for this purpose.

A.A. Simkin

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[Transliterated Symbols]

2979 ТУ = TU = tekhnicheskoye usloviye = Technical Specification

2979 ЦНИИЧМ = TsNIIChM = Tsentral'nyy nauchno-issledovatel'skiy institut chernoy metallurgii = Central Scientific Research Institute of the Ferrous Metallurgy

PILE FABRICS – have a file cover on the right side, which is formed by the weft or warp threads. Depending on the kind of threads which form the pile, a distinction is made between weft-pile and warp-pile fabrics (plush, velveteen, velvet cord, ribbed velvet). The former are made from cotton yarn and are used in technology as furniture-decorating materials (Fig. 1), the latter (velvet, plush, artificial mink, etc.) have a more complex structure and consist of two or three warps



Fig. 1. Structural diagram of velvet cord. 1) Warp; 2) weft; 3) pile (weft).

and of one weft (Fig. 2). The pile warp, depending on the fabric type, can consist of compound silk, artificial viscose, capron and other threads, and also of wool, silk, staple (viscose, capron) yarn. Twisted cotton yarn is used in the ground warp. Cotton, flax or jute yarn is used for the backing or tightening warp. The same kinds of yarn can be used in the weft. Warp-pile fabrics come with raised, sheared and raised-sheared pile (Fig. 3). The quality of pil fabrics is determined by the character of the raw material, density and length of the pile. Velvet has the shortest and most dense pile, while fur plush has the longest pile.

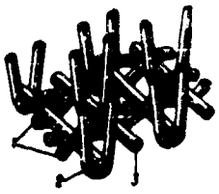


Fig. 2. Structural diagram of plush with single-weft pile fastening. 1) Ground warp; 2) pile warp; 3) weft.



Fig. 3. Structural diagram of carpet fabric with raised pile. 1) Ground warp; 2) pile warp; 3) backing warp; 4) weft.

The ZIS, ATIMK, LYuKS brand plus carpets with single-weft pile fastening have a special structure. They do not have a backing warp, and the high strength is achieved by special impregnation and doubling with cotton fabric. These carpets are used in automotive vehicles and aircraft. Carpet fabrics with a pile from synthetic fabrics with an elastic flexible (rubber) sublayer should be regarded as most effective for automotive vehicles, ships, aircraft and other transportation facilities.

Pile fabrics are manufactured with the following piles: from rayon (GOST 6057-62), from natural silk (GOST 7081-61) and from wool (TU MKhP 30533-48).

V.G. Nabatov

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[Transliterated Symbols]

2982 ГОСТ = GOST = Gosudarstvenny obshchesoyuznyy standart = All-Union State Standard

2982 ТУ МХП = TU MKhP = Tekhnicheskoye usloviye Ministerstva Khimicheskoy Promyshlennosti = Technical Specifications of the Ministry of Chemical Industry

PLASMA ATOMIZATION OF TUNGSTEN – application of layers of tungsten by atomization with a plasma torch.

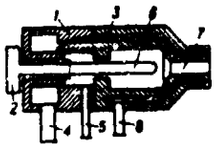


Figure. Diagram of plasma torch.

This method is used for producing certain tungsten components, such as critical nozzles and insertion pieces for rocket engines, crucibles of various sizes and shapes, etc., and for depositing layers of tungsten on the surface of components fabricated from other materials. The plasma torch is a device that provides a stream of ionized gas at a very high temperature (up to 16,500°). Structurally, the torch consists (see Figure) of a housing 1 with a water-cooling jacket 3, a mechanism 2 for advancing the electrode 6, and a nozzle 7. Electric power and water for cooling the housing and nozzle are supplied through two connecting pipes 4 and 8. The working gas is supplied through a rube 5. The operational principle of this device consists in passing the working gas (argon, helium, nitro-

TABLE 1

Ultimate Strength of Atomized-Tungsten Specimens (at High Temperatures in a Vacuum)

| Темп-ра испытания (°С) 1 | 23° | 540° | 1093° |
|---|---|---|---|
| $\sigma_в$ (кг/мм²) 2 | 3.6–4.7 | 14.3 | 7.4–10.7 |

1) Test temperature (°C);
2) kg/mm$^2$.

TABLE 2

Variation in the Coefficient of Linear Expansion of Atomized-Tungsten Specimens as a Function of Temperature

| Темп-ра испытания (°С) 1 | 220° | 650° | 850° | 1093° |
|---|---|---|---|---|
| $\alpha \cdot 10^6$ | 2.7 | 2.85 | 2.9 | 3 |

1) Test temperature (°C).

gen, hydrogen, or a mixture of these gases) through an electric arc struck between the electrode and the nozzle. Power is generally supplied from a dc generator, although alternating current is used in some cases. In passing through the nozzle, the gas compresses the electric arc, so that the electrical conductivity of its outer regions is markedly reduced. The temperature of the plasma formed under the action of the arc is thus substantially increased. The atoms of the working gas are broken down to ions in the arc zone, a process that entails expenditure of a definite amount of energy. At the tip of the torch the ions again recombine into atoms and release a large amount of heat, so that the atomized particles are heated to a very high temperature (above their melting point). Plasma atomization of tungsten can be carried out by feeding tungsten wire or powdered tungsten into the arc zone. Molten tungsten particles escape from the torch at high speed and are deposited on the component to be treated. Good results have been achieved in applying tungsten to rocket nozzles of graphite. Such nozzles can function satisfactorily at temperatures of up to 3000° and gas-flow speeds of approximately 1600 m/sec. Graphite without a tungsten coating is subject to severe damage under these conditions.

In order to produce thin-walled components with precise dimensions plasma-atomized tungsten is deposited on rotating aluminum or brass templates, which are then removed by etching. The temperature of the surface to be metallized generally does not exceed 260°, but it can be cooled if necessary. The high speed and temperature of the atomized particles insures that they will adhere well and that the metal will have high strength and a smooth surface. When this process is carried out in air there is a considerable rise in the oxygen content of the finished product, while its nitrogen content increases only slightly. In order to make the metal denser the component is heat-treated in a

vacuum at 2000-2200° for 1-2 hr. The density of the metal increases from 83-87% to 85-89% of its theoretical density after heat treatment.

Atomized-tungsten specimens exhibit brittle fracture and an elongation of 0.5%. The lattice parameter of atomized tungsten a = 3.164-3.165 A.

References: Metalwork. Product., 1958, Vol. 102, No. 48, page 2088; J. Metals, 1959, Vol. 11, No. 1, page 40.

O.Z. Budzinskiy

PLASTICITY OF GUM RUBBER AND RUBBER MIXTURES. The principal characteristics of these materials, which are viscous-elastic, are governed by their average molecular weight, the flexibility of the chain, and the force of the intermolecular interactions. In rubber mixtures an important role is played by softeners, which increase plasticity, and fillers (soots), which reduce it. Irreversible deformation characteristically depends on temperature. The plasticity of gum rubber and rubber mixtures to a considerable extent governs the ease with which they can be mixed, molded, and extruded. The quantity inverse to plasticity is the elastic restorability of gums and rubber mixtures.

References: Dogadkin, B.A., Khimiya i fizika kauchuka [Chemistry and Physics of Gum Rubber], Moscow-Leningrad, 1947; Fiziko-mekhanicheskiye ispytaniya kauchuka i reziny [Physicomechanical Testing of Gums and Rubbers], Collection, Moscow, 1960, pages 91-109.

N.N. Lezhnev

PLASTICIZED (pressed) WOOD – wood subjected to special heat treatment in the compressed state; it is obtained by hot pressing of bars (one-piece or glued together), impregnated or not impregnated before pressing. Plasticized wood is distinguished by the method of manufacture, properties and intended use. By changing the plasticized wood is obtained with specified properties. Natural wood can be heated before

TABLE 1

Physicomechanical Properties of Plasticized Wood Compressed in One Direction (Moisture Content 7-10%)

| 1 Древесина | 2 Объемный вес (г/см³) | Предел прочности 3 (кг/см²) при сжатии вдоль волокон 6 | при скалывании вдоль волокон 7 | при статическом изгибе 8 | 4 Удельная работа при изгибе (кгм/см²) | 5 Торцовая твердость (кг/мм²) |
|---|---|---|---|---|---|---|
| 9 Пластифицированная древесина малого объемного веса (0,90–1,05 г/см³) | | | | | | |
| 10 Береза | 1.02 | 1270 | 185 | 1640 | 0.4–0.5 | 12 |
| 11 Бук | 1.05 | 1070 | 220 | 1740 | 0.4–0.5 | 12 |
| 12 Ель | 1.05 | 1080 | 190 | 1620 | 0.4–0.6 | 10.5 |
| 13 Сосна | 1.06 | 950 | 185 | 1700 | 0.3–0.4 | – |
| 14 Пластифицированная древесина легкого объемного веса (1,05–1,15 г/см³) | | | | | | |
| 10 Береза | 1.15 | 1250 | 255 | 1800 | 0.5–0.7 | 14–15 |
| 11 Бук | 1.12 | 1300 | 255 | 1850 | 0.6–1.0 | 12–14 |
| 13 Сосна | 1.10 | 1100 | 150 | 1970 | 0.4–0.6 | – |
| 15 Пихта | 1.18 | 1330 | 215 | 1660 | 0.6–0.8 | – |
| 16 Пластифицированная древесина среднего объемного веса (1,18–1,25 г/см³) | | | | | | |
| 10 Береза | 1.25 | 1380 | 305 | 2050 | 0.6–0.7 | 17–20 |
| 11 Бук | 1.25 | 1280 | 300 | 2200 | 0.5–0.4 | 15–20 |
| 13 Сосна | 1.24 | 1035 | 190 | 2000 | 0.3–0.5 | 14–16 |
| Пихта 15 | 1.23 | 1180 | 215 | 1800 | 0.4–0.8 | 14–20 |
| 17 Лиственница | 1.18 | 1150 | 180 | 1800 | | 12–16 |
| 18 Пластифицированная древесина тяжелого объемного веса (1,30–1,42 г/см³) | | | | | | |
| 10 Береза | 1.40 | 1450 | 300 | 2800 | 0.8–1.10 | 21–31 |
| 11 Бук | 1.40 | 1510 | 310 | 2500 | – | 23–30 |
| 12 Ель | 1.39 | 1450 | 300 | 1900 | 0.8 | 14–25 |
| 13 Сосна | 1.30 | 1340 | 220 | 1700 | 0.5 | 18–25 |
| 15 Пихта | 1.42 | 1500 | 290 | 1970 | 0.5 | 14–18 |
| 17 Лиственница | 1.30 | 1500 | 190 | 1650 | 0.3 | 15–22 |

1) Wood; 2) specific weight (g/cm$^3$); 3) ultimate strength (kg/cm$^2$); 4) modulus of resilience in bending (kg-m/cm$^3$); 5) end hardness (kg/mm$^2$); 6) in compression along the fibers; 7) in cleaving along the fibers; 8) in static bending; 9) low specific weight (0.90-1.05 g/cm$^3$) plasticized wood; 10) birch; 11) beech; 12) spruce; 13) pine; 14) light specific weight (1.05-1.15 g/cm$^3$) plasticized wood; 15) fir; 16) medium specific weight (1.18-1.25 g/cm$^3$) plasticized wood; 15) fir; 16)

ium specific weight (1.18-1.25 g/cm$^3$) plasticized wood; 17) larch; 18) heavy specific weight (1.30-1.42 g/cm$^3$) plasticized wood.

pressing through the plates of the press and the molds (contact heating) or by steaming through. Depending on the pressing direction, a distinction is made between the following kinds of wood compression: transverse one-directional, transverse two-directional and contour. Most extensively used is plasticized wood compressed in one direction, produced by stationary and separation methods when pressing wood bars in one direction across the fibers. The physicomechanical properties of plasticized woods of the hard- and softwood species depend on the degree of compression in pressing which is characterized by the specific weight (Table 1).

Plasticized wood compressed in two directions is produced by compressing the bars in one direction across the fibers, and then in another direction, perpendicular to the first. Two-directional compressing is used for obtaining heavy plasticized wood of soft- and hardwood species.

Contour compressed plasticized wood is obtained by pressing a cylindrical bar of wood, first steamed through or heating in holten petrolatum, into a metal tube of a smaller diameter. The cylindrical, contour pressed blanks are dried in the tube and heat treated.

The physicomechanical properties of plasticized wood depend on the initial moisture content of the wood. When the moisture content of the natural wood is low (less than 8%), a material is obtained with a moderate resistance to cleaving and low stability. When the starting moisture content is 15-18%, the stability of plasticized wood is increased, but it can become charred with an attendant reduction in the strength indicators. When plasticizing wood with different moisture contents use is made of different regimes of pre-heating and heat treatment.

Higher-stability plasticized wood is obtained by intensive and uniform heat treatment, usually by the stationary method, in which all the operations of preheating the wood bars, their step by step compression as they are heated, heat treatment and cooling are performed in the hydraulic press platens.

Plasticized wood serves as a substitute for ferrous and nonferrous metals, textolite, and other materials in components and equipment which are used in various branches of industry. It is extensively used for the making of components of machines operating under impact loads (weaving machine chases, gears, knock-out tools for obtaining shapes from sheet metal, balls for pulverizing mills, inserts placed under railraod rails to reduce the wear of crossties, sliding bearings and other friction components, particularly those working in abrasive medium). Plasticized wood does not jam shafts and wears them out less. The wear of contour compressed wood liners is by a factor of two less than that of bronze liners and at the same time they reduce the lubricant consumption. Connecting rods of combine harvesters made from plasticized wood operate 3-5 times as long as connecting rods from natural wood. It was established that the service life of axles when using plasticized wood liners is increased several fold with attendant low liner wear and reduction in lubricant consumption.

The resistance to impact cleaving and the impact hardness of plasticized wood with various specific weight are shown in Table 2.

Due to its high resistance to impact loads plasticized wood is used primarily for making critical weaving shuttle bodies.

The wear of plasticized wood on dry friction at the abrasive surface of Amsler's machine (load 2 kg/cm$^2$, path 3000 m) is hown in Table 3.

TABLE 2

Physicomechanical Properties of Plasticized Wood

| 1 Объемный вес ($г/см^3$) | 2 Сопротивление ударному скалыванию ($кг \cdot м/см^2$) | | 3 Ударная твердость ($кг/мм^2$) | |
|---|---|---|---|---|
| | в радиальном направлении 4 | в тангенциальном направлении 5 | радиальная 6 | тангенциальная 7 |
| 8 Береза | | | | |
| 1.06±0.15 | 0.130 | 0.120 | 1600 | 1940 |
| 1.20±0.05 | 0.180 | 0.180 | 2235 | 2700 |
| 1.30±0.05 | 0.245 | 0.200 | 2550 | 2820 |
| 9 Бук | | | | |
| 1.00±0.15 | 0.150 | 0.140 | 1730 | 2050 |
| 1.20±0.05 | 0.230 | 0.200 | 1780 | 2000 |
| 1.30±0.05 | 0.265 | 0.225 | 2700 | 3030 |

1) Specific weight ($g/cm^3$); 2) resistance to impact cleaving ($kg-m/cm^2$); 3) impact hardness ($kg/mm^2$); 4) in the radial direction; 5) in the tangential direction; 6) radial; 7) tangential, 8) birch; 9) beech.

TABLE 3

Wear of Plasticized Wood on Dry Friction

| 1 Материал | 2 Объемный вес ($г/см^3$) | 3 Износ поверхности (мм) 4 торцовой | 5 радиальной | 6 тангенциально |
|---|---|---|---|---|
| 7 Береза пластифицированная с пропиткой технической глюкозой | 1.40 | 0.12 | 1.04 | 1.43 |
| 8 Пихта пластифицированная | 1.33 | 0.20 | 1.82 | 1.60 |
| 9 Ель пластифицированная | 1.30 | 0.30 | 1.97 | 2.82 |
| 10 То же с пропиткой минеральным маслом | 1.30 | 0.43 | 1.92 | 2.20 |
| 11 То же с пропиткой технической глюковой | 1.30 | 0.25 | 1.55 | 1.40 |
| 12 Лиственница пластифицированная | 1.35 | 0.45 | 2.10 | 1.55 |
| 13 То же с пропиткой минеральным маслом | 1.27 | 0.10 | 1.08 | 1.07 |
| 14 Дуб пластифицированный | 1.28 | 0.22 | 0.70 | 0.62 |
| 15 Дуб натуральный | 0.70 | 1.63 | 4.32 | 4.18 |

1) Material; 2) specific weight ($g/cm^3$); 3) surface wear (mm); 4) end; 5) radial; 6) tangential; 7) plasticized birch, impregnated by technical glucose; 8) plasticized fir; 9) plasticized spruce; 10) same as above, impregnated by mineral oil; 11) same as above, impregnated by technical glucose; 12) plasticized larch; 13) same as above, impregnated by mineral oil; 14) plasticized oak; 15) natural oak.

References: Genel', S.V., Drevesnyye plastiki v tekhnike [Wood Plastics in Technology], Moscow, 1959; Nysenko, N.T. and Genel', S.V. Plastifikatsiya tsel'noy drevesiny [Plasticization of Whole Wood], Mos-

cow-Leningrad, 1958; Khukhryanskiy, P.N., Pressovaniye i gnut'ye dreves-
iny [Pressing and Bending of Wood], Moscow-Leningrad, 1956.

PLASTICIZERS (gelatinizers) – substances added to high-molecular polymers to reduce their softening (vitrification) temperature and increase their flexibility and frost-resistance. Plasticizers are employed principally in the production of plastics, rubbers, and artificial leather (facilitating their processing) and are added to paints.

Characteristics of Plasticizers

| Пластификаторы 1 | Удельный вес 2 | Показатель преломления 3 | Температуры (°С): 4 кипения 5 | плавления 6 | воспламенения 7 | Растворимость в воде (вес. %) 8 |
|---|---|---|---|---|---|---|
| Диэтилфталат 9 | 1.118 | 1.499 | 295 22 23 | −0,3 | 152 | 0,09 |
| Дибутилфталат 10 | 1.050 | 1.490 | 335 | −35 | 168 | 0,03 |
| Диоктилфталат 11 | 0,982 | 1.484 | 230 при 5 мм рт. ст. | −55 | 192 | 0,01 |
| Дибутилсебацинат 12 | 0,936 | 1.4391 | 344 | 5,5 | 178 | 0,1 |
| Диоктилсебацинат 13 | 0,913 | 1.4520 | 256 при 5 мм рт. ст. | −48 | 210 | — 24 |
| Диэтиладипинат 14 | 1.002 | 1.426 | 245 | 14 | — | 0,060 |
| Диметилциклогексил-адипинат 15 | 1,091 | 1.4685 | 230 | 45 | 189 | Нерастворим |
| Триэтилфосфат 16 | 1.068 | 1.405 | 210 | −56 | 116 | Растворим |
| Трибутилфосфат 17 | 0,973 | 1.4248 | 289 | −80 | 146 | 0,60 |
| Трифенилфосфат 18 | 1.185 | 1.563 | 220 | 49 | 225 | 0,002 25 |
| Трикрезилфосфат 19 20 | 1.172 | 1.556 | 260 при 10 мм рт. ст. | −35 | 220 | — |
| н-бутилстеарат | 0,855 | 1.446 | 220 | 20 | 183 | 0,2 |
| Камфара 21 | 1,000 | — | 204 | 178 | 93 | 0,170 |

1) Plasticizer; 2) specific gravity; 3) index of refraction; 4) temperature (°C); 5) vaporization; 6) melting; 7) combustion; 8) solubility in water (% by weight); 9) diethylphthalate; 10) dibutylphthalate; 11) dioctylphthalate; 12) dibutylsebacinate; 13) dioctylsebacinate; 14) diethyladipinate; 15) dimethylcyclohexyladipinate; 16) triethylphosphate; 17) tributylphosphate; 18) triphenolphosphate; 19) tricresylphosphate; 20) n-butylstearate; 21) camphor; 22) at; 23) mm Hg; 24) insoluble; 25) soluble.

Plasticizers in which polymers swell are referred to as primary; for example, complex diesters of dicarbonic acids are primary for vinyl polymers. Secondary plasticizers are substances in which polymers swell little or not at all; they are not used independently, but are generally mixed with primary plasticizers. Chlorinated paraffins, chlorinated naphthalene, high-boiling hydrocarbon fractions, etc., are secondary

plasticizers for vinyl resins. Polar plasticizers generally mix readily with polar polymers, while nonpolar plasticizers mix readily with nonpolar polymers. As the plasticizer content of a polymer increases its static strength (tensile, compressive) drops, while its impact strength and elongation are greatly enhanced; its modulus of elasticity also undergoes a substantial decrease. Addition of polar polymers usually leads to a drop in dielectric characteristics. The properties of the most frequently used plasticizers are shown in the table.

The principal requirements imposed on plasticizers are compatibility over a wide temperature and concentration range, nonvolatility, resistance to water and other solvents under operational conditions, resistance to aging under the action of light, heat, atmospheric oxygen, etc., nontoxicity, lack of odor, and good dielectric characteristics.

References: Barg, E.I., Tekhnologiya sinteticheskikh i plasticheskikh mass [Technology of Synthetics and Plastics], Leningrad, 1954; Kargin, V.A., Slonimskiy, G.A., Kratkiye ocherki po fiziko-khimii polmerov [Brief Outline of the Physical Chemistry of Polymers], Moscow, 1960; Konovalov, P.G., Plasticheskiye massy, ikh svoystva i primeneniye v promyshlennosti [Plastics, Their Properties and Industrial Applications], Moscow, 1961; Zoehrer, K., Merz, A., Kunststoffe [Synthetics], 1957, Vol. 47, No. 3, page 102; Koshelev, F.F., Klimov, N.S., Obshaya tekhnologiya reziny [General Rubber Technology], 2nd Edition, Moscow, 1958; Tager, A.A., Fiziko-khimiya polimerov [Physical Chemistry of Polymers], Moscow, 1963.

R.S. Barshteyn

PLASTIC LUBRICANTS -- lubricants used when it is necessary to simlify the design and reduce the size and weight of mechanisms, in open or difficult-to-seal friction units, in friction units which do not require elimination of heat or which operate over a broad range of temperatures and speeds, in hard-to-reach friction units not requiring frequent changes of lubricant, for prolonged preservation of machinery and mechanisms, and as a sealer-lubricant. These lubricants are obtained by adding 5-30% of a solid thickener to liquid oils. Petroleum oils and synthetic products (diesters, polyalkyleneglycols, polysiloxanes, fluorocarbons, etc.) are used in the manufacture of plastic lubricants. The thickeners are usually soaps of higher fatty acids. Calcium (lubricant greases), lithium, and sodium lubricants are the most commonly employed. Lubricants thickened with special products are used in unusual cases (exposure to high temperatures, aggressive media, etc.). These materials combine the properties of liquid oils and solid greases, so that they can be employed in open, unsealed mechanisms, and applied to inclined and vertical surfaces. Plastic lubricants become flowable under loads of 1-30 $g/cm^2$ and reliably lubricate the friction surfaces. However, it is in many cases difficult and sometimes impossible to ensure circulation of the lubricant through the friction unit. Plastic lubricants are consequently unsuitable for cooling such units. Dilution of these materials with liquid oils during the winter is not recommended, since this has a negative effect on the functioning of mechanisms. Depending on their purpose, we can distinguish antifriction, protective and sealing lubricants. Some lubricants serve as both

antifriction and protective materials, and sometimes as a [illegible] in addition.

Antifriction lubricants are widely used in technology, being intended primarily for rolling-contact bearings. It is recommended that friction units be filled to no more than 30-70% of their volume with lubricant. This reduces the deterioration of the lubricant during operation and the danger that it will overheat and escape from the mechanism. The maximum permissible operational temperature is 60-80° for hydrocarbon, calcium and aluminum lubricants, 120-150° for sodium and lithium lubricants, 170-200° for lubricants containing complex soaps, and 250-350° for lubricants thickened with synthetic products. There are lubricants which can function at especially low temperatures, down to -80°. Antifriction plastic lubricants can be successfully utilized in low- and high-speed friction units, including high-speed bearings (more than 60,000 rpm). As a result of their good antisiezing characteristics, many of these lubricants are recommended for use in heavily loaded friction units. Calcium, hydrocarbon, and lithium lubricants have good water resistance. Fluorocarbon and other lubricants are resistant to aggressive media (acids, alkalies, etc.). Friction units are generally greased manually or with mechanical, pneumatic, or manual grease guns. Manual and automatic oilers are employed, as is pump-forced delivery of the lubricant in centralized lubrication systems.

Protective lubricants are used to protect metal articles against corrosion during prolonged storage. The principal advantage of greases over other anticorrosion coatings (paints, chromium, etc.) lies in their ease of application and removal. Protective lubricants applied to friction surfaces do not affect the normal operation of the mechanism, often simultaneously serving as an antifriction lubricant. The

time for which metal articles can be protected against corrosion depends on the storage conditions and type of lubricant and reaches 10 years or more.

Sealing lubricants are used for hermetic sealing of threaded joints, various valves and stop cocks, vacuum systems, etc. In addition to special sealing lubricants, many antifriction and protective lubricants can be used as sealing materials.

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V.V. Sinitsyn

PLASTICS BASED ON CELLULOSE ESTERS – materials in the form of powders or granules (etrols) and consisting of an appropriate cellulose ester, a plasticizer, a filler, and a dye. Etrols also contain fungicides, which make them fungus-resistant, and lubricants, which keep the finished products from sticking to the press-form. Etrols are produced in special mixers, on rollers, and in pug mills, generally from acetal cellulose, cellulose acetobutyrate, and ethyl cellulose. Table 1 shows the principal characteristics of etrols based on acetal cellulose.

TABLE 1

Principal Characteristics of Etrols Based on Acetal Cellulose

| 1 Показатели | 2 Этролы | | | |
|---|---|---|---|---|
| | 3 | 4 | 5 | 6 |
| 7 Удельный вес не более | 1.4 | 1.4 | 1.4 | 1.32 |
| 8 Уд. ударная вязкость (кг·см/см², не более) | 35 | 35 | 20 | 15 |
| 9 Временное сопротивление статическому изгибу (кг/см², не менее) | 500 | 500 | 500 | 100 |
| 10 Твердость по Бринелю (кг/мм², не менее) | 6.5 | 6.0 | 6.0 | 4.0 |
| 11 Теплостойкость по Мартенсу (°С, не менее) | 60 | 60 | 60 | 50 |
| 12 Водопоглощение за 24 часа (г/мм², не более) | 0.4 | 0.3 | 0.3 | 0.5 |
| 13 Текучесть по видоизмененному методу Рашига (мг/сек, не менее) | 10 | 15 | 15 | 6 |

1) Characteristic; 2) etrols; 3) 2DT-43 colored; 4) 2DT-55 colored; 5) 2DT-55 black; 6) D-30 clear; 7) specific gravity, no more than; 8) impact strength (kg·cm/cm$^2$, no less than); 9) short-term resistance to static bending (kg/cm$^2$, no less than); 10) Brinell hardness (kg/mm$^2$, no less than); 11) Martens thermostability (°C, no less than); 12) water absorption over 24 hr (g/mm$^2$, no more than); 13) flowability by modified Raschig's method (mg/sec, no less than).

TABLE 2

Principal Characteristics of Etrols Based on Cellulose Acetobutyrate

| 1 Показатели | 2 Этролы | | |
|---|---|---|---|
| | 3 АБЦЭ-45-20 | 4 АБЦЭ-38-2 | 5 АБЦЭ-38-12 |
| 6 Удельный вес | 1,2 | 1,2 | 1 |
| 7 Удельная ударная вязкость (кг·см/см², не менее) | 50 | 50 | [illegible] |
| 8 Предел прочности при изгибе (кг/см², не менее) | 500—550 | 400—450 | [illegible] |
| 9 Предел прочности при растяжении (кг/см²) | 300—350 | 280 | [illegible] |
| 10 Относительное удлинение (%) | 70—80 | 50 | [illegible] |
| 11 Модуль упругости при изгибе (кг/см²): | | | |
| 12 при 20° | 8000—10 000 | 9000—10 000 | 1[illegible]—15 000 |
| 13 при 60° | 20 000—23 000 | 22 000—25 000 | 2[illegible]—29 500 |
| Твердость по Бринеллю (кг/см², не менее) | 4,5 | 5,0 | [illegible] |
| 14 Теплостойкость по Мартенсу (°С, не менее) | 50 | 50 | 50 |
| 15 Водопоглощение за 24 часа при нормальных условиях (г/мм², не более) | 0,2 | 0,2 | 0,2 |
| 16 Электрич. прочность при 50% относит. влажности (кв/мм) | 10—16 | — | — |
| 17 Диэлектрич. проницаемость при 50% относит. влажности | — | 3,5—6,4 | — |
| 18 Тангенс угла диэлектрич. потерь (50 гц) при 50% относит. влажности | | 0,01—0,04 | |

1) Characteristic; 2) etrols; 3) ABTsE-45-20; 4) ABTsE-38-2; 5) ABTsE-38-12; 6) specific gravity; 7) impact strength (kg·cm/cm². no less than); 8) ultimate bending strength (kg/cm², no less than); 9) ultimate tensile strength (kg/cm²); 10) relative elongation (%); 11) modulus of elasticity on bending (kg/cm²); 12) at; 13) Brinell hardness (kg/cm², no less than); 14) Martens thermostability (°C, no less than); 15) water absorption over 24 hr under normal conditions (g/mm², no more than); 16) electrical strength at 50% relative humidity (kv/mm); 17) dielectric permeability at 50% relative humidity; 18) tangent of dielectric-loss angle (50 cps) at 50% relative humidity.

Acetal cellulose etrols are converted to finished products by extrusion and pressure casting at pressures of 300-400 kg/cm² and temperatures of 130-160°. These materials are used in the production of automobile dashboards, steering wheels, aircraft controls and fittings, and general-consumption merchandise (eyeglass cases, handles, dishware, watch and camera cases, radio-receiver cabinets, telephones, etc.).

Table 2 shows the principal characteristics of etrols based on cellulose acetobutyrate.

Components of acetobutyrate etrol are distinguished by high resistance to moisture and hot weather, being resistant under tropical conditions (high humidity, elevated temperatures, and severe solar radiation). Cellulose-acetobutyrate etrols are processed by pressure casting at 170-215°, pressing at a pressform temperature of 125-188°,

and extrusion at a nozzle temperature of 170-225°, with pressures of 550-2200, 32-350, and 70-700 kg/cm$^2$ respectively. Cellulose-acetobutyrate etrol is used in aircraft, automobile, and machine building and in the manufacture of sanitary-engineering equipment (washstands, basins, bathtubs, hydrant and toilet cocks, mixers for baths, washers, drains, overflows, pipe fittings, etc.). It is also employed in the production of gas and petroleum pipelines and pipes for discharging contaminated water. Cellulose acetobutyrate pipes used to carry petroleum have a capacity 40% higher than that of metal tubes, since paraffin products do not precipitate from the petroleum to clog them.

Ethyl cellulose etrol and components fabricated from it are resistant to concentrated alkalis, acids, and various salts, are difficult to ignite, burn very poorly, do not decompose or liberate toxic gaseous products when heated to high temperatures, are frost-, heat-, and water-resistant, are highly plastic and thermoplastic, and mix well with many plasticizers, oils, and resins.

Precision-casting models, metal-molding equipment, cast and pressed products, and lacquers are manufactured from ethyl cellulose etrol. This material is produced in three types, K, N, and NI, in accordance with TU MKhP 1958-52. Each type is in turn subdivided into three variants: variant 50 with a viscosity of 40-80 centipoises, variant 100 with a viscosity of 81-120 centipoises, and variant 150 with a viscosity of 121-180 centipoises. The types and variants of ethyl cellulose etrol are designated by letters and numbers: K-50, K-100, K-150, N-50, N-100, N-150, NI-50, NI-100, and NI-150. Ethyl cellulose etrols employed in the manufacture of automobile steering wheels have the following characteristics (no less than): impact strength - 40 kg·cm/cm$^2$, Brinell hardness - 4 kg/cm$^2$, and Martens thermostability - 35°. Etrols prepared from cellulose tripropionate and cellulose acetopropionate are

used for producing small quantities of cellulose-ester-based plastics.

References: Kruger, D., Atsetiltsellyuloza i drugiye organicheskiye efiry tsellyuloza [Acetylcellulose and Other Organic Cellulose Esters], translated from German, Moscow, 1938; Ushakov, S.N., Efiry Tsellyulozy i plasticheskiye massy na ikh osnove [Cellulose Esters and Plastics Based on Them], Leningrad-Moscow, 1941; Sedlis, V.I., Efiry tsellyulozy i plasticheskiye massy na ikh osnove [Cellulose Esters and Plastics Based on Them], Leningrad, 1958; Plasticheskiye massy [Plastics], Collection of Articles 1, edited by R.P. Akit and S.N. Ushakov, Leningrad, 1935; Plasticheskiye massy [Plastics], Collection of Articles 2, edited by S.N. Ushakov, Leningrad, 1937; Plasticheskiye massy [Plastics], Collection of Articles 3, edited by S.N. Ushakov, Leningrad-Moscow, 1939.

G.O. Radchenko

PLASTIC DEFORMATION – a residual change in the size or shape of a loaded body not accompanied by disruption of its continuity. In a number of cases the differentiation of plastic deformation from fracture is arbitrary and depends on the sensitivity of the method used to detect the initial stages of fracture, such as early cracks; for example, the second (steady) stage of Creep is classified as fracture on microscopic investigation, since microcracks have developed, while macroscopically it is still regarded as plastic deformation, since macroscopic damage is not present. Deformation persisting after the load is removed is occasionally elastic-plastic. This is true in cases where the loading is characterized by a nonuniform stress distribution in the plastic region (e.g., during bending, torsion, extension of notched specimens, etc.); in this case the proportion of elastic deformation is determined by the magnitude of the residual stresses (see Diffusion plasticity, Twinning, and Translational slip).

Ya.B. Fridman

PLASTIC FLOW – plastic deformation with time. We can distinguish "cold" plastic flow, which occurs at temperatures below the recrystallization point, and "hot" plastic flow, which occurs at temperatures above this point. Many pressure-working processes (stamping, pressing, embossing) can be regarded as plastic flow of the material over the surface of the die or press. The theory of plastic flow is that branch of the mathematical theory of plasticity which assumes that the stresses at a given moment are proportional to the rate of plastic deformation.

Ya.B. Fridman

PLASTIC FOAMS – see Gas-filled plastics.

PLASTICITY – the ability of a material to undergo residual deformation (deformation persisting after removal of the deforming forces) without failing. Plasticity is a very useful technical property of the majority of metals and other structural materials. We can distinguish thermal plasticity (which appears only at elevated temperatures and is a general characteristic of solids) and nonthermal plasticity (which is retained at very low temperatures and occurs only in certain metals, including aluminum, copper, nickel, etc.). The lack (or low magnitude) of plasticity in metals, ceramics, and silicate materials is termed brittleness. Plasticity or brittleness depends both on the characteristics of the material and the deformation conditions (temperature, deformation rate, degree of deformation, etc.).

Ya.B. Fridman

PLASTICS BASED ON PENTAERYTHRITOL - see Pentaplast.

PLATING OF ALUMINUM ALLOYS – surface coating of aluminum-alloy semifinished products with a thin layer of aluminum or aluminum-based alloys to provide corrosion protection or improve their decorative appearance (see Alclad). Sheets, plates, and tubes of D16, D1, and other alloys are plated with a thin layer of pure aluminum, while V95 alloy is plated with aluminum containing 1% Zn. Sheets and plates are plated during hot rolling. The thickness of the plating layer amounts to no less than 7.5% of the sheet thickness for sheets 0.3-0.7 mm thick, 4% of the sheet thickness for sheets 0.8-1.9 mm thick, and 2% of the sheet thickness for sheets 2 mm or more thick. In order to improve the decorative appearance of sheets (e.g., to obtain a polished surface) the thickness of the plating layer should be no less than 8% of that of the sheet (intensified plating, indicated by "UP," e.g., D16ATUP for D16 alloy). A technological plating (of pure aluminum) with a thickness of up to 1.5% of that of the semifinished product is employed in rolling sheets and plates from AMg5, AMg6, and certain other alloys. Such plating is intended to facilitate the rolling process and improve the appearance of the finished sheets. Hollow blanks with internally cast aluminum tubes are used in the manufacture of tubes with internal plating. The aluminum layer is strongly bonded to the base metal by pressing. Solders can be applied in the form of a thin plating layer; for example, aluminum sheets are plated with a thin layer of eutectic silumin (APS). Aluminum sheets and plates can also be plated with stainless steel, nickel, or copper.

Ye.D. Zakharov

PLATING OF MOLYBDENUM – see Molybdenum sheets.

**PLATINUM**, Pt – a chemical element in group VIII of the Mendeleyevian periodic system, with an atomic number of 78 and an atomic weight of 195.09. It has the stable isotopes $Pt^{190}$ (0.012%), $Pt^{192}$ (0.78%), $Pt^{194}$ (32.9%), $Pt^{195}$ (33.8%), $Pt^{196}$ (25.2%), and $Pt^{198}$ (7.19%). Its most important radioactive isotope, $Pt^{197}$, is obtained by irradiating Pt with neutrons. The Pt content of the earth's crust is $5 \cdot 10^{-7}$% by weight. Platinum is a metal and has a density of 21.45 g/cm$^3$ and a $t^{\circ}_{pl}$ of 1769°. It is used in the manufacture of chemical vessels and components of equipment exposed to strong chemical agents. Platinum electrodes are employed in various types of chemical production, including the isolation of radioactive isotopes. The most important characteristics of platinum are its high melting point, chemical stability, constant weight at high and low temperatures, and ability to accelerate chemical reactions. Platinum is used both in pure form and in alloys. See Precious metals.

O.Ye. Zvyagintsev

PLIABILITY – a property of a material (system) characterized by the ratio of elastic displacement to applied stress. An absolutely solid (undeformable) body would have zero pliability. This factor is the inverse of rigidity. Reserve elastic energy increases with pliability and a change in pliability consequently has a great influence on the kinetics of deformation and fracture. Pliability increases as modulus of elasticity decreases (rubber has a higher pliability than aluminum, aluminum has a higher pliability than steel, etc.); it varies with changes in the size or shape of the body (e.g., when the length of a bolt is increased its pliability also increases, etc.). An increase in pliability is useful in some cases (e.g., to cushion impact and shock and to "adapt" a structure to forced displacements, e.g., more pliable elements are more resistant to sharp temperature changes) and detrimental in others (e.g., because of an increase in the rate at which friction develops). Pliability is characterized by a coefficient, such as $l/EF$ for axial extension of a rod, where $l$ is the length of the rod, E is its modulus of normal elasticity, and F is its cross-sectional area. For torsion the pliability coefficient equals $l/GI_p$, while for bending it equals $l/EI$, where $l$ is the length of the rod, G is its shear modulus, $I_p$ is the polar moment of inertia of its cross-section, and I is the axial moment of inertia of its cross-section.

Ya.B. Fridman

**PLYWOOD** – is a wood material, a plane sheet obtained by bonding together three or more layers of cross-grained mainly shelled veneer. The external layers are called face-veneers, the internal ones – the core. The face-veneer is made from a high-quality wood. Particular layers of plywood may be made from metal, peat, and other materials. Plywood is manufactured from birch, alder, pine, cembra-pine, ash, and beech wood. In order to prevent buckling and cracking, the plywood is made from symmetrically arranged veneer layers of the same kind of wood and of the same thickness. The following types of plywood are distinguished: with regard to the method of manufacture, dry-hot, dry-cold, and wet-hot bonded plywood, and with regard to the thickness of the layers, equal-laminated and nonequal-laminated plywood. Depending on the utilization, the plywood is subdivided into commercial structural (or ordinary) plywood, special plywood, plywood treated with bakelite, plywood faced on the one or on both sides with planed precious-wood veneers, and decorative plywood. Considering the sheet dimensions, the plywood is subdivided into the following types: square plywood, longitudinal plywood, in which the dimension along the grains of the face is greater than the width of the sheet (e.g., 1525 × 1220 mm), and transversal plywood, in which the dimension across the grains of the face is greater than the length of the sheet (e.g., 1220 × 1525 mm). The most marketable sizes produced by the plants in the USSR are: 1525 × 1525 mm, and 1525 × 1220 mm. The plywood sheets may have a thickness within 1 to 12 mm; sheets thicker than 12 mm are termed plywood plates. The following plywood grades, differing in waterproofness, are manufactured: FSF,

with high waterproofness, bonded by means of phenol-formaldehyde type adhesives; FK and FBA with moderate waterproofness, bonded by means of carbamide or albumin-casein adhesives, and FB, with limited waterproofness, bonded by means of protein glues. The plywood grades are standardized according to the legal GOST and TU.

Mechanical Properties of Glued Birch Plywood (1-12 mm thick sheets)

| Показатели 1 | Фанера, склеенная белковыми клеями 2 | Фанера, склеенная фенолоформальдегидной или смоляными клеями 3 |
|---|---|---|
| Предел прочности (кг/см²): 4 | | |
| 5 при растяжении вдоль волокон рубашки | 700—810 | 810—750 |
| 6 при растяжении под углом 45° к волокнам рубашки | 150 | 300 |
| 7 при растяжении поперек волокон рубашки | 400—450 | 450 |
| Модуль упругости (кг/см²): | | |
| 8 при растяжении вдоль волокон рубашки | 110000 | 120000—130000 |
| при растяжении под углом 45° к волокнам рубашки | 17000 | 28000—30000 |
| при растяжении поперек волокон рубашки | 54000 | 65000—80000 |
| Предел прочности (кг/см²): | | |
| 9 при скалывании по клеевому слою в сухом состоянии | 15—27 | 18—27 |
| 10 при скалывании по клеевому слою после кипячения в воде в течение 1 часа | 8—7 | 14—16 |
| Объемный вес (г/см³) 11 | 0,7 | 0,6—0,77 |
| Число слоев шпона 12 | 3—11 | 3—11 |

1) Characteristics; 2) plywood glued by protein glues; 3) plywood bonded by bakelite film or resin adhesives; 4) limit strength (kg/cm$^2$); 5) on stretching along the face grains; 6) on stretching at an angle of 45° to the face grains; 7) on stretching across the face grains; 8) modulus of elasticity; 9) on cleaving along the bond line in dry state; 10) on cleaving along the bond line after boiling in water for 1 hour; 11) density; 12) number of veneer layers.

Nontrimmed and trimmed plywood is distinguished, the latter being trimmed and sorted after bonding. "Ground" or "polished by discs and pressed" plywood means the grade of finishing, and "even" or "formed" plywood means the shape of the plywood. The psysicomechanical properties of plywood are characterized by the moisture content, the moisture capacity, the density, the specific heat, the heat conductivity, the sound conductivity, etc. The moisture of plywood bonded by means of adhesives and bakelite film must not surpass 12%, and that of plywood

glued by protein glues using the dry-hot method must not surpass 15%. The moisture capacity of the plywood depends on the air humidity and the temperature and is somewhat lower than that of the wood. The density of the plywood depends on the sort of wood, the bonding conditions, the type of the adhesive, the thickness and number of the layers.

The specific heat of plywood is near that of compact wood. The coefficient of heat conductivity of plywood is somewhat lower than that of compact wood; it can be assumed equal to 0.095 kcal$\cdot m^2 \cdot hr \cdot °C$ for glued plywood.

Plywood is a good sound absorber and an effective material for facing walls in living-rooms. The following factors affect the mechanical properties of plywood: the sort of wood, the density, the humidity, the structure of the sheet, the type of adhesive, the method of bonding, and flaws; birch is reputed to be the best kind of wood in this regard; the characteristics of alder, fir and pine are somewhat poorer.

Faced plywood, with one or both faces made from planed precious-wood veneers, is manufactured for the furniture industry, for the dressing of rooms, and for other purposes. Decorative plywood coated with a film of synthetic resins is manufactured for the same purposes. Metallized, reinforced and fireproof plywoods are plywood varieties. Metallized plywood is manufactured by sprinkling its surface with diverse molten metals. Reinforced plywood is a plywood joined with metal sheets (iron, steel, and other materials). Fireproof plywood is impregnated with various chemical salts which cause its refractoriness. Veneers and plywood are readily flexible and retain any given shape. This property is utilized in the manufacture of barrel staves, plywood pipes, etc.

References: Lebedev, V.S., Fanernoye proizvodstvo [Plywood Manufacture], Moscow-Leningrad, 1956

V.S. Lebedev

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[Transliterated Symbols]

3011 ГОСТ = GOST = Gosudarstvennyy obshechesoyuznyy standart =
= State All-Union Standard

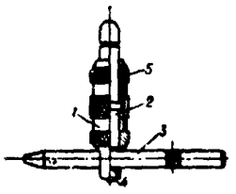
3011 ТУ = TU = tekhnicheskiye usloviya = technical specifications

POISSON'S RATIO — the absolute ratio of relative transverse deformation to relative longitudinal deformation, designated as $\mu$. Poisson's ratio is generally determined from the results of simultaneous measurement of longitudinal and transverse deformation during tensile testing of a long, broad plate or from the formula $\mu = E/2G - 1$, where E is the modulus of normal elasticity and G is the shear modulus.

Typical values of Poisson's ratio in the elastic region at room temperature are 0.28 for steel, 0.3 for aluminum alloys, 0.33 for magnesium alloys, and 0.35 for titanium alloys. The coefficient of transverse deformation in the plastic region is assumed to be 0.5.

N V. Kadobnova

POLDI APPARATUS – a portable device for evaluating the hardness of metals by the Brinell double-impression method. It consists of a tube containing a striker, a calibrating device (generally a steel bar of known hardness HB), a ball, and a spring to press the striker against the calibrating device. The calibrating device moves freely in slots in the tube. The apparatus is positioned perpendicular (by eye) to the surface of the specimen or component to be tested and the upper face of the striker is hit with a locksmith's hammer. This produces impressions of the ball on the surface of the component and the lower face of the calibrating device; measurement of the diameters of these impressions ($d$ and $d_e$ respectively) permits rough determination of the hardness HB of the component from the formula $HB = HB_e \frac{D-\sqrt{D^2-d^2}}{D-\sqrt{D^2-d_e^2}}$, where D is the ball diameter. In order to increase the accuracy with which HB is determined the test is repeated 2-4 times and the arithmetic mean of the values obtained for HB is computed. The Poldi apparatus yiel's sufficiently reliable results only if the calibrating device and the component are fabricated from materials with similar mechanical characteristics (principally hardness).




Poldi apparatus: 1) Tube; 2) striker; 3) calibrating device; 4) ball; 5) spring.

References: Shaposhnikov, N.A., Mekhanicheskiye ispytaniya metallov [Mechanical Testing of Metals], 2nd Edition, Moscow-Leningrad, 1954.

I.V. Kudryavtsev and D.M. Shur

POLISHING OF ALUMINUM ALLOYS – surface working of aluminum and aluminum-alloy parts designed to produce a very clean surface or to improve the decorative appearance of the parts (production of a mirror surface). Polishing is employed as a preliminary operation prior to anodizing (see Anodizing of aluminum alloys) or as a final finishing operation. Polishing has a favorable effect on many of the physical-chemical characteristics of aluminum and aluminum-alloy parts. Under laboratory conditions, it is employed in metallography in order to produce polished sections in the investigation of alloy structure, in the study of microhardness, optical properties, etc.

Three types of polishing are distinguished: mechanical, electrochemical, and chemical. Mechanical polishing reduces to removing microirregularities from the previously worked surfaces (grinding, turning) by means of an abrasive. This is done on polishing machines with elastic wheels of felt, felting, cloth, coarse calico, etc., to which fine abrasive powders (Nos. 120, 180, 240) are applied: emery, aluminum oxide, chromium oxide, or pastes based on these materials. Products of complex shape are polished with the aid of hand drills fitted with elastic wheels, or by hand. Optimum polishing-wheel speed is 2000-3000 rpm.

Electrochemical polishing is an electrochemical process taking place at an anodic surface and in direct proximity thereto, causing a gloss to appear and improving the microrelief of the surface. There is no one single theory satisfactorily accounting for all phenomena observed in the process of electrochemical polishing. One of the early

hypotheses, which has received very full experimental confirmation is the viscous-film hypothesis. According to this theory, the rough surface of the metal is covered in the course of anodic dissolution with a viscous film of solution products whose thickness varies at different portions of the surface. On projections, its thickness is correspondingly less than on depressions, owing to which the resistance to the passage of currents at these sections will also be different. According-

TABLE 1

Electrolytes Used for Electrochemical Polishing of Aluminum Alloys

| 1 Состав электролита | Анодная плотность тока (а дм²) 2 | Напряжение на клеммах ванны (в) 3 | Темп-ра электролита (°С) 4 | Время полирования (мин.) 5 |
|---|---|---|---|---|
| Фосфорная к-та 34%<br>Серная к-та 34%<br>Хромовый ангидрид 4%<br>Вода 28% 6 | 20—35 | 11<br>Не выше 30 | 80—90 | 1—10 |
| Фосфорная к-та 50%<br>Серная к-та 39%<br>Хромовый ангидрид 3%<br>Вода 8% 7 | 15—30 | 12<br>То же | 75—85 | 1—10 |
| Фосфорная к-та 600 мл<br>Серная к-та 400 мл<br>Глицерин 10 мл 8 | 10—15 | 5—15 | 60 | 15 |
| Натрий углекислый 150 г<br>Тринатрийфосфат 50 г<br>Вода 1000 мл 9 | 2.5—5.4 | 10 | 72—82 | 8—10 |
| Борфтористоводородная кислота 25 г<br>Вода 1000 мл 10 | 2.8 | 10—25 | 30 | 5—10 |

1) Electrolyte composition; 2) anodic current density (amp/dm$^2$); 3) voltage across bath terminals (b); 4) electrolyte temperature (°C); 5) polishing time (min); 6) phosphoric acid 34%, sulfuric acid 34%, chromium trioxide 4%, water 28%; 7) phorphoric acid 50%, sulfuric acid 39%, chromium trioxide 3%, water 8%; 8) phosphoric acid 600 ml, sulfuric acid 400 ml, glycerine 10 ml; 9) sodium carbonate 150 g, trisodium phosphate 50 g, water 1000 ml; 10) hydrofluoboric acid 25 g, water 1000 ml; 11) not above 30; 12) same.

ly, a higher current density is established on projections than on depressions, and the projections go into solution more vigorously. The ultimate result is smoothing out of the surface, i.e., formation of an even bright surface. Electrochemical polishing, as a rule, should follow mechanical polishing or machining alone. It gives a bright

TABLE 2

Electrolytes Employed in Chemical Polishing of Aluminum Alloys*

| 1 Состав электролита | 2 Темп-ра электролита (°С) | Время полирования (сек.) 3 |
|---|---|---|
| Натр едкий 360—450 г<br>Натр азотнокислый 360—450 г<br>Натр азотистокислый 170—210 г<br>Тринатрийфосфат 70—90 г<br>Вода 500 мл 4 | 100—140 | 5—20 |
| Фосфорная к-та (уд. в. 1,7) 78 мл<br>Азотная к-та (уд. в. 1,4) 11 мл<br>Серная к-та (уд. в. 1,84) 11 мл<br>Сернокислое железо 0,86 г 5 | 110—120 | 45—60 |
| Фосфорная к-та (уд. в. 1,7) 1000 мл<br>Аммоний азотнокислый 85—110 г 6 | 95—110 | 1,5—2,5 мин. 9 |
| Азотная к-та 13%<br>Кислый фтористокислый аммоний 16%<br>Вода 71% 7 | 55—65 | 15—30 |
| Фосфорная к-та (уд. в. 1,7) 85%<br>Уксусная к-та (концентрированная) 10%<br>Азотная к-та (уд. в. 1,4) 5%<br>Азотнокислая медь ~2 г 8 | 80—100 | 2—15 мин. 9 |

*The first three electrolytes are used in domestic industry.

1) Electrolyte composition; 2) electrolyte temperature (°C); 3) polishing time (sec); 4) sodium hydroxide 360-450 g, sodium nitrate 360-450 g, sodium nitrite 170-210 g, trisodium phosphate 70-90 g, water 500 ml; 5) phosphoric acid (specific gravity 1.7) 78 ml, nitric acid (specific gravity 1.4) 11 ml; sulfuric acid (specific gravity 1.84) 11 ml, iron sulfate 0.86 g; 6) phosphoric acid (specific gravity 1.7) 1000 ml, ammonium nitrate 85-110 g; 7) nitric acid 13%, ammonium oxyfluoride 16%, water 71%; 8) phosphoric acid (specific gravity 1.7) 85%, acetic acid (concentrated) 10%, nitric acid (specific gravity 1.4) 5%, cupric nitrate ~2 g.

gloss to the surfaces of aluminum and low-alloy steel parts which is better retained in a subsequent anodizing process than the gloss imparted by mechanical polishing. There are many electrolytes used for electrochemical polishing of aluminum and aluminum alloys, but only

some of them have found commercial application. Table 1 gives the most common electrolytes.

Chemical polishing is a process that replaces electrochemical polishing, but which requires no external supply of current. At present there is no generally recognized theory for chemical polishing. Some investigators explain the effect of surface equalization during chemical polishing by the viscous-film theory (see above), while others assume that in chemical polishing an important role is played by passivating oxide films. Chemical polishing is simpler and more economical than electrochemical polishing, but a bright glossy surface can only be obtained on pure aluminum or aluminum alloys with a low magnesium content (up to 2-3%). Numerous electrolytes exist for chemical polishing of aluminum and aluminum alloys, but only a few of them have found commercial application. Table 2 gives the electrolytes employed in industry.

References: Tegart, V., Elektroliticheskoye i khimicheskoye polirovaniye metallov [Electrolytic and Chemical Polishing of Metals], Translated from English, Moscow, 1957; Popilov, L.Ya., Tekhnologiya elektropolirovaniya metallov [Technology of Electropolishing of Metals], Moscow-Leningrad, 1953; Vernik, S., Pinner, R., Khimicheskaya i elektroliticheskaya obrabotka alyuminiya i yego splavov [Chemical and Electrolytic Treatment of Aluminum and Aluminum Alloys], Translated from English, Moscow, 1960; Shreyder, A.V., Oksidirovaniye alyuminiya i yego splavov [Oxidation of Aluminum and Its Alloys], Moscow, 1960.

N.A. Makarov

**POLYACRYLATES** – polymers of acrylic acid and its derivatives – esters, nitriles, amides, as well as products of copolymerization of acrylic derivatives with one another or with other unsaturated hydrocarbons. Polyacrylates are colorless, highly transparent, and light-resistant. They are similar to quartz in ultraviolet transmission. They have specific gravities of 1.12-1.25. Polyacrylates are stable with respect to dilute alkalies and acids; they are prepared as molding powders or in blocks and sheets. The powders are processed into finished parts by molding and injection molding. Polyacrylate sheets may be stamped, blow-formed, or vacuum-drawn. Of greatest practical importance are polymers of esters of acrylic acid and particularly methacrylic acid (methyl methacrylate, etc.) as well as polymers and copolymers of acrylonitrile. Polyacrylates are used in the production of films, lacquers, and cements. Polymethyl methacrylate is used for unbreakable transparent plastic (see Transparent Plastic). Polyacrylonitrile is widely employed in the production of strong thermally resistant fibers (see Modified Polyacrylonitrile Fiber), as well as a copolymer in the production of butadiene nitrile rubber.

References: Losev, I.P., Petrov, G.S., Khimiya iskusstvennykh smol [Chemistry of Artificial Resins], Moscow-Leningrad, 1951; Losev, I.P., Trostyanskaya Ye.B., Khimiya sinteticheskikh polimerov [Chemistry of Synthetic Polymers], 2nd edition, Moscow, 1964.

Ye.S. Osikina

POLYACRYLIC ADHESIVE – is a compound based on the polymers of acrylic and methacrylic esters. Polyacrylic adhesives are supplied with and without solvent. A low heat resistance is the main disadvantage of the polyacrylic adhesives, a fact that limits the field of their application (these adhesives are used mainly for the bonding of nonmetallic materials). The PK-5 adhesive is a composition of the linear acrylate polymer (PMA) with a multifunctional product of the methacrylic series (MGF-9); it resists heat up to 60°, and contains a solvent (acetone); it is prepared by mixing a solution of PMA with the MGF-9 product, a filler (cement), and an accelerator (benzoyl peroxide); the working life of the adhesive is at least 48 hours. PK-5 is applied by brushing; the pieces are kept in the open air for 20-40 minutes at 20°, then they are joined and held under pressure for 6 hrs (Table 1).

TABLE 1

Strength of Metals Bonded by PK-5 Adhesive as a Function of the Temperature

| 1 Показатели клеевого соединения | 2 Температура (°С) | | |
|---|---|---|---|
| | −60 | 20 | 60 |
| 3 Предел прочности при сдвиге (кг/см²): | | | |
| 4 дуралюмина | 65 | 165 | 70 |
| 5 стали 1Х18Н9Т (НІТ) | 65 | 150 | 70 |
| 6 Предел прочности при отрыве дуралюмина (кг/см²) | 80 | 150 | 80 |

1) Characteristics of the adhesive joint; 2) temperature (°C); 3) shearing strength (kg/cm²); 4) for Duralumin; 5) for IKh18N9T (YaIT) steel; 6) ultimate peel strength for Duralumin (kg/cm²).

The strength of the adhesive joint is not affected by long periods

at high temperatures (80°) or by alternating temperatures (±60°). PK-5 resists kerosene, oils and gasoline, it does not corrode ferrous and nonferrous metals, and it is stable against fungi. On the basis of the relatively small shrinkage of the PK-5 it was possible to develop the V-77 paste which is used to seal unevennesses on metallic surfaces. VK-32-70 is a composition of the methacrylic derivative TMGF-11, the sicative 7640, and an inhibitor of the polymerization. It is used to bond pieces of organic glass and also to join organic glass with certain thermoplastic materials. It does not cause the appearance of microcracks ("silver-like luster") on the surface of organic glasses.

There exist two modifications of the VK-32-70 adhesive which differ in their curing rates and the strengths of their adhesive joints. VK-32-70a cures 2-2.5 times slower than VK-32-70b, but the strength of its joints is considerably higher. It is used to bond shaped objects made from organic-glass sheets for stressed structures; the VK-32-70b is used when no load is acting on the objects. The joined pieces of organic glass cannot be subsequently formed and are unsuitable for optical purposes. The adhesive consumption is 100-150 $g/m^2$. The adhesive is not toxic. A change in the thickness of the adhesive layer from 0.01 to 9.75 mm does not affect the strength of the joint. The holding time under the press is 4 hours for bonding at 65°, 3 days (until the test) for VK-32-70a at normal temperature, and 1.5 days for VK-32-70b (Tables 2 and 3). Elevated (80°) and alternating (+60°) temperatures and also water (30 days) and atmospheric phenomena do not affect the strength of the adhesive joints.

TABLE 2

Strength of Organic Glass Bonded by VK-32-70a Adhesive

| Темп-ра склеивания (°C) 1 | Предел прочности на сдвиг (кг/см²) при темп-ре испытания: 2 | | | Предел прочности на отрыв (кг/см²) при темп-ре испытания: 3 | | |
|---|---|---|---|---|---|---|
| | 20° | 60° | −60° | 20° | 60° | −60° |
| 65 | 250 | 212 | 405 | 237 | 190 | 360 |
| 20 | 86 | 112 | 90 | 87 | 97 | 91 |

1) Bonding temperature (°C); 2) shearing strength (kg/cm$^2$) at a test temperature of; 3) peel strength (kg/cm$^2$) at a test temperature of.

TABLE 3

Strength of Organic Glass Bonded at 20° with a Polybutylmethacrylate Film by Means of the VK-32-70B Adhesive

| 1 Вид испытания | Предел прочности (кг/см²) при темп-ре 2 испытания (°C): | | |
|---|---|---|---|
| | 20° | 60° | −60° |
| 3 Контрольные образцы | 6.5 | 4 Разрушение пленки | 9 |
| 5 Термич. обработка в течение 500 час. при 80° | 31 | 9 | 40 |
| 6 Действие переменных темп-р (±60°) в течение 30 циклов | 50 | 20 | 52 |
| 7 Действие воды 30 суток | 29 | 10 | 20 |
| 8 Воздействие атм. условий в течение 2 лет | 50 | 8 | 61 |

1) Type of the test; 2) ultimate strength (kg/cm$^2$) at a test temperature of; 3) control specimens; 4) the film becomes destroyed; 5) heat treatment at 80° for 500 hrs; 6) effect of 30 cycles of alternating temperatures (±60°); 7) effect of water after 30 days; 8) effect of atmosphere during 2 years.

D.A. Kardashev

POLYACRYLONITRILE FIBER – synthetic carbon-chain fiber from a linear polymer of the nitrile of acrylic acid (with a molecular weight from 40,000 to 100,000 and degree of polymerization from 800 to 2000). It is produced in the form of staple fiber and rayon (general $N_m$ 120, 90 and 75, elementary $N_m$ 2500-3600) under the name nitron (USSR) and Orlon-81 (USA). Polyacrylonitrile fibers are formed by the wet method from a solution of polyacrylnitrile in dimethylformamide, ethylcarbonate or thiocyanates. Polyacrylonitrile fibers are distinguished by high strength, resistance to light and heat, resistance to oxidizers, oils, organic solvents and various acids. The polyacrylonitrile fiber Orlon-81 is more resistant to nuclear radiation than the majority of other fibers. After 42 hours of irradiation by gamma-rays Orlon-81 does not decrease in strength; cotton, viscose rayon and nylon under these conditions lose approximately half of their strength. Orlon-81 held for 26 hours in a nuclear reactor with a neutron emission rate of $2.3 \cdot 10^7$ particles per $cm^2$ loses about 25% of its strength. Under these conditions nylon loses more than half of its strength and viscose rayon loses all its strength. Polyacrylonitrile fibers have a low thermal conductivity whic approaches that of wool. Shortcomings of polyacrylonitrile fibers are: poor dyeability, low wear resistance, combustibility, insufficient resistance to concentrated solutions of alkalies and certain acids, ease of electrification and low felting ability. Specific weights 1.15-1.17, moisture content under standard conditions 0.8-1.2%. Softening temperature 235-250°. The fiber is frost resistant to -30°—40°; at -40° the strength increases up to 135%, at a lower tem-

perature polyacrylonitrile fibers become brittle. At 120-130° the fiber does not lose strength for several weeks. As a result of heating for 60 hours at 200° the Orlon fiber loses 50% of strength and 30% of its weight with the attendant formation of black, heat-resistant Orlon fiber which withstands temperatures up to 1000°. Polyacrylonitrile fiber is resistant to atmospheric conditions (when held for 1-1.5 years it loses only 20-23% of its strength, other fibers lose 90-95%), to the effects of smoke and gas, bacteria, moths and decay. The dielectric constant of polyacrylonitrilic fibers at 60 cps is 6.5. An electrostatic field with a potential difference of several thousand volts is formed when the fibers are processed on textile machines, for which reason polyacrylonitrilic fibers are processed by antistatic compounds. Polyacrylonitrilic fibers are stable in glacial acetic acid, chloroform, 88% formic acid. Orlon-81, for example, is resistant at room temperature (strength losses up to 10%) when treated by aqua regia for 20 days at 20°, it is stable when treated by 25% $H_2SO_4$ for 7 days at 75°; when treated by 40% $HNO_3$ for 30 weeks at 20°, when treated by 5% NaOH for 15 weeks at 20°, when treated by 3% NaCl for 7 weeks at 20°; is little resistant (strength losses from 30 to 75%) in 37% HCl when held for 5 weeks, when held in 40% $HNO_3$ for one day at 75°, when held in a boil-3% solution of $KMnO_4$ for 15 minutes; it breaks down in a 5% solution of NaOH at 79° within a week, and in a 20% solution of NaOH at 100° within 8 hours.

The rupture length of polyacrylonitrile fibers in the dry state is 45-55 km, the strength loss in the wet state is 2-6%, in a loop 34-36%, in a node 29-31%; the elongation of dry fiber is 14-17%, of wet fiber 14-16%; the ultimate tensile strength 52-62 $kg/mm_2$; the initial modulus (at 1% elongation) is 8-8.3 $kg/mm^2$; elasticity (elastic restoration when elongated by 4%) is 78-85%. The wear resistance of polyacryloni-

trile fibers is low (by a factor of 6-7 lower than the resistance of viscose rayon); the longevity (number of double flexures to failure) 6740-14,725. Polyacrylonitirile fibers are used for making of anode bags, battery separators for electrolysis, bags for capture of dust and gases, filtering fabrics, protective covers (the fiber is a good absorber of resins), fishing nets and tackles, awnings, tarpaulins, sails, tents, curtains, etc.

References: Rogovin, Z.A., Osnovy khimii i tekhnologii proizvodstva khimicheskikh volokon [Fundamentals of the Chemistry and Technology of Chemical Fibers Production]. Pages 673-93, 2nd edition, Moscow, 1957; Pakshver, A.B., and Geller B.E., Khimiya i tekhnologiya proizvodstva volokna nitron [The Chemistry and Technology of Nitron Fiber Production]. Moscow, 1960; Monkriff, R.W., Khimicheskiye volokna [Chemical Fibers], translated from English, Moscow, 1961; Sherman, J.V., "Textile World," Vol. 97, No. 3, page 101 and 215, 1947.

V.M. Bukhman

POLYAMIDE ADHESIVE – is a solution of polyamide resins in ethyl alcohol. The usual polyamides are very rarely used as adhesives. The introduction of polar groups (treatment with formaldehyde) causes the formation of methylol polyamides which have high adhesive properties.

The adhesive based on the methylol polyamide resin PFE2/10 is a 25-30% solution of the resin in an alcohol-water mixture and has a viscosity of 20-60 centipoise; it is adhesive to silicate glass and organic glass, to metals, ceramics, leather, concrete, paper, plastics and other materials. It cures in the presence of catalysts at both room and elevated temperatures. The adhesive joints resist oils, fats, gasoline, kerosene, diluted and concentrated alkalis and other chemical reagents. The adhesive is used in the leather and footgear industry, in the polygraphic, foodstuff and machine-building industries and in other industrial branches.

The MPF-1 adhesive is a methylol polyamide resin modified by a phenol formaldehyde condensation product of the resol type; it has strong adhesive properties and is suitable for the binding of metallic structures working under stress, and also for the joining of metals with glass-textolites and other materials in objects working in the temperature range of ±60°. It is prepared by mixing methylol polyamide with phenol formaldehyde resin. The liquid adhesive is applied to the surfaces to be joined, dried, and then a film prepared from the liquid adhesive is laid on, and the object is then assembled and pressed at 1.0-5.0 $kg/cm^2$ pressure and a temperature of 155±5° for 1 hour. The MPF-1 compound has a high strength in the case of nonuniform peeling

off, it is shakeproof and has a high endurance. The strength of the adhesive joints is somewhat weakened by the action of transformer oil and alcohol.

Water and water vapor reduce the strength of the adhesive joints; it is recommended, therefore, that the butts of the bonded parts working in a moist or tropic climate be protected by coatings of varnish and paint.

D.A. Kardashev

POLYAMIDE CORD FILAMENT is a synthetic material made from polyamide resins. It is produced under the names: kapron, anid, enant (USSR), caprolan, nylon 66 (USA), amilan, nylon 6 (Japan), and others. The polyamide cord filament surpasses most of the known natural and chemical fibers in strength. With temperature increase the strength and elastic modulus of the polyamide cord filaments, particularly the kaprons, decrease; at temperatures above 100° there is also a sharp drop in the resistance to thermal aging. For the physical, chemical, and mechanical properties of the polyamide cord filaments see Polyamide Fiber, Anid, Nylon 6, Nylon 66, Enant. Additives – antioxidants – are used with the polyamide cord filaments to improve the thermal and sunlight resistance (see Kapron). After one hour at a temperature of 190° the polyamide cord filaments without additives lose 60% of their strength, with the additives they lose 5-10%.

Polyamide cord filament is used primarily in producing tire cord (cord filament) which surpasses viscose cord in impact strength (impact resistance increases 10 times), resistance to repeated deformation, strength at high operational speeds, service life in tires, and lower moisture content. Deficiencies of tires with polyamide cord filament in comparison with viscose cord are: increased wear rate of the tires (by a factor of 2-3 times), formation of flat spots when vehicles are parked, and increase of elongation during operation. To reduce the elongation the polyamide cord filaments are subjected to additional hot stretching and fixation at 150-200°. To improve the adhesion of the polyamide cord filament with the rubber, the cord is first coated with

a solution containing the product of polycondensation of resorcine and formaldehyde. The polyamide cord filament is produced with a circular section, however it has been established that a triangular cross section of the polyamide cord filament improves the bonding with the rubber, while with a hollow section there is an increase of its area (without change of weight) which may be of assistance in reducing heat formation in tires.

References: Floyd, D.E., Polyamides, translated from English, Moscow, 1960; Konkin, A.A., Rogovina, A.A., and Birger, G.Ye., "KhV" [Chemical Fibers], 1961, No. 1; Suleymanova, Z.I., ibid., 1960, No. 3; Nemchenko, E.A., ibid., No. 4; Dyomina, N.V., et al., ibid., No. 5.

E.M. Ayzenshteyn

**POLYAMIDE FIBER** – chemical fiber from synthetic hetero-chain polymers (polyamides) whose macromolecules have alternating amide NHCO and methylene $CH_2$ groups. Valuable service properties of polyamide fibers are: high strength (40-50 km for a tensile elongation of 20-25% for the filament fiber, 70-75 km for a tensile elongation of 12-15% for the cord fiber); low loss of strength in the wet state (not more than 10% of the dry strength), in tests in the knot and in the loop; high elasticity, complete reversibility of deformations (when elongated by 6-8% from the original length the reversible deformation comprises 30-40% of the tensile elongation); high wear resistance, by approximately a factor of 10 higher than that of cotton and by a factor of 20 higher than of viscose fiber; moderate specific weight (1.00-1.14), high resistance to biologic effects (moths, carpet bettle, mildew and decay micro-organisms); high resistance to alkalis and to the majority of ordinary solvents (aceton, benzol, alcohols, esters, chloridated hydrocarbons). Shortcomings of polyamide fibers: comparatively low initial modulus (by a factor of 2-5 smaller than that of dacron-type polyester fiber); low resistance to the action of concentrated mineral and certain organic (formic, glacial acetic) acids and oxidizers, low heat resistance; thermoplasticity (ability to "flow" at elevated temperatures under a moderate load); low resistance to the action of atmospheric factors and to aging by heat; inflammability (when a fabric from polyamide fibers burst into flames, it "sheds" hot pieces of molten polymer, whereupon the burning ceases); not too high electric insulation properties which are due to the high moisture absorption of polyamide fibers (3.5-4.5% of the weight

of the fiber at 65% relative air humidity); poor binding of staple polyamide fibers (as a result of smooth surface and round cross section) with the attendant separation of staple polyamide fibers from mixed fabrics onto their surface; low stability of loops in knit products from monofiber. Certain shortcomings of polyamide fibers can be partially remedied. Introduction into the polyamide of moderate amounts (0.02-0.5% of the weight of the fiber) of manganese and chrome salts before formation of the polyamide fibers increases the fiber's resistance to atmospheric factors; additions of haloid compounds of potassium, sodium, phosphates, naphthol and salicylic acid improve the resistance of polyamide fibers to aging by heat. The heat resistance can be improved perceptibly by increasing the degree to which the polyamide fibers are drawn in the process of their production.

Physical Properties of Various Polyamide Fibers

| 1 Свойства | 2 Тип волокна | | | | |
|---|---|---|---|---|---|
| | капрон (перлон, дедерон, найлон 6) 3 | энант (найлон 7) 4 | рильсан (ундекан, найлон 11) 5 | 6 анид (найлон 66) | 7 найлон 610 |
| 8 Темп-ра плавления (°С) | 215 | 225 | 185 | 255 | 209 |
| 9 Темп-ра размягчения (°С) | 196 | 205 | 176 | 235 | — |
| 10 Теплоемкость (кал/г·град) | 0.353 | 0.452 | 0.510 | 0.353 | — |
| 11 Уд. вес | 1.14 | 1.10 | 1.0—1.05 | 1.16 | — |

1) Properties; 2) type of fiber; 3) capron (Perlon, dederon, nylon-6); 4) enant (nylon-7); 5) Rilsan (undekan, nylon-11); 6) Anid (nylon 66); 7) nylon 610; 8) melting temperature (°C); 9) softening temperature (°C); 10) specific heat (cal/g·degree); 11) specific weight.

Polyamide fibers are used for obtaining engineering products [aviation and automobile cord, cables, filter, parachute and sieve (from monofiber) fabrics, fire-fighting hoses, seine and gill nets, special kinds of paper, easily meltable binder for the production of nonwoven materials].

Polyamide fibers (filament threads, staple fibers, monofiber No. 300, 600 and 900) are widely used for the production of consumer goods. The introduction of 10-15% of staple polyamide fiber into wool fabrics substantially increases their wear resistance and service life.

References: Klare, G., Khimiya i tekhnologiya polyamidnykh volokon [The Chemistry and Technology of Polyamide Fibers], translated from German, Moscow, 1956; Hoppf, A.B., Müller, A and Wenger, F., Poliamidy [Polyamides], translated from German, Moscow, 1958.

Yu. Vs. Vasil'yev

**POLYAMIDE MONOFIBER** is polyamide filament of various diameter. It is produced in the USSR (kapron), USA (nylon 66), France (rilsan), GDR and FRG (perlon) and in other countries in the form of a monofiber (Nm 300-1300) and filaments of comparatively large diameter (usually 0.1-2.0 mm). Polyamide monofiber is the most elastic and strongest of all the known monofilament threads; it surpasses natural bristle by a factor of 20 in wear resistance. Physical and chemical properties are: specific weight 1.14 (1.14; 1.04) (here and hereafter the figures in parentheses give indices respectively for nylon 66 and rilsan); moisture content at standard conditions 3.5-4.0% (4.0-4.5; 1.0-1.5); at 95% relative humidity 7.0-8.0 (8.0;-); softening temperature 170° (235; 175); $t_{pl}$ 215° (250; 189); cold resistance -70°; coefficient of linear thermal expansion (per 1°) 11-14.$10^{-5}$ (4.0·$10^{-5}$; 9.9·$10^{-5}$); heat content 0.4-0.5 cal/gram 0.4, 0.5); thermal conductivity 5.4-8.7·$10^{-4}$ cal/cm-sec-deg (6.6·$10^{-4}$; 5.7·$10^{-4}$). Resistance to sunlight is comparatively low, but may be improved by introducing suitable stabilizers into the fiber (see Kapron). For details on other properties see Polyamide Fiber. Breaking strength of polyamide nomofiber depends on its thickness and degree of elongation at high temperatures and increases linearly with increase of diameter. For example, the breaking load of perlon filament 0.3 mm in diameter is 4 kg, with 1.0-mm diameter it is 40-45 kg, with 1.7-mm diameter it is 110-130 kg. The breaking length of monofiber is 40-45 km with an elongation of 25-35%. Depending on diameter, the ultimate tensile strength of polyamide monofiber varies from 30 to 50 kg/mm$^2$; with a diameter of 0.5 mm it is 27-40 kg/mm$^2$.

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Polyamide fiber is widely used for technical purposes and for consumer products. Polyamide fibers of various thickness are used to fabricate flexible hose, strings for tennis racquets, woven bags, edging fabrics, fishing gear, surgical silk; polyamide "wire" is used as a replacement for metallic sieves and also for fabricating belt transporters; polyamide bristle is irreplaceable in the production of various brushes, since it is resistant to the action of many chemical reagents: alcohols (except methyl and ethyl), chlorine-containing solvents (carbon tetrachloride, chloroform, trichlorethylene), petroleum products (gasoline, ligroin, kerosene), aromatic hydrocarbons (benzene, toluol), esters (methylacetate, butylacetate), and many detergents.

References: Hopff G., Mueller A., and Wenger F., Polyamides, translated from German, M., 1958; Floyd D.E., Polyamides, translated from English, M., 1960; Rogovin Z.A., Osnoy khimmi i tekhnologii proizvodstva khimicheskikh volokon (Fundamentals of Chemistry and Technology of Production of Chemical Fibers), 2nd edition, M., 1957.

E.M. Ayzenshteyn

POLYAMIDES – plastics based on synthetic high molecular weight compounds containing amido groups as the basis for the chain. They are classified as carbamide, polycarbamide, and linear ("homogeneous" and "mixed"). The polyamides are obtained as follows: the carbamides by polycondensation of amides of multibasic acids with aldehydes (see Amino Plastics); the polycarbamides by multistage polymerization of diisocyanates with diamines; "homogeneous" types chiefly by polycondensation of higher amino acids or diamines with dicarboxylic acids, "mixed" types by combined condensation of caprolactam and salts of diaminodicarboxylic acids. The polyamides also include the polyurethanes obtained by multistage polymerization of diisocyanates and glycols.

TABLE 1

Physical and Mechanical Properties of Polyamides

| Показатели [1] | Капр | П-68 [3] | Анид [4] | АК-7 | П-54 | П-54б |
|---|---|---|---|---|---|---|
| Удельный вес [5] | 1,13–1,15 | 1,11 | 1,14 – 1,13 | 1,14 | 1,10–1,12 | 1,12 |
| [6] Коэфф. теплопроводности $\cdot 10^4$ (ккал/сек·см·°С) | 6,0 | 7,5 | 6–7 | 6–8 | 7–5 | 7–5 |
| [7] Удельная теплоемкость (кал/г·°С) | 0,55 | 0,3–0,5 | 0,5–0,55 | — | — | — |
| [8] Коэфф линейного термического расширения на $1° \cdot 10^5$ | 6–15 | 10–12 | 7–13 | 10–11 | 13–13,5 | 13–13,5 |
| Теплостойкость (°С): [9] по Мартенсу | 50–55 | 60 | 65 | — | — | — |
| [10] по Вика [11] | 160–180 | 205–210 | 220–230 | 205 | 115 | 85–87 |
| [12] Морозостойкость (°С) | –20 | –20 | — | — | –40 | –45 |
| [13] Воспламеняемость | [25] Самопроизвольное затухание | | | | | |
| [14] Водопоглощение (%) за 24 часа [15] | 1,5–5,0 | 0,5 | 0,5–0,7 | 1,5 | — | — |
| [16] предельное | 12 | 3,5 | — | 8 | 9,5 | 8–10 |
| Предел прочности [17] (кг/см²): | | | | | | |
| [18] при растяжении | 500–840 | 400–600 | 500–750 | 500–650 | 500–600 | 300–450 |
| [20] при изгибе [19] | 800–1050 | 900 | 900–1000 | 1000–1200 | 280–300 | 180–190 |
| при сжатии | 700–800 | 750–900 | 700–1000 | 750–950 | — | — |
| [21] Удлинение при разрыве (%) | 150–200 | [26] более 100 | 50–100 | 60–100 | 300–350 | 400–425 |
| Модуль упругости [22] ($кг/см^2 \cdot 10^{-3}$) | 15 | 12–20 | 15–20 | 15 | 3 | 3 |
| [23] Уд. ударная вязкость (кг·см/см²) | 150–170 | 100–120 | 150 | 130–160 | 200–250 | 150–180 |
| Твердость по Бринеллю [24] (кг/см²) | 10–12 | 14–15 | — | 15–18 | 4–5 | 3–4 |

1) Characteristic; 2) Kapron; 3) P-xx; 4) Anid; 5) specific gravity; 6) thermal conductivity coefficient $\cdot 10^4$ (kcal/sec·cm·°C); 7) specific heat (cal/g·°C); 8) coefficient of linear thermal expansion, $1° \cdot 10^5$;

9) heat resistance (°C): 10) Martens; 11) VIKA; 12) frost resistance (°C); 13) combustibility; 14) water absorption (%); 15) in 24 hr; 16) maximum; 17) ultimate strength ($kg/cm^2$); 18) in tension; 19) in bending; 20) in compression; 21) elongation at rupture (%); 22) modulus of elasticity ($kg/cm^2 \cdot 10^{-3}$); 23) specific impact toughness ($kg \cdot cm \cdot cm^2$); 24) Brinell hardness ($kg/cm^2$); 25) selfextinguishing; 26) more than.

Of the large number of linear polyamides, the following have found practical application: Kapron-polycaprolactam (produced in the Federal Republic of Germany under the trademark Ultramid B, in the United States as Nylon 6, in Czechoslovakia as Silon, in the German Democratic Republic as Perlon and Dederon); P-68 resin, a polymer of hexamethylene diamine and sebacic acid (produced in the United States as Nylon 610); Anid, a polymer of hexamethylene diamine and adipic acid (produced in the United States as Nylon 66, in the Federal Republic of Germany as 86 Ultramid A); AK-7 and P-54 resins, mixed polyamides made from salt AG and caprolactam, and P-548 resin, a mixed polyamide made from salt AG, salts AG, SG and caprolactam. A method has been developed for anion polymerization of caprolactam directly in the molds in the presence of alkali catalysts and acetyl caprolactam. The resulting material has high molecular weight and good physical-mechanical properties. Products of any size and weight may be manufactured by this method.

Polyamides are solid crystalline horny substances with specific gravities of 1.1-1.2 and melting points of from 180° to 250°. Polyamide color depends on the composition and purity of the initial products and varies from colorless to yellow-brown. Polyamides are odorless. Polyamides are produced as small granules. They have fairly good physical-mechanical properties (Table 1), ensuring their use as structural materials in machine building.

To a considerable degree, the properties of polyamides, and particularly the mechanical properties, are determined by the relationship

by the relationship of the amorphous and crystalline phases: the greater the crystallinity of the polymer, the harder and stiffer it will be. The polyamides are not electrical insulators, owing to their polar construction, but they are used as dielectrics in inert media. Their dielectric properties depend on moisture. Table 2 shows the dielectric properties of dry polyamides.

TABLE 2

Dielectric Properties of Polyamides

| 1 Показатели | 1 Капрон | 3 П-68 | 4 Анид | АК-7 | 3 П-54 | 3 П-548 |
|---|---|---|---|---|---|---|
| 5 Уд. поверхностное электросопротивление (ом) | $10^{13}$ | $12 \cdot 10^{13}$ | — | $7 \cdot 10^{13}$ | $12 \cdot 10^{13}$ | $12 \cdot 10^{13}$ |
| 6 Уд. объемное электросопротивление (ом·см) . . . . | $10^{13}$—$2 \cdot 10^{14}$ | $10^{13}$—$2 \cdot 10^{14}$ | $10^{13}$—$10^{14}$ | $2 \cdot 10^{14}$ | $10^{13}$—$5 \cdot 10^{14}$ | $10^{13}$—$4{,}5 \cdot 10^{14}$ |
| 7 Тангенс угла диэлектрич. потерь: | | | | | | |
| 8 при 50 гц | 0,018 | — | — | — | — | — |
| 9 при $10^6$ гц | 0,06—0,08 | 0,035 | 0,02—0,05 | 0,033—0,08 | 0,025—0,03 | 0,025—0,03 |
| 10 Диэлектрич. проницаемость при $10^6$ гц . . . . | 4—5 | 0,8—4,6 | 3,4—3,6 | 4,6 | 3,8—4,6 | 3,8—4,6 |
| 11 Дугостойкость (сек) . . . . | 130—140 | 130—140 | — | 130—140 | 130—140 | — |
| 12 Электрич. прочность (кв/мм) | 15—18 | 15 | 15 | 21 | 15 | 15 |

1) Characteristics; 2) Kapron; 3) P-68; 4) Anid; 5) specific surface electrical resistance (ohms); 6) electrical bulk resistivity (ohm·cm); 7) dielectric loss tangent; 8) at 50 cps; 9) at $10^6$ cps; 10) dielectric constant at $10^6$ cps; 11) arc resistance (sec); 12) electrical strength (kv/mm).

Polyamides have good wear resistance and a low coefficient of friction, which explains their wide application in friction elements. To improve the antifriction properties of polyamides, fillers (graphite and molybdenum disulfide) are introduced during synthesis, in the melt, or during mixing of solid components; they increase the supporting power of bearings and impart selflubricating properties to the material. Polyamides are stable in tropical conditions and, in particular, resist termites, which attack many types of plastic. They lose mechanical strength and become brittle when exposed to direct sunlight; this is particularly true of thin products of the film type. The light resis-

tance of polyamides can be increased by introducing compounds with copper (particularly copper naphthenate) or manganese salts; for polycaprolactam films, the most frequently used compounds are β-naphthol and dibenzyl phenol, etc., in amounts of 0.5%. Polyamides are hydrophilic, and varying influence of moist and dry media will lead to a reduction in mechanical properties and crack formation. The least water resistance is polycaprolactam, which absorbs up to 12% water, while the most water resistant are rilsan-polyamides (polycondensate of ω-amino undecanoic acid). In air of normal humidity (of the order of 65%) polyamide products contain, depending on their form, 0.5-3% water. The rate of water absorption for polyamides depends on the product wall thickness and the temperature of the water. Boiling in water makes polyamide products elastic and soft, but after drying they become harder and stiffer than before boiling. This is explained by washing out of low-molecular products that act as plasticizers. In order to stabilize their properties and dimensions, polyamide products are heated in an inert fluid (oil, glycerine, etc.). Polyamides are stable under the action of 1-2% organic and mineral acids, alkalies, and other chemical substances not possessing the properties of strong acids or oxidizing properties. Polyamides are attacked by acids in higher concentrations. "Homogeneous" polyamides are stable under the action of most solvents except for substances containing strong polar groups. Polyamides dissolve well in phenol, cresol, and concentrated acids (sulfuric, muriatic, and other acids). "Mixed" polyamides dissolve in an alcohol-water mixture. Polyamides are nearly impenetrable for solvent vapors, against which they are resistant, but are penetrable by water and alcohol vapors.

Polyamides are employed in the form of fibers, films, shapes, cast parts, cements, and coatings. Polyamides can take on various colors. The dye is introduced either in bulk (in the melt) or in the fin-

ished products. Finished products are dyed in water dye baths. For bulk dying, it is necessary to employ heat-resistant dyes that will withstand the polyamide melting temperature (as a rule, inorganic pigments are used).

Three types of polyamide films are produced: No. 548, PKRT-3, and PK-4 (in three grades, A, B, and C). Type PKRT-3 and No. 548 films are employed as oil, gasoline, and benzene-resistant sealing materials. Type PK-4 is used for gas-typed packing and sealing material, as well as to cover greenhouses (it transmits ultraviolet light). The films have a specific gravity of 1.1, and a tensile strength ($kg/cm^2$) as follows: No. 548, 300, PKRT-3-200, PK-4-300-800 along the width and 150-250 along the length.

Shaped parts made from polyamides (bars, tapes, hoses, etc.) are made by extrusion or casting from the melt, while products of intricate shape are made chiefly by injection molding.

Type MPF-1 cement is based on a polyamide (this solution of methyl polyamide resin and bakelite varnish in ethyl alcohol), as is Kapron cement (solution of polycaprolactam in a mixture of phenol and ethyl alcohol), as well as type PFE-2/10 cement (a solution of methyl polyamide resin in an alcohol-water mixture). Polyamide cements are used to bond polyamides, steel, aluminum, copper, leather, glass, and other materials. The bond strength reaches 150-220 $kg/cm^2$.

As anticorrosion materials used to protect metal and concrete, polyamides are applied by gas-flame deposition or a vortex method, depending on the size of the surface to be covered. The valuable combination of physical-mechanical properties and good chemical stability with respect to a large number of aggressive media ensure the wide use of polyamides.

In addition to the areas listed, polyamides are used in the manu-

facture of small structural machine elements (cylindrical and conical gears, bolts, selflocking nuts, hammer heads, belt-driven pulleys, the belts themselves, shuttles and thread guides of looms, runners of ring-twisting machines, tubing for oil and gas lines, etc.). Polyamides have become quite important as a packing material for hydraulic systems. They are used to manufacture gaskets and collars that last longer than leather or rubber products. Polyamides are used for impellers of centrifugal pumps, turbine drills, and similar elements. The definite structural similarity between polyamides and animal tissue (albumin) makes it possible to use them in medicine (for surgical sutures, in eye surgery, for artificial blood vessels, to replace bone, etc.). In light industry, polyamides are used to replace leather and to treat textile fibers in order to increase the wear resistance of the cloth.

S.M. Perlin

POLYAMINOTRIAZOLIC FIBER – synthetic hetero-chain fiber from hydrazine- and dicarboxylic acids (most frequently adipic or sebacic) base polymers. Pilot production is assimilated in England. Polyaminotriazolic fibers are resistant to hydrolitic separation, including to alkalis, at elevated temperatures; are insufficiently resistant to the action of concentrated acids and oxidizers; by their resistance to atmospheric and sun effects they are close to polyamide fibers; are soluble in cyanohydrin and multi-atomic alcohols; are successfully dyeable in various colors by acid and dispersion dyes used for acetate rayon. The specific weight of polyaminotriazolic fibers is 1.12, $t^{\circ}_{pl}$ is 230-300° (depending on the number of methylene groups in the polymer molecule); moisture absorption (under standard conditions) 3-4% (the hydrophily decreases with an increase in the number of methyl groups); rupture length 36-40 km (to increase the strength and melting temperature the fiber is treated by aldehydes, ketons, acetylizing reagents); relative elongation 20%; the initial modulus of elasticity is higher than that of polyamide fibers and slightly lower than that of polyester fibers.

Possessing valuable properties, both specific and common to polyamide and polyester fibers, polyaminotriazolic fibers will come into extensive use in the national economy.

References: Rogovin, Z.A., Osnovy khimii i tekhnologii proizvodstva khimicheskikh volokon [Fundamentals of the Chemistry and Technology of Chemical Fiber Production]. 2nd edition, Moscow, 1957; Fibers from Synthetic Polymers, edited by R. Hill, translated from English, Moscow, 1957.

E.M. Ayzenshteyn

POLYARYLATES — see polyesters.

POLYCARBONATES – thermoplastic polymers based on polyesters of carbonic acid and dioxy compounds of aliphatic and aromatic series. Polycarbonates based on 4,4-dioxydiphenyl-2,2-propane have been studied in great detail, and have found wide application. They are produced under the name of polycarbonate or Diflon (USSR), Makrolon (Federal Republic of Germany), Lexan (United States), and Penlayt (Japan). Polycarbonates have a white surface, are odorless and flavorless, physiologically harmless, stable under light, air, and oxygen. Polycarbonates are chemically stable in the presence of petroleum, aliphatic hydrocarbons, ethyl alcohol, water, dilute mineral and organic acids (20% solution of hydrochloric, sulfuric, nitric, 40% hydrofluoric, 20-100 acetic, and 10-100 muriatic acid), aqueous solutions of salts, to animal and vegetable oils, fats, detergents, bleaches, photochemicals, food products, and many disinfectants; they are attacked by solutions of caustic alkalies, ammonia, and amines; they dissolve well in chlorinated hydrocarbons (methylene chloride, chloroform). Polycarbonates do not flow when cooled. Thus, for example, when a specimen is tested in the stressed state (220 $kg/cm^2$), no noticeable deformation is found in the course of a year; this property is particularly valuable when polycarbonates are used for structural purposes. They have good impact resistance. The material is weakly combustible. Polycarbonates maintain their initial dimensions well after service under quite varied conditions. Owing to their negligible water adsorption, polycarbonate parts, even in water, show little change in dimensions. Extended heating over the 80-150° temperature range leads to a change in certain of the phy-

## Physical-Mechanical Properties of Polycarbonates

| | |
|---|---|
| 1 Температура плавления (°С) | 235—300 |
| 2 Удельный вес | 1.2 |
| 3 Временное сопротивление: | |
| 4 при сжатии (кг/см²) | 900—950 |
| 5 при растяжении (кг/см²) | 670—780 |
| 6 при изгибе (кг/см²) | 1000—1200 |
| 7 Модуль упругости (кг/см²) | 22000 |
| 8 Уд. ударная вязкость (кг·см/см²) | 350—500 |
| 9 Удлинение при разрыве (%) | 80—110 |
| 10 Теплостойкость по ВИКА (°С) | 150—160 |
| 11 Твердость по Бринеллю (кг/мм²) | 15—16 |
| 12 Усадка при литье (%) | 0.6—0.7 |
| 13 Водопоглощение (%): | |
| 14 за 24 часа | 0.1 |
| 15 за 7 дней | 0.30 |
| 16 Удельное поверхностное сопротивление (ом) | $2.1 \cdot 10^{16}$ |
| 17 Удельное объемное сопротивление (ом·см) | $1.5 \cdot 10^{16}$ |
| 18 Тангенс угла диэлектрич. потерь при частоте $10^6$ гц | 0.007 |
| 19 Диэлектрич. проницаемость | ~3 |
| 20 Среднее пробивное напряжение (кг/мм) | 10—20 |
| 21 Коэфф. термич. расширения (20—90°С), 1/°С | $(6 \div 7) \cdot 10^{-4}$ |
| 22 Рабочая температура эксплуатации (°С) | 23 от +135° до —100°С |

1) Melting point (°C); 2) specific gravity; 3) ultimate strength; 4) in compression ($kg/cm^2$); 5) in tension ($kg/cm^2$); 6) in bending ($kg/cm^2$); 7) modulus of elasticity ($kg/cm^2$); 8) specific impact resistance ($kg \cdot cm/cm^2$); 9) elongation at failure (%); 10) thermal resistance, VIKA (°C); 11) Brinell hardness ($kg/mm^2$); 12) casting shrinkage (%); 15) water adsorption (%); 14) in 24 hr; 15) in 7 days; 16) surface resistivity (ohms); 17) bulk resistivity (ohm·cm); 18) dielectric loss tangent at frequency of $10^6$ cps; 19) dielectric constant; 20) mean breakdown voltage (kg/mm); 21) coefficient of thermal expansion (20-90°C), 1/°C; 22) working service temperature (°C); 23) from +135° to −100°C.

sical-mechanical characteristics: there is an increase in heat resistance (Martens); tensile strength and bending strength improve, while there is a reduction in impact strength. Polycarbonates are worked into products by die casting and extrusion. Before processing, polycarbonates are carefully dried at 110°. Ordinary casting machines are used for die casting. Owing to the high viscosity of the molten polymer, pressures reach 2000 $kg/cm^2$. When the polymer temperature is 240-300° during the die-casting process. The physical-mechanical properties of the polycarbonates are shown in the table.

III-17P2

Polycarbonates are used as a structural material in the manufacture of tanks, baling parts, various automotive and radio parts, etc. Polycarbonate films are widely employed in the electrical and audio industries, as well as for domestic products.

V.N. Kotrelev, T.D. Kostryukova

POLYDICHLOROSTYRENE – see polystyrene.

POLYDISPERSION – the ability of dispersed systems to form a disperse phase with particles of different dimensions. In monodisperse systems, in contrast to polydisperse systems, the disperse phase consists of particles of nearly the same size. Polydispersion is characterized by the difference between the largest and smallest particle diameters. In many cases, polydispersion causes a reduction in the dispersion of the system owing to association of smaller particles with larger particles; this is considered harmful. In practice, attempts are frequently made to reduce polydispersion and convert a polydispersed system into a monodispersed system; this is particularly important for emulsions. For polymers, polydispersion (or polymolecularity) is defined as the degree of inhomogeneity with respect to molecular weight. It is characterized by the molecular-weight distribution, which indicates the relative content of micromolecules of various sizes in the polymer.

N.M. Pul'tsin

POLYEPOXY FOAMS – gas-filled plastics with a closed-cellular structure produced from ED-6 epoxy resin and a hardener. They are manufactured in types PE-1, PE-2, and self-extinguishing PE-2. The table shows the principal raw materials and physicomechanical characteristics of polyepoxy foams.

Principal Raw Materials and Physicomechanical Characteristics of Polyepoxy Foams

| Показатели и сырье 1 | ПЭ-1 2 | | ПЭ-2 3 | | ПЭ-2 самозатухающий 4 | |
|---|---|---|---|---|---|---|
| Объемный вес (г/см³) 5 | 0,1 | 0,2 | 0,1 | 0,2 | 0,07–0,12 | 0,2–0 |
| Основное сырье 6 | Эпоксидная смола и м-фенилендиамин 13 | | Эпоксидная смола, м-фенилендиамин, 2,4-толуиленди-изоцианат 14 | | Эпоксидная смола, хлорэндиковый ангид; 2,4-толуиленди-изоцианат 15 | |
| Структура 7 | Замкнутая 16 | | | | Равномерно-пористая 17 | |
| Предел прочности при сжатии (кг/см²) 8 | 8–12 | 20–30 | 8–12 | 20–30 | 3,0–9,0 | 20–40 |
| Удельная ударная вязкость (кг·см/см²) 9 | 0,5–0,8 | 1,0–1,3 | 0,5–0,8 | 1,0–1,3 | 0,2–0,3 | 0,5–0,7 |
| 10 Водопоглощение за 24 часа (кг/м²) | 0,1 | 0,1 | 0,1 | 0,1 | 0,2 | 0,1 |
| 11 Теплостойкость (°С) | 100–110 | 100–110 | 130–140 | 130–140 | 140–160 | 140–160 |
| Горючесть 12 | Горит 18 | | | | Гаснет при вынесении из пламени 19 | |

1) Characteristics and raw materials; 2) PE-1; 3) PE-2; 4) self-extinguishing PE-2; 5) bulk weight ($g/cm^3$); 6) principal raw materials; 7) structure; 8) ultimate compressive strength ($kg/cm^2$); 9) impact strength ($kg \cdot cm/cm^2$); 10) water absorption over 24 hr ($kg/m^2$); 11) heat resistance (°C); 12) combustibility; 13) epoxy resin and m-phenylenediamine; 14) epoxy resin, m-phenylenediamine, 2,4-toluileneisocyanate; 15) epoxy resin, chlorendic anhydride, 2,4-toluileneisocyanate; 16) closed; 17) uniformly porous; 18) burns; 19) burning ceases on removal from flame.

All types of polyepoxy foam are used as structural and pouring materials for filling hollow forms and products. The advantages of these materials include the simplicity of their manufacture (without pressing), the fact that they can be poured, and their high mechanical strength (for PE-1 and PE-2).

POLYESTER ACRYLATES — see Polyesters.

POLYESTER ADHESIVE – is a solution of diverse polyester resins or of compounds based on unsaturated polyesters (maleates) and some monomers (styrene). It is used to bond metal with glass, copper, aluminum foil, and cork, and also to bond diverse types of heat insulations onto metallic surfaces. The one-component adhesive compound AMK contains polyester resins, a siccative, and a solvent; it is used to bond textile materials with metals. Its shelf life is 1 year. The viscosity in the state of application is 15-25 seconds according to the Ford-Engler test. The consumption of the adhesive is 180-200 $g/m^2$ in the case of a double-layer application. The bonding conditions are: temperature 15--35°; drying time for the first layer 2 hours, and for the second layer, together with the heat insulation, 24 hours, or 6-8 hours when heated to 70-100°. The peel strength of the joint between the AOD fabric and (plated) Duralumin is not less than 75 $kg/cm^2$ after 4 hours drying at 100-105°. The working temperature of the adhesive joints must not be higher than 150°. The adhesive does not corrode metals, and resists water, liquid fuels and mineral oil. The compound DGMS is used as a sealing and simultaneously as an adhesive material; it is prepared immediately before use from the unsaturated polyester DGM (75%) and styrene (25%) with addition of benzoyl peroxide (0.5-1.0%).

A filler – ground quartz sand – is added to the DGMS compound in order to avoid shrinkage and cracking during sealing and bonding. The working life of the compound is dependent upon the quantity of the added initiator and lasts up to 24 hours or more. The curing is carried out at high temperatures. The shearing strength of Duralumin joints

[illegible]

bonded with DGMS (with 0.5% benzoyl peroxide) is 99 kg/ [illegible], [illegible] kg/cm$^2$ at 60°, and 18 kg/cm$^2$ at 100°.

D.A. Kardashev

POLYESTER FIBER – synthetic hetero-chain fiber from polyethylene-terephthalate (product of condensation polymerization of terephthalic acid, or its dimethyl ester and ethylene glycol) which has a high heat resistance and elasticity. It is produced under the names Lavsan (USSR), Terylene (England), Dacron (USA), Lanon (GDR), Trevira, Diolen (FRG), Tetoron (Japan), Tergal (France), Svitlen (Czechoslovakia), Terlenka (Netherlands), Terital (Italy), Elana (Poland), etc., in the form of filament thread (standard and high-strength) and staple fiber (in the cut form and in clusters), the shiny fiber being used for engineering purposes and the matted or dyed fiber for consumer goods.

Physicochemical properties of polyester fibers; specific weight 1.38, moisture content 0.4-0.5% (under standard conditions) and 0.5-0.7% (at 20° and 95% relative humidity), double refraction coefficient 0.20-0.25, softening temperature 230-240°, $t°_{pl}$ 255-260°, zero strength temperature 248°, specific heat 0.32-0.35 cal/g·°C, thermal conductivity $3.36 \cdot 10^{-4}$ (from 90 to 190°), integral heat of wetting of unstretched fiber 0.57, of stretched fiber 1.18 cal/g, surface heat of wetting $4 \cdot 10^{-4}$ cal/cm$^2$, has a heat resistance exceeding all the known natural and chemical fibers except for Teflon (range of working temperatures from −70 to +175°), at −50 the fiber's strength increases by 35-40% (the elongation decreases, but the fiber does not become brittle), at 180° it retains 50% of its strength which is completely restored when cooled to 20°, when heated in air to 180° for 500 and 1000 hours the starting strength is retained by, respectively, 28.8 and 24.6% (polyamide and cellulose hydrate fibers are completely destroyed under these

conditions), shrinkage in boiling water 5-11%, the highest thermal stabilization effect is achieved at 190-220°, it melts near a fire but inflames with difficulty and ceases burning after the source of fire is removed. The electrical properties vary insignificantly up to 180° and in the presence of moisture; no charring upon contact with a spark or electric arc, dielectric constant 3.0-3.2 (at 25° and from 60 to $10^6$ cps), tangent of dielectric losses angle 0.002-0.003 (at 60 cps), 0.004-0.006 (at $10^3$ cps) and 0.013-0.016 (at $10^6$ cps), specific volume resistivity $1 \cdot 10^{19}$ ohm·cm, specific surface resistivity $4.8 \cdot 10^{11}$ ohm (at 100% relative humidity); resists the effect of atmospheric factors and sunlight (after being held in the sun for 600 hours lose 60% of strength, unlike polyamide fibers which fail under these circumstances); is subject to photochemical destruction by ultraviolet radiation. Polyester fibers are soluble in creosol and other phenol-type compounds, they are partially soluble with attendant disintegration, in concentrated sulfuric and nitric acids; it breaks down in concentrated alkaline solutions at high temperatures, resists acetone, carbon tetrachloride, dichloroethane, and other solvents, resists the action of oxidizing and reducing substances, microorganisms, moths, mildew and carpet beetles. Is surface dyed by dispersion acetate, azo and vat dyes in the presence of "transfer agents" (oxydiphenyl, salicylic acid, etc.) at 110-120° and elevated pressures; has only moderate adhesion to natural and synthetic rubbers (the adhesion can be improved by treating the fiber by polyisocyanide resins).

Mechanical properties of polyester fibers: their strength is not below that of polyamide fibers, rupture length of the staple fiber is 28-45 km, of filament thread 40-45 km (standard) 54-63 km (high-strength); strength loss is not observed in the wet state, in the loop it is 20% (higher for high-strength fibers), in the node 30%, ultimate

tensile strength of the filament fiber [illegible]-58 kg/mm$^2$ (for high-strength fiber), [illegible]-53 kg/mm$^2$ (for standard fiber), for staple fibers it is 42-56 kg/mm$^2$; the rupture elongation is the same in the dry and wet states being 10-15% for the high-strength thread, 20-25% for the ordinary thread and 25-40% for the staple fiber; the modulus of elasticity is from 500 to 1560 kg/mm$^2$ (higher than that of other fibers) depending on the degree to which the fiber is drawn; the initial modulus of elasticity (in 1% elongation) for filament fibers is 10.8 kg/mm$^2$, for staple fibers 2.5 kg/mm$^2$ (decreases with an increase in temperature), the shear modulus in torsion is 130-150 kg/mm$^2$; high elasticity (5-8% elongations of the filament thread are completely reversible, in greater elongations the part of reversible deformation decreases more than for polyamide fibers) which for the staple fiber is close to the elasticity of natural wool, and it exceeds it in the wet state (wet fabrics from polyester fibers recovers 85% of its previous state 15 seconds after crumpling, while wool fabric recovers only 20%); the abrasion resistance to multiple flexture is also lower than that of polyamide fibers, but by a factor of 2.5 higher than that of viscose fiber, the static coefficient of friction 0.58. Shortcomings of polyester fibers: difficulty in dyeing by standard methods, high electrifiability, round cross section and smooth surface, which promote the peeling-effect of high-number fibers, stiffness of products from the pure fiber (see Modified polyester fiber). Polyester fiber is used in the pure form and mixed with fibers of other kinds. The following engineering items are made from polyester fibers in the filament form: cord for rubber-engineering products, conveyor belts, V-shape and flat belts, sewing threads for the leather industry, high-pressure fire-fighting and industrial hoses, gasoline and oil resistant hoses, strings, tow lines, fishing nets and trawl nets, electric insulation materials, dyeing sacks, net-woven

sacks for underwear washing, filter fibers, sails, tents, tarpaulins, fabrics for washing calenders, cloth for paper-making machines; the staple fibers are used for producing: yacht sails, tarpaulins for covering of automobiles, sea-going vessels, railroad cars, warehouses, work and protective clothing, felt (for filters and paper-making machines).

References: Petukhov, B.V., Poliefirnoye volokno. (Terilene, lavsan) [Polyester Fibers. (Tyrelene, Lavsan)]. Moscow, 1960; Fibers from Synthetic Polymers, edited by R. Hill, translated from English, Moscow, 1957.

E.M. Ayzenshteyn

POLYESTER MALEINATES – see Polyesters.

POLYESTERS – macromolecular compounds obtained by polycondensation of polybasic acids or their anhydrides with polyatomic alcohols. Both nat al (amber, copal, shellac, etc.) and artificial polyesters are known. The term polyesters comprehends a large group of macromolecular compounds for which practical applications have been found for the glyptal resins, polyethylene terephthalates, polyester maleinates, and polyester acrylates.

Glyptal thermosetting resins have good adhesion to various materials, including glass and mica, and are widely employed in the manufacture of varnishes used as anticorrosion coatings in the manufacture of insulating materials (micanite, mycalex, etc.).

Polyethylene terephthalate has found wide application; it is produced under various names: Lavsan (USSR), Mylor (United States), Terilene (Great Britain), Svitlen (Czechoslovakia), Lanon (German Democratic Republic), Khastofen, Diolen (Federal Republic of Germany), etc. Films, fibers, and various products (tubing, packing, etc.), are made from polyethylene terephthalate. Polyethylene terephthalate is a crystalline polymer of a milky white color, transparent, with a white surface. It has a molecular weight of about 20,000, and a melting point of 265°. It may be obtained in the amorphous state upon rapid cooling. The basic physical-mechanical properties of polyethylene terephthalate are: specific gravity of the amorphous polymer, 1.33, of the crystalline polymer 1.45, of the oriented fiber 1.38; specific heat capacity 0.25-0.32 cal/g·C°; thermal conductivity $3.36 \cdot 10^{4}$ cal/cm·sec·°C; the material is elastic at –60°; it burns with difficulty; water absorption af-

ter 7 days is 0.5%; the working temperature range is from −70° to +175°; tensile strength is 1750 kg/cm$^2$; modulus of elasticity is 35,200 kg/cm$^2$; surface resistivity at 100% relative humidity is $4.8 \cdot 10^{11}$ ohms; bulk resistivity is $1 \cdot 10^{19}$ ohm·cm; the dielectric constant is 3-3.2; the dielectric loss tangent at 60 cps is 0.002-0.003, and at $10^6$ cps is 0.013-0.0015; the electrical strength is 180 kv/mm. Polyethylene terephthalate is stable under the effects of mineral and organic acids (including hydrofluoric and phosphoric acids), solvents (carbon tetrachloride, trichloroethane, acetone, benzene, gasoline, alcohols); when heated, it dissolves in phenol, tricresol, nitrobenzene; it is attacked by nitric acid. New polyesters of linear structure have also been developed — polyacrylates, "pentaplasts," polymers of olefine oxides, etc. Of particular interest are linear polyesters — polyacrylates, obtained by polycondensation of diatomic phenols with dicarboxylic acids or their anhydrides. Polyacrylates possess good heat resistance (300-500°), mechanical strength, chemical stability, and good dielectric properties.

Polyester maleinates (PEM) and polyester acrylates (PEA) are solutions of resins with molecular weights of 400-10,000 in styrene, methyl methacrylate, or other unsaturated monomers. Setting of PEM and PEA occurs without evolution of secondary substances, so that it is possible to obtain products without the use of pressure. In the case of cold setting (at room temperature) the initiator and accelerator may be, respectively, isopropylbenzene hydroperoxide (cumene hydroperoxide) and cobalt naphthenate; where the materials are set at elevated temperatures, benzoyl peroxide and dimethyl aniline are employed. Polyester maleinates are almost exclusively in the manufacture of large fiber-glass-reinforced-plastic products. The filler is glass fiber in the form of cloth, mat, braids, and filaments. Sometimes inert fillers

and thixotropic additives are introduced into the composition.

Industry produces four types of polyester maleinate resins: PN-1 (VTU 33085-60), PN-2, PN-3 (VTU 33122-60), and PN-4 (VTU P 220-60 LSNKh). Type PN-1 is the most widely employed. Polyester maleinates and fiber-glass reinforced plastics based on them are inflammable. Antimony trioxide, chloroparaffin, dichlorostyrene, and phosphorous-organic compounds are introduced to reduce flammability. Another way of producing selfextinguishing polyester maleinates lies in the introduction into the polyester chain of atoms of chlorine, phosphorous, and certain other elements. Selfextinguishing polyesters are also obtained where a monoatomic alcohol is used in the form of pentaerythrite dichlorohydride with the addition of other chlorine-containing substances (chlorendic anhydride, polyvinylchloride, etc.), as well as where the phthalic anhydride is replaced by tetrachlorophthalic anhydride. Polyester acrylates exhibit negligible shrinkage, high heat resistance, and better adhesive characteristics, including adhesion to glass, than polyester maleinates. Three grades of polyester acrylates are produced: TGM-3 (VTU No. BU-71-54) – a product of condensation of methacrylic acid and triethylene glycol, MGF-9 (VTU No. BU-9), a product of the condensation of methacrylic acid, phthalic anhydride, and triethylene glycol, TMGF-11 (VTU No. BU-11), a product of the condensation of methacrylic acid, phthalic anhydride, and glycerine. On the basis of these PEA, binders have been developed for fiber-glass reinforced plastics 911MS (mixture TMGF-11 and MGF-9) and 39E BS (mixture TGM-3 and MGF-9). Polyester acrylates are employed chiefly in the production of fiber-glass reinforced plastics and in the varnish and paint industry. Owing to their good adhesive characteristics, they are also used in the manufacture of cements.

An unsaturated polyester resin is produced as grade MA-3 (VTU 30-

1244-61 LSh.Kh); it is a space copolymer of polyester maleinate with polyester acrylate, and it is used in the manufacture of large products from fiber-glass reinforced plastics.

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S.M. Perlin

**POLYETHYLENE** – a thermoplastic material, the product of polymerization of ethylene. Polyethylene is produced in the following forms: high-pressure (VD), low-pressure (ND), and medium-pressure (SD) which is similar in its characteristics to low-pressure polyethylene, but which has a more orderly linear structure. There exist polyethylenes obtained under superhigh pressures, under the effects of radiation, etc. Cable polyethylene is also produced (TU MKhP 2524-53) – a mixture of high-pressure polyethylene with polyisobutylene (which see). The added polyisobutylene increases the elasticity of the composition, improves workability, and reduces the tendency toward during thermal aging. Polyethylene is characterized by good mechanical strength, dielectric properties, resistance to radioactive emission, low gas penetrability and water absorption, and light weight.

Polyethylene is characterized by its resistance to the effects of concentrated acids (except for nitric acid), alkalies, solutions of salts and alcohols. In gasoline, benzene, toluene, halogen-producing hydrocarbons, ethers, and acetone, polyethylene will swell. Upon heating, polyethylene will dissolve in some of these solvents, but upon cooling, it separates from the solution.

High-pressure polystyrene is produced by polymerization of ethylene at pressures in excess of 1000 atm and temperatures of up to 200° in the presence of slight amounts of initiator; low-pressure polystyrene is obtained by polymerization of ethylene dissolved in gasoline or other solvent at a pressure of 4-5 atm at temperatures of up to 60° in the presence of organometallic compounds. The table shows the proper-

Properties of Polyethylene

| 1 Показатели | 2 Марки | |
|---|---|---|
| | 3 ВД | 4 НД |
| 5 Молекулярный вес | 18 000—35 000 | 70 000—150 000 |
| 6 Удельный вес (при 20°) | 0,92—0,93 | 0,94—0,96 |
| 7 Удельная ударная вязкость (кг·см/см²) | 28 Не ломается | |
| 8 Температура размягчения (°С) | 108—120 | 29 Выше 135 |
| 9 Температура хрупкости (°С) | —70 и ниже 30 | —70 и ниже 30 |
| 10 Предел прочности (кг/см²): | | |
| 11 при разрыве | 120—160 | 220—450 |
| 12 при изгибе | 120—170 | 200—380 |
| 13 при сжатии | 125 | 200—360 |
| 14 на срез | 140—170 | 200—360 |
| 15 Относительное удлинение (%) | 150—600 | 200—900 |
| 16 Модуль упругости (кг/см²) | 1500—2500 | 5000—8000 |
| 17 Хладотекучесть | Слабая 31 | Очень 32 слабая |
| 18 Удельная теплоемкость (кал/г·°С) | 0,5—0,7 | 0,55 |
| 19 Теплопроводность (кал/сек·см·°С) | 0,0007 | 0,001 |
| 20 Температурный коэффициент линейного расширения на 1° в интервале 0—50° | $22 \cdot 10^{-4}$ | $10 \cdot 10^{-5}$ |
| 21 Тангенс угла диэлектрич. потерь при $10^6$ гц | 0,0002—0,0004 | 0,0002—0,0005 |
| 22 Диэлектрич. проницаемость при $10^6$ гц | 2,2—2,3 | 2,1—2,4 |
| 23 Электрич. прочность (кв/мм) | 45—60 | 45—60 |
| 24 Удельное объемное сопротивление (ом·см) | $10^{17}$ | $10^{17}$ |
| 25 Удельное поверхностное сопротивление (ом) | $10^{14}$ | $10^{14}$ |
| 26 Водопоглощение за 24 час. (%) | 0,01 | 0 |
| 27 Усадка при литье (%) | до 2,5 | 2—3 |

1) Characteristics; 2) grades; 3) VD; 4) ND; 5) molecular weight; 6) specific gravity (at 20°); 7) specific impact resistance ($kg \cdot cm/cm^2$); 8) softening temperature (°C); 9) brittle point (°C); 10) ultimate strength ($kg/cm^2$); 11) in tension; 12) in bending; 13) in compression; 14) in shear; 15) relative elongation (%); 16) modulus of elasticity ($kg/cm^2$); 17) cold flow; 18) specific heat capacity (cal/g·°C); 19) thermal conductivity (cal/sec·cm·°C); 20) thermal coefficient of linear expansion per 1° over 0-50° range; 21) dielectric loss tangent at $10^6$ cps; 22) dielectric constant at $10^6$ cps; 23) electrical strength (kv/mm); 24) bulk resistivity (ohm·cm); 25) surface resistivity (ohms); 26) water absorption in 24 hr (%); 27) shrinkage in casting (%); 28) does not break; 29) above; 30) and below; 31) slight; 32) very slight.

ties of polyethylene.

Polyethylene properties can be modified as follows: by combining polyethylenes obtained by different methods, for example, high-pressure polyethylene with low-pressure polyethylene; it may be combined with other polyolefines; it may be obtained by copolymerization of poly-

ethylene with propylene, etc. During working and service, under the effect of high temperature as well as under the effect of sunlight, aging processes occur in polyethylene that lead to impairment of physical-mechanical and electrical properties. Antioxidants and stabilizers are introduced into polyethylene to retard aging processes. The long-term permissible working temperature for high-pressure polyethylene does not exceed 60-70°, and 90-100° for low-pressure polyethylene.

High-pressure polyethylene is a flexible corniculate product with low hardness; it is characterized by good frost resistance (-70°), high water resistance, and good electrical insulating properties. It is produced in the following grades: PE-150, PE-300, PE-450, and PE-500 (the numbers indicate the minimum relative elongation in tension, %). Depending on the amount of plasticity or the height of the specimen above the load (from 0.7 to 2 mm) measured at 130°, each grade of high-pressure polyethylene is divided into 5 types, from I to V. The greatest flow in die casting is exhibited by high-pressure polyethylene with a maximum relative elongation and high plasticity, for example, PE-500, type I or II. Products made from these low-molecular materials have decreased shape stability at elevated temperatures. At -60°, high-pressure polyethylene has roughly 2.8 times the strength at 20°, while at 80°, the strength is less by a factor of 3.5. When the temperature rises from 20° to 60°, the compression and bending strengths decrease by factors of 2.5-2.7, while the shear strength drops from 140-170 to 75-90 kg/cm$^2$. The bulk resistivity of high-pressure polyethylene is quite independent of temperature up to 100°, and falls in the $10^{15}$-$10^{18}$ ohm·cm range. At temperatures above 100°, it drops sharply, reaching $10^{10}$ ohm·cm at 120°. The dielectric loss tangent is relatively independent of temperature up to 100° and of frequency up to $10^8$-$10^9$ cps. Cast high-pressure polyethylene is produced at 150-200° and a specific pressure of 300-700 kg/

/cm$^2$; parts are molded at a specific pressure of 70-150 kg/cm$^2$ and are cooled in the die under pressure. High-pressure polyethylene is produced as granules with a bulk density of 500-540 g/liter.

Low-pressure polyethylene has better mechanical properties (at 100°, the ultimate strength of low-pressure polyethylene in tension equals 100-150 kg/cm$^2$, which is 4-5 times better than the corresponding value for high-pressure polyethylene). The relative elongation of low-pressure polyethylene at 100° is roughly 4.5 times greater, while for high-pressure polyethylene it drops by a factor of 2.5 (with respect to the elongation at 20°). The yield point for admissible stress for low-pressure polyethylene at 20° is 200-250 kg/cm$^2$; the elongation at the beginning of flow will then be 15-30%. The dielectric constant of low-pressure polyethylene is quite independent of frequency and temperature. The dielectric loss tangent depends on the degree of purity of the material. At temperatures up to 100°, the bulk resistivities of low-pressure and high-pressure polyethylene differ little, but at 120°, low-pressure polyethylene has higher values of the order of $10^{13}$ ohm·cm. Low-pressure polyethylene is manufactured in the following grades: L (cast), E (for extrusion), and P (for molding). Casting is carried out at 200-270°; the use of the higher temperature helps to increase the shape stability of the products. The casting mold is heated to 50-70°. Low-pressure polyethylene is molded at 150-180° and a specific pressure of 50-100 kg/cm$^2$, with subsequent cooling in the mold. Low-pressure polyethylene is produced as a finely dispersed powder with a bulk density of 100-300 g/liter, as well as in granulated form.

The fundamental properties of cable polyethylene are as follows: electrical strength no less than 35 kv/mm; dielectric constant at $10^6$ cps no more than 2.5; dielectric loss tangent at $10^6$ cps no more than 0.0005; water absorption after 30 days, no more than 0.15 mg/cm$^2$; plas-

ticity at 130°, 1.5-2.0 mm; softening point, in the 105-130° range.

Polyethylene is used as jacketing for high-frequency, submarine, and other types of cable; as a protective material in chemically aggressive liquids (concentrated mineral acids, alkalies, salts, peroxides, etc.); as sheet linings for equipment and tanks, sprayed coatings, for piping produced by extrusion, for molded and cast parts (slidevalves, valves, cocks, funnels for hydrofluoric acid, etc.). The lack of toxicity of polyethylene and its inertness make it possible to use it as material for unbreakable containers. Owing to its low combustibility, polyethylene is used to replace celluloid in the manufacture of many products. Screw extruders are used to make polyethylene tubing of any length. Tubing up to 63 mm in diameter is wound into coils; larger-diameter tubing is produced in the form of 3- and 6-m segments. Wall thickness of polyethylene tubing varies. Very light-weight tubing (specific gravity 0.92), flexible, simply and easily joined, sanitary, physiologically harmless, may be used in low-temperature operation. Owing to its elasticity, polyethylene tubing can easily withstand hydraulic shock, is an outstanding absorber of noise and other sound caused by liquid flows. For the same cross section, the carrying capacity of polyethylene tubing is greater than that of metal tubing. High-pressure polyethylene film produced in the form of rolls wound on laminated-Bakelite spools, is widely employed. Up to 300-400 m of material is wound on a roll; it is up to 1400 mm wide and 30-200 mm thick. The film has the following properties: ultimate strength in tension 150-170 $kg/cm^2$; relative elongation in tension (%), longitudinal up to 400, transverse up to 500; water absorption less than 0.01%. Polyethylene film is used to make bags and covers for packing tools and various metal parts, balloons for investigating the upper atmosphere, electrical insulation for radio electronic components, as packing material for

food products and pharmaceutical preparations. Prerolled polyethylene is used to produce 1-20 mm thick sheets intended for the manufacture of inserts and other technical components.

Polyethylene blocks measuring 500 × 400 × 200 mm and 200 × 200 × × 100 mm are molded in special block presses.

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A.N. Vardenburg

POLYETHYLENE FIBER – synthetic fiber from high-pressure polyethylene (produced under 2000-3000 atm and 200°) with a branched-out structure and from low-pressure polyethylene (produced at 3-7 atm and 30-70°) with a linear polymer structure. Medium-pressure polyethylene (produced at 30 atm and 132°), whose properties resemble those of low-pressure polyethylene, is also known. Polyethylene fibers are produced abroad under the names Courlene, Marlex, Polythene, etc. The fibers are obtained from polyethylene on a special endless-screw machine in the form of monofiber (d = 0.004-0.2 mm) or on a melting grating in the form of filament fiber with an elementary number 1500-1600. Fibers from low and medium pressure polyethylene with a degree of crystallization of 70-85% have better physicomechanical properties than high-pressure polyethylene fiber with a degree of crystallization up to 60%. This is characterized by the following data (numbers in parentheses pertain to fibers from low and medium pressure polyethylene): specific weight of high pressure polyethylene fiber 0.92 (0.95) $T_g$ −45° (−45°), $t°_{pl}$ 105-110° (130-135°), ash content (0.05-0.1%), rupture length 9.0-13.5 km (49.5--63.0), ultimate strength 8.3-12.4 kg/mm$^2$ (47.0-59.8), strength in the node 7.4-11.11 km (41.0-52.0), relative rupture elongation 45-50% (25-30%), fiber shrinkage: 5-8% (3-5%) at 75° and 60-70% (12-15%) at 100°, thermal conductivity $7\cdot10^{-4}$ ($1\cdot10^{-3}$) cal/cm·sec·°C, resistivity at 25° $3\cdot10^{17}$ ohm·cm ($8\cdot10^{16}$), tangent of dielectric losses angle at 25° and kc $6\cdot10^{-4}$ ($3\cdot10^{-4}$).

Polyethylene fibers are distinguished by high resistance to alkalis and acids, are not soluble in alcohols and esters but swell in hy-

drocarbons. Have a high resistance to decay and mildew. Polyethylene fibers are dyed by pigment dyes in the mass.

Shortcomings of polyethylene fibers: low melting temperature and not too high resistance to photo- and thermal-oxidization failure as compared with polyacrylonitrilic and polyester fibers. To improve these properties stabilizing reagents are added to the polymers. Polyethylene fibers are widely used for engineering purposes (as filter fibers in the chemical and food industries, electric insulation materials, ropes, strings, cords, sieves) and for the production of decorative and upholstery fabrics.

References: Henstead, W., "Man-Made Text.," Vol. 34, No. 407, page 46, 1958; Overgage, E., and John, J., "Brit. Plast.," No. 1, page 10, 1961.

M.P. Zverev

POLYETHYLENE PIPES – see Polyethylene.

POLYETHYLENE TEREPHTHALATE – see Polyesters.

**POLYFORMALDEHYDE** – a product of formaldehyde polymerization. It is a white crystalline powder with a melting point of 180°, characterized by high stability: it retains stiffness and mechanical strength up to 120°, resists abrasion, organic solvents, and oils. At room temperature, polyformaldehyde does not dissolve in any known organic solvent, but is attacked by concentrated inorganic acids and alkalies. The good physical-mechanical properties of polyformaldehyde combine with good dielectric properties. Polyformaldehyde is quite amenable to processing by extrusion, casting, and molding. Extrusion is carried out on 1- or 2-screw extruders at 170-190° with rapid cooling of the resulting products and subsequent granulation. When products are manufactured from polyformaldehyde by casting, the polymer must first be extruded and granulated. The basic characteristics of polyformaldehyde are: specific gravity 1.4, specific impact resistance 30-40 $kg \cdot cm/cm^2$ for specimens obtained by casting – 90-120 $kg \cdot cm/cm^2$; ultimate strength in bending 750-900 $kg/cm^2$, in compression 1300 $kg/cm^2$, in tension 600-700 $kg/cm^2$; Brinell hardness 30 $kg/cm^2$, coefficient of linear expansion $1 \cdot 10^{-6}$, VIKA heat resistance 176°, Martens heat resistance 100°; melting point 180°, moisture absorption 0.2%, bulk resistivity $1.2 \cdot 10^{15}$ ohm·cm, dielectric loss tangent at $10^6$ cps, 0.003; dielectric constant 3.1. Polyformaldehyde takes colors well and retains its properties over an extended period of time.

Polyformaldehyde is used as a structural material in the manufacture of gears, inserts for sliding-friction bearings, automobile parts, components of electrical fittings. Polyformaldehyde film is very strong.

Polyformaldehyde film may also be used in the production of fibers.

**POLYISOBUTYLENE** – a thermoplastic product of polymerization of isobutylene in the presence of boron fluoride. Polyisobutylene is characterized by good elasticity and frost resistance (of the order of –70°). Depending on process conditions, polyisobutylene may be obtained with various degrees of polymerization and various physical properties. The following grades of polyisobutylene are produced industrially; they differ in molecular weight: P-50, 50 thousand; P-85, 70-100 thousand; P-118, 100-135 thousand; P-155, 135-175 thousand; P-200, 175-225 thousand. Polyisobutylene is produced abroad under the names of Oppanol and Vistanex.

Polyisobutylene has a specific gravity of 0.91-0.93, a value that varies negligibly as a function of molecular weight. Polyisobutylene dissolves in aliphatic and aromatic hydrocarbons, carbon tetrachloride, and carbon disulfide. The higher the molecular weight of the polyisobutylene, the more slowly it dissolves. At room temperature, polyisobutylene is stable in the presence of dilute and concentrated hydrochloric acid, sulfuric acid, phosphoric acid, muriatic acid, acetic acid, as well as weak and concentrated alkalies, calcium permanganate, hydrogen peroxide, and chromic acid. At temperatures above 80°, polyisobutylene carbonizes in concentrated sulfuric acid, while it decomposes in concentrated nitric acid. The permissible long-term working temperature does not exceed 70° for polyisobutylene. It swells in animal fat and vegetable oils, is insoluble in monatomic and polyatomic alcohols, ketones, and esters; it is quite impervious to gas, and has high resistance to penetration by water vapor. Polyisobutylene has the

following dielectric properties: electrical strength, 16-20 kv/mm; bulk resistivity, $10^{16}$ ohm·cm; dielectric constant at 50 cps, 2.2-2.4; dielectric loss tangent at 50 cps, 0.0002-0.0005. Processes destructive to polyisobutylene are accelerated in sunlight; its mechanical characteristics deteriorate, and it becomes tacky. Introduction of carbon black improves the light resistance of polyisobutylene. Atomic radiation ($\gamma$ rays and neutrons) attacks polyisobutylene, turning it into a viscous liquid. Polyisobutylene retains its elasticity over a temperature range of from −50° to +100°; at 180-200°, it becomes plastic, while at temperatures above 350°, it decomposes. Polyisobutylene must be plasticized before mixture with ingredients. Polymer destruction occurs at low plasticization temperatures. With increasing temperature, plasticization effect diminishes, and at temperatures above 100°, almost no change in plasticity is observed. Polyisobutylene mixes in any proportions with natural and synthetic rubbers. A major drawback with polyisobutylene is its cold flow, i.e., the ability to deform at room temperatures and low under moderate stresses. Polyisobutylene cannot be vulcanized with sulfur. Unfilled polyisobutylene has moderately good mechanical characteristics, which improve with increasing molecular weight. Of the fillers, only carbon black and graphite improve the breaking strength of polyisobutylene. The physical and mechanical characteristics of filled polyisobutylenes are given in the table.

Polyisobutylene is employed for anticorrosion coatings, processing of technical products and fabrics resistant under chemical reagents; in the manufacture of tacky electrical insulating tape, as well as in the production of coated chemically stable plates; when mixed with natural and divinyl styrene rubbers or polyethylene, it is used for cable insulation. The introduction of polyisobutylene into reclaim compounds imparts good elastic properties and moldability in vulcanization. Low-



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Physical-Mechanical Characteristics of Filled Polyisobutylenes

| 1 Показатели | 2 Марки | |
|---|---|---|
| | 3 П-200 | 4 П-118 |
| 5 Предел прочности при разрыве (кг/см²) | 10 11 До 60 | До 20 |
| 6 Относительное удлинение (%) | Св. 1000 | Св. 1000 |
| 7 Остаточное удлинение (%) | 4 | 20—50 |
| 8 Эластичность по отскоку (%) | 12 | — |
| 9 Твердость по ТМ-2 | 35 | 27 |

1) Characteristics; 2) grades; 3) P-200; 4)P-118; 5) tensile strength ($kg/cm^2$); 6) relative elongation (%); 7) residual elongation (%); 8) recoil elasticity (%); 9) hardness, TM-2 standard; 10) up to; 11) above.

molecular polyisobutylene (molecular weight up to 10,000) is used in the petroleum industry to improve the quality of lubricating oils.

References: Reshetov, A.N. and Makarova, Ye.I., Poliizobutileny i primeneniye ikh v tekhnike [Polyisobutylenes and Their Application in Technology], Leningrad-Moscow]. 1952; Borodina, I.V., Nikitin, A.K., Tekhnicheskiye svoystva sovetskikh sinteticheskikh kauchukor [Technical Properties of Soviet Synthetic Rubbers], Leningrad-Moscow, 1952; Labutin, A.L., "KhNiP" [Lexan], 1957, Vol. 2, No. 3, page 359; Koshelev, F. F., Klimov, N.S., Obshchaya tekhnologiya reziny [General Technology of Rubber], 2, Edition, Moscow, 1958.

M.D. Gordin (deceased), A.K. Vardenburg

POLYISOBUTYLENE ADHESIVE – is a solution of isobutylene polymers either in organic solvents or in the monomers. It is used mainly for the production of sticky adhesives and to bond polyisobutylene and other polymer materials working within the temperature range of ±60°. The adhesives are prepared from polymers with a molecular weight of 3000-8000; high-molecular products (with a molecular weight up to 250,000) with mineral fillers are used to bond rubbers and linoleum. The solution of polyisobutylene in monomeric styrene containing benzoyl peroxide is recommended as a sublayer for the bonding of polyisobutylene sheets on metals.

The B-12 adhesive based on polyisobutylene (20 parts by weight) and petroleum asphalt (80 parts by weight) is used to bond rubber and polyisobutylene sheets on metal. It is prepared from a mixture of two petroleum asphalts (with the softening points 60° and 106°) and two polyisobutylenes with a molecular weight of 50,000 and 200,000 at a temperature of 120-130°. The bonding is carried out at 150°. The peel strength of a PSG-200 polyisobutylene joint with concrete amounts to 11 kg/cm$^2$ after 10 days, and that of a joint with wood amounts to 4.5 kg/cm$^2$. The adhesive is used only in a heated state. Addition of 4% iron resinate dissolved in styrene or benzene accelerates the curing of the adhesive. The strength of the adhesive joints of PSG-200 with metal decreases at elevated temperatures. The adhesive (without addition of the accelerant) may be stored in a cool and dark place for 2 months; it is volatile, toxic and inflammable.

D. A. Kardashev

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**POLYMERS** – macromolecular compounds formed during the processes of polymerization, polycondensation, etc., from a large number of simple molecules (monomers). The dimensions of the linear macromolecules are thousands of times greater than the dimensions of ordinary molecules. The repeating group of atoms, which is usually the initial substance (the monomer) is called the monomer unit of the polymer macromolecules. The number of monomer units in the chain is called the degree of polymerization (n). The product of n and the molecular weight of 1 monomer unit equals the molecular weight M of the polymer. Polymers with M = $= 10^4$-$10^6$ are called high polymers, while polymers with lower molecular weight are called oligomers. Polymers whose chains are constructed from identical monomer units are called homopolymers, while those constructed from diverse monomer units are called copolymers. Copolymers (linear) whose mean chain is made up of repeating segments, formed by a group of identical monomer units (blocks) are called block copolymers. In addition to linear polymers, they may also be branched and spatially cross-linked polymers. If the main chain of a macromolecule consists of single monomers, and the side branches of other monomers, such branched polymers are called grafted copolymers. The main chain of a polymer may contain either identical atoms (homogeneous-chain polymers) and unlike atoms (straight-chain heteropolymers). In addition to the very common carbon-chain polymers, whose main chain contains only carbon atoms, we frequently encounter copolymers whose main chain contains, in addition to carbon atoms, atoms of oxygen, nitrogen, sulfur, etc. Inorganic polymers contain no carbon atoms. Polymers are widely used as the ini-

tial product in the creation of various structural polymer materials – fibers, rubbers, plastics, fiberglass-filled plastics, coatings, etc.

Depending on structure, temperature, thermal history, and nature of mechanical treatment, as well as temporary test conditions, may be in viscous-flow, highly elastic, crystalline, or glass-like states.

On the basis of physical structural attributes, polymer materials may be classified into five main groups: 1) amorphous (the majority of plastics and rubber), 2) amorphous oriented (fibers and film materials); 3) crystallizing (crystallizing rubbers); 4) crystalline isotropic; 5) crystalline oriented (the same as the second group).

On the basis of chemical structural attributes, polymers are classified as linear, branched, and spatially structured, or grid (cross-linked). The structure of the chain in a macromolecular compound of exactly the same chemical composition may differ owing to the appearance of stereoisomerism in various forms. The most important stereoisomers are the atactic, isotactic, and sindiotactic polymers.

A basic physical characteristic of polymer construction is the flexibility of their chains, which is limited by the size of the rigid sections (segments) including a certain number of monomer units, from which the macromolecule is constructed. The segments are able to rotate with respect to neighboring segments. Another characteristic of polymers is the sharp difference in the nature of the interaction forces within the chain and within different chains. Atoms in a polymer chain are connected by chemical forces, while the chains are connected by intermolecular forces, which are considerably weaker than the chemical forces. The structural features of polymers and the extensive possibilities for continuously varying their properties by changing the structure give them a nearly unlimited field of application in technology. The mechanical properties of polymers are a complex of proper-

ties determining their behavior under mechanical forces. Polymers are characterized by: 1) well-defined relaxation properties, appearing in delay of deformation and stress relaxation; 2) the dual nature of elasticity: ordinary elasticity, characteristic of solids, and highly elastic behavior; 3) effect of molecular orientation on strength; 4) the important role of physical-chemical processes in the instability of mechanical processes (effect of aggressive media, aging processes); 5) the activating effect of mechanical forces on chemical processes in polymers, leading to a change in structure and the development of fatigue phenomena. Polymers, moreover, display two types of irreversible deformation: at low stresses, the molecular flow mechanism is the same in general outline as for ordinary liquids (diffusion); under high stresses, "chemical" flow is observed. The fundamental mechanical properties of polymers include deformation, strength, and friction properties.

Deformation properties of polymers. Under small deformations, crystalline polymers behave as ordinary solids, while under high stresses they undergo a phase transition of the first kind from the basic, generally isotropic phase to the oriented phase, with the chains located along the ten ion axis.

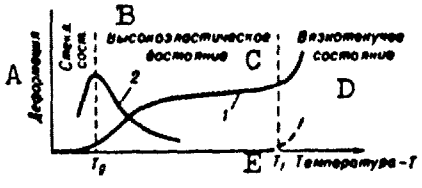



Fig. 1. Thermomechanical curve (1) and mechanical-loss curve (2) for amorphous polymer. A) Deformation; B) glassy state; C) highly elastic state; D) viscous-flow state; E) temperature.

Under low stresses, amorphous polymers may go into the glassy (solid) highly elastic, or viscous-flow states (Fig. 1). The transition

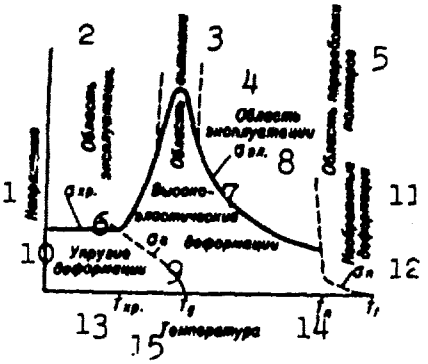



Fig. 2. Deformation-strength state diagram for amorphous polymers: $T_{khr}$) Limit of transition from temperature region of brittleness to temperature region of destruction in oriented state; $T_g$) vitrification temperature; $T_p$) limit of transition from temperature region of high elasticity to region of plasticity; $T_f$) flow temperature; $\sigma_{khr}$) brittle strength; $\sigma_v$) limit of forced elasticity; $\sigma_{el}$) strength of highly elastic material (stress calculated in terms of specimens cross section at rupture); $\sigma_p$) yield point; 1) Stress; 2) operating region; 3) drying region; 4) operating region; 5) region of polymer processing; 6) $\sigma_{khr}$; 7) highly elastic deformation; 8) $\sigma_{el}$; 9) $\sigma_v$; 10) elastic deformations; 11) irreversible deformations; 12) $\sigma_p$; 13) $T_{khr}$; 14) $T_p$; 15) temperature.

temperatures $T_g$ (vitrification temperature) and $T_f$ (flow temperature) between one state and another depend on the type and structure of the polymer, its molecular weight, the plasticizers introduced into the polymer materials, etc., as well as the frequency or time of application of the force. Such states are observed under mechanical actions (see vitrification temperature and thermomechanical curve).

All factors leading to a reduction in intermolecular interaction (plasticization, transition to nonpolar polymer), cause a reduction in $T_g$ and $T_f$. The introduction of chemical transverse bonds (for example, by vulcanization of rubbers) leads to a sharp increase in $T_f$, but causes almost no change in $T_g$. A reduction in the molecular weight of linear polymers to some specific limit will not change $T_g$, but will reduce $T_f$. Where the molecular weight is sufficiently low, corresponding to the dimentions of a chain segment, the highly elastic properties

disappear completely, and when heated the polymers at once go from the glassy to the viscous flow state.

Under low stresses, polymers in the glassy state display only elastic deformation with a Youngs Modulus of 200-600 $kg/mm^2$, as a Youngs Modulus for steel of 20,000 $kg/mm^2$, while in the highly elastic state, two forms of deformation appear, but the highly elastic form exceeds the elastic form by roughly a factor of $10^3$-$10^4$, so that in practice the former will equal the entire polymer deformation. The highly elastic modulus of uniaxial tension equals 0.2-0.02 $kg/mm^2$.

Under high stresses, amorphous polymers exhibit more complex deformation properties (see strength of polymers), superficially similar to the deformation properties of crystalline polymers.

It is characteristic of solid polymers that at stresses exceeding the so-called limit of forced elasticity $\sigma_v$, highly elastic deformation develops, and the polymer goes from the isotropic to the solid anisotropic state (highly elastic forced deformation). At stresses below the limit $\sigma_v$, glassy polymers experience elastic deformation, in the main. It is only under the compelling action of external forces or stresses in excess of $\sigma_v$ that highly elastic deformation develops.

In the highly elastic state at temperatures exceeding $T_g$, the relaxation time is small, so that highly elastic deformation develops at once at any stresses. It is characterized by low modulus of elasticity and high mechanically reversible strains many times in excess of the initial specimen dimensions. Raw and cured rubbers as typical highly elastic materials in the temperature range between $-70^\circ$ and $+100^\circ$ or above. Under small deformations (several %), the stress is proportional to the strain throughout the entire region of high elasticity. The coefficient of proportionality (the modulus E of high elasticity) depends on the time regime of testing owing to the relax-

ation properties of polymers. At high extensions, reaching hundreds of percent, there is strong orientation of macromolecules. The tension process concludes in failure, which comes about earlier the higher the temperature.

At some temperature $T_p$ and above, up to $T_f$, the material will pass through the plastic limit $\sigma_p$ under tension (Fig. 2). In this region, a linear polymer is characterized by a stress-strain diagram similar to that for plastic metals.

The fundamental property of macromolecules is their flexibility, which appears clearly above $T_g$, where thermal motion is quite vigorous. Macromolecule flexibility is the factor responsible for the highly elastic properties of polymers. The difference between highly elastic deformation and ordinary elastic deformation lies in the fact that elastic deformation of a polymer in the glassy state is associated with a change in the average distances between particles, while highly elastic deformation is associated with displacement of the monomer units in the flexible chains, and a change in chain form with no change in the average distance between them. Highly elastic deformation appears most clearly in grid polymers (rubber), which are produced with transverse "cross linking" of the linear macromolecules (vulcanization of rubber). Cross linking hinders irreversible displacements of macromolecules and flow of the polymer as a whole. Thus grid polymers are capable of regaining their shape after unloading, just like elastic solids. In other properties, they resemble liquids. Liquids and grid polymers are amorphous substances with a coefficient of bulk thermal expansion and compressibility that are similar, and far less than for solids; they both obey the Pascal law. At the same time, highly elastic deformation of grid polymers differs from deformation of solids, but is similar to the molecular-kinetic natur of gas elasticity; the stresses in a deformed

rubber, like the pressure in a compressed gas, is proportional to the absolute temperature. It is the structure of highly elastic materials that is associated with this combination of properties of solids, liquids, and gases.

High elasticity is observed for polymers of quite diverse chemical natures: for typical hydrocarbons, for example, polyethylene when molten, polyisoprene (natural rubber), polyisobutylene, for silicone rubbers, such as polydimethylsiloxane, for inorganic polymers, such as polyphosphonitrile chloride, as well as for inorganic glasses above $T_g$.

The relaxation properties of polymers appear most clearly in the transition region between the glassy and highly elastic states, and for linear polymers when the material goes over to the viscous-flow state as well. Fundamental to the understanding of the mechanics of polymers and a key to the explanation of the various physical states are the relaxation properties of these materials. The molecular nature of relaxation, the properties of liquids and amorphous polymers are exactly the same. Both atoms and molecules in low-molecular liquids are compelled by thermal motion to go from one equilibrium configuration into another, and this is the case with segments of linear macromolecules, which are displaced from one position to another. Here the frequency of segment transition from one equilibrium state to the next depends on the height of potential barriers and the temperature, as well as on the stress — the higher the stress, the more easily segments will go in the direction of the force, and the more difficult it is for them to go in the opposite direction. The development of chain deformation proceeds by successive displacement of segment, i.e., the process takes place in time. Thus highly elastic deformation lags behind the stress. As a result, under periodic stress variations, at each deformation cycle there will be mechanical losses, represented on the diagram by a hysteresis

loop. In other words, the phenomenological cause responsible both for stress lagging behind strain and mechanical losses is internal friction.

Over a period of oscillation or over the observation time, highly elastic deformation will not at once reach its maximum value, since the variation in chain configuration caused by the applied force will take place gradually, rather than instantaneously, due to internal friction.

At elevated temperatures, the "settled life" time of each segment is so small for rubbers that after application of a load, the chains deform very rapidly (after $10^{-3}$-$10^{-5}$ sec at 20°, depending on the type of rubber).

In grid polymers, the relaxation properties are reflected in stress relaxation, highly elastic aftereffects, mechanical losses, and dynamic properties that differ from static characteristics. Under a prescribed deformation, the stress will decrease with time. If a constant load is applied to the rubber, or a periodic load of constant amplitude, the strain will increase in the course of time. In the first case, there is static creep, and in the second dynamic creep (highly elastic aftereffects). Both in the process of stress relaxation, and in the process of aftereffects, the modulus of high elasticity decreases, approaching the equilibrium value $E_\infty$.

The mechanical losses of amorphous polymers reach their maximum value when the relaxation time $\theta$ becomes comparable with an oscillation.

Maximum mechanical losses are observed at $T_g$ (Fig. 1). In the highly elastic state, mechanical losses (of rubbers) depend on frequency and rate of deformation. The dynamic rubber modulus E, like the mechanical losses, depend on frequency and rate of deformation. This is associated with the fact that in dynamic regimes, the work done by external forces is exerted not only against the highly elastic forces, but also against friction forces. As a consequence, as experiment has shown, for static

and dynamic deformation regimes, the modulus of high elasticity consists of two parts, $E = E_\infty + E_1$, where $E_\infty$ is the equilibrium modulus, and $E_1$ the nonequilibrium part of the modulus, contributing, respectively, to the highly elastic forces and internal-friction forces resisting deformation of the rubber. The limiting value of the highly elastic dynamic modulus is the modulus $E_0'$.

The equilibrium modulus depends chiefly on the degree of transverse cross linking (vulcanization). The nonequilibrium part of the modulus, like the internal friction, depends essentially on the number of polar groups in the rubber chain, and on the amount of active filler, i.e., on the nature and intensity of intermolecular interaction. As the temperature decreases, the frequency rises, and the rate of deformation goes up, the nonequilibrium part of the modulus $E_1$ and the mechanical losses increase, reaching a maximum when the grid polymer goes over to the glassy state. Table 1 gives several dynamic characteristics for various grid polymers with equilibrium modulus $E_\infty = 9$ kg/cm$^2$; they were found by the method of spontaneous contraction at 20°. The increase in $E_0'$ with increasing polarity of the rubber illustrates the roll of intermolecular interaction for the internal friction of these polymers. (The determination of $T_g$ was made with spontaneous contraction, i.e., at a deformation rate of about $10^3$ sec$^{-1}$).

TABLE 1

| Каучук 1 | НК 2 | СКБ 3 | СКН-30 4 | СКН-18 4 | СКН-26 4 | СКН-40 4 |
|---|---|---|---|---|---|---|
| $T_g$ (°C) | −50 | −39 | −43 | −27 | −20 | −10 |
| $E_0'$ (кг/см²) 5 | 12.7 | 17.0 | 20.5 | 26.0 | 32.0 | 48.0 |
| Механические потери (условные единицы) 6 | 2.0 | 4.5 | 6.8 | 8.0 | 11.0 | 20.0 |

1) Rubber; 2) NK; 3) SKB; 4) SKN-xx; 5) $E_0'$ (kg/cm$^2$); 6) mechanical losses (arbitrary) units.

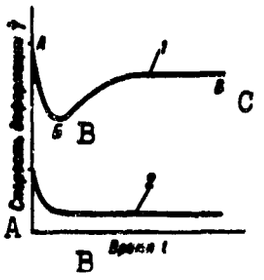



Fig. 3. Change in rate of polymer shear deformation during viscous flow under constant high (1) and low (2) shear stress. A) Rate of deformation $\dot{\gamma}$; B) time, t.

Internal friction (see Internal friction, Viscosity) nearly always (except in shock absorbers) plays a negative role in operation, i.e., it leads to the formation of heat. Under multiple and impact deformations, mechanical losses lead to a temperature rise, which has a harmful influence on fatigue strength and wear.

The rheological properties of polymers. In addition to elastic and highly elastic deformations, under limiting conditions, irreversible deformations appear in polymers; these are associated with a specific complex of rheological properties. As a rule, flow investigations are carried out under shear deformation, and less frequently in tension or compression. Under low stresses, linear polymers (rubbers, plastics) begin to flow noticeably above the yield point, while spatially structured polymers do not flow until the temperature of chemical breakdown of the space grid is reached. Under sufficiently high stresses, all polymers may flow at any temperature. The flow mechanisms are quite different for the two cases. In this connection, all viscous-flow processes can be classified into two fundamental forms, which in the ensuing discussion are arbitrarily called "physical" flow (for linear polymers alone), taking place by displacement of macromolecular segments in the direction of viscous flow without disruption of molecules or changes in the polymer chemical structure, and "chemical" flow (for

both linear and spatially structured, or grid, polymers).

All types of flow play a commanding role in the processes used to work polymers: "physical" flow is encountered in various processes used to treat linear polymers, while "chemical" flow is used both in working and in operations with polymer products at high temperatures or under high stresses.

Polymer flow is characterized by: high viscosity in connection with the high molecular weight of polmers; the special role of stress, which reduces viscosity during processing; the fact that the temperature coefficient of viscosity is unaffected by many factors, including molecular weight and stress; and by the development of elastic deformation in polymer viscous flow.

Irreversible macromolecular displacement occurs under conditions of deformation. At the first instant after application of the stress, the shear-strain rate $\gamma$ is at a maximum (point A, see Fig. 3), i.e., highly elastic deformation and flow at once develop simultaneously. The rate of highly elastic deformation then rapidly drops to zero (point B), where the highly elastic stress, reaching a maximum, is balanced by the external stress. On section BC, we observe only irreversible flow, at a rate that increases owing to partial disruption of the hypermolecular structures, and then enters the stationary flow stage. At very low flow rates, disruption of the intermolecular structure of a linear polymer is almost entirely absent, and the relationship (curve 2) has the monotonic form most frequently cited in the literature. Here the rate of highly elastic and viscous deformation components is reduced, and true viscosity rises to the limiting value, owing to the increase in internal friction as the macromolecules straighten out in the direction of the applied forces.

Strength properties of polymers are closely associated with the

deformation property (see Strength of polymers, fatigue of materials, time dependence of strength).

The friction properties of polymers are also among the most important mechanical properties of these materials. The friction force $F = cS$, where $c$ is a coefficient that depends on experimental conditions and the nature of the rubbing surfaces, S is the actual contact area, depending on the mechanical properties of the friction pair, the surface roughness, and the value of normal load. Friction in solid polymers is similar in nature to friction of solids. The only difference lies in the fact that for solid polymers, the actual contact area is formed as a result of forced elastic deformation at the areas of contact, while for metals, it is formed by plastic deformation.

Particular interest attaches to friction in rubber-like grid polymers on solid surfaces, since the nature of friction in such materials is basically different from that in solids. The chains of the space network of grid polymers at the actual contact sites engage with the surface of a solid for a limited time $\theta$, and then break away, and go to new contact sites, a distance $\lambda$ apart, on the average. This process takes place under the influence of thermal motion and is analogous to the transfer of macromolecular segments from one equilibrium position to another in the polymer itself. Each elementary act of transition is associated with an expenditure of energy (activation energy), required to overcome adhesive forces. Under the influence of a tangential force F, equal to the friction force for a steady process, the probability of chain transitions two new contact sites will not be the same in all directions. The probability of a transition in the direction of the force F will be slight. As a result, the rubber will be observed to slip with respect to the backing at a rate $v$ which, according to the relaxation theory of friction (for $v > 0.001$ mm/min), will equal

(8)

where $\theta_0$, $\lambda$ are constants, T is the absolute temperature, $\gamma = \lambda/N_k$, $N_k$ is the number of chains in contact with the solid surface, which depends on the actual contact area and the density of the polymer space network, and $U_0$ is the activation energy for the friction process, which depends on the type of rubber.

TABLE 2

Thermal Conductivity of Solids and Rubbers

| 1 Вещество | 2 Теплопроводность (кал/см сек °С) |
|---|---|
| 3 Медь | 0,92 |
| Алюминий 4 | 0,48 |
| 5 Железо | 0,13 |
| Сталь 6 | 0,12 |
| 7 Стекла | $2 \cdot 10^{-3}$ |
| Резины 8 | $0,4-0,8 \cdot 10^{-3}$ |

1) Substance; 2) thermal conductivity (cal/cm·sec·°C); 3) copper; 4) aluminum; 5) iron; 6) steel; 7) glass; 8) rubber.

TABLE 3

Heat Capacity of Solids and Polymers

| Вещество 1 | Теплоемкость (кал/г °С) 2 |
|---|---|
| 3 Медь | 0,09 |
| Железо 4 | 0,11 |
| Стекла | 0,20 |
| Лед 6 | 0,42 |
| 7 Пластмассы | 0,5 |
| Резины 8 | 0,30—0,50 |

1) Substance; 2) heat capacity (cal/g·°C); 3) copper; 4) iron; 5) glass; 6) ice; 7) plastics; 8) rubber.

Thermophysical properties of polymers. The most important thermophysical properties of materials include thermal conductivity, heat capacity, and thermal expansion (and shrinkage). The thermophysical constants are required for thermal calculations pertaining to processing and operation of polymer products. Such calculations are of parti-

TABLE 4

Coefficients of Linear Expansion

| Вещество 1 | Коэффициент линейного расширения ($\alpha \cdot 10^4$ град$^{-1}$) 2 |
|---|---|
| 3 Алюминий | 0.24 |
| Сталь 4 | 0.10 |
| 5 Железо | 0.11 |
| Лед 6 | 0.51 |
| 7 Стекло (неорганическое) | 0.03—0.09 |
| 8 Стекло (органическое) | 0.7—1.2 |
| Резины 9 | 1.2—2.3 |

1) Substance; 2) coefficient of linear expansion ($\alpha \cdot 10^4$ deg$^{-1}$); 3) aluminum; 4) steel; 5) iron; 6) ice; 7) glass (inorganic); 8) glass (organic); 9) rubbers.

cular importance in connection with heat formation under multiple loading, in vulcanization processes for rubbers and ebonites, etc. The thermoconductivity of rubbers used in the manufacture of automotive and aircraft tire casings is the most important factor in determining tire service life.

As we can see from Table 2, of the most important materials, the rubbers have the poorest thermoconductivity, which raises the hazard of heat accumulation within the rubber in products subject to periodic loads, and the associated development of dangerous aging processes. Since the introduction of carbon black as a filler increases rubber thermoconductivity, technical-grade rubbers have roughly twice the thermoconductivity of the initial rubbers. Thermal conductivity is almost invariant from one rubber to another (0.3-0.4 cal/cm·sec°C).

The heat capacity together with the density (for rubbers, the latter is equal almost exactly to 1g/cm$^3$, or somewhat more) determine the most important thermophysical quantities — the thermal diffusivity and the thermal activity. It is clear from Table 3 that the heat capacity of plastics and rubbers is close to that of the glasses. The heat capacity of rubber drops with increasing filler content. For unvulcanized

rubbers it amounts to 0.45-0.50 cal/g·°C, and for vulcanized rubbers it is somewhat lower (Table 3).

The thermal expansion of rubbers on heating and thermal shrinkage on cooling are of great practical significance, particularly in shrinkage calculations for products molded in dies. Table 4 gives by use of the coefficient of linear expansion for the most important materials. It is clear from the table that rubber has the greatest thermal shrinkage (10 to 20 times that of the metals). Thus we can see the need to consider shrinkage of rubber products in designing dies.

Thermal shrinkage is a factor responsible for loss of tightness by packing elements at low temperatures (see packing properties of rubbers). Losses of packing properties occur owing to solidification of rubber at low temperatures and the sharp difference between the coefficients of expansion for metal and rubber. The coefficients of linear expansion for rubbers in the vitrified state are several times greater than for steel, so that rubber shrinkage takes place at a considerably more rapid rate. Thus at seals, the contact stress is reduced, leading to a total loss of tightness.

Thermal shrinkage and expansion are frequently used as a method for investigating the structural vitrification and softening of polymers.

The gas permeability of polymers is one of the most important operating characteristics. Rubbers possess fairly high gas permeability, being hundreds of times better in this respect than metals. As a rule, the high gas permeability of polymers is a negative property from the engineering viewpoint, since gas permeability determines the service lives of various containers filled with hydrogen or helium.

The gas permeability of polymers fluctuates within a wide range, depending on the nature of the gas and the structure of the polymer.

The greatest gas permeability is exhibited by unvulcanized rubbers of normal chemical structure, containing no polar groups in the molecule (natural rubber, SKBM [Buna], etc.). Common structural elements for creating a seal are rubber vacuum packing parts. The greater $T_g$, the lower the gas permeability. Gas permeability is greater for frost-resistant polymers with low vitrification temperature than for non-frost-resistant types. As a consequence, polymers cannot be expected to simultaneously satisfy demands for good frost resistance and low gas permeability with respect to all gases, although there may be exceptions to this rule among the polymer materials.

The electrical properties of polymers are of great significance in electrical and radio equipment.

Plastics, vulcanized and unvulcanized rubbers, and ebonites are employed as insulating materials in electrical equipment and the cable industry. Rubbers with moderately reduced resistance (antielectrostatic rubbers) are employed as a material that carries off static charges appearing on the surface of the rubber during friction with solid surfaces, gases, and air. The current-conducting properties of rubbers are very sensitive to temperatures and deformations. In addition to the typical polymers — dielectrics — there exist polymers (with systems of conjugate multiple bonds) which resemble inorganic semiconductors and paramagnetic materials in their electrical and magnetic properties. The electrical properties of polymers are also used in the study of their structure. The fundamental electrical characteristics of polymers (dielectrics) are the specific electrical conductivity, electrical strength (electrical field strength at which breakdown occurs), the dielectric constant, and the dielectric losses.

Polymer electrical conductivity is basically determined by the presence of low-molecular impurities, which are ion sources. Ion mobil-



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ity is determined by their interaction with the monomer units of the polymer chains, so that an increase in monomer-unit mobility (for example, as the temperature increases above $T_g$, leaps to an increase in electrical conductivity. In the vitrified state, the specific electrical conductivity of polymers $\cong 10^{-15}$-$10^{-18}$ $(ohm \cdot cm)^{-1}$, while for rubbers, depending on composition and production technology, it may increase from $10^{-15}$ to 1 $(ohm \cdot cm)^{-1}$. With increasing temperature (below $T_g$), the electrical conductivity of polymers rises exponentially. The polymer breakdown voltage depends on the presence of polar groups increasing the breakdown voltage, as well as on the content of moisture and air inclusions, which sharply reduce electrical strength. The breakdown of voltage of polymers equals $10^5$-$10^7$ v/cm, for ebonite it equals $2\text{-}8 \cdot 10^5$ v/cm, and for rubbers is $1\text{-}2 \cdot 10^5$ v/cm. Here the temperature is of significance for the electrical strength of rubbers.

The frequency and temperature dependence of dielectric constant and dielectric loss tangent $\tan\delta$ for polymers is qualitatively the same as for other dielectrics. Two types of dielectric losses have been established for polymers, corresponding to two types of kinetic units in polymers: the dipole-elastic losses are caused by motion of individual segments of chains or their groups. The dipole-radical losses are associated with the motion of smaller and more mobile kinetic units, in particular polar radicals. Accordingly, there are two mechanisms to account for the dielectric constant of polymers. The maximum $\tan\delta$ values for certain polymers are given in Table 5.

The electrical relaxation time of polymers is expressed by an exponential formula similar to the formula for mechanical relaxation time. In many cases, the maximum mechanical and dielectric losses coincide or are nearly the same. The activation energy for dipole-radical losses (~10 kcal/mole) is roughly an order of magnitude less than the appar-

TABLE 5

Dielectric Losses for Certain Polar and Nonpolar Polymers (at $10^3$ cps)

| 1 Полимер | 2 Дипольно-эластические потери | 3 Дипольно-радикальные потери |
|---|---|---|
| 4 Полистирол | $3 \cdot 10^{-4}$ | — |
| 5 Поливинилкарбазол | $10^{-1}$ | — |
| 6 Полиэтилен | $3 \cdot 10^{-4}$ | — |
| 7 Поливинилацетат | $3 \cdot 10^{-1}$ | $2 \cdot 10^{-1}$ |
| 8 Полиметилметакрилат | $3 \cdot 10^{-2}$ | $7 \cdot 10^{-2}$ |
| 9 Полиэтилметакрилат | $8 \cdot 10^{-3}$ | $6 \cdot 10^{-2}$ |
| 10 Полиметилакрилат | $10 \cdot 10^{-3}$ | $2.7 \cdot 10^{-2}$ |

1) Polymer; 2) dipole-elastic losses; 3) dipole-radical losses; 4) polystyrene; 5) polyvinyl carbazole; 6) polyethylene; 7) polyvinyl acetate; 8) polymethyl methacrylate; 9) polyethyl methacrylate; 10) polymethyl acrylate.

ent activation energy for dipole-elastic losses (80-150 kcal/mole). Stereoregularity, chemical structure, as well as polymer crystallization, which hinders dipole orientation, have a substantial influence on dielectric losses.

G.M. Bartenev

Modification of Polymers

Directional changes (modifications) in the physical, mechanical, and chemical properties of polymers may occur under the influence of various factors. Polymer-analogous transformations are most frequently used for polymer modification, as well as for macromolecular reactions, orientation, and crystallization of polymers.

Modification by the method of polymer-analogous transformations consists in replacing single functional groups of a polymer by others without changing its structure or the chain length. The result of such a transformation is a considerable change in solubility, degree of crystallization, vitrification temperature, viscosity, strength, and other polymer properties. Such reactions include, for example, the derivation of ethers and esters of cellulose; synthesis of polyvinyl



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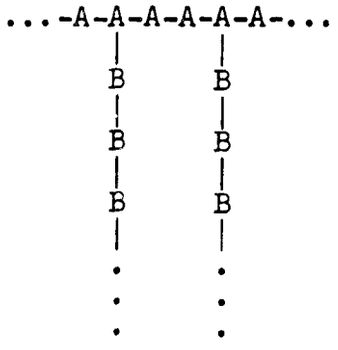
alcohol by saponification of polyvinyl acetate, etc.

This group of methods also includes intramolecular detachment of functional groups, or ring formation. This method is used to synthesize polyvinylenes and other polymers containing a system of conjugate double bonds, and possessing increased thermal stability. Intramolecular ring formation, taking place under conditions favoring the formation of stressed rings, leads to an increase in stiffness and vitrification temperature of the polymer. This reaction is used to produce so-called cyclorubber — a hard and brittle product employed in the production of cements and protective coatings.

Modification by the method of macromolecular reactions — block copolymerization, the process of obtaining grafted copolymers, "cross-linking" of polymers.

A macromolecule of a block copolymer contains chains (blocks) of the same chemical composition, separated by polymer segments of another chemical composition or by low-molecular cross-linking groups. Block copolymers are constructed in accordance with the following general scheme: A-A-A-B-B-A-A-A-B-B-B-B-, where A and B are groups of different chemical composition.

Graft copolymers are obtained by "grafting" of side chains to the main polymer chain. A graft copolymer may be represented schematically as follows:



I-18P18

Cross-linking of macromolecules consists in the formation of emical bonds between them, resulting in the creation of a rigid ructure. Typical examples of production of a cross-linked polymer are lcanization of rubber by means of sulfur, oxides, or salts of carbox- ic acids of polyvalent metals, etc. The formation of a three-dimen- onal structure increases the resistance of the material to thermal, hemical, or mechanical actions, produces insolubility, and almost com- lete absence of swelling. Polymers containing complexing groups, upon nteraction with salts of metals yield intermolecular coordinate-co- alent (chelate) bonds. Coordination bonds appearing together with onic bonds increased the stability of compounds under hydrolysis and he effects of high temperatures.

Orientation and crystallization of polymers increase the inter- olecular bonds on crystallization, so that there is an increase in he modulus of elasticity and hardness of the polymer, as well as an ncrease in the tensile strength. Orientation of polymers (both amor- hous and crystalline) leads to the appearance of anisotropy in the echanical and physical-chemical properties: thus, the strength of riented polymers is higher in the direction of orientation than in ne perpendicular direction.

A polymer is usually oriented by stretching in one direction. A onoriented crystalline polymer is stretched at temperatures lower than ne melting point of the crystalline segments, but higher than the oftening point of amorphous segments. Here in addition to orientation f crystalline segments, there may be an increase in the polymer crys- allinity owing to crystallization of macromolecules in amorphous re- ions. Amorphous polymers are subjected to considerable orientation at emperatures close to the softening point.

A.I. Polyakov



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Economic Effectiveness of Using Polymers in the National Economy

The production of polymer materials is oriented toward utilization of available and inexpensive raw materials based on petrochemistry (petroleum and petroleum-refining products, natural and by-product petroleum gases) as well as coke chemistry and certain types of vegetable raw materials.

Plastics occupy a special position with respect to the polymer materials; they are widely employed in all sectors of the national economy. Great advantage is gained when plastics are used to replace nonferrous metals in electrical industry, in chemistry and petroleum machine building, as well as in construction. As an example, 1 ton of epoxy resin used in electrical equipment yields a savings of more than 4 tons of copper. The cable industry alone, which makes wide use of polyethylene and vinyl blend, can free hundreds of thousands of tons of lead for other needs of the national economy.

In the USSR, the production of plastics in 1961 increased by 20% over the 1960 level, and by 17% in 1962 as compared with 1961. According to preliminary calculations, for each 1 $m^3$ of steel, roughly 0.3 $m^3$ of plastics will be produced.

The basic fields of application of plastics as structural materials are the following: 1) large elements and parts and housings, loaded or unloaded (fiberglass reinforced plastics, polycarbonates, polyformaldehyde, polyamides, polypropylene, phenoplasts, cloth laminate, wood plastics, copolymers of styrene, Viniplast, polymethyl methacrylate); units on parts with good friction characteristics (asbestos-fiber filled plastics, asbestos-cloth laminates, rubber-asbestos compounds); 3) parts, elements, and thin coating layers with good antifriction characteristics and increased wear resistance (polyformaldehyde, polyamides, polyfluoroethylene resin, cloth laminate, wood plas-

tics); 4) parts, elements, tubing and coatings with good chemical stability (pentone, polyfluoroethylene resin, polypropylene, polyethylene, polyvinyl chloride, epoxy resins, phenol, furane, and other resins); 5) elements, parts, and coatings with good electrical insulating characteristics (polyfluoroethylene resins, silicone materials, polycarbonate, pentone, polyethylene, polypropylene, polyvinyl chloride, polystyrenes and their copolymers, fiberglass plastics, phenoplasts, aminoplasts, epoxy, polyester, furane, and other resins); 6) adhesives (epoxy, polyamide, phenol, polyvinyl butyral, carbamide, silicone, etc.); 7) decorative and secondary parts and elements (phenoplasts, polystyrene and its copolymers, polyethylene, polypropylene, polyamides, polyacrylates, etrols, aminoplasts).

The basic structural materials in the manufacture of large bearing or loaded structural elements in aircraft, machine-tool, or ship construction are reinforced plastics and, in particular, fiberglass reinforced plastics. They are lighter than aluminum by a factor of 1.5, than steel by a factor of 4.5, and are not inferior in strength to nonferrous metals and alloys. Fiberglass-reinforced plastics have found wide application as substitutes for metal in the manufacture of body and chassis parts in transportation, automotive-vehicle and agricultural-machine building, rocket construction, etc. On the average, this yields a 20-30% decrease in the weight of parts and in operating expenditures. For housing parts and other medium-size and small parts very widely employed in machine building to replace cast iron and steel, phenoplasts, fiberglass-laminates, and other structural plastics are employed. In the manufacture of large-size and housing elements, block Capron has also come to be of significance — it is a product of high-speed low-temperature polymerization of caprolactam; this has permitted a considerable expansion in the field of application of Capron, an im-

provement in the characteristics of the parts produced (water absorption, strength, hardness), has permitted elimination of internal stresses in products, and a sharp reduction in expenditures for high-priced molding machines and dies.

Friction parts made from plastic (brake shoes, clutches, linings, strips, clutch disks, etc.) set up a high braking effect, withstand increased impact loads and temperatures, do not wear on parts in contact with them, for example, railway-car brake shoes made from 6KV-10 compound yield a 3-5 times increase in service life as compared with cast iron shoes, have double the coefficient of friction, and one fourth the weight; they permit an increase in train speed, reduce rail wear on braking sections, etc. A wide variety of antifriction parts are made from plastics (sliding-friction bearings, pillow-blocks, sleeves, rollers, gears, gear wheels, packing, working elements of hydraulic machinery, etc.). This produces savings in nonferrous metals and electric power, increases service life, raises productivity of equipment, etc.

The good chemical and corrosion resistance of many forms of plastics have made them irreplaceable in the production of various chemical apparatus and other types of equipment operating in aggressive media (heat exchangers, column and reaction apparatus, tanks, piping, pumps, fans, filters, compressors, etc.). Here the chief advantage lies in the sharp increase in service life, as well as in savings on stainless steel, lead, and other scarce materials. Plastics are also used in the manufacture of all possible types of inserts, washers, sleeves, rings, valves, linings, coatings, and so forth, for which the increased service life provides a significant savings in operating cost. Another promising trend is the utilization of plastics in composite materials and thin coatings. Rolled steel clad with polyvinyl chloride is very workable and gives good service life in operation; it finds wide em-

ployment in railway-car, ship, and aircraft construction, and in the chemical, furniture, radio, and other industries. Plastics are effectively used in process equipment; thus, by manufacturing dies (for casting, bending, and drawing) from epoxy resins, labor consumption is reduced by a factor of 5-6, and cycles by a factor of 4-5. Plastic casting patterns are low in weight, resistant to corrosion, warping, and swelling, preserve their initial dimensions under long-term service, and are simple to make and repair. It is also extremely advantageous from the economic viewpoint to use investment (shell, jacket) molds made from pulverized bakelite, as compared with sand molds: greater casting precision, a reduction in liquid metal used by 15-20%, and a 7-8 fold reduction in mold materials, an average increase in productivity of 30%, and better working conditions in the casting process, improved casting quality, reduced rate of rejection, and rapid return of additional capital expenditures (1-1.5 years). The utilization of plastics in machine building yields an economy of 65-100 rubles for each ton of castings. The manufacture of machine elements and parts from plastics, owing to the considerable reduction in the number of process operations (5-10 fold, on the average), reduces process labor consumption by a factor of 3-5. At present, more than half of the plastics produced in the USSR are used as structural materials in various branches of machine building, and particularly in the electrical-equipment and instrument industries.

The coefficients of utilization for mold materials (ratio of part net weight to the weight of the raw materials used in its manufacture) are very important indicators; for various processing methods they fluctuate (according to plan data) over the following ranges: compression molding 0.89-0.92, die casting 0.93-0.95, extrusion of hoses and tubing 0.92-0.95, vacuum- and pneumatic molding 0.95.



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Expenditures on the manufacture of 1 ton of structural parts and semifinished products from plastics (neglecting expenses for material) amount to the following, on the average (in rubles): molded, 400-600, cast, 600-800, vacuum- and pneumatic molded, 400-500, polyethylene film, 300-400, tubing, 200-300, Viniplast and polyvinyl chloride blend, 100-200.

Synthetic rubbers are finding ever wider application as the basic material in the manufacture of many structural parts. The chief consumer of natural rubber is the tire and rubber industry. Rubber products based on general-purpose synthetic rubbers (divinyl styrene, oil-black masterbatch, polydivinyl, isoprene, etc.) and special-purpose synthetic rubbers (polychloroprene, divinyl nitrile, silicone, polyurethane, fluorine, and other rubbers) as well as rubber-like materials (Thiokol, polyisobutylene, etc.) are considerably better than natural rubbers in many characteristics (service life, resistance to various solvents and chemical reagents, to atmospheric and light effects, in elasticity, abrasion resistance, heat and cold resistance). From the production viewpoint, the chief synthetic rubbers are polyisoprene rubbers, regular-structure polydivinyl rubber, copolymers of ethylene with α-olefins, etc.

Chemical fibers are widely employed as structural materials. Many chemical fibers are better than natural fibers (cotton, wool, silk) with respect to breaking strength, elasticity, shrinkage, stability under multiple deformation, abrasion, resistance to aggressive media, hygroscopicity, and heat resistance.

In the USSR, over a 5-year period, the production of chemical fibers rose from 166 to 310 thousand tons, i.e., it nearly doubled. The USSR is fourth in the world and second in Europe in the production of chemical fibers. Table 4 shows the effectiveness of using chemical fi-

bers for technical purposes.

TABLE 6

Economic Effect of Using 1 Ton of Chemical Fiber (Capron) for Technicological Purposes

| 1 Области применения | Экономия (тыс. руб.) от снижения 2 | |
|---|---|---|
| | 3 себестоимости | 4 капитальных затрат |
| 5 Шинная промышленность | 3.5 | 8.5 |
| 6 Резинотехническая промышленность (на примере транспортерных лент) | 8—10 | 25—80 |
| 7 Производство канатов | 3—8 | 9—12 |
| 8 Производство электроизоляционных материалов (взамен натурального шелка) | 30—60 | 8—10 |
| 9 Рыбная промышленность (орудия лова) | 2—2,5 | 4—9 |
| 10 Производство технических сукон и других технических тканей (взамен натуральной шерсти) | 5 | 10 |

1) Field of application; 2) savings (1000 rubles) resulting from a decrease in; 3) cost; 4) capital expenditure; 5) tire industry; 6) rubber industry (using conveyor belt as an example); 7) production of cable; 8) production of electrical insulating material (to replace natural silk); 9) fishing industry (nets and related gear); 10) production of technical cloths and other technical fabrics (to replace natural wool).

The economic effect of this of using polymer materials and products as structural materials is comprised of the radical improvement in parameters of machines, equipment, structures, etc. (reduction in metal volume and weight, increased service life, reliability productivity, comfort, etc.) and related savings in operating expenditures by the industrial consumers; the possibility of obtaining enormous savings of metals, and other more expensive materials than wood, wool, silk, cement, etc.); the use of less expensive methods for manufacturing structures (reduction in labor consumption, costs, capital expenditures, faster schedules for preparing for production of new products); a considerable improvement in working conditions. With allowance for differences in the specific gravities of materials and their physical-mechanical characteristics, 1 ton of structural elements and parts made

from plastics may, on the average, actually replace 3-5 tons of metal, while 1 ton of fiberglass reinforced plastic (in loaded or bearing structural elements) will replace 2-2.5 tons of rolled steel.

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Sazhin, B.I., ibid., 1960, Vol.29, No. 7, Bartenev, G.M., in the book, Tr. 3 Vses. konferentsii po treniyu i iznosu v mashinakh [Transactions of the Third All-Union Conference on Friction and Wear in Machines], Vol. 2, Moscow, 1960, pages 7-14; Kargin, V.A., Sogolova, T.I., "Zhurnal fiz. khimii," [Journal of Physical Chemistry], 1957, Vol. 31, No. 6, pages 1328-36; the same "Problemy fiz. khimii" [Problems in Physical Chemistry], 1958, No. 1, pages 18-21; Tobolsky, A.V. Properties and Structure of Polymers, N.Y.-London, (1960); Flory, P.J., Principles of Polymer Chemistry, [N.Y.], 1953; Ferry, J.D., Viscoelastic Properties of Polymers, N.Y.,-London, [1961]; Schallamach A., "Proc. Phys. Soc. B," 1953, Vol. 66, part 5, pages 386-92; the same, "Wear," 1957/58, Vol. 1, pages 384-417; McKelvey, J.M., Polymer Processing, N.Y., 1962; Bueche, F., Physical Properties of Polymers, N.Y., 1962.

N.P. Fedorenko, I.V. Rakhlin

POLYMONOCHLOROSTYRENE – see <u>polystyrene</u>.

POLYNOSE FIBER – artificial cellulose hydrate fiber. Is produced primarily as a staple fiber. Known under the names Z-54 (Belgium), Toramomen (Japan), C-28 (England), etc. Polynose fibers differ in a number of manners from standard and high-strength viscose fibers and are characterized by high dry strength (30-40 km), insignificant loss of strength in the wet state low elongation (8-10% in the standard

$$\left(\frac{\text{strength in the wet state}}{\text{strength in the standard state}} = 0.8\right),$$

and 12-13% in the wet state); high deformation modulus (800-1000 $kg/mm^2$) and high elasticity (when the fiber is elongated by 3%, 70-75% of its initial length is restored immediately as compared with 45-50% for ordinary viscose fiber); insignificant shrinkage and high dimensional stability of products after repeated washings; low swelling by weight (50-60%), high resistance to alkalis (8% NaOH), thus coming close with respect to these indicators to cotton fiber. The remaining properties of polynose fibers are close to the indicators of viscose staple fiber. Fields of application: engineering shrinkless fabrics, fishing tackles, work clothing.

References: "Skinner's Silk and Rayon Rec." Vol. 33, No. 11, pages 1084-85, 1959; "Man-Made Text.," Vol. 37, No. 435, pages 42-47, 1960.

G.G. Finger

POLYOLEFINES – products of the polymerization of unsaturated hydrocarbons in the ethylene series. Of practical importance are polyethylene, polypropylene, polyisobutylene, as well as the copolymers of ethylene, propylene, and isobutylene.

A.N. Vardenburg

POLYOLEFIN FIBER – synthetic carbon-chain fiber from poly-α-olefins of various structures (stereoregular, atactic, stereoblock copolymer). Stereoregular polymers have a crystalline structure, atactic polymers

Comparative Characterization of Physicochemical Properties of Polyolefin Fibers with Different Polymers Serving as Bases

| 1 Свойства | 2 Волокна на основе | | | | |
|---|---|---|---|---|---|
| | полиэтилена разветвленного (высокого давления) 3 | полиэтилена линейного (низкого давления) 4 | полипропилена стереорегулярной структуры 5 | поли-3-метилбутилен-1 6 | 7 поли-4-метилпентилен-1 |
| Уд. вес . . . . . 8 . . . . . | 0,92 | 0,95 | 0,92 | 0,90 | 0,83 |
| Относительная влажность (при стандартных условиях) (%) . . . . . 9 . . . | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 10 Усадка за 20 мин. (при 100%-ном удлинении) (%) | 50—60 | 40--50 | 10—15 | 6—12 | 6—10 |
| 11 Начальный модуль упругости (кг/мм²) . . . . . | 1,38 | 9,5 | 9,66—11,59 | 16,2—18,0 | — |
| 12 Разрывная длина (км) 13 . | 9,0—13,5 | 49,5—63,0 | 49,5—63,0 | 45,0—55,0 | 55—60 |
| Область размягчения (°С) . | 90—100 | 120—130 | 160—165 | 250—260 | 230 |
| 14 Потеря прочности (при 100° по сравнению с 20°) (%) . | 100 | 80 | 40 | 20 | — |
| Удлинение (%) . . . 15 . . | 45—50 | 25—30 | 15—25 | 18—30 | 10—15 |

1) Properties; 2) fibers on the base of; 3) branched (high pressure) polyethylene; 4) linear (low pressure) polyethylene; 5) polypropylene with a stereoregular structure; 6) poly-3-methyl-butylene-1; 7) poly-4-methyl-pentylene; 8) specific weight; 9) relative moisture (under standard conditions) (%); 10) shrinkage after 20 minutes (on 100% elongation) (%); 11) initial modulus of elasticity (kg/mm$^2$); 12) rupture length (km); 13) softening range (°C); 14) strength loss (at 100° in comparison with 20°) (%); 15) elongation (%).

have properties of amorphic polymers, the properties of stereoblock copolymers depend on the relative proportions of stereoregular and atactic structures in the molecular chain. The atactic and stereoblock copolymer structures have a plastifying effect on stereoregular polymers.

Polyolefin fibers are obtained from a melt of the polymer on a special endless-screw machine; fiber made from polypropylene can also

be formed from the solution.

Polyolefin fibers possess satisfactory physicomechanical properties, chemical resistance to acids, substantial frostproof qualities; do not absorb moisture (see Table). Shortcomings of polyolefin fibers: tendency to thermal oxidation failure in the presence of atmospheric oxygen and to photo-destruction (only moderate resistance to light). These shortcomings are eliminated by adding stabilizing reagents to the polymers.

Polyolefin fibers are used in engineering as filter, insulation and structural materials; polypropylene fibers in the pure form and mixed with other fibers are also used for making of consumer goods.

References: Zverev, M.P., "KhV," [Chemical Fibers], No. 6, page 3, 1960; Fourne, F., "Textil-Praxis," [Textile Practice], No. 1, S.7, 1960; Erlich, V.L., "Text. Res. J.," Vol. 59, No. 9, page 679, 1959.

M.P. Zverev

POLYPHENE – see Fibers made from fluorine-containing polymers.

POLYPROPYLENE – a rigid thermoplastic material with good mechanical properties and a softening point of the order of 150-160°, obtained by polymerization of propylene in the presence of metal-containing catalysts. Polypropylene has also the tendency toward formation of cracks under operating conditions than does polyethylene; polypropylene products do not deform at temperatures up to 130-150° and extended boiling in water; they have a cold resistance from –15 to –30°. The electrical-insulating properties, moisture- and chemical-stability of polypropylene are no poorer than those of polyethylene, while wear resistance of rubbing parts is the same as for the polyamides. Aging processes, associated with increased oxidizability occur more rapidly with polypropylene than with polyethylene. Polypropylene products deform, owing to aging processes, under conditions of extended heating, particularly at temperatures close to the melting point. In order to retard the processes of thermal aging during working and service, as well as to increase light stability, small amounts of antioxidants and carbon black are introduced into polypropylene. The permissible long-term working temperature is 100°. Stabilized polypropylene will withstand heating to 120° for 3 months or to 140° for 100 hr. Intense atomic radiation causes molecular cross-linking in polypropylene, resulting in increased hardness, brittleness, and a higher melting point. Polypropylene is stable to the effects of 80% sulfuric acid and 40% alkali, does not swell in oil, is insoluble at 20° in organic solvents, but swells slightly in some of them. It is not recommended that polypropylene be used in strongly oxidizing media. At temperatures in excess of

80°, it is soluble in aromatic and chlorinated hydrocarbons. It is easily welded in a nitrogen jet at 20°. It can be bonded by polychloroprene and epoxy adhesives, but the bond is inadequate in strength; metal coatings are applied to polypropylene by spraying or dipping of the products, heated to 250-300°, and then immersed in the molten polymer. The basic characteristics of polypropylene are given in the Table.

Basic Characteristics of Polypropylene

| 1 Показатели | 2 Полипропилен | |
|---|---|---|
| | 3 прессовочный | 4 литьевой |
| 5 Удельный вес | 0,90—0,92 | |
| 6 Температура плавления (°С) | 160—170 | |
| 7 Усадка при литье (%) | 2—3 | 1,5—2 |
| 8 Удельная ударная вязкость (кг·см/см²) | 24 Не ломаются | |
| 9 То же, с надрезом | ~5 | >7 |
| 10 Удлинение при разрыве (%) | >650 | >650 |
| 11 Предел прочности (кг/см²): | | |
| 12 при разрыве | 320 | 310 |
| 13 при сжатии | 1100 | 1080 |
| 14 Модуль упругости при изгибе (кг/см²) | 13000 | 10000 |
| 15 Динамич. модуль упругости (кг/см²) | 20000 | 19000 |
| 16 Теплостойкость по ВИКА (°С) | 90 | 85 |
| 17 Теплоемкость (кал/г·град) | 0,26 | 0,26 |
| 18 Температурный коэфф. линейного расширения α·10⁻⁵ на 1°С (30—120°) | 16 | 18—21 |
| 19 Удельное объемное сопротивление (ом·см) | $10^{16}$ | $10^{16}$ |
| 20 То же, после пребывания в воде в течение 5 суток | $>10^{16}$ | $>10^{16}$ |
| 21 ε при $10^6$ гц | 2,5 | 2,3 |
| 20 То же, после пребывания в воде в течение 5 суток | 2,5 | 2,5 |
| 22 tg δ при $10^6$ гц | 0,0005 | 0,0006 |
| 20 То же, после пребывания в воде в течение 5 суток | 0,0005 | 0,0012 |
| 23 Электрич. прочность (кв/мм) в пленках толщиной 0,1—0,2 мм | 80 | 70 |
| 20 То же, после пребывания в воде в течение 5 суток | 70—80 | 70 |

1) Characteristics; 2) polypropylene; 3) molded; 4) cast; 5) specific gravity; 6) melting point (°C); 7) casting shrinkage (%); 8) specific impact resistance (kg·cm·cm$^2$); 9) the same, with notch; 10) elongation at failure (%); 11) ultimate strength (kg/cm$^2$); 12) in tension; 13) in compression; 14) modulus of elasticity in bending (kg/cm$^2$); 15) dynamic modulus of elasticity (kg/cm$^2$); 16) VIKA heat resistance (°C); 17) heat capacity (cal/g·deg); 18) thermal coefficient of linear expansion $\alpha \cdot 10^{-5}$ per 1°C (30-120°); 19) bulk resistivity (ohm·cm); 20) the same, after holding in water for 5 days; 21) ε at $10^6$ cps; 22) tan δ at $10^6$ cps; 23) electrical strength (kv/mm) in 0.1-0.2 thick films; 24) does not break.

The yield point of polypropylene in tension is about 300 kg/cm$^2$ (20°); at 100°, it drops to 120 kg/cm$^2$. The minimum notch impact strength is observed at −20°; as the temperature drops further to −100°,

this characteristic remains almost unchanged. The values of tan $\delta$ and $\varepsilon$ (at $10^6$ cps) very little as the temperature rises to 120°.

Polypropylene is worked by die casting at 190-250° and a specific pressure of 700-1500 kg/cm$^2$. When polypropylene is cast, die temperature is 50-100°. Polypropylene is molded at 200-250° and at a specific pressure of 100-120 kg/cm$^2$; pneumatic molding is carried out at 170-210°. When polypropylene products are placed in service at temperatures in excess of 50°, there will be additional shrinkage of the order of 10-15% of the total shrinkage during product manufacture. The basic areas of application are: electrical insulation, packing films, chemically resistant tubing, instrument parts, high-strength fiber. Polypropylene is produced as a transparent colorless and odorless crystalline powder.

A.N. Vardenburg

POLYPROPYLENE FIBER – synthetic carbon-chain fiber from polypropylene of various structures (atactic, isotactic and stereoblock copolymer), the relative proportions of which in the polymer depends on the nature and quantity of the catalizer used in synthesizing the polymer [$TiCl_3$, $Al(C_2H_5)_3$]. The fiber is obtained from a melt on a special endless-screw machine in the form of filament fiber and monofiber. The raw material is propylene which forms upon cracking and pyrolysis of petroleum. Polypropylene fibers are dyed by pigment dyes in the mass or by copolymerization of propylene with a component which has an affinity to the dye. Plastification of the polypropylene reduces the strength of the fiber, but is entirely suitable for the production of consumer goods. To prevent destruction of the fiber an antioxidant (~ 1%) is introduced into the polymer before forming. Polypropylene fibers have the lowest specific weight of all the other fibers (0.90-0.91), $T_g$ –20°, $t°_{pl}$ 165-170°. Thermal conductivity $2.1 \cdot 10^{-4}$ cal/cm·sec·°C. Resistivity at 30° comprises $5 \cdot 10^{15}$ ohm·cm, at 130° it decreases to $9 \cdot 10^{12}$ ohm·cm, tangent of dielectric losses angle at 25° and 70° and 1 kc, $3 \cdot 10^{-4}$. The rupture length of polypropylene fibers is from 50 to 63 km, strength losses in the loop 17-18%. The ultimate tensile strength varies from 45.0 to 56.7 kg/mm$^2$, the elongation comprises 17-25%. Polypropylene fibers have a high resistance to alkalis and acids, are not soluble in alcohols and esters, have a good resistance to decay and mildew, but swell in hydrocarbons; are not sufficiently resistant to trichloroethene, perchloroethene, toluene and benzol. Polypropylene fibers are used for the production of filters, work clothing, naval rope,

strings and decorative fabrics; in the pure form and in mixtures with other fibers they are used for the production of knit goods, woven and nonwoven articles.

References: Zverev, M.P. "KhV," [Chemical Fibers], No. 6, page 3, 1960; "Materie plast." [Plastics] No. 8, page 723, 1960.

M.P. Zverev

POLYSTYRENE – a thermoplastic. It is produced by block, emulsion, or suspension polymerization of styrene in the presence of a catalyst (peroxides, mineral acids, halogens of metals, etc.). Polystyrene is a solid elastic material, colorless, transparent (it transmits 90% of visible light); it is perfectly waterproof (after being held for a month in water, the weight of the sample does not increase); it possesses chemical stability to alkalies and acids, in addition to concentrated nitric acid; it is mildew resistant; it dissolves in the aromatic hydrocarbons, in many ethers, and is insoluble in alcohols and gasoline. At 250-300°, polystyrene depolymerizes with evolution of the initial monomer and various aromatic products. Polystyrene is easily worked by die casting, extrusion, blowing, molding; it can be machined. Table 1 shows the main characteristics of polystyrene.

TABLE 1

Fundamental Characteristics of Polystyrene

| 1 Показатели | 2 Полистирол | |
|---|---|---|
| | 3 блочный | эмульсионный 4 |
| 5 Удельный [illegible] | 1.05 | |
| 6 Модуль упругости при растяжении (кг/см²) | 11 000 – 32 000 | |
| 7 Удлинение при разрыве (%) | 0.4 – 0.7 | 1.5 – 3.5 |
| 8 Ударная вязкость (кг·см/см²) | 12 – 18 | 15 |
| 9 Температура стеклования (°С) | 80 | |

1) Characteristic; 2) polystyrene; 3) block; 4) emulsion; 5) specific gravity; 6) modulus of elasticity in tension ($kg/cm^2$); 7) elongation at failure (%); 8) specific impact resistance ($kg \cdot cm/cm^2$); 9) vitrification temperature (°C).

TABLE 2

Characteristics of Block Polystyrene

| 1 Показатели | 2 Марка Д | 3 Марка Т |
|---|---|---|
| 4 Предел прочности при изгибе (кг/см²) | 800 | 850 |
| 5 Уд. ударная вязкость (кг·см/см²) | 12–15 | 12–18 |
| 6 Теплостойкость по Мартенсу (°С) | 80 | 80 |
| 7 Диэлектрич. проницаемость при $10^6$ гц | 2,6 | 2,6 |
| 8 Тангенс угла диэлектрич. потерь при $10^6$ гц | $3 \cdot 10^{-4}$ | $4 \cdot 10^{-4}$ |

1) Characteristic; 2) grade D; 3) grade T; 4) ultimate strength in bending ($kg/cm^2$); 5) specific impact resistance ($kg \cdot cm/cm^2$); 6) Martens heat resistance (°C); 7) dielectric constant at $10^6$ cps; 8) dielectric loss tangent at $10^6$ cps.

TABLE 3

Mechanical Characteristics of Polystyrene Film

| 1 Показатели | 2 Пленка | |
|---|---|---|
| | 3 нерастянутая | 4 растянутая |
| 5 Предел прочности на разрыв (кг/см²) | 250–280 | 900–1000 |
| 6 Удлинение при разрыве (%) | 0–1 | 3–5 |
| 7 Число двойных перегибов до разрушения | 0 | От неск. сотен до неск. тысяч, 8 в зависимости от толщины |

1) Characteristic; 2) film; 3) unstretched; 4) stretched; 5) tensile strength ($kg/cm^2$); 6) elongation at failure (%); 7) number of double flexures to failure; 8) from several hundred to several thousand, depending on thickness.

The drawbacks of polystyrene include brittleness, high nsitivity to notching, tendency to aging, crack formation, as well as low heat resistance. Catalytic polymerization in a saturated-hydrocarbon medium at 30-120° in a nitrogen atmosphere may be used to produce a polystyrene of isotactic structure, crystallizing well, and possessing the following properties: softening point 220-230°, specific impact resistance 95 $kg \cdot cm/cm^2$, Brinell hardness 30 $kg/mm^2$, surface resistivity $2 \cdot 10^{14}$ ohms, bult resistivity $1.8 \cdot 10^{17}$ ohm·cm, dielectric constant 2.8,

average breakdown voltage 27.5 kv/mm. Plasticizers (phthalates, phosphates) increase the flexibility of polystyrene, while fillers (quartz powder, silica gel, marble flour, mica powder, talc, zinc oxide) increase heat resistance, hardness, static strength, and brittleness. In order to reduce packing of polystyrene parts, they are subjected to a special heat treatment.

Block polystyrene (GOST 9440-60) is produced in two grades: D (uncolored) and T (colored). Table 2 shows the characteristics of block polystyrene.

In addition, block polystyrene is produced in rolled form, and rolled nitrile rubber.

Emulsion polystyrene is produced in the following forms: grade A powders (for widely consumed products), grade B (for technical products), grade V (for the production of foamed plastics), grade S (for products with fine pores), as well as in the form of granules. In grades A and B, emulsion polystyrene has the following characteristics: ultimate strength in bending no less than 900 $kg/cm^2$, specific impact resistance 15 $kg \cdot cm/cm^2$, and at 65% moisture 0.002; dielectric constant at 65% moisture 2.7.

Products made from emulsion polystyrene are more resistant to cracking than products made from block polystyrene.

Block polystyrene is used in the manufacture of transparent colorless film and red, yellow, green, and violet filaments. Strips of film and filaments are at least 300 m long, film is 10 and 12 mm wide and 0.45 mm thick. Filament diameter is 0.4-1.1 mm. Ultimate strength in tension is: films no less than 7.4, filaments 6.5-7.5 $kg/mm^2$. Elongation of film and filaments at failure is at least 3.1%. The dielectric loss tangent at $10^6$ cps is $4.5 \cdot 10^{-4}$. The dielectric constant is no more than 2.75. The strength and flexibility of polystyrene film increases

when it is stretched (see Table 3).

By drawing it is possible to obtain (on the basis of oriented amorphous polymers) frost-resistant shells, hoses, and tubing (without the use of plasticizers, which impair the static strength and dielectric characteristic).

Polystyrene films (capacitor and electrical-insulation) are transparent colorless strips 150 and 400 mm long, 0.10 and 0.[illegible] mm thick, and from 20 to 100 mm wide. The ultimate strength in bending is at least 5 kg/mm$^2$; the bulk resistivity is $1 \cdot 10^{17}$ ohm·cm; the dielectric constant is 2.3-2.75; the breakdown voltage is 110 kv/mm.

Applications of polystyrene are limited by its inadequate heat resistance. By polymerization of chlorinated styrenes (in the ring and in the chain) and in particular, of paradichlor-substituted polystyrenes, it is possible to obtain heat-resistant polymonochlorostyrene (PMKhS) and polydichlorostyrene "Stiramik" (PDKhS). PMKhS is a transparent plastic with a softening point about 90°. It is similar to polystyrene in its physical-mechanical properties. The ultimate strength in bending is 400-500 kg/cm$^2$, the specific impact resistance 3.5-4.5 kg·cm/cm$^2$; the dielectric loss tangent at $10^6$ cps is 0.0006, the dielectric constant 2.8, the bulk resistivity $1.0^{15}$ ohm·cm. PDKhS is a transparent material with a specific gravity of 1.38-1.40; the Martens heat resistance is 115°; it burns with a selfextinguishing flame, withstands boiling in water; the ultimate strength (kg/cm$^2$) in bending is 600, in tension 450; the specific impact resistance is 3-4 kg·cm/cm$^2$; the water resistance (weight increment in 24 hr) is 0%; the bulk resistivity is $10^{16}$-$10^{17}$ ohm·cm; the dielectric loss tangent at $10^6$ cps is 0.0002-0.0004; at $10^6$ cps, the dielectric constant is 2.6. The material is used as a heat-resistant high-frequency dielectric in the manufacture of medical instruments, as a varnish resistant to chemically active me-

dia, and in optics in the manufacture of lenses with a high index of refraction.

In the production of molded materials from polystyrene, the initial components (polystyrene, filler, coloring, plasticizers) are mixed, and the result rolled at 80-120°. The basic characteristics of polystyrene plastics are: specific gravity 1.05-1.65, ultimate strength (kg/$cm^2$) in tension 300-500, in bending 400-800; specific impact resistance 5-15 kg·cm/$cm^2$; Brinell hardness 12-21 kg/$mm^2$; Martens heat stability 65-85°; bulk resistivity $5 \cdot 10^{15}$-$5 \cdot 10^{17}$ ohm·cm; surface resistivity $10^{15}$-$10^{17}$ ohms; dielectric loss tangent at $10^6$ cps, 0.0002-0.0004; coefficient of thermal expansion $6\text{-}11 \cdot 10^{-5}$; dielectric constant at $10^6$ cps, 2.2-2.8.

Polystyrene and polystyrene-based plastics are used in the manufacture of radioelectronic parts, films for high-frequency capacitors, bases for capacitors and under support and through insulators, antennas, tube panels, coil frames, chemical laboratory vessels (it is suitable for storage of hydrofluoric acid), storage-battery containers, chemical-apparatus components, type in printing devices, molding compounds, varnishes, foamed plastics.

References: Losev, I.P., Trostyanskaya, Ye.B., Khimiya sinteticheskikh polimerov [Chemistry of Synthetic Polymers], 2nd Edition, Moscow, 1964; Vardenburg, A.K., Plasticheskiye massy v elektrotekhnicheskoy promyshlennosti [Plastics in the Electrical Industry], Moscow-Leningrad, 1963.

N.P. Gashnikova

POLYSTYRENE FIBER – synthetic carbon-chain fiber from atactic or stereoregular polystyrene, which is only used for engineering purposes. It is also produced under the name Styroflex. Polystyrene fibers have a high resistance to alkalis and acids and do not swell in water. A shortcoming of polystyrene fibers is not too high elasticity (particularly this is true of fibers from atactic polystyrene). Fibers from isotactic polystyrene are distinguished by higher heat resistance, strength and other valuable properties than fibers from atactic polystyrene. The specific weight is 1.04 (1.08) (the numbers in parentheses pertain to isotactic polystyrene), $T_g$ = 80°, $t°_{pl}$ (220-230). Shrinkage of atactic polystyrene fiber at 100° is 20% (2), it is soluble in hydrocarbons (isotactic polystyrene fibers only swell). The rupture length of atactic polystyrene fibers is 8.7-9.6 km (57-60), strength losses in the node 72.4-74.0% (56-55). Ultimate tensile strength 9-10 kg/mm² (62-65); elongation 5-6% (6-7). Polystyrene fibers are used for making monofiber.

References: Zverev, M.P., "KhV," [Chemical Fibers], No. 6, page 3, 1960; Cleerman, K.J., Koram H.J. and Williams, J.L., "Industrie Plastiques Modernes" [Modern Industrial Plastics], Vol. 6, Nos. 7-9, 1954.

M.P. Zverev

POLYSTYRENE FOAM – a light, thermoplastic, gas-filled material based on polystyrene. It is produced commercially in types PS-1, PS-2, PS-4, and PS-B and variety A for products with a bulk weight of no more than 0.05 g/cm$^3$ and variety B for products with a bulk weight of more than 0.05 g/cm$^3$. All types of polystyrene foam are produced in the form

TABLE 1

Physicomechanical Characteristics of Polystyrene Foams

| Показатели 1 | 2 ПС-1 | | | 3 ПС-2 | 4 ПС-4 | |
|---|---|---|---|---|---|---|
| 5 Объемный вес (г/см³) | 0,06 | 0,1 | 0,2 | 0,2 | 0,03 | 0,06 |
| 6 Предел прочности при сжатии (кг/см²) | 3,0 | 10,0 | 30,0 | 30,0 | 2,00 | 4,8 |
| 7 Модуль упругости при сжатии (кг/см²) | — | 550 | 2000 | 2000 | — | 335 |
| 8 Удельная ударная вязкость (кг·см/см²) | — | 1,1 | 1,9 | 1,7 | — | 0,94 |
| 9 Коэффициент теплопроводности (ккал·м·час·°С) | 0,028 | 0,033 | 0,044 | 0,045 | 0,025 | 0,028 |
| 10 Водопоглощение за 30 суток (кг/м²) | — | 0,05 | 0,06 | 0,07 | — | 0,24 |
| 11 Усадка при 60° за 24 часа (%) | — | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 |
| 12 Макс. рабочая темп-ра (°С) | 60 | 60 | 60 | 60 | 70 | 70 |
| 13 Тангенс угла диэлектрич. потерь при $10^{10}$ гц | — | $1,2 \cdot 10^{-3}$ | $2,4 \cdot 10^{-3}$ | $0,6 \cdot 10^{-3}$ | — | — |
| 14 Диэлектрич. проницаемость при $10^{10}$ гц | — | 1,1 | 1,28 | 1,36 | — | — |
| 15 Уд. объемное электрич. сопротивление (ом·см) | — | $10^{13}$ | — | — | — | — |
| 16 Уд. поверхностное электрич. сопротивление (ом) | — | $10^{12}$ | — | — | — | — |
| 17 Пробивное напряжение (кв/мм) | — | 2—7 | 5—6 | 5—6 | — | — |

1) Characteristic; 2) PS-1; 3) PS-2; 4) PS-4; 5) bulk weight (g/cm$^3$); 6) ultimate compressive strength (kg/cm$^2$); 7) modulus of elasticity on compression (kg/cm$^2$); 8) impact strength (kg·cm/cm$^2$); 9) coefficient of thermal conductivity (kcal/m·hr·°C); 10) water absorption over 30 days (kg/m$^2$); 11) shrinkage over 24 hr at 60° (%); 12) maximum working temperature (°C); 13) tangent of dielectric-loss angle at $10^{10}$ cps; 14) dielectric permeability at $10^{10}$ cps; 15) deep electrical resistance (ohm·cm); 16) specific skin resistance (ohms); 17) breakdown voltage (kv/mm).

TABLE 2

Physicomechanical Characteristics of Type PS-B [illegible]-styrene Foam as a Function of Bulk Weight

| 1 Показатели | 2 Объемный вес (г/см³) | | | | |
|---|---|---|---|---|---|
| | 0,02 | 0,03 | 0,04–0,05 | 0,06–0,07 | 0,1 |
| 3 Предел прочности при сжатии при 10%-ной деформации (кг/см²) | 1,3–1,5 | 2,0–2,5 | 2,5–4,0 | 4,5–[illegible] | 6–7 |
| 4 Предел прочности при растяжении (кг/см²) | 1,8–2 | 2,6 | 2,5–3,5 | 4,[illegible]–5 | 4,5 |
| 5 Предел прочности при изгибе (кг/см²) | 1,3–1,5 | 2,0–2,5 | 3,0–5,0 | 5,0–[illegible]0 | 12–14 |
| 6 Удельная ударная вязкость (кг·см/см²) | 0,1–0,3 | 0,3 | 0,3–0,[illegible] | 0,4–[illegible] | 0,4–0,5 |
| 7 Коэффициент теплопроводности при 20° (ккал/м·час·°С) | 0,03 | – | 19 – 20 | 0,04 | – |
| 8 Водопоглощение (объемные %): | | | | | |
| 9 за 24 часа | | | От 0,5 до 1,25 | | |
| 10 за 7 суток | | | До 2,35 | | |
| 11 Гигроскопичность при 100% влажности за 48 часов (%) | | | От 0,2 до 0,5 | | |
| 12 Потеря в весе за 24 часа (%): | | | | | |
| 13 при 60° | | | От 0,6 до 1,0 | | |
| при 90° | | | От 2,0 до 2,5 | | |
| 14 Теплостойкость (°С) | | | 60–70 | | |
| 15 Морозостойкость (°С) | | | –60,–65 | | |
| 16 Тангенс угла диэлектрич. потерь при $10^{10}$ гц | – | – | – | [illegible] $10^{-4}$ | – |
| 17 Уд. объемное электрич. сопротивление (ом·см) | – | – | – | [illegible] | – |
| Уд. поверхностное электрич. сопротивление (ом) 18 | – | – | – | [illegible] | – |

1) Characteristic; 2) bulk weight ($g/cm^3$); 3) ultimate compressive strength on 10% deformation ($kg/cm^2$); 4) ultimate tensile strength ($kg/cm^2$); 5) ultimate bending strength ($kg/cm^2$); 6) impact strength ($kg \cdot cm/cm^2$); 7) coefficient of thermal conductivity at 20° (kcal/m·hr·°C); 8) water absorption (% by volume); 9) over 24 hr; 10) over 7 days; 11) hygroscopicity over 48 hr at 100% humidity (%); 12) loss in weight over 24 hr (%); 13) at; 14) heat resistance (°C); 15) frost resistance (°C); 16) tangent of dielectric-loss angle at $10^{10}$ cps; 17) deep electrical resistance (ohm·cm); 18) specific skin resistance (ohms); 19) from; 20) to.

TABLE 3

Physicomechanical Characteristics of the Incombustible (Self-Extinguishing) Modification of PS-B

| 1 Показатели | 2 Объемный вес (г/см³) | | | | |
|---|---|---|---|---|---|
| | 0,02 | [illegible] | [illegible] | [illegible] | [illegible] |
| 3 Предел прочности при сжатии при 10% деформации (кг/см², не менее) | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 4 Предел прочности при изгибе (кг/см²) | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Водопоглощение за 7 суток (%) 5 | | 7 | [illegible] | | |
| 6 Коэффициент теплопроводности (ккал/м·час·°С) | – | [illegible] | [illegible] | [illegible] | – |

1) Characteristic; 2) bulk weight ($g/cm^3$); 3) ultimate compressive strength on 10% deformation ($kg/cm^2$, no less than); 4) ultimate bending strength ($kg/cm^2$); 5) water absorption over 7 days (%); 6) coefficient of thermal conductivity (kcal/m·hr·°C); 7) from; 8) to.

of shaped products of complex configuration and rectangular slabs 1000-2000 mm long, 700-2000 mm wide, and 40-70 mm thick. Polystyrene foams have good mechanical characteristics, low water absorption, and high thermal and electrical insulating characteristics, which depend on the bulk weight of the material: as its bulk weight increases its mechanical characteristics improve and its water absorption decreases, although its heat-insulating properties deteriorate. Polystyrene foam of types PS-1, PS-2, and PS-B does not corrode metals when in direct contact with them; the presence of up to 1% of alkali agents in PS-4 foam causes it to corrode galvanized steel when in direct contact with it. Foams of this type are worked with carpenter's hand tools or on woodworking machine tools; heated sheets of polystyrene foam can be bent or stamped. This material can be stably bonded to itself, to metals, to wood, and to plastics with VIAM B-3, BF-2, or PU-2 glue. The glue is applied with a brush or spatula in a uniform layer of 100-250 $g/m^2$. The drawbacks of polystyrene foam include its low solubility in the majority of organic solvents, its combustibility, and its relatively low working temperature, of the order of 60-70°. Table 1 shows the physicomechanical characteristics of PS-1, PS-2, and PS-4 foams, while Table 2 shows those of PS-B.

In addition to ordinary combustible PS-B, there is now an incombustible (self-extinguishing) modification of PS-B, whose principal characteristics are shown as a function of bulk weight in Table 3.

Polystyrene foam of types PS-1, PS-4, and PS-B is used as a heat-insulating material in refrigeration engineering; PS-1 and PS-4 foams are also used as a light filler in the production of floating, life-saving, and ferry devices. PS-1 and PS-2 foams are used as radio transparent materials in radio engineering, in the manufacture of radar deflectors, and for ceiling bell jars and optical lenses.

References: Moiseyev, A.A., Durasova, T.F., KhP, 1957, No. 3, pages 13-19; Pavlov, V.V., in collection: Penoplastmassy [Plastic Foam], Moscow, 1960, pages 64-80; Kerzhkovskaya, Ye.M. et al., Svoystva i primeneniye penoplasta PS-B [Characteristics and Applications of PS-B Plastic Foam], Leningrad, 1960 (Leningr. dom. nauch.-tekhn. propagandy. Obmen peredovym opytom. Ser. Sintetich. materialy [Leningrad House for Scientific-Technical Information. Exchange of Advanced Experience. Synthetic-Materials Series], No. 5); Zokhin, G.I., Bykov, A., SM, 1960, No. 7; Aleksandrov, A.Ya., Borodin, M.Ya., Pavlov, V.V., Konstruktsii s zapolnitelyami iz penoplastov [Structures with Plastic-Foam Fillers], Moscow, 1962.

A.A. Moiseyev

POLYSULFUDE RUBBER – ... Thiokol.

POLYURETHANE ADHESIVE – is a compound based on the interaction of polyisocyanates with hydroxyl containing polyesters. The polyurethane adhesive is used to bond metals with nonmetallic materials. The adhesive joints are heat resistant up to 60-80°. There are well-known adhesive grades which cure both at normal temperature and after heating. The PU--2 adhesive is a compound based on the condensation of an aliphatic dicarboxylic acid with multivalent alcohols (product 24) and polyisocyanate (product 102-T). The product 24 is a waxlike polyester; it is used as a 50% acetone solution with a viscosity of 10-32 centipoises. A filler (cement) is added to the adhesive. The product 102-T is toxic, therefore, accident prevention rules must be observed when working with it. The PU-2 adhesive is prepared in a special mixer at 18-20°: the thoroughly mixed product 24 is poured in at first; the viscosity of the stock increases gradually during the mixing process, the mixture becomes a paste, and finally a solid product results. In the bonding process, the adhesive layer is exposed for 20-120 minutes, and then pressed at 3 $kg/cm^2$ nad 105±5° for 4 hours. 0.5-1.0% water, calculated with regard to the total weight of the solution, is added to the solution of the product 24 before use in order to increase the strength of the adhesive joint; the working life of this compound is at least 2 hours. Adhesive joints formed on the basis of PU-2 adhesive are stable up to 100°; they have a high frostproofness (see Table 1). The characteristics of PU-2 adhesive joints are quoted in the Tables 1-3.

The shearing strength of Duralumin specimens bonded with PU-2 adhesive and exposed for 4 years to the effect of the atmosphere decreases

at first and then remains stable at a level of 100 kg/cm$^2$. The impact resilience of Duralumin joints bonded by PU-2 lies between 5.5 and 9.3 kg·cm/cm$^2$. Action of alternating temperatures (±60°) for 200 hrs does not affect the strength of the joints which are also stable against fuels and oils.

TABLE 1

Strength of PU-2 Adhesive Joints

| 1 Темп-ра испытания (°С) | 2 Предел прочности при симметричном отрыве (кг/см²) | 3 Погонное разрушающее усилие при неравномерном отрыве (кг/см) |
|---|---|---|
| −60 | 485 | 29 |
| +20 | 345 | 43 |
| +60 | 210 | 23 |

1) Test temperature (°C); 2) ultimate strength in the case of symmetrical peel (kg/cm$^2$); 3) peel strength per linear unit (kg/cm) in the case of nonuniform peel.

TABLE 2

Endurance of Metal Joints Bonded by PU-2 Adhesive

| 1 Металл и продолжительность испытаний | 2 Предел длительной прочности при сдвиге (кг/см²) при темп-ре: | | | | |
|---|---|---|---|---|---|
| | 20° | 60° | 80° | 100° | 120° |
| 4 Дуралюмин, часы . . . 3 . . | 1500 | 300 | 300 | 100 | 100 |
| Дуралюмин . . . | 115 | 65 | 15 | 5 | — |
| Сталь ЭЯ1Т . . . 5 | 160 | 110 | 80 | 40 | 20 |

1) Metal and test time; 2) ultimate shearing endurance (kg/cm$^2$) at the temperature; 3) hours; 4) Duralumin; 5) EYaIT steel.

TABLE 3

Fatigue Strength of Metal Joints Bonded by PU-2 Adhesive ($N = 6 \cdot 10^6$ cycles)

| 1 Металл | 2 Предел выносливости при сдвиге (кг/см²) при темп-ре: | | | |
|---|---|---|---|---|
| | 20° | 60° | 80° | 100° |
| Дуралюмин . 3 . | 40 | 15 | 12 | 10 |
| Сталь ЭЯ1Т . . . 4 | 79 | 55 | 40 | 30 |

1) Metal; 2) shearing fatigue strength (kg/cm$^2$) at the temperatures; 3) Duralumin; 4) EYaIT steel.

D.A. Kardashev

POLYURETHANE FIBER – synthetic hetero-chain fiber from hexamethylene diisocyanide and tetramethylene glycol. Is produced under the names Perlon V, Dorlon (GDR and FRG), etc. As to its properties polyurethane fiber occupies a place intermediate between polyamide and polyester fibers. Specific weight 12.1, moisture content (under standard conditions) 1-1.5%, at 95% relative humidity 2.?%, degree of swelling 6%, softening temperature 165-175°, $t°_{pl}$ 183, brittleness temperature –25, –30°, specific heat 0.4-0.5 cal/g·°C, thermal conductivity 8.4 cal/cm·sec·°C, linear expansion coefficient 12-14 degrees $^{-1}$·$\cdot 10^{-5}$, dielectric constant at $10^6$ cps 3.4, tangent of dielectric losses angle at $10^6$ cps 0.02-0.03, specific volume resistivity $2.7 \cdot 10^{1}$ ohm·cm (when stored in water for long periods of time it is $3.5 \cdot 10^{18}$ ohm·cm), breakdown voltage 260 kv/mm, rupture length 40-45 km, loss of strength in the wet state 5% in the loop 10%, rupture elongation 12-14%, the initial modulus of elasticity is higher than that of polyamide and lower than that of polyester fibers. Polyurethane fibers are characterized by resistance to oxidizing and reducing reagents and to microorganisms. The exceed polyamide fibers by their resistance to atmospheric factors, acids and alkalis. They are soluble in phenol, hot formic acid, boiling dimethylformamide, cresol and strong acids. Can be only dyed by dispersion acetate dyes. As the number of methyl groups in the fiber's macromolecule decreases, its hygroscopicity, melting temperature and strength decrease. Shortcomings of polyurethane fibers: poor dyeability, difficulty in processing, which limits its application in the form of textile fibers. The following are produced from polyurethane fibers in

the form of monofiber: fishing equipment, surgical rayon, mesh articles, artificial britle (products from Perlon V have the rigidity of metal wire), chemically resistant filter materials, acid resisting coverings, drive belts, cable insulation.

References: Korshak, V.V. and Vinogradova, S.V. Geterotsepnyye poliefiry [Hetero-Chain Polyesters]. Moscow, 1958; Fibers from Synthetic Polymers, edited by R. Hill, translated from English, Moscow, 1957; Hopff, G. Müller, A. and Wenger, F., Poliamidy [Polyamides], translated from German, Moscow, 1958; Moncruiff, R.W., Chemical Fibers, translated from English, Moscow, 1961.

E.M. Ayzenshteyn

POLYURETHANE FOAMS – light self-frothing materials based on isocyanates and polyesters and characterized by a closed-cellular (plastic foam) or open-porous (porous plastic) structure. In addition to their basic components, these materials contain other substances that influence the frothing process and the characteristics of the final product, including activators (fatty and aromatic amines, organic-acid salts, alkali phenolates, etc.), emulsifiers (fatty-acid sulfonates, cellulose esters), gas-forming agents (water, organic acids), fillers and dyes. The production of polyurethane foam consists of three stages: mixing of the components and formation and setting of the foam. This material is produced in rigid (types PU-101 and PPU-3), elastic, and semirigid (PU-102V) variants. Table 1 shows the physicomechanical characteristics of the rigid type PU-100, while Table 2 shows those of type PPU-3.

The basic characteristics of elastic polyurethane foam include: color – white to light yellow, bulk weight – 0.03-0.07 g/cm$^3$, tensile strength – 0.09-1.2 kg/cm$^2$, tearing strength – 0.06-0.8 kg/cm$^2$, compressive stress required for 50% deformation – 0.06-0.08 kg/cm$^2$, residual deformation – no more than 15%, coefficient of thermal conductivity – 0.03-0.035 kcal/m·hr·°C, acoustic absorption at frequencies of 100-10,000 cps – 10-90%, working temperature – up to 100°, $SO_4$-ion content – no more than 0.05%, chloride-ion content – no more than 0.03%. Rigid polyurethane foams are resistant to dilute acids, alkalis, oils, and gasoline and are not subject to fungal infestation. These materials can be used to protect equipment against mechanical damage and atmospheric agents. The principal drawback of polyurethane foam is its combustibil-

TABLE 1

Physicomechanical Characteristics of Type PU-101 Polyurethane Foam

| Показатели 1 | 2 ПУ-101 | 3 ПУ-101А | 4 ПУ-101Б | 5 ПУ-101Т | 6 ПУ-102В |
|---|---|---|---|---|---|
| 8 Объемный вес (г/см³) . 7 . . | 0,1 | 0,2 | 0,06 | 0,2 | 0,1 |
| Предел прочности при сжатии (кг/см²) . . . . . | 8,0 | 25 | 2 | 33 | 2,9 |
| 9 Уд. ударная вязкость (кг·см/см²) . . . . . | 0,4 | 0,6 | 0,5 | 0,4 | 1,9 |
| 10 Линейная усадка за 24 часа (%, не более) . . . . . | 0,3 (при 150°) | 0,5 (при 170°) | 0,6 (при 130°) | 1,4 (при 200°) | 0,5 (при 100°) |
| 11 Водопоглощение за 24 часа (кг/м²) . . . . . | 0,1 | 0,1 | 0,2 | 0,1 | 0,15 |
| 12 Коэффициент теплопроводности (ккал/м·час·°С) . . | 0,027 | 0,049 | 0,021 | 0,039 | 0,037 |
| 13 Диэлектрич. проницаемость при $10^{10}$ гц . . . . . | 1,1 | 1,23 | 1,05 | 1,24 | 1,15 |
| 14 Тангенс угла диэлектрич. потерь при $10^{10}$ гц . . . | 0,0015 | 0,005 | 0,001 | 0,005 | — |
| 15 Рабочая температура (°С) | 130—150 | 170 | 100 | 200 | 100 |

1) Characteristic; 2) PU-101; 3) PU-101A; 4) PU-101B; 5) PU-101T; 6) PU-102V; 7) bulk weight (g/cm$^3$); 8) ultimate compressive strength (kg/cm$^2$); 9) specific impact strength (kg·cm/cm$^2$); 10) linear shrinkage over 24 hr (%, no more than); 11) water absorption over 24 hr (kg/m$^2$); 12) coefficient of thermal conductivity (kcal/m·hr·°C); 13) dielectric permeability at $10^{10}$ cps; 14) tangent of angle of dielectric loss at $10^{10}$ cps; 15) working temperature (°C); 16) at.

TABLE 2

Physicomechanical Characteristics of Type PPU-3 Polyurethane Foam

| Показатели 1 | 2 Объемный вес (г/см³) | | | |
|---|---|---|---|---|
| | 0,05 | 0,10 | 0,15 | 0,20 |
| 3 Предел прочности при сжатии (кг/см²) . . . . . | 2,6 | 9,5 | 16,0 | 29,0 |
| 4 Предел прочности при статическом изгибе (кг/см²) | 8,0 | 10 21,0 11 | 28,0 | 40,0 |
| Уд. ударная вязкость (кг·см/см²) . 5 . . . . . | 0,5 | 0,8 | 1,3 | 1,5 |
| 6 Линейная усадка за 24 часа при 120° (%) . . . . . | | От 0,5 до 0,8 | | |
| Тангенс угла диэлектрич. потерь при $10^{10}$ гц 7 . . | $2 \cdot 10^{-3}$ | $3,7 \cdot 10^{-3}$ | — | $8 \cdot 10^{-3}$ |
| 8 Диэлектрич. постоянная . . . . . | 1,08 | 1,13 | — | 1,26 |
| Макс. рабочая температура (°С) . 9 . . . . . | | 120° | | |

1) Characteristic; 2) bulk weight (g/cm$^3$); 3) ultimate compressive strength (kg/cm$^2$); 4) ultimate static-bending strength (kg/cm$^2$); 5) impact strength (kg·cm/cm$^2$); 6) linear shrinkage over 24 hr at 120° (%); 7) tangent of angle of dielectric loss at $10^{10}$ cps; 8) dielectric constant; 9) maximum working temperature (°C); 10) from; 11) to.

ity, which can be substantially reduced by special additives. Self-extinguishing polyurethane foam has been developed.

Rigid polyurethane foams are used as light load-bearing and radio-engineering fillers for laminated structures, as pouring compounds, and in the manufacture of heat-insulating products, radio components, buoyant and nonsubmersible devices, and products resistant to gasoline, kerosene, and organic oils; elastic polyurethane foams are used as damping materials, for heat and sound insulation, and in the manufacture of thermal clothing, sponges, toys, etc.

References: Moiseyev, A.A., Durasova, T.F., KhP, 1958, No. 7, Pavlov, V.V., Goryachev, M.S., Durasova, T.F., in collection: Penoplastmassy [Plastic Foams], Moscow, 1960, page 131; Kafengauz, A.P., Yudicheva, Ye.I., Ibid., page 117; Borodin, M.Ya. et al., Penoplastmassy [Plastic Foams], Moscow, 1959 (Peredovoy nauchno-tekhn. i proizv. opty [Advanced Scientific-Technical and Production Experience], Report 19, No. M-59-$\frac{183}{7}$); Losev, I.P., Tuzhilkin, I.M., Tr. Mosk. khim.-tekhnol. in-ta im. D.I. Mendeleyeva [Transactions of the Moscow Chemical-Technological Institute imeni D.I. Mendeleyev], No. 23, 1956, page 120; Aleksandrov, A.Ya., Borodin, M.Ya., Pavlov, V.V., Konstruktsii s zapolnitelyami iz penoplastov [Structures with Plastic-Foam Fillers], Moscow, 1962.

A.A. Moiseyev

POLYVINYL ACETAL ADHESIVE – is a solution of the diverse acetals of the polyvinyl alcohol in organic solvents or films of these polymers (polyacetals). The derivatives of the formaldehyde (formvar) the acetaldehyde (al'var), and the butyric aldehyde (butvar) are the most widely used; mixed acetals, polyvinyl-butyral-furfural, etc., for example, are rarely used. The polyvinylacetal adhesive is used to bond the most diverse materials. Polyvinyl butyral has the greatest technical importance; it contains esters of the sebacic and phtalic acids as plasticizers; it is used mainly for the production of colorless and transparent films which are applied as an adhesive for silicate glass in the production of triplex glass. Films from butvar and some other polyacetals are obtained by extrusion and subsequent drawing. The polyvinyl butyral films are transparent, this fact permits it to be used in the manufacture of transparent objects whose strength surpasses the strength of the initial material. Joints with a high strength (200 kg/ /$cm^2$) are obtainable by bonding Duralumin with polyvinyl acetal adhesive (under heating at 150-160°). The adhesive joints have a low heat-resistance: the strength at 60° amounts to approximately 20% of the initial strength.

D.A. Kardashev

POLYVINYL ACETATE – a product of polymerization of the vinyl ester of acetic acid (vinyl acetate). The following grades of polyvinyl acetate are manufactured depending on function and production method: pearl, emulsion, varnish, and block. Technical grades of polyvinyl acetage are classified according to molecular weight and viscosity of a molar solution of the polymer in benzene: low-viscosity 17-15, medium-viscosity 15-40, and high-viscosity 40-60 centipoise.

The characteristic properties of polyvinyl acetate are: colorlessness and transparency, adhesiveness, solubility in organic solvents (alcohol, esters, chlorinated and aromatic hydrocarbons and their mixtures, insolubility in water, kerosene, and oils. Polyvinyl acetate mixes well with mineral fillers and is manufactured into products by molding, calendering, and pulverization. Polyvinyl acetate has the following physical-mechanical characteristics: specific gravity 1.19, index of refraction 1.4665, ultimate strength ($kg/cm^2$) in tension 150-250, in bending 300-400, elongation at fracture 80-100%, modulus of elasticity in bending 17,000-20,000 $kg/cm^2$, specific impact toughness 5.8 $kg \cdot cm/cm^2$, thermal stability (°C), Martens 30-32, VIKA 44-50, coefficient of linear thermal expansion $8.6 \cdot 10^{-5}$, water absorption over 24 hr at 20° 1-2%, temperature of transition to viscous-flow state 120°, vitrification temperature –28°, unstable in acids and alkalies, becomes brittle at –5°, moisture permeability (diffusion coefficient) $1.2\text{-}2.8 \cdot 10^{7}$ $g/cm \cdot hr \cdot mm$ Hg.

Owing to a combination of several technically valuable properties and the ability to be worked into products by all the familiar methods

used for thermoplastics, polyvinyl acetate is employed in the plastics, varnish and paint, adhesives, and other industries: the high-viscosity block form as an organic binder for powdered and fibrous mineral fillers used in the production of plastics intended for the manufacture of identifying signs, decorative containers, boxes, etc.; the low-viscosity form in the molten state as a highly adhesive cement used in the bonding of cloth, paper, porcelain, glass, metal, leather, wood, and plastic, as well as in the production of alcohol varnishes producing colorless light-resistant bright finishes; the emulsion form in the production of water-thinned paints, and also in the manufacture of seamless composition floors, washable wallpaper, artificial suede, and imitation leather.

N.P. Gashnikova

POLYVINYL ACETATE ADHESIVE – is a solution of the vinyl acetate polymer in organic solvents, and of an emulsified adhesive composition. Methyl or ethyl acetate (70% solvent + 30% polymer), acetone (65-30% solvent + 35-70% polymer), or toluene (75% solvent + 25% polymer) are used as solvents. Polyvinyl acetate adhesive is used in the production of abrasives to bond fabrics and paper. The disadvantages of the polyvinyl acetate adhesive are: fluidity in cold state, low waterproofness and low heat resistance. The pure polymer, heated up to the softening point, may also be used for bonding. The monomer of the vinyl acetate is recommended as an polymerizing solvent; the product of a partial polymerization may also be used. Emulsified adhesives are obtained by polymerization of the monomer in an aqueous medium together with emulsifiers and accelerators. Cheapness, incombustibility and harmlessness are the advantages of the aqueous emulsion systems (60% polyvinyl acetate and 40% water).

D.A. Kardashev

POLYVINYCHLORIDE ADHESIVE – is a solution mainly of perchlorovinyl in commercial dichloroethane. It is primarily used to bond leather and certain materials based on thermoplastic polymers (polyvinylchloride, polyacrylates). The PV-16 adhesive is a solution of perchlorovinyl resin in dichloroethane, plasticized by dibutyl phthalate; it is used to bond organic glasses by means of a film formed from plasticized butyl methacrylate (BMA). The viscosity of the adhesive is 15-18 seconds measured by the VZ-1 apparatus. The adhesive consumption is 100 $g/m^2$, the working life is 30 days. The bonding conditions are: 4 hours at normal temperature under a pressure of 1-1.2 $kg/cm^2$, without a previous drying in open air. The shearing strength of the joints or organic glasses (using a BMA film) is at least 2 $kg/cm^2$. The presence of the dichloroethane in the adhesive causes the appearance of microcracks ("silver-like luster") on the surface of the organic glass. Some copolymers, especially the copolymer with vinyl acetate, and also a triple copolymer (vinyl chloride-vinyl acetal-vinly maleate) are used as a basis for adhesive compounds for nonmetallic materials.

D.A. Kardashev

POLYVINYL BUTYRAL – a product of the polymerization of polyvinyl alcohol and butyraldehyde. Polyvinyl butyral has the following properties: specific gravity 1.1, Martens thermal resistance 48-55°, Brinell hardness 11-12 $kg/mm^2$, ultimate strength ($kg/cm^2$): in bending 800-1400, in tension, 450-550; relative elongation 15-25%, modulus of elasticity 22,000 $kg/cm^2$, specific electrical stiffness resistance $4 \cdot 10^{16}$ ohms, electrical bulk resistivity $3 \cdot 10^{16}$ ohms·cm, dielectric constant at $10^3$ cps 3.4, at $10^6$ cps 0.024, acid number (KOH) 1.4, saponification number 0.5, decomposition temperature 240°. Polyvinyl butyral dissolves in acetone, ethyl acetate, butyl acetate, butyl alcohol, ethanol, toluene, mixtures of benzene with butyl alcohol, ethanol with toluene, and particularly well in a mixture of 72% ethyl acetate, 18% ethyl alcohol, 5% butyl acetate, and 5% amyl acetate. Films formed by polyvinyl butyral resist the action of ultraviolet rays and oxidation, have good mechanical strength, elasticity, atmospheric resistance, good resistance to wear, and adheres strongly to metals. The drawbacks of polyvinyl butyral include low bending strength (particularly under rapid flexing). Polyvinyl butyric containing 15-35% plasticizer, with a frost resistance down to –60°, has a tensile strength of 250-350 $kg/cm^2$ with an elongation of up to 400%. Modified by phenol aldehyde resin with added mineral filler, polyvinyl butyral forms type PFN-12 compound, which has an adhesive strength of no less than 100 $kg/cm^2$, a direct impact resistance of 50 kg/cm, a shear strength of 19 $kg/cm^2$, and contains no more than 3.5% of volatiles. It is applied hot in order to equalize and smooth seams on the surfaces of vehicle cabs and bodies.

Commercial polyvinyl butyral – Butvar (GOST 9439-60) is produced as a white powder, and is used in the form of film, varnish, and adhesive. Films are produced by pouring from solution (type PP) or by slitting and extrusion (type PSh); varnish-grade polyvinyl butyral is also produced (LA and LB) for varnishes and primers, while adhesive-grade polyvinyl butyral (KA and KB) is made for adhesives and powders for hot spraying. Polyvinyl butyral is used in the manufacture of gasoline- and oil-resistant type VL-515 enamels, used without primers to protect metal surfaces under tropical climatic conditions. Polyvinyl butyral (GOST 9438-60) with a light-absorption coefficient not exceeding 2% per 1 mm is used in the manufacture of laminated safety glass for aircraft, automotive, and marine applications. Polyvinyl butyral and phenol resins are used as the basis for manufacturing types BF-2, BF-4, and BF-6 adhesives. Polyvinyl butyral with added zinc or lead chromate, chromium phosphate, and phosphoric acid is used in the manufacture of undercoats (used to passivate metals) that adhere strongly to metal, wood, leather, plastics, are hard and quite elastic, and do not change color under the effects of light and heat.

References: Ushakov, S.N., Polivinilovyy spirt i yego proizvodnyye [Polyvinyl Alcohol and Its Derivatives], Vol. 1, Moscow-Leningrad, 1960.

N.P. Gashnikova

POLYVINYL CHLORIDE FIBER – synthetic carbon-chain fiber. Produced under a variety of names in the form of rayon and staple fiber: Rhovyl, Fibrovyl, Thermovyl, Isovyl (France), Movil (Italy), Teviron (Japan); in the form of staple fiber: PCV (FRG), in the form of fiber and bristle: PeCeV (GDR). Polyvinyl chloride fibers are formed from solutions by the dry or wet methods, and also by extrusion from the softened polymer. Their use is made difficult by their limited solubility in accessible solvents. Polyvinyl chloride fibers are distinguished by higher chemical resistance than the majority of natural and synthetic fibers, incombustibility and noninflammability, low thermal conductivity, high electric insulation properties and high resistance to light. Shortcomings of polyvinyl chloride fibers are: low heat resistance, difficulty in dyeing ease of electrification.

The physicochemical and mechanical properties of polyvinyl chloride fibers are: specific weight 1.39, moisture content under standard conditions 0%, softening temperature 65-75° (PCV, Rhovyl, Fibrovyl), 95-100° (PeCeV, Thermovyl), failure onset temperature 180°, thermal conductivity coefficient 6.4 cal/cm·sec·°C, dielectric constant at 800 cps 3.1-3.4, tangent of dielectric losses angle at 18° and 800 cps 0.02, breakdown voltage 50 kv/mm, dielectric permeability at 20° 4.1, at 120° 14.1, electric strength at 20° 15.7, at 120° 5.2, specific surface resistivity $10^{16}$ ohms, rupture length 22-34 km, wet loss of strength 0, in the loop 16%, ultimate tensile strength 30-45 kg/mm$^2$, elongation in the dry and wet states 25-28% (PCV, Rhovyl, Fibrovyl), 70-90% (PeCeV), 150-180% (Thermovyl). Resist the action of diluted and concentrated

mineral and organic acids at room temperature (with the exception of $HNO_3$), the action of alkalis and oxidizers. Are soluble in certain ketons and chlorinated hydrocarbons (mixtures of acetone and carbon bisulfide, cyclohexanon, tetrahydrofurane, methylene chloride, etc.), swell in simple and complex esters, aromatic hydrocarbons, dioxane, propylene oxide.

Polyvinyl chloride fibers are used for industrial purposes (filter fabrics, work clothing, diaphragms, etc.) and for consumer goods. Polyvinyl chloride fibers are used in the pure form and together with other fibers. In order to form polyvinyl chloride fibers from acetone solutions of polymers they are modified either by additional chlorination or by copolymerization with vinyl acetate (see HH-Vinyon), acrylonitrile, vinylidine chloride.

References: Rogovin, Z.A., Osnovy khimii i tekhnologii proizvodstva khimicheskikh volokon [Fundamentals of the Chemistry and Technology of Chemical Fiber Production]. 2nd edition, Moscow, 1957; Koch, P.A., "Z. ges. Textilind." [J. Text. Ind.], Vol. 60, No. 1, page 17, 1958; Vol. 61, No. 3, page 78, 1959.

Z.A. Zazulina

POLYVINYL CHLORIDE FOAM – a light material based on polyvinyl chloride and a gas-forming agent. It can be produced with isolated (plastic foam) and communicating (poroplast) cells. This material is manufactured in rigid (PKhV-1) and elastic (PKhV-E) variants. The elasticity of polyvinyl chloride foam is regulated by the amount of plasticizer (dibutylphthalate, tricresyl phosphate) added to the initial mixture. Foam of types PKhV-1 and PKhV-E is resistant to acids, alkalis, liquid fuels, and organic solvents. Tables 1-3 show the characteristics of polyvinyl chloride foams.

TABLE 1

Coefficient of Thermal Conductivity of PKhV-1 Plastic Foam (kcal/m·hr·deg)

| Объемный вес ($г/см^3$) 1 | 2) Температура (°С) | | |
|---|---|---|---|
| | −90 | 20 | 60 |
| 0,05 | 0,028 | 0,022 | 0,020 |
| 0,10 | 0,030 | 0,036 | 0,034 |
| 0,20 | 0,034 | 0,045 | – |

1) Bulk weight ($g/cm^3$);
2) temperature (°C.

The elastic polyvinyl chloride foam PKhV-E is used primarily as a shock-absorbing material and in the manufacture of clothing. Type PKhV-1 foam is used as a light filler for various structures; PKhV-1 is also employed in the manufacture of various life-saving devices (life belts, life jackets, rafts, etc.). In ship building PKhV-1 is used for heat insulation and as a light filler for unsinkable structures; in the commercial fishing industry it is employed in the manufacture of

TABLE 2

Mechanical Characteristics of PKhV-1 Plastic Foam (Bulk Weight – 0.1 g/cm$^3$) as a Function of Temperature

| Показатели 1 | 2 Температура (°С) | | |
|---|---|---|---|
| | –60 | 20 | 60 |
| Предел прочности 3 (кг/см$^2$): | | | |
| при сжатии 4 | 17 | 10 | 3.5 |
| при растяжении 5 | 23 | 20 | 13 |
| при сдвиге 6 | 7 | 7 | 4 |
| при изгибе 7 | 26 | 22 | 15 |
| Модуль упругости 8 (кг/см$^2$): | | | |
| при сжатии | 1500 | 800 | 50 |
| при растяжении | 1500 | 900 | 50 |
| при сдвиге | 200 | 185 | 150 |
| Уд. ударная вязкость (кг·см/см$^2$) 9 | 0.7 | 0.8 | 1.1 |

1) Characteristic; 2) temperature (°C); 3) ultimate strength (kg/cm$^2$); 4) on compression; 5) on extension; 6) on shear; 7) on bending; 8) modulus of elasticity (kg/cm$^2$); 9) impact strength (kg·cm/cm$^2$).

TABLE 3

Principal Physicomechanical Characteristics of Polyvinyl Chloride Foams

| Показатели 1 | 2 ПХВ-1 | | | 3 ПХВ-Э |
|---|---|---|---|---|
| 4 Объемный вес (г/см$^3$) | 0.06 | 0.1 | 0.2 | 0.2 |
| 5 Предел прочности (кг/см$^2$): | | | | |
| при сжатии 6 | 2.3 | 9.0 | 26.0 | — |
| при растяжении 7 | — | 20 | 45 | 4.1 |
| при изгибе 8 | — | 20 | 40 | — |
| 9 Модуль упругости (кг/см$^2$): | | | | |
| при сжатии | — | 800 | 2050 | — |
| при растяжении | | 900 | 1300 | — |
| при сдвиге 10 | — | 185 | 485 | — |
| 11 Относительное удлинение при растяжении (%) | — | 2–3 | 5–7 | 75 |
| Удельная ударная вязкость (кг·см/см$^2$) 12 | 0.7 | 1.0 | 1.5 | — |
| 13 Коэффициент теплопроводности (ккал/м·час·°С) | 0.022 | 0.036 | 0.045 | 20 0.057 |
| Водопоглощение за 30 суток (кг/м$^2$) 14 | 19 — | — | 0.3 | 20 0.88 |
| 15 Усадка при 60° за 24 часа (%) | до 1 | до 1 | до 1 | 5 (при 40°) |
| 17 Горючесть 16 Макс. рабочая темп-ра (°С) | ±60 | ±60 | ±60 | 40 |
| | По удалении источника пламени горение прекращается 18 | | | |

1) Characteristic; 2) PKhV-1; 3) PKhV-E; 4) bulk weight (g/cm$^3$); 5) ultimate strength (kg/cm$^2$); 6) on compression; 7) on extension; 8) on bending; 9) modulus of elasticity (kg/cm$^2$); 10) on shear; 11) relative tensile elongation (%); 12) impact strength (kg·cm/cm$^2$); 13) coefficient of thermal conductivity (kcal/m·hr·°C); 14) water absorption over 30 days (kg/m$^2$); 15) shrinkage of 24 hr at 60° (%); 16) maximum working temperature (°C); 17) combustibility; 18) combustion ceases when flame is removed; 19) up to 1; 20) at.

floats. The resistance of polyvinyl chloride foams to organic solvents has resulted in their wide use for floats for measuring the fuel level in various types of equipment. Type PKhV foam causes corrosion of many metals when in direct contact with them and protection by painting is consequently necessary.

References: Moiseyev, A.A., Durasova, T.F., in collection: Penoplastmassy [Plastic Foam], Moscow, 1960, pages 19-45; Sudakov, V.N., Ibid., pages 81-90; Ivanov, A.N., Petrakov, Ya.K., Rybnoye khozyaystvo [Fishing Industry], 1951, No. 5, pages 9-10; Berlin, A.A., Moiseyev, A.A., Ibid, 1950, No. 8, pages 10-13; Rubber World, 1959, Vol. 139, No. 4, pages 542-546, 549; Aleksandrov, A.Ya., Borodin, M.Ya., Pavlov, V.V., Konstruktsii s zapolnitelyami iz penoplastov [Structures with Plastic-Foam Fillers], Moscow, 1962.

A.A. Moiseyev

POLYVINYL CHLORIDE PLASTICS — thermoplastic materials based on synthetic macromolecular polyvinyl chloride or copolymers of vinyl chloride with other monomers. Polyvinyl chloride is a white finely dispersed powder dissolving in dichloroethane, cyclohexanone, tetrahydrofurane, methylene chloride, dioxane, and other organic solvents as well as plasticizers, swelling in acetone, benzene, toluene, and not dissolving in water, alcohol, or gasoline. Several grades are produced with molecular weights of 30,000-120,000. Both hard and soft polyvinyl chloride plastics may be made from polyvinyl chloride, while varnish and enamel coatings are made from various solutions of polyvinyl chloride. Rigid polyvinyl chloride plastics such as Viniplast (VP) contain no plasticizers. Viniplast is produced by hot rolling or extrusion on a screw extruder at 160-190° of a composition whose components are polyvinyl chloride resin, a stabilizer, and lubricating additives. There are three different grades of VP (GOST 9639-61); VN — opaque, in natural color, or dyed; VP — transparent, colorless, or dyed, and VNT — nontoxic (see the table). Viniplast is produced in films, sheets, tubes, rods, welded bar, and other shapes.

Film VP is used to line various equipment and in the manufacture of sheet VP. Sheet VP is made either by compressing several layers of film on multistage hydraulic presses at 170-175° and specific pressures of up to 80 $kg/cm^2$ or by extrusion on a screw extruder with a slot head. Like the film from which it is made, sheet VP exhibits well-defined anisotropy. Sheet VP is produced in thickness of from 2 to 20 mm, lengths of 1300-1500 mm, widths from 500 to 600 mm. Viniplast tubes,

Physical-Mechanical and Dielectric Properties of Viniplast

| 1 Показатели | 2 Марки | | |
|---|---|---|---|
| | ВН 3 | ВП 4 | ВНТ 5 |
| 6 Предел прочности при растяжении (кг/см², не менее) | 650 | 500 | 450 |
| 7 Уд. ударная вязкость (кг·см/см², не менее) | 80 | 70 | 50 |
| 8 Предел прочности при изгибе (кг/см², не менее) | 1000 | 900 | 900 |
| 9 Теплостойкость по Вика (°С, не менее) | 75 | 70 | 70 |
| 10 Уд. объемное электрич. сопротивление (только для винипласта, к-рому предъявляются электроизоляционные требования) (ом·см, не менее) | $5 \cdot 10^{16}$ | $1 \cdot 10^{16}$ | $1 \cdot 10^{16}$ |

1) Characteristic; 2) grade; 3) VN; 4) VP; 5) VNT; 6) tensile strength ($kg/cm^2$, no less than); 7) specific impact toughness ($kg \cdot cm/cm^2$, no less than); 8) ultimate strength in bending ($kg/cm^2$, no less than); 9) VIKA thermal stability (°C, no less than); 10) electrical bulk resistivity (only for Viniplast, which must meet electrical-insulation standards) (ohm·cm, no less than).

rods, welded bar, and other shapes are obtained by extruding the appropriate composition on screw extruders with a machine head temperature of 170-200°. In contrast to sheet and film VP, Viniplast tubing is more uniform in different directions. Viniplast (TU MKhP No. 4251-54) is produced with outside diameters of from 12.5 to 162 mm and inside diameters from 8 to 150 mm. Viniplast rods are made in diameters from 2.8 to 58 mm. For tubing of various inside diameters and wall thicknesses, admissible pressures for temperatures of up to 40° are 0.5-6 $kg/cm^2$.

On the basis of the standards for tubing and fittings for VP lines, Viniplast pressure tubing is produced in the following types, depending on nominal pressure: light-weight "L," medium-weight "S," and heavy-weight "T" with nominal pressures, respectively, of 2.5, 6, and 10 $kg/cm^2$ and outside diameters of from 10 to 160 mm. Viniplast nuts, valves, handwheels, unions, storage-battery-tank inserts, and other products are made from pellets by impact molding at 300-350 $kg/cm^2$. Viniplast is re-

sistant to acids: 40% sulfuric acid up to 60°, sulfurous acid, oil of vitriol to 20°, 50% nitric acid at 50°, nitrose, 100% acetic acid, 50% muriatic acid, hydrofluoric acid (at concentrations of up to 40% and 20°), phosphoric acid (dilute and concentrated); it also resists alkalies (in concentrations of up to 50%), ammonia, chlorinated lime, 10% hydrogen peroxide, concentrated permanganate solution, solutions of all salts, ozone, formaldehyde, carbon disulfide, hydrogen sulfide solution. Viniplast is nonhydroscopic; at room temperature over a 2-month period, it takes in less than 0.01% moisture. Viniplast is insoluble in methyl, ethyl, and higher alcohols or glycerine; it swells in aromatic and chlorinated hydrocarbons. Viniplast is an excellent anticorrosion, construction, and electrical-insulation material; up to 80° it is hard and rigid, from 80° to 160° it is elastic, and above 160° it is plastic (viscous-flow state). Under long-term loads (3000 hr), the rupture strength of VP drops to 190 $kg/cm^2$. When notched, its impact strength drops sharply (to 18% of the initial value). Viniplast can be sawn, filed while turning, drilled, ground, polished, etc.; when heated, it may be given any shape. If Viniplast is molded in a highly elastic state, after cooling and reheating to the molding temperature, it will lose the form which it has been given. When molded in the viscous-flow state, the shape will be retained. Thin sheets and films of VP are easily vacuum formed. Viniplast welds well, with the weld-seam strength reaching 80-90% of the strength of the material. Welding is carried out by means of hot air heated to 230-270°, with a special welding bar and welding fixture. Thin films may be welded by high-frequency currents. The welding process may be automated. Viniplast will bond to itself and to other materials (concrete, metal, wood) with the aid of a 10-20% solution of chlorinated polyvinyl chloride resin in dichloroethane, methylene chloride, acetone, or other solvent, as well as for other types of adhesive

made up of a combination of a solvent for chlorinated polyvinyl chloride resin with an epoxy resin or rubber. Viniplast is widely employed in various industries to replace nonferrous and ferrous metals. In the chemical industry, it is used in the transportation of aggressive liquids and gases, to line metal pipe and equipment, in similar parts of electrolysis baths, in the manufacture of fans, air ducts, distillation columns, etc.; in the electrical industry, VP is used to make separators between anode and cathode plates of storage batteries, storage-battery-container inserts, and tubes for lightening dischargers. Viniplast is used in the manufacture of engravings, drains, etc. Viniplast is an arc-arresting material. The basic drawback to VP is its low impact viscosity, especially at negative temperatures; this drawback can be overcome by using rollers to combine polyvinyl chloride resin with certain elastomers, for example, methyl vinyl pyridine rubber, with chlorinated polyethylene, and other materials, at elevated temperatures. The resulting polyvinyl chloride plastics have 10 to 12 times the impact strength of ordinary polyvinyl chloride plastics, and will resist impact loads at temperatures down to −30°. High-impact-strength polyvinyl chloride plastics are used in the production of tubing, various shapes, wrapping films, electrical cable insulation, large bottles and hollow objects for the food industry. High-impact-strength polyvinyl chloride plastics are worked by molding, extrusion on screw extruders, injection molding, etc.

Soft polyvinyl chloride plastics are made by mixing polyvinyl chloride resin with a plasticizer, stabilizer, and dye at 70-120° with subsequent rolling at 150-160° or extrusion. Plasticizers combine with the polyvinyl chloride resin to expand the region of highly elastic deformation of polyvinyl chloride, shifting it sharply toward negative temperatures. As a result, soft polyvinyl chloride plastics at room

temperatures or even at negative temperatures are elastic materials.

In order to produce long films of uniform thickness, the rolled material is passed through a multiroller calender, with the maximum roller temperature 5-10° above the rolling temperature. The production of soft polyvinyl plastics on 2- or multi-screw extruders is a more advanced and economical method that makes it possible to eliminate hand labor, and to mechanize and automate the entire production process. Various types of soft polyvinyl chloride plastics are used to produce electrical insulation for wire and cable, type V-118 wrapping film (TUMKhP 786-56) employed to cover aircraft engines and various machines in order to preserve them. Plasticized polyvinyl chloride is used in the manufacture of linoleum (with or without a special fabric base; GOST 7251-54; TU 74-62). The cast plasticized resin (TUMKhP 1374-46, TUMKhP 2024-49) is used as a packing material. It is produced with a thickness of 1-5 mm, a length of 1000 mm, a width of 600 mm, a breaking strength of 70-100 kg/cm$^2$, a relative elongation of 80-150%, a frost resistance from −15° to −40°. Screw extruders are used to make various products from soft polyvinyl chloride plastics (flexible elastic hoses, tubing, tape, staircase railings, baseboard moldings, etc.). Tubing and strips are produced with and without coloring. Flexible polyvinyl chloride tubing for insulation of wire, as well as for water and oil lines is made with inside diameters of from 1.0-50.0 mm, wall thickness of from 0.3-2.0 mm, lengths of no less than 5 m, and for operating temperatures of from −10° to +60°. A special frost-resistant plasticized resin is used to manufacture tubing with inside diameters of 8-16 mm, a wall thickness of 0.9 mm, a length of at least 2 m. The tubing has a frost resistance of −50°, a tensile strength of 90 kg/cm$^2$, and a relative elongation of 200%. Polymer plasticizers make the plasticized resin gasoline and oil resistant. Through the use of special stabilizers it

is possible to obtain soft and hard polyvinyl chloride plastics that are perfectly clear or tinted various colors. As a rule, a polyvinyl chloride plasticized resin contains 30-40% plasticizer. Strongly plasticized soft polyvinyl chloride molding plastic and hydroplastic (TU MPKhP 2742-53) contain from 70 to 90% plasticizer, and are produced in three grades: SM molding plastic – a composition used to make molds for casting plaster and cement architectural modeled elements, in the casting of wax patterns for decorative and precision casting, three-dimensional sculpture, relief electroformed copies; SM hydroplastic is used to fill cavities in fittings for metal-cutting machines; DM hydroplastic – a composition used to fill cavities in various clamping devices, and capable of moving through narrow channels under pressure.

Polyvinyl chloride obtained by the latex method is mixed with plasticizers and other components to produce a paste; gelatinizing completely at elevated temperatures, it forms a rubber-like soft plasticized resin. Polyvinyl chloride linoleum or materials simulating leather, waterproof cloth, oilcloth, etc., are produced by application of a paste to a cloth through a filter or with the aid of a wiper followed by gelatinization at elevated temperature (160°). Polyvinyl chloride pastes are also used to produce cast products (printer's rollers, plugs, cuffs, etc.). For products of complex shape (gloves, boots, etc.) the method of dipping is used. Films obtained by the dipping method have a breaking strength of about 100 $kg/cm^2$ and an elongation of about 400-500%.

Polyvinyl chloride solutions are used in the production of corrosion-resistant varnish film coatings; the solutions used most frequently for this purpose are based on chlorinated polyvinyl chloride resin, which is more soluble than polyvinyl chloride. Chlorinated polyvinyl chloride resin (VTU MKhP 4575-55) is a product obtained by additional

chlorination of polyvinyl chloride, containing up to 64-68% chlorine, and characterized by good solubility.

In the paint and varnish industry, chlorinated polyvinyl resin is used as the basis for manufacture of atmosphere-resistant, anticorrosion varnishes and enamels. A combination of chlorinated polyvinyl chloride and epoxy resin is used to produce cements for bonding Viniplast or plasticized resin to one another, and also to bond them to wood, metal, and concrete. Polyvinyl chloride resin is also used as a basis for the production of rigid and elastic foam and porous materials (see polyvinyl chloride foamed plastic).

The joint polymerization of vinyl chloride with other monomers (vinyl acetate, methyl acrylate, butyl acrylate, vinylidene chloride, etc.) yields new macromolecular compounds – copolymers whose physical properties depend heavily on the initial relationship of the monomers. The copolymers have better solubility, better viscosity, and greater elasticity than pure polyvinyl chloride owing to internal plastification. The copolymers are more stable chemically, burn less easily, and are easily worked. The following are the most common and of greatest industrial importance: the copolymer of vinyl chloride with vinyl acetate with a monomer relationship of 80:20 – vinylite (TUMPKhP No. 4232A-54), used in the manufacture of floor tiles, long-playing records, etc.); type MA-20 chlorovinite – the copolymer of vinyl chloride and methyl acrylate, with a monomer relationship of 80:20 (VTU 3636-52), used in the manufacture of transparent films for mapmaking, geodesy, and other purposes; the copolymer of vinyl chloride with butyl acrylate, with monomer relationships of 80:20 (SKhB-20) or 75:25 (SKhB-25), used in the production of high-quality electrical insulation (bulk resistivity in excess of $10^{14}$ ohm·cm with frost resistance to –50°). for conductors and cables. The copolymers of vinyl chloride with vinylidene

chloride, having high (more than 70%), medium (30-60%), and low (to 20%) content of vinylidene chloride are used in the extrusion, molding, or injection molding of rigid or plasticized parts and elements; tubing, films, fibers, varnishes and paints, impregnation materials, phonograph records, etc.

G.V. Struminskiy

POLYVINYLIDENE CHLORIDE FIBER (sarana) – synthetic carbon-chain fibers from copolymers of vinylidene chloride with vinyl chloride, acrylonitrile and other monomers. It is produced under a variety of na names: Soviden (USSR), Permalon and Velon (USA), Tygon (England), Kurehalon (Japan), Clorene (France). It is obtained by forming the softened polymer. It is produced in the form of monofiber (No. 3-225), threads consisting of several monofibers and staple fiber (No. 400-900).

Physicochemical and mechanical properties of polyvinilidene chloride fibers: specific weight 1.68-1.75; does not absorb moisture under standard conditions, maximum moisture absorption 0.1%, softening temperature 115°, $t°_{pl}$ 150-160°, decomposition temperature 177°, thermal conductivity coefficient 6.3 cal/cm·sec·°C, transition temperature $T_g$–10°, $T_T$ 172°, it ignites with difficulty and is extinguished spontaneously, high resistance to light (after being subjected for a year to atmospheric factors it loses 10-15% of its strength); refraction coefficient 1.61, is not susceptible to the action of decay microorganisms, the dielectric constant and the tangent of the dielectric losses angle (at 25° and 50% relative humidity, 60 and 1000 cps) 3-5 and 0.03-0.15, respectively; specific volume resistivity at 50° $10^{14}$-$10^{16}$ ohm-cm, breakdown voltage 40-120 kv/mm; resistant to 30% $H_2SO_4$, 10% HCl, 10% $NHO_3$ at a temperature of 70°, to alkalis (with the exception of ammonia), alcohols and alifatic, aromatic and haloid derivative hydrocarbons, ketons, complex and simple esters up to a temperature of 40°, swells in cyclohexanone and dioxane at elevated temperatures. Rupture length 16-36 km, does not lose strength in the wet state, ultimate tensile

strength 27-60 kg/mm$^2$, elongation in the dry and wet state 15-25%, initial modulus of elasticity 100-200 kg/mm$^2$, friction coefficient 0.55. Polyvinilidine chloride fiber is used for the manufacture of filtering materials, upholstery and decorative fabrics, fishing nets, mosquito nets, carpets, etc.

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Z.A. Zazulina

PORCELAIN – is a compact, sintered ceramic material, impervious to water and gases, white in color and transparent in thin layers, obtained by firing a mixture of clay (kaolin), quartz and feldspar. Special types of porcelain contain supplements (zircon, talcum, alumina, ascharite, etc.). Porcelain is subdivided into a weak and a hard type. Varieties of hard porcelain are: electrotechnical porcelain (see Electrotechnical ceramics), chemical and refractory porcelain. Porcelain is covered with a glaze in order to decrease the permeability to water and gases. The thermomechanical and dielectric properties of the porcelain depend on the initial composition of the bulk. The refractoriness of porcelain increases by increasing the proportion of argillaceous materials; an increased quartz proportion improves the mechanical strength. Normal porcelain has a Mohs hardness of 7-8. Porcelain is impervious to gases up to 1300°; beryllia porcelain remains vacuum-tight up to 1500°. The whiteness of porcelain is gaged photometrically according to GOST 7591-55. Porcelain is acidproof up to 98-99%, and alkaliproof up to 84-86%. Porcelain resists all acids except hydrofluoric acid. Special types of porcelain are used for the manufacture of pyro metric objects. The properties of the main types of technical porcelain are listed in the Table.

## Properties of the Main Types of Technical Porcelain

| Свойства 1 | Виды фарфора 2 | | | | |
|---|---|---|---|---|---|
| | Твердый (электротехнич. и химич.) 3 | | Цирконовый | Кордиеритовый | Тальковолевошпатовый |
| | неглазурованный 4 | глазурованный 5 | 6 | 7 | 8 |
| Объемный вес (г/см³) 9 | 2,4—2,6 | 2,4—2,6 | 3,4—3,8 | 2,1—2,5 | 2,6 |
| 10 Предел прочности при сжатии (кг/см²) 11 | 2500—4000 | 3000—6000 | 6000 | 2500—4500 | 5000—9000 |
| при разрыве | 100—400 | 150—500 | 800—850 | 200—320 | 500—900 |
| 12 при изгибе | 400—700 | 500—1000 | 1300—1600 | 450—1000 | 900—1500 |
| Модуль упругости $10^6$ 13 | | 0,6—0,8 | 1,4—1,6 | 0,46—1,0 | 0,85—1,06 |
| 14 Коэфф. линейного расширения $\cdot 10^6$ | | 4,0—6,5 (20—700°) | 4,8—4,9 (20—1000°) | 2—4 (20—1000°) | 6—8 (20—800°) |
| Теплоемкость (кал/г·°С) 15 | | 0,19—0,3 | 0,17 | 0,2—0,23 | 0,19—0,20 |
| Теплопроводность (ккал/м·час·°С) 16 | | 1,0—1,2 | 2,5—3,0 | 1,2—1,5 | 1,3—1,4 |
| 17 Диэлектрич. проницаемость | | 5—6 | 8,5—9,5 | 4—5 | 6—7 |
| Пробивное напряжение при 50 *пер* (кв/мм) 18 | | 25—35 | 20—25 | 5—20 | 35—40 |
| 19 Удельное объемное (сопротивление ом·см) | | | | | |
| при 20° | | $10^{13}$—$10^{14}$ | — | $10^{11}$—$10^{14}$ | $10^{14}$—$10^{16}$ |
| 20 при 300° | | $10^{6}$—$10^{7}$ | — | $10^{7}$—$10^{9}$ | $10^{8}$—$10^{9}$ |
| Скорость распространения звука (м/сек) 21 | | 4900—5200 | — | — | — |

1) Properties; 2) porcelain types; 3) hard (electrotechnical and chemical); 4) nonglazed; 5) glazed; 6) zircon; 7) cordierite; 8) talcum-feldspar; 9) density ($g/cm^3$); 10) compression strength; 11) tensile strength; 12) bending strength; 13) modulus of elasticity$\cdot 10^6$; 14) coefficient of linear expansion$\cdot 10^6$; 15) specific heat (cal/g·°C); 16) heat conductivity (kcal/m·hr·°C); 17) dielectric constant; 18) breakdown voltage at 50 cps (kv/mm); 19) specific volume resistance (ohm·cm); 20) at ...°; 21) sound velocity (m/sec).

V.L. Balkevich

POROPLASTS – see Gas-filled plastics.

POROPLASTS BASED ON POLYVINYLFORMAL – foam products obtained by condensation of polyvinyl alcohol and formaldehyde. They have be elastic or rigid, depending on the processing method. White poroplasts of this type with open pores, which are rigid under ordinary conditions and elastic in a moist atmosphere, are produced under the designations PVF-1 and MPVF (USSR), polyvinylformal foam (USA, Japan, Federal Republic of Germany, and France), and ivalon (England).

Physical and Mechanical Characteristics of Poroplasts Based on Polyvinylformal

| 1 Показатели | 2 ПВФ-1 | 3 МПВФ | 4 Пенополивинилформаль (США) | 5 Пенополивинилформаль (ФРГ) |
|---|---|---|---|---|
| 6 Объемный вес (г/см³) | 0.08–0.13 | 0.1 | 0.1–0.5 | 0.03–0.09 |
| 7 Предел прочности (кг/см²): | | | | |
| 8 при сжатии | 4–10 | 3.2 | 12 | – |
| 9 при растяжении | 5–10 | 5.5 | 24 | 2.7 |
| 10 Теплостойкость (°С) | 100–105 | 100 | 70–80 | 105 |
| 11 Водопоглощение (%) | 1000 | 1200 | – | 170–230 |

1) Characteristics; 2) PVF-1; 3) MPVF; 4) polyvinylformal foam (USA); 5) polyvinylformal foam (Federal Republic of Germany); 6) bulk weight ($g/cm^3$); 7) ultimate strength ($kg/cm^2$); 8) on compression; 9) on extension; 10) thermal stability (°C); 11) water absorption (%).

Dry poroplasts of this type are thermostable at temperatures of up to 105° for several days; they become thermoplastic at 120° and are readily deformed. Their color is altered by prolonged holding at 140°. Between 200 and 240° they decompose, forming $CH_2O$ and $H_2O$; when boiled in water their volume decreases by 10-30%. They are deformed by compression. These poroplasts have a high chemical stability (they dissolve

completely only in concentrated acids); they are partially decomposed in 10% sulfuric or hydrochloric acid. They are consolidated by 40% sodium hydroxide, 12% sodium chloride, chlorobenzene, petroleum ether, and hydrophilene. These poroplasts are used for heat-insulation (in aircraft, refrigerators, and household air conditioners), in the manufacture of lifebelts and liferafts, for filling the floatation compartments of boats, as a core for laminar assemblages (in order to provide rigidity and strength conjoined with minimal weight), in construction, in polygraphy, and for polishing and washing sponges in the ceramics industry. Sponges fabricated from these materials are physiologically harmless, easily sterilized by boiling in water, and resistant to microorganisms and fungii; they are used in medicine. Polyvinylformal porcplasts can also be employed as filter materials, being readily cleaned by rinsing in water.

References: Berlin, A.A., Osnovy proizvodstva gazonapolnennykh plastmass i elastomerov [Principles of the Production of Gas-Filled Plastics and Elastomers], Moscow, 1954; Ushakov, S.N., Polivinilovyy spirt i yego proizvodnyye [Polyvinyl Alcohol and Its Derivatives], Vol. 2, Moscow-Leningrad, 1960; Tarakanova, Ye.Ye., Mikhanov, S.A., Astrozhnikov, Yu.V., Promyshlenno-ekonomicheskiy byulleten' [Industrial-Economic Bulletin], 1962, No. 5 (11) (Vladimirskiy Sovnarkhoz); Braun, R., Kunstoffe [Synthetics], 1960, Vol. 50, No. 12, pages 729-732.

Ye.Ye. Tarakanova

POROUS PENETRABLE CERAMICS – are ceramic materials characterized by an open porosity with fixed pore sizes and gas permeability; they

TABLE

| 1 Вид и назначение изделий | 2 Коэфф. воздухопроницаемости ($м^3 \cdot см/м^2 \cdot ч \cdot мм$ вод. ст.) | 3 Размер пор средний (мк) | 4 Пористость кажущаяся (%) | 5 Предел прочности при сжатии ($кг/см^2$) | 6 Форма и размер изделий (мм) |
|---|---|---|---|---|---|
| 7 Шамотные изделия для фильтрации водно-спиртовых растворов | 8 Не менее 12 | 110–150 | 30–35 | 80 | 9 Диски Ø 175, l 20 |
| 10 Шамотные изделия для фильтрации жидкого воздуха от твердой углекислоты | 12–18 | 100±20 | 30–35 | 115 | 11 Трубы Ø от 70 до 400, l от 290 до 1000 |
| 12 Для очистки жидкого кислорода от графитовой пыли | 1.5–2.0 | 20±5 | 20–25 | 250 | 11 Трубы Ø от 18 до 26, l 85–192 |
| 13 Для очистки газообразного кислорода от графитовой пыли | 6–8 | 50±5 | 25–30 | 180 | 11 Трубы Ø от 35 до 64, l 162 |
| 14 Для очистки газообразного воздуха от пыли адсорбентов | 16–22 | 120±20 | 30–35 | 100 | 11 Трубы Ø 89, l 305 |
| 15 Для очистки жидкого воздуха от пыли адсорбентов | 12–18 | 100±20 | – | 115 | 11 Трубы Ø 220, l 290 |
| 16 Для разгрузки и пневмотранспорта порошкообразных и пылящих материалов | 3–5 | 80±10 | 25–30 | 150 | Плиты шириной от 250 до 410; 17 длиной от 300 до 560; толщиной от 20 до 30 |
| 18 Для очистки сточных вод | 5–7 | 90±10 | 25–30 | 150 | 19 Плиты 19 300×300×25 |
| 20 Сетки для гидролизной и химической пром-сти и карбюраторы | 2–3 | 25±5 | 25–30 | 150 | 21 Трубы Ø 70, l 250 |
| 22 Бактериологич. фильтры | 2–3 | 25±5 | 25–30 | 200 | 21 Трубы Ø 40, l 150 |
| 23 Фильтрующие элементы для очистки воздуха от пыли и масла | 4–6 | 60±5 | 25–30 | 150 | 21 Трубы Ø 60, l 130 |
| 24 Трубы для очистки азотно-водяной смеси | 8–10 | 90±10 | 30–35 | 150 | Ø 30, l 700 |

Note: l = length

1) Type and purpose of the product; 2) coefficient of air permeability ($m^3 \cdot cm/m^2 \cdot hr \cdot mm$ water column); 3) mean dimension of the pores (microns); 4) apparent porosity (%); 5) compression strength ($kg/cm^2$); 6) shape and size of the products (mm); 7) fireclay products for the filtration of water-alcohol solutions; 8) not less than; 9) discs; 10) fireclay products for separation of carbon dioxide from liquid air by filtration; 11) pipes with a diameter from ... to ..; 12) purification of liquid

oxygen from graphite dust; 13) purification of gaseous oxygen from graphite dust; 14) purification of gaseous air from the dust of absorbents; 15) purification of liquid air from the dust of absorbents; 16) discharge and pneumatic conveying of powdered materials; 17) plates with a width from ... to ..., a length from ... to ..., and a thickness from .... to ...; 18) purification of sewage; 19) plates; 20) candles for the hydrolysis and yeast industry, and bubblers; 21) pipes; 22) bacteriological filters; 23) filter units for purification of air from dust and oil; 24) pipes for the purification of a nitrogen-ammonia mixture.

are used for the mechanical purification of gases and fluids, for separation and enrichment of gases, for the pneumatic conveying of powdered materials, and for the performance of a number of technological processes in the chemical industry, including high-temperature reactions. The porosity of the products lies between 30 and 50% and is caused by fillers (fireclay, sand, glass cullet, etc.) with a fixed granulometric size of the grains and the selection of an appropriate binder (clay, bentonite, water glass, etc.). The gas permeability and the size of the pores change in a wide range (sizes of the pores from 300 to 0.1 microns). Filters, plates, pipes, discs are made chiefly from porous permeable ceramics. Porous permeable ceramics possess a high resistance to acids (apart from hydrofluoric and phosphoric acid). Fireclay products are stable to the action of diverse aqueous salt solutions and, in contrast to the quartz product, they prove a good heat endurance, which permits the use of them at 1000-1500° and at sharp temperature drops. The technical requirements to the main types of porous permeable ceramics are quoted in the Table.

References: Matveyev M.A., and Smirnova K.A., poristyye silikatnyye izdeliya [Porous Silicate Products], Moscow, 1956; Berkman A.S., Poristaya pronitsyemost' keramiki [The Pentrability of Porous Ceramics], Moscow, 1959.

V.L. Balkevich

POWDERED METALLIC MATERIALS (cermet materials) – metallic materials obtained by powder metallurgical methods, i.e., pressing a mixture of powders and then heat-treating (sintering) them at a temperature below the melting point of principal component. Additional postsintering cold or hot working of the blanks is employed in some cases. Other technological variants are characterized by combination of pressing and sintering into a single operation, by use of other powder-molding methods (hydrostatic pressing, vibration pressing, extrusion, rolling, or preparation of Cermet dross) instead of pressing, and by special preliminary treatment of the powders before molding. Use of powdered metallic materials has the following advantages. 1) It is possible to produce materials whose manufacture by smelting or casting is less convenient, more difficult, or technical impossible, e.g., certain high-melting compounds and alloys and compositions based on these compounds (solid alloys based on tungsten carbide or high-hot-strength alloys based on titanium carbide); compositions of metals that do not mix in the molten state, particularly when their are substantial differences in their melting temperatures (W-Cu); compositions of metals and nonmetals (metal-plastics, Mo-$ZrO_2$, copper-graphite); porous metals (for bearings, filters, packings, and acoustical insulation), etc. 2) It is possible to produce powdered metallic materials with structural characteristics that ensure an increase resistance to cyclic temperature and stress factors (thermostability and vibration resistance) and to nuclear radiation. 3) It is possible to produce certain powdered metallic materials more economically, e.g., in the form of

finished products not requiring machining. In a number of cases powdered metallic materials have replaced nonferrous metals (porous iron is employed instead of cast bronze for bearings, collars of porous iron rather than copper are used for artillery shells, etc.).

In certain cases powdered metallic materials manufactured from pure initial powders contain fewer impurities and correspond more precisely to the desired composition than ordinary cast alloys, which are contaminated with impurities from the walls of the casting forms. However, the oxygen and gas contents of these materials are usually somewhat higher than those of similar materials obtained by arc or electron-beam smelting.

The production of powdered metallic materials is small, accounting for less than 0.1% of the total metal production. They include a number of very important materials: tungsten filaments for incandescent bulbs, vacuum-tube components of W, Mo, and Ta, copper-graphite brushes for generators and electric motors, magnetic components for computers, materials for atomic reactors, porous fuel elements for high-efficiency production of electrical power, etc.

Materials produced from methyl fibers are a new variety of powdered metallic materials (see Fibrous cermet).

Soviet specialists have developed a new method for producing powdered metallic materials – preliminary conglomeration of metallic powders (before molding) into aggregates consisting of a number of particles. The linear size of such aggregates is one or more orders of magnitude greater than that of the initial particles. In order to obtain aggregates the powders are mixed with binders or plasticizers. Aggregagates of the desired type (equiaxial, spherical, fibrous, laminar, etc.) are then molded from this mixture. The aggregates are annealed in some cases (in order to increase their strength). Powdered metallic

materials are manufactured from the aggregates by the usual techniques. The macrostructure of the initial aggregates is retained in the sintered products (Fig. 1). The advantages of materials produced by this method include better pressibility and higher thermostability, errosion resistance, and wear resistance. This technique permits production of powdered metallic materials with structural elements of the desired size and shape. Even when unaggregated powders are employed, the structure of sintered powdered metallic materials has a number of features that distinguish it from that of cast metals. It can be seen in Fig. 2, which shows porous sintered copper, that during sintering the initial powdered particles were aggregated into groups varying somewhat in size and shape. Closer contact is observed between the particles (granules) in each group than between the groups of particles (grains). This means that the intragroup porosity is less than the intergroup porosity. The strength and the majority of the other characteristics of powdered metallic materials are governed by the weakest (contact) cross section of the component passing wholly through the contact point and the pores, some of the cross section (through the pores) being disregarded. Since the weakest cross section passes between the groups of particles and not through them, it is these groups (grains) and not the particles (granules) that are the structural elements governing the properties of the powdered metal. As can be seen in Fig. 3, which shows red bronze as an example of a compact nonporous powdered-metal alloy, the copper particles (granules) aggregated during sintering to form small groups containing almost no red, the majority of the latter lying between the groups. In both porous and nonporous powdered metallic materials the grains are usually smaller than in smelted alloys of the same composition. Preferential orientation (texture) has a less pronounced unfavorable influence in these materials. The structure of fi-

brous metals (Fig. 4) differs still further from that of cast metals and is distinguished by especially high strength.



Fig. 1. Macrostructure of a heat-resistant material manufactured from powder subjected to preliminary laminary aggregation. 10x.



Fig. 2. Structure of porous sintered copper manufactured from electrolytic powder. The white areas are particles aggregated into groups during sintering, while the black areas are pores. 200x.



Fig. 3. Powdered lead bronze containing 35% lead. The white areas are copper and the black areas lead. 500x.



Fig. 4. Macrostructure of article pressed from copper fibers. 10x.

As a result of their finer-grained structure, considerable number of defects, and higher oxide content powdered metallic materials have characteristics that differ somewhat from those of the corresponding cast metals, even after being reduced to the completely compact, nonporous state. The strength indices ($\sigma_b$, $\sigma_{0.2}$, $\sigma_{pts}$, $\sigma_{izg}$, $\sigma_{-b}$, and $\sigma_{-1}$) of completely compacted materials are equal to or somewhat higher than those of cast metals (after deformation and annealing). Their indices

TABLE 1

Characteristics of Articles Rolled from Store Poisson Powdered Steel and Cast Electric Steel*

| 1 Свойства | 2 Сталь Стора | Электро- 3 сталь |
|---|---|---|
| $\sigma_{0,2}$ (кг/мм²) 4 | 28 | 27 |
| $\sigma_в$ (кг/мм²) 4 | 41 | 41 |
| δ (%) | 31 | 28,5 |
| ψ (%) | 65 | 65 |
| $a_н$ (кгм/см²) 5 | 10,8 | 12,5 |
| Порог хладноломкости 6 (°С) | −25 | −40 |

*C content – 0.13%. Normalization at 950°.

1) Characteristic; 2) Store st el; 3) electric steel; 4) kg/mm$^2$; 5) kg-m/cm$^2$; 6) threshold of cold-shortness (°C).

of deformability δ, ψ, and f and, particularly, their impact strength $\alpha_n$ are usually lower than those of cast metals. The threshold of cold-shortness generally lies at higher temperatures for compacted powdered metallic materials than for cast metals. The vibration resistance and thermal stability of the former are higher. The detrimental influence of texture during pressure working is less pronounced in powdered metals. It can be seen from Table 1 that, all other characteristics being equal, rolled powdered steel has a somewhat lower impact strength and a higher threshold of cold-shortness than iron or cast electric carbon steel of similar composition. As a result of its more favorable structure, extruded powdered beryllium has a higher strength, plasticity, and heat resistance than cast vacuum-extruded beryllium, despite its higher oxide content (see Beryllium). Aircraft-turbine compressor blades, which function at 370°, are an example of the high vibration resistance of powdered metallic materials; they are manufactured from powdered

iron impregnated with a copper alloy. This material has a $\sigma_b$ = 60-75 kg/mm$^2$ at a $\delta \approx 6\%$ and a vibration resistance 3-4 times that of stainless and 8 times that of carbon steel. The difference in hot strength, particularly long-term hot strength, is attributable to the nature of the corresponding oxides, which are present in large quantities in powdered metals. Pressed aluminum powder containing 6-16% high-hot-strength aluminum oxide has a higher long-term hot strength than the best types of cast aluminum alloys (see Sintered aluminum powder). Conversely, powdered molybdenum, whose oxides are volatile, has a lower long-term hot strength, a higher creep rate, and a shorter time to fracture under equal tensile stresses than melted molybdenum (Table 2).

TABLE 2

Characteristics of Recrystallized Powdered Molybdenum and Arc-Smelted Molybdenum During Prolonged Vacuum Tensile Testing

| 1 Темп-ра (°C) | 2 Удельная нагрузка (кг/мм²) | 3 Продолжительность испытания до разрыва (часы) | | 6 Минимальная скорость ползучести (% в час) | |
|---|---|---|---|---|---|
| | | 4 порошковый молибден | 5 плавленый молибден | 4 порошковый молибден | 5 плавленый молибден |
| 870 | 14 | 7.8 | 70.4 | – | 0.4 |
| 980 | 8.8 | 18.5 | 87.7 | – | 0.6 |
| 980 | 7 | 157.7 | 482 | 0.027 | 0.013 |
| 1090 | 7 | 2.4 | 27.0 | – | 0.75 |

1) Temperature (°C); 2) load (kg/mm$^2$); 3) test time to fracture (hr); 4) powdered molybdenum; 5) smelted molybdenum; 6) minimum creep rate (% per hr).

TABLE 3

Ultimate Strength and Yield Strength for Porous Contact Iron and Copper

| 1 Металл и пористость (%) | 2 $\sigma_{вз}$ (кг/мм²) | 2 $\sigma_{т.кон}$ (кг/мм²) |
|---|---|---|
| Cu, 30–40% | 20–23 | 16–18 |
| Cu, 5–10% | 20–23 | 9–10 |
| Fe, 30–40% | 32–34 | 30–33 |
| Fe, 5–10% | 32–34 | 18–20 |

1) Metal and porosity (%); 2) kg/mm$^2$.

The values of E, $\alpha$, $\lambda$, and $\rho$ are the same for nonporous powdered metals as for smelted metals. Compact nonporous metals obtained from thin fibers have the highest strength. For example, after pressure working and annealing cast copper has a $\sigma_b$ = 20-23 kg/mm$^2$, i.e., the same as nonporous powdered copper, while compact copper produced from fibers $\mu$ in diameter as a considerably higher strength ($\sigma_b$ = 30-31 kg/mm$^2$).

The porosity of porous powdered metals reaches 60% by volume. A number of the characteristics of porous metals, including E, $\sigma_b$, HB, and $\rho$ are determined by the weakest cross section passing through the contact sites and the pores between them (the contact cross section). Research has shown that in any cross section of a porous material stresses not exceeding the elastic limit are almost all concentrated in a comparatively small area, which equals the ratio of the contact cross section to the nominal cross section of the powdered specimen. This makes it possible to determine the contact cross section of a powdered metal (the ratio of the modulus of elasticity of the porous metal, $E_{por}$, to that of the nonporous compact metal, $E_k$):

$$E_{пор}/E_к = \alpha, \qquad (1)$$

where $\alpha$ is the ratio of the contact cross section to the nominal cross section of the specimen. If we divide one of the strength indices of the material by the contact cross section $\alpha$ calculated from Eq. (1) we can find the contact strength for a porous metal:

$$S_к = S_{пор}/\alpha, \qquad (2)$$

where $S_{por}$ is a strength index for the modulus of elasticity (e.g., $\sigma_b$, $\sigma_{0.2}$, or E) of the porous metal and $S_k$ is this same index for the compact cross section $\alpha$. Table 3 shows the contact $\sigma_{bk}$ and $\sigma_{0.2k}$ for porous iron and copper. The value of $\sigma_{bk}$ are approximately equal to those of $\sigma_b$ for cast iron and copper after deformation and annealing (for

cast copper after deformation and annealing $\sigma_b$ = 20-24 kg/mm$^2$, while for cast iron $\sigma_b$ = 30-35 kg/mm$^2$). As porosity decreases the value of $\sigma_{0.2k}$ drops from that of $\sigma_{0.2}$ for notched specimens of the corresponding metals to that of $\sigma_{0.2}$ for unnotched specimens. The influence of pores on the value of $\sigma_{0.2}$ is thus analogous to that of notching.

For porous metals the contact cross section $\alpha$ is defined as a function of porosity and relative density by the formula:

$$\alpha = S_{пор}/S_к = \vartheta^n \frac{\vartheta - \vartheta_0}{1 - \vartheta_0} = (1 - \Pi)^n \frac{\Pi_0 - \Pi}{\Pi_0}, \qquad (3)$$

where $\Pi$ is the porosity (fractional pore volume), $\vartheta$ is the relative density (the ratio of the density of the porous metal to that of the nonporous metal), $\vartheta_0$ and $\Pi_0$ are the initial values for the powder before pressing and sintering, $S_{por}$ is the value of a given characteristic of the porous metal, and $S_k$ is the value of the corresponding characteristic of the compact metal. Since $\frac{\vartheta - \vartheta_0}{1 - \vartheta_0} \approx \vartheta^{n-1}$, where $n \geq 1$, Eq. (3) can be roughly rewritten in the form:

$$\alpha = S_{пор}/S_к = (1 - \Pi)^m = \vartheta^m, \qquad (4)$$

where $m \geq 3$; the maximum value of $\alpha = S_{por}/S_k$ corresponds to the minimum value $m = 3$.

Figure 5 shows the validity of Eq. (3) for the E and $\sigma_b$ of porous copper with $\vartheta_0 = 0.18$ and $\Pi_0 = 0.82$. It can also be seen from Fig. 5 that the values of E and $\sigma_b$ are rather close to those given by the formula $\alpha = S_{por}/S_k = \vartheta^3$. Equations (3) and (4) are also suitable for calculating the HB, HV, and electrical conductivity of porous metals. It must be kept in mind that the hardness of compact powdered metals may be approximately 30% higher than that of cast metals after deformation and annealing.

Using Eq. (4) the corresponding characteristics of a porous material are easily calculated. For example, when $m = 3$ the $\sigma_b$ of a porous

metal amounts to 51% of the $\sigma_b$ of the compact metal at a porosity of 20% (a relative density of 0.8), 34% at a porosity of 30%, and 12.5% at a porosity of 50%. It also follows from Eq. (4) that when the density is reduced by 1% the characteristic in question decreases by m%. The strength of plastic metals drops uniformly by about 3% for each 1% decrease in density. The strength of brittle materials drops rapidly as density is reduced at low porosities (m ≈ 10), but decreases far more thoroughly when the porosity is further increased (m < 3).

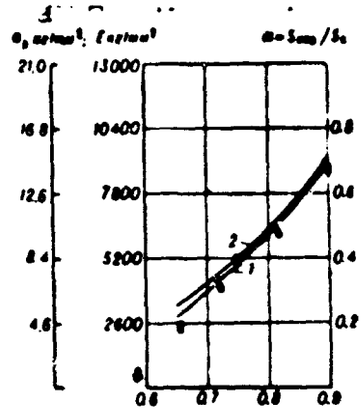



Fig. 5. Mechanical characteristics of sintered copper as a function of porosity (the dots represent experimental values of $E_1$ and the crosses experimental values of $\sigma_b$): 1) Theoretical curve calculated from Eq. (3); 2) theoretical curve calculated from the formula $\alpha = S_{por}/S_k$ = = ϑ3. a) kg/mm².

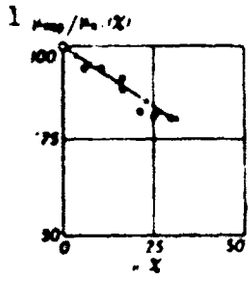



Fig. 6. Coefficient of porosity μ of iron as a function of porosity. 1) $\mu_{por}/\mu_k$ (%).



Fig. 7. Macrostructure of porous filter sintered from spherical powdered bronze. 10×.

TABLE 4

Thermostability of Composition Based on Titanium Carbide, Chromium Carbide, and Graphite

| 1 Размер структурных элементов (мк) | 2 Число теплосмен до появления первых трещин |
|---|---|
| Неагрегированный порошок, 3 частицы <10 | 0.5 (полный цикл) |
| 4 Агрегаты 125 | 10.5 |
| 5 То же 160 | 14 |
| » 200 | 13.5 |
| » 315 | 11.5 |
| » 350 | 11 |
| » 350 | 10 |

1) Size of structural elements (μ); 2) number of thermal cycles to appearance of initial cracks; 3) unaggregated powder with particles <10 μ; 4) aggregates; 5) the same; 6) incomplete cycle.

The ratio $\sigma_b$/HB is approximately 0.3-0.40 for porous plastic metals at optimum values of $\sigma_b$. Porous metals are characterized by a decrease in Poisson's ratio μ as porosity increases. A formula has been suggested to define μ as a function of relative density ϑ and porosity П:

$$\mu_{пор} = \frac{\Phi\mu_к}{1-(1-\Phi)\mu_к} = \mu_к \frac{1-П}{1-П\mu_к}. \qquad (5)$$

where $\mu_{por}$ is the Poisson's ratio of the porous metal and $\mu_k$ is that of the compact metal.

Thus, when $\mu_k$ = 0.295 $\mu_{por}$ = ~93% of the value of $\mu_k$ at 10% porosity, 81% at 25% porosity, and 77% at 30% porosity. Figure 6 shows that the experimentally determined values of $\mu_{por}$ for porous iron as a function of porosity are quite close to the values calculated from Eq. (5). The corrosion resistance, heat resistance, and hot strength of porous metals also drop sharply as their porosity increases. In certain cases thermostability is somewhat increased by a rise in porosity, but in materials with an insufficient hot strength this characteristic decreases as porosity increases. The coefficient of thermal expansion is virtual-

ly independent of porosity.

An important characteristic of porous powdered metals is their permeability, i.e., the amount of liquid or gas that can pass through a unit cross-sectional area under given conditions. In accordance with D'Arcy's law

$$Q=\frac{\gamma}{\eta}\cdot\frac{\alpha}{l}\Delta P, \qquad (6)$$

where Q is the quantity of liquid in g passing through 1 $cm^2$ of surface per sec (the permeability), $\gamma$ is the specific gravity of the liquid, $\eta$ is its viscosity, $\alpha$ is the permeability coefficient (with a dimension of $cm^2$), $l$ is the wall thickness, and $\Delta P$ is the pressure drop. All other experimental conditions being equal, Q and $\alpha$ are proportional and their dependence on various factors consequently has the same character. The permeability is roughly proportional to the square of the particle diameter (the square of the pore diameter) and to the second-sixth power of the porosity:

$$Q=k_1\Pi^n; \quad \alpha=k_2\Pi^n. \qquad (7)$$

where $k_1$ and $k_2$ are proportionality factors and n = const = 2-6. The lower value, n = 2, corresponds to the permeability of porous materials with spherical particles of uniform size, while the upper value, n = = 6, corresponds to that of materials with irregular particles of varying size.

Figure 7 shows the structure of porous materials (filters) with spherical particles. A very important requirement imposed on permeable materials is uniform permeability over the entire cross section of the product. It follows from Eq. (7) that the permeability is altered by n% when the porosity is varied by 1%. Materials with the lowest value of n, i.e., those consisting of spherical particles of uniform size, consequently exhibit the most uniform permeability. Permeability also

depends on wall thickness. In actuality, permeability does not vary in inverse proportion to the wall thickness $\ell$, as D'Arcy's law requires, but in inverse proportion to $\ell^b$, where $b \geq 1$. The lowest value of b, close to unity, is exhibited by materials consisting of spherical particles. Permeability can thus vary with three factors – the particle size of the initial powders, the porosity, and the wall thickness of the finished product.

TABLE 5

Classification of the Most Important Types of Powderered Metallic Materials and Their Principal Applications

| Type of Material | Type of Product | Characteristics and Composition of Material | Principal Applications |
|---|---|---|---|
| Friction materils | Friction elements of brake devices | Alloys based on iron or copper with certain alloying metals (W, Cr, Cu, Pb, etc.) and nonmetalic components (quartz, silica, barite, asbestos, graphite, etc.) added. These materials have a high coefficient of friction and good wear resistance. They are used in the form of bimetallic components on a steel base | Aircraft wheel brakes, drive elements of hydraulic-transmision tanks, excavator brakes, and unit brake assemblies |
| The same | Antifriction elements of friction pairs | Porous components in the form of bushings manufactured from iron or bronze powders with up to 4% graphite added. Their porosity ranges from 15 to 30%. The pores are filled with oil, so that the components are self-lubricating. Their distinguishing characteristic is their low coefficent of friction and high wear resistance | Friction units of aircraft, automobiles. tractors, conveyors, textile machinery, cash registers, machine tools, and other types of equipment |

| | | | |
|---|---|---|---|
| Electronic materials | Magnets | Magnetic alloys based on iron, nickel, cobalt, and aluminum with various alloying metals added. Resins are added to certain of these alloys as a dielectric component. They are distinguished by a more uniform structure and consequently by higher quality than cast cermet magnets. They are produced in the form of plates, bushings, strips, rings, etc. | Communications equipment, medical instruments, and ignition units |
| The same | Contacts | Alloys of high-melting metals (most frequently tungsten and molybdenum) with highly conductive metals (copper, silver, etc.). They have a high erosion resistance and mechanical strength combined with good electrical conductivity | Electrodes for resistance welding and various spark devices. Contact units for auxiliary equipment |
| The same | Electrical brushes | Compositions of graphite materials and metals (copper, silver, etc.). They have good electrical erosion resistance combined with high conductivity | Various types of current correctors |
| Tool materials | Hard alloys | Sintered alloys of high-melting-metal carbides and metals of the iron group (Co, Ni, Fe). They are distinguished by high hardness and wear resistance. They are produced in the form of various types of plates for tools | Cutting, drilling, stamping, and drawing tools |
| The same | Diamond-metal articles | Alloys of high-melting metals with Ni, Co, or Fe or solid alloys containing diamond dust | Tools for drilling especially hard rocks or for dressing grindstones |

| | | | |
|---|---|---|---|
| Special alloys | High-hot-strength or heat-resistant alloys | Alloys of high-melting compounds (carbides, borides, silicides, or nitrides) and metals or graphite. They are distinguished by high hot strength, while some exhibit high heat resistance | Components of jet aircraft, stationary turbines, and pumps which must operate while exposed to gaseous corrosion. Rocket components |
| The same | Vacuum-tight alloys | Alloys of iron and high-melting metals (W, Mo, Nb, Ta, etc.) | Components of vacuum equipment; |
| Porous materials | Filters | Articles of bronze, nickel, iron, stainless steel, etc. shot having high porosity. They are produced in the form of rings, plates, leaves, caps, and various shapes | Purification of liquids and vapors in the chemical and petroleum industries, in aircraft and automobiles, etc. |
| The same | Through-flow elements of cooling systems | Porous articles in the form of sheets, plates, and sleeves of nichrome, stainless steel, nickel, and other metals with a porosity of 20-60% | Systems for cooling structural units by through-flow of an evaporated liquid or gas through porous elements |
| Porous materials | Components with a fibrous structure | These materials are manufactured from fine wire usually in sheet form. They are similar in structure to felt and are distinguished by high porosity (up to 90%) and satisfactory strength | Filters, bases for heat-insulating coatings, acoustical insulation |
| Compact materials | Component with minimum residual porosity (no more than 0.5%) | Components produced from the most diverse metals and used to replace components obtained by machining, in order to save metal | The same applications as components fabricated by other methods. Deformed compact sintered articles are equal in strength to articles manufactured by machining from ordinary cast and deformed metals. The strength of undeformed compact sintered articles is less by a factor of approximately 2 |

Porous fibrous materials have a broader porosity range, from zero to morethan 90%, than powdered materials. The dependence on mechanical characteristics, electrical conductivity, and thermal conductivity on porosity obeys Eq. (4), but the values of $\underline{m}$ are lower. Thus, the value of $\underline{m}$ for $\sigma_b$ is 2.3-3. In addition, at $\Pi = 0$ the $\sigma_b$ of fibrous metals is 20-30% higher than that of ordinary powdered metals and cast metals of the same composition. At the same porosity fibrous materials may consequently have a higher $\sigma_b$ than powdered metals (by a factor of up to 2). The $\alpha_n$ and plasticity indices of fibrous metals may be 5-10 times as great as those of powdered metals with the same porosity. The most porous fibrous metals have a very low contact cross section $\alpha$ (one or several %) and consequently a very low modulus of elasticity (E). As a result of their low E and $\alpha$ porous fibrous metals are very effective acoustical and thermal insulators. There are materials of metal fibrous that absorb 94% of acoustical energy at room temperature and 87% at 400°. Porous fibrous materials also have a higher heat resistance than the corresponding powdered metals.

One of the principal uses of the new materials consisting of preliminarily aggregated powders is attributable to their higher thermal stability than ordinary powdered metals or cast alloys. Table 4 compares the heat resistance of specimens prepared from compositions based on titanium carbide, chromium carbide, and graphite in the form of ordinary powders and of powders preliminarily conglomerated into equiaxial aggregates.

The finished specimens were subjected to cyclic heat treatment consisting of rapid heating to 1200° and quenching in water at room temperature. It can be seen from Table 4 that the heat resistance of the preliminarily aggregated materials was an order of magnitude higher than that of the ordinary powdered metallic materials prepared from

unaggregated powder. Materials obtained from spherical aggregates have an especially high thermostability. The classification and principal application of the most important types of powdered metallic materials are shown in Table 5.

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The above nomenclature of powdered metallic material is not exhaustive and includes only the basic types and varieties that have come into wide commercial use.

Cermet products can be molded by various methods, prime among which are the following. Cold pressing – pressing of powders in steel pressforms in hydraulic or mechanical presses at pressures of 0.5-8 $t/cm^2$. When powders of low pressibility are to be molded various binders (paraffin, gum rubber dissolved in gasoline, gelatin dissolved in water, etc.) are added and removed by evaporation during subsequent sintering. This method is the most commonly employed and is used principally for molding small components with simple shapes. Hydrostatic molding - powder poured into a rubber mold is subjected to compression in all directions through a fluid medium. This method is used for molding large components of complex shape. Nozzle forming is employed in the manufacture of articles of the tube or rod method. In essence, this method consists in plasticizing the powder with various organic substances (e.g., paraffin) and forcing the plasticized mass through an aperture of the desired shape under pressure. Rolling of powders is employed in the manufacture of sheets and strips. In essence, this method consists in direct rolling of the powders in a mill with horizontal rollers.

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POWDER MAGNETIC DEFECTOSCOPY – see Magnetic defectoscopy.

PRECIOUS METALS – gold, silver, and metals of the platinum group (platinum, palladium, iridium, rhodium, osmium, and ruthenium), whose principal virtues are their high corrosion resistance, high-temperature oxidation resistance, and high melting temperature. The principal properties of the precious metals are shown in Table 1. The electrical and thermoelectric properties of these metals are greatly altered by the presence of small quantities of impurities. Their temperature coeffi-

TABLE 1

Properties of Precious Metals

| Свойства 1 | Ru | Rh | Pd | Ag | Os | Ir | Pt | Au |
|---|---|---|---|---|---|---|---|---|
| 2 Порядковый номер | 44 | 45 | 46 | 47 | 76 | 77 | 78 | 79 |
| 3 Атомный вес | 101.07 | 102.905 | 106.4 | 107.870 | 190.2 | 192.2 | 195.09 | 196.97 |
| 4 Плотность (г/см³) | 12.4 | 12.44 | 12.02 | 10.50 | 22.5 | 22.4 | 21.4 | 19.32 |
| 5 Кристаллич. решетка | Гексагональная плотноупакованная 14 | α-простой куб., β-кубическая гранецентрированная 15 | Кубическая гранецентрированная 16 | Кубическая гранецентрированная 16 | Гексагональная плотноупакованная 14 | Кубическая гранецентрированная 16 | Кубическая гранецентрированная 16 | Кубическая гранецентрированная 16 |
| 6 Параметры решетки | $a = 2.7003$ Å<br>$c = 1.5824$ | $a = 3.211$ Å<br>$\beta = 3.7957$ Å | $a = 3.8824$ Å | $a = 4.0774$ Å | $a = 2.7353$ Å<br>$c = 1.5789$ | $a = 3.8312$ Å | $a = 3.916$ Å | $a = 4.0704$ Å |
| $t_{пл}$ | 2250 | 1960 | 1552 | 960.5 | ~3000 | 2610 | 1769 | 1063 |
| $t^{\circ}_{кип}$ | ~4900 | ~4500 | 3980 | 2212 | ~5500 | ~5300 | 4530 | 2947 |
| 7 $c$ (0–100°) (кал/г·°С) | 0.057 | 0.0604 | 0.0584 | 0.0559 | 0.0318 | 0.0312 | 0.0317 | 0.0316 |
| 8 $\lambda$ при 25° (кал/см·сек·°С) | — | 0.213 | 0.17 | 1.00 | - | 0.141 | 0.164 | 0.712 |
| 9 $\rho$ (мком·см) при 0° | 6.83 | 4.3 | 10.0 | 1.456 | 9.5 | 4.92 | 9.83 | 1.937 |
| 9 $\rho$ (мком·см) при 25° | 7.427 | 4.9 | 10.8 | 1.609 | 9.66 | 5.40 | 10.6 | 2.121 |
| 9 $\rho$ (мком·см) при 100° | 9.262 | 6.26 | 12.6 | 2.061 | 12.43 | 6.86 | 13.1 | 2.857 |
| 10 Температурный коэффициент электросопротивления $10^4$ | 35.9 | 45.7 | 37.7 | 40.33 | 42.0 | 39.25 | 37.27 | 36.9 |
| 11 *НВ* в отожженном состоянии (кг/мм²) | 220 | 130 | 49 | 50 | 400 | 164 | 37 | 18 |
| 12 $E$ (кг/мм²) | 42 000 | 38 000 | 12 600 | 8200 | 56 700 | 52 000 | 17 500 | 7800 |
| 13 $\sigma_в$ (кг/мм²) | — | 50 | 18.5 | 18 | — | 23 | 13.5 | 13.9 |
| $\delta$ (%) | — | 7 | 24–30 | 50 | — | 2 | 31 | 50 |
| $\psi$ (%) | — | — | — | 90 | — | — | — | 90 |

1) Property; 2) atomic number; 3) atomic weight; 4) density ($g/cm^3$); 5) crystal lattice; 6) lattice parameters; 7) $c$(0–100°; cal/g·°C); 8) $\lambda$ at 25° (cal/cm·sec·°C); 9) $\rho$($\mu$ ohms·cm) at; 10) temperature coefficient of electrical resistance $\times 10^4$; 11) HB in annealed state ($kg/mm^2$); 12) $E$($kg/mm^2$); 13) $\sigma_b$ ($kg/mm^2$); 14) hexagonal, closely packed; 15) α – simple cubic; β – cubic face-centered; 16) cubic face-centered.

cient of electrical resistance or thermoelectromotive force is consequently used for determination of purity (spectral analysis has been

found to be insufficiently sensitive). Platinum, palladium, silver, and gold have a low hardness, a high elongation, and a large reduction in cross-sectional area; they are easily machined, retaining their plasticity at high degrees of deformation. Rhodium and iridium are inelastic at room temperature and can be rolled and wire-drawn only at 1200-1400°. Ruthenium and osmium, which have hexagonal lattices, are inelastic even at 1500°. Iridium, rhodium, ruthenium, and osmium plates and wire can be manufactured by cermet methods. Platinum, gold, and silver are virtually unoxidized in air, even when molten. Osmium and ruthenium are easily oxidized by heating in air. Osmium forms the volatile, poisonous oxide $OsO_4$, while ruthenium is oxidized to $RuO_2$. Iridium, rhodium, and palladium are oxidized to a lesser extent when heated. Iridium, ruthenium, and rhodium are insoluble in acids and even in boiling aqua regia. Platinum and gold dissolve in aqua regia on heating, but are resistant to other acids. Palladium reacts with nitric, hydrochloric, and sulfuric acids on heating. The metals of the platinum group readily form brittle alloys with carbon when heated. The majority of the precious metals are used in the form of alloys for structural purposes. Especially high requirements are imposed on precious-metal alloys: in alloying these elements it is necessary to maintain their corrosion resistance and the invariability of their other characteristics at high temperatures. Small additions of nonprecious metals substantially reduce their corrosion resistance; the alloying elements are thus usually precious metals as well and sometimes actually increase the corrosion resistance of the base metal. Thus, the resistance of platinum and palladium is increased by addition of iridium, rhodium, or ruthenium. Electroplating of metals with silver, gold, or palladium protects them from oxidation (see Anticorrosion coatings). Silver has one drawback, tarnishing in the presence of hydrogen sulfide, and silvered

instruments or components are consequently ol' plated; gold coatings, however, are porous. Palladium coatings are less porous and more corrosion-resistant. As a result of its very high reflectivity (~100%) silver is employed in the manufacture of mirrors. However, rhodium coatings are preferred in Soviet technical mirrors, reflectors, projectors, and measuring instruments. Rhodium has a coefficient of reflection of ~80% and a high corrosion resistance. Rhodium plating is also used to give mechanical strength to the components of watches and other precision instruments. Silvering of wires is utilized in high-frequency electronics. Thermocouples of precious metals and their alloys are used for measuring high-temperatures; one advantage of these devices is the fact that they can be used in an oxidizing atmosphere. The LeChatelier platinum/platinum-rhodium thermocouple, in which the positive electrode is an alloy of platinum and 10% rhodium and the negative electrode is pure platinum, is well known; it is used for prolonged measurements at temperatures of up to 1300° and for very brief measurements at temperatures of up to 1600°. Thermocouples of the alloys described below are recommended for measuring higher temperatures (Table 2).

TABLE 2

Thermocouples for Working at High Temperatures

| Положительный электрод a + | Отрицательный электрод b − | Предельная темп-ра C (°C) | Термоэлектродвижущая сила (мв) d |
|---|---|---|---|
| 1. Платина + 13% родия e | Платина + 1% родия f | 1450° | 16.5 |
| 2. Платина + 30% родия | Платина + 6% родия | 1800° | 13.85 |
| 3. Платина + 40% родия | Платина + 20% родия | 1800° | 4.5 |
| 4. Родий | Платина + 20% родия | 1800° | 7.51 |
| 5. Иридий g | Иридий + 40% родия | 2000° | 12.61 |
| 6. Платина + 10% родия | Золото + 30% палладия + 10% платины | 1200° | 55—60 мв °C k |
| 7. Платина + 10% родия | Золото + 40% палладия | 1200° | — |
| 8. Серебро h | Палладий + 40% серебра | 900° | 80 мв/°C |

a) Positive electrode; b) negative electrode; c) maximum temperature (°C); d) thermoelectromotive force (mv); e) platinum; f) rhodium; g)

iridium; h) silver; i) gold; j) palladium; k) μv/°C.

The readings of thermocouples may vary during operation. The Le-Chatelier thermocouples designated as Nos. 3, 4, and 6 have the greatest constancy. The wire for resistance thermometers for measuring temperatures of from −200° to +500° to within 0.01° is made of pure platinum, which has a high temperature coefficient of resistance and stable electrical properties. The resistors (potentiometers) for automatic instruments and deformation-measuring devices are made of precious-metal alloys. The latter should have a low temperature coefficient of resistance, a low thermoelectromotive force when coupled with copper, high durability, nonoxidizability, and a high melting point. The following alloys of palladium, silver, and, less frequently, other metals, are widely used for these purposes: 60% palladium +40% silver (similar to constantan in the constancy of its resistance at different temperatures); 50% palladium +50% silver; 20% palladium +80% silver; 5% palladium +95% silver; 90% palladium +10% ruthenium; 85% palladium +15% copper; 60% palladium +40% copper; 80% palladium +20% nickel; 90% palladium +10% molybdenum; 90% palladium +10% tungsten; 80% palladium +20% tungsten; 75% palladium +25% tungsten; 30% palladium +65% silver +5% copper; 98% gold +2% chromium (after annealing at 200° this alloy has a stable resistance of ~33 μ ohms•cm, a temperature coefficient of $10^{-6}$ per °C, and a thermoelectromotive force of 7-8 μv/°C when coupled with copper); 82% silver +10% manganese +8% tin (after aging at 175° for 10 hr this alloy has a specific resistance of 50 μohms•cm, a temperature coefficient of zero, and a thermoelectromotive force of 0.5 μv/°C when coupled with copper). An alloy containing from 97.5 to 70% platinum and from 2.5 to 30% iridium has high corrosion and mechanical resistance and high hardness at room and elevated temperatures. Electri-

cal-resistance heating elements for laboratory furnaces, which operate at 1800°, are manufactured from rhodium strips produced by the cermet method. This temperature can be achieved in furnaces with windings of an alloy of platinum with 30% rhodium, whose melting point is approximately 50° lower than that of pure rhodium. Furnaces with rhodium and platinum heating elements can operate in oxidizing atmospheres. Pure platinum is the metal most widely used for furnace heating elements. When the winding is located outside the furnace crucible or tube the hearth temperature may reach 1300°, while when the heating element is within the hearth it may reach 1500°. Furnaces with platinum heating elements require a starting rheostat, since the electrical resistance of platinum undergoes a large change as it is heated. The physical properties of the precious metals permit their wide use for discontinuous electrical contacts, (relays, magnetos, voltage regulators, telephones, and other equipment and instruments). Pure silver, pure gold, and alloys of gold and silver, gold and platinum, and gold, silver, and platinum can be used for contacts when working with weak currents at low voltages. Alloys of palladium and silver (from 60 to 5% palladium) are widely used for low-current, moderate-voltage communications equipment. When working with large currents a spark discharge occurs between the contacts and erosion develops; the contacts may become welded together. An electric arc develops between the contacts at still higher circuit voltages. It is consequently necessary to increase the mechanical pressure on the contacts and thus to increase their hardness and resistance to mechanical wear. Alloys of platinum and iridium (up to 30% iridium) are regarded as the most suitable materials for such contacts. Alloys of ruthenium and osmium, platinum and 15% ruthenium, or platinum and osmium (up to 7%) can be used as substitutes for the costly iridium. In order to reduce the erosion of high-power platinum con-

tacts the platinum is alloyed with tungsten (up to 10% of the latter). Palladium alloyed with iridium, ruthenium, copper, tungsten, etc., is often used as a substitute for platinum in contacts. An alloy of palladium and 18% iridium, which has high elasticity, has come into use in the manufacture of spring contacts for aviation equipment. Contacts fabricated by the cermet method with silver as the current-carrying component are of practical significance. Hard alloys for "iridium tips" for fountain pens, the bearing points of the pivots of critical measuring instruments and watches, tips for the pivots on which the magnetic needles of navigational compasses rotate, and similar purposes are produced from iridium, osmium, and ruthenium. Natural osmic iridium, which consists of iridium (40-50%), osmium (30-40%), platinum (5-10%), ruthenium (5-15%) and other impurities, is widely used for the tips of especially critical components. A grain of this mineral up to 1 mm in diameter is silver-soldered, sharpened to a point, and polished. Utilization of natural osmic iridium entails a number of difficulties as a result of the irregular grain size and the loss in sharpening. The artificial alloys employed for this purpose are extremely varied and complex: osmium-tungsten-nickel, ruthenium-tungsten-cobalt, ruthenium-tungsten-nickel, iridium-osmium-ruthenium, etc. Pure gold and silver are used for the fuses of especially critical electronic instruments. Magnetic alloys of precious metals, which have a high coercive force, are employed in small instruments. A quenched and tempered platinum alloy containing 22.2% iron by weight has a coercive force H = 1570 oersteds and a residual inductance B = 5830 gausses. A quenched and tempered platinum alloy containing 23.3% cobalt by weight has the characteristics H = 2700 oersteds and B = 4500 gausses. "Silmanal" ($Ag_5MMAJ_1$) which contains 86.7% silver, 8.8% manganese, and 4.5% aluminum by weight, has the characteristics H = 300-590 oersteds and B = 6300 gaus-

ses. When quenched from 250° this same alloy has a coercive force of 6100 oersteds. The residual inductance of "Silmanal" remains unchanged under the influence of external magnetic fields and serves as a "magnetic spring" in instruments with rotating magnets. Alloys of platinum and rhodium (from 3.5 to 10% of the latter abroad and 7% in the USSR) are suitable for heating boats and draw plates in the production of fiberglass. Only these alloys, which have a high melting point, provide mechanical strength at 1400° and corrosion resistance in molten glass. Chemical apparatus and vessels of precious-metal alloys are used when high-temperature corrosion resistance is required. Vessels of platinum or palladium are employed in the distillation of hydrofluoric acid and the production of fluorine compounds. However, reaction vessels or their components are rarely made wholly of precious metals; the equipment or component in question is generally clad in a precious-metal foil, which cuts costs considerably. Moreover, almost none of the metal is lost while the apparatus is in use and, on replacement, the foil is completely recovered as scrap. Platinum-clad apparatus has come into use not only in the production of high-purity chemicals, but also in comparatively large-scale chemical production processes and in the foodstuffs industry. In those cases where the chemical stability and high melting point of platinum or palladium is not sufficient it is replaced by alloys of platinum and metals which improve these properties: iridium (5-25%), rhodium (3-10%), and ruthenium (2-10%). Platinum is also employed for insoluble electrodes in certain electrochemical processes. Thus, the anodes of equipment for the electrochemical production of hydrogen peroxide, persulfates, and organic peroxides are made of platinum. This metal has long been used as a material for laboratory vessels (crucibles, dishes, electrodes, capillaries, combustion boats for organic analysis, spatulas, grids, filter cones, forceps tips, etc.). In

order to give dishes and crucibles higher mechanical strength they are sometimes fabricated from platinum alloys containing 1-3% rhodium. Platinum undergoes great softening at high temperatures, which makes it inconvenient to use this metal for vessels. Production of platinum articles by the cermet method, adding barium, zirconium, and beryllium oxides in quantities of 0.05-0.1%, appears promising, since these additives give the platinum mechanical strength at 1200-1300°. Crucibles of pure iridium are used at 2000-2300°. The largest amount of platinum metals is consumed by the chemical and petroleum-refining industries, which employ them as catalysts. The apparatus in which ammonia is burned to produce nitric acid utilizes grids of alloys containing 93% platinum and 7% rhodium or 93% platinum, 3% rhodium, and 4% paladium. These alloys are drawn into wire 0.05-0.09 mm in diameter, which is then woven into a grid with 1024 strands per $cm^2$. In the organic syntheses for hydrogenation of alcohols, hydrocarbons, heterocyclic compounds, olefins, polyolefins, aldehydes, acid ketones, etc., platinum or palladium is used as the catalyst for reduction of the nitrogen and heterocyclic compounds and for other reactions, while rhodium is used as the catalyst for hydrogenation of cyclic compounds. The catalysts for refining of petroleum fuels and production of high-octane gasolines are usually based on platinum and, less frequently, palladium. Catalysts are rarely prepared from the compact metals, but are employed in a finely pulverized state on carriers (asbestos, chamotte, charcoal, aluminum oxide, silica gel, etc.) or in the form of highly dispersed powders. The catalyzing metals should be pure and should not contain "poisonous" impurities. Thus, for example, the platinum-radium alloy employed in the oxidation of ammonia should not contain gold, which substantially reduces its catalyzing activity. Precious-metal alloys are used in the manufacture of medical instruments; noncorroding needles for hyperder-

mic syringes are produced from a platinum alloy containing 10% iridium, while cautery tips are made of platinum. A considerable quantity of precious metals is used in dentistry and jewelry-making.

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O.Ye. Zvyagintsev

PREFORMING – compressing the molding powder, primarily in the cold state. Preforming facilitates and simplifies the measuring out of the molding powder, removes a substantial amount of air from it, eliminates dust and losses which are inevitable in dosing by weight, reduces the volume of the loading chamber of the die, reduces the holding time in molding, makes it possible to use high-frequency heating. The process is performed on high-productivity preforming machines. Usually the preforms are produced in the form of disks up to 40 mm in diameter and up to 20 mm high.

In individual cases, particularly for fibrous and lamellar molding powders, use is made of shaped preforming, in which the preforms are imparted the configuration of the future products, and the preform mold or the molding powder is heated to 50-60° and preforming is perforemd at a pressure of 600-1500 $kg/cm^2$.

M.G. Gurariy

PRESERVATION OF ALUMINUM ALLOYS – is the protection of aluminum or of aluminum alloys against corrosion during transport and storage. The selection of the preservation method depends on the conditions and the time of the storage and on the presence of protecting coatings. Semi-finished products (sheets, plates, pipes, profiles, stamped pieces, rods, forged pieces, and wires) are mainly protected by mineral greases and a subsequent packing. The greases K-15 (neutral) and Kp-15 (GOST 9185-59), commercial vaseline (GOST 782-59) and mixtures of commercial vaseline and industrial oil grades 12 or 20 (GOST 1707-51) in a 50:50 ratio in summer, and 30:70 in winter (respectively) heated to 60 to 80° are used for the preservation of sheets. The preserved sheets are piled into packets, each sheet being interlaid with a paper of the following grades: base paper for paraffinization ODP-35 (GOST 5175-53); galosh (packing) paper (OST NKLes 8281/131); telephone paper (GOST 3563.47) and wrapping paper grade A or V (noncolored, GOST 8273-57), which are oiled with the same mixtures. The sheet packets are wrapped in two layers of some of the above-mentioned grades of oiled paper and in one layer of bitumen paper (GOST 515-56) or waterproof wrapping paper (GOST 8828-61). The sheets are packed into framework-boxes with or without plywood, or in compact boxes from planed planks. The moisture content of the wood and plywood must not exceed 18%. Sheets of alloys of the Duralumin type may be packed into containers; in this case no paper is interlaid between the oiled sheets (see Abrasion of Aluminum Alloys). Aside from the preservation by means of greases, sheets of aluminum alloys may be preserved by covering them with adhesive paper.

Commercial vaseline and mixtures of commercial vaseline with industrial oil of the grades 12 or 20 in a ratio of [illegible] respectively) are used for the preservation of plates, pipes, profiles, stamped pieces, rods, forged pieces and wires. The preserved semifinished products are wrapped separately or in packets in two layers of paper of the following grades: ODP-35 base paper for paraffinization: subpergament (GOST 1760-53); galosh paper, placard paper (non-colored, OST NKLes 255), telephone and wrapping paper of the grades A and V (non-colored), oiled with 30% commercial vaseline and 70% industrial oil, or paraffinized paper (standard 305 AMTU-52) and one layer of bitumen paper. The semifinished products are packed into compact plywood boxes, in framework-boxes reinforced by wood-bars or planks, or in compact wood-boxes made from planed planks. The moisture content of the plywood and the wood must not exceed 18%. Rods with a diameter of 22 to 50 mm are transported without oil preservation in boxes; rods with a diameter greater than 50 mm are transported without oiling or packing on shelvings in roofed wagons. Plates of aluminum alloys with a thickness of more than 20 mm are neither preserved nor packed; they are transported in roofed wagons, and each pile must be secured by wooden boards to avoid damages. Forged pieces having a weight of more than 20 kg may be transported without oiling and packing. Wire bundles are packed into mats, sacking, or wrapping fabric and bound with binder twine.

Mineral greases and mineral oils preventing a corrosion in storerooms are used to preserve machine parts, units and finished products; consistent greases, especially commercial vaseline and PP-95/5 grease (GOST 4113-48) are used for external preservation. The grease AMS-3 (GOST 2712-52) is used to preserve aluminum alloys under severe conditions (great humidity and sea fog). Liquid oils are used to preserve the internal hollows of the objects. The preserved pieces, units and

finished objects are wrapped in paraffinized and wrapping paper and packed into compact boxes, painted on the inside and out and covered on the inside by Ruberoid (GOST 2165-51), roofing leather (GOST 1887-51) or bitumen-paper.

Anodized pieces of aluminum alloys are not preserved by oiling when stored in storerooms for less than 1 year; preservation by oiling is carried out when they are stored longer than 1 year. Painted or varnished pieces are not preserved by oiling.

The storeroom for pieces, units, finished and semifinished products must be provided with heating and ventilating facilities. The relative humidity must not surpass 70%. The temperature must be kept from 10 to 35°. Strong changes in temperature and humidity of the air are not permissible.

Ye.P. Bel'chikova, O.I. Zapol'skaya

PRESERVATION OF MAGNESIUM ALLOYS – is the protection of magnesium alloys against corrosion during transportation and storage. Protection by means of chromium films is the most widely spread and practicable method (see Oxidizing of Magnesium Alloys); passivation in a solution of chromium trioxide is also used (see Pickling of Magnesium Alloys). The pieces may be kept without protection for 15-20 days under working conditions. Chromate films give a reliable protection for 3 months. When stored under normal storeroom conditions for up to 6 months, the semifinished products and pieces covered with a chromate film are supplementarily preserved by liquid neutral dehydrated oils: industrial oil of the grades 12 or 20 (GOST 1707-51), transformer oil (GOST 982--56), or aviation oil of the grades MK-22 or MS-20 (GOST 1013-49). The preservation of pieces can be ensured for one year by using gun-grease (GOST 3003-51) or commercial vaseline (GOST 782-59) thickened by a 2-4% ceresin (GOST 2488-47). The protective properties of the grease gradually lose their strength after the time mentioned above. Pieces and semifinished products are preserved according to their special specifications by gun-grease, wrapping in paper and packing into boxes when transported over long distances. The boxes must bear the inscription "Keep dry!" The railroad transport is carried out in roofed wagons, truck car transport must be carried out under a canvas cover. The consumer must open the boxes containing the semifinished products immediately upon reception. The preservation of assembled equipment, objects and spare parts made from magnesium alloys and covered with paints and varnishes depends upon the conditions and duration of the storage. A

lengthy storage under normal [illegible] jackets from polyvinylchloride or polyethylene film with [illegible] a gel as a drier. Outside of the storeroom, the preservation of the objects can be ensured (up to 10 years) by packing them into metal containers filled with dry nitrogen with a dew point of —5°. A surplus pressure must be in the container.

References: Timonova M.A. Zashchita magniyevykh splavov ot korrozii [Protection of Magnesium Alloys Against Corrosion] in the Collection: Magniyevyye splavy [Magnesium Alloys], Moscow, 1950.

M.A. Timonova

PRESSED CORK – a press-composition based on low grades of cork-oak bark and the waste from unit-cut articles manufactured from medium- and high-grade cork bark, using a plasticized glue. Small amounts of urotropine, glycerin, and paraffin are added to the composition to give it higher elasticity and mold resistance. The prepared mass is thoroughly mixed, poured into molds, held in a thermal furnace at 130-140° for several minutes, and moved on to the cutting machines. Pressed cork (and linings made of it) should not decompose in less than 1 hr in 45° water, should have a uniform structure with particles clearly visible at the cut surface, and should not have rough areas or crumbled edges. Pressed cork is used as a sealing liner in the automobile, tractor, and foodstuffs industries and in the manufacture of lifesaving devices for marine and river craft. Certain types of sporting goods are also produced from this material.

M. G. Pokhmel'nykh

PRESSED MAGNETS are magnets produced by pressing mixtures of powders of the highly coercive Alni and Alni with Co alloys together with a polymerizing dielectric (7-10% by volume). The energy of the pressed magnets usually constitutes about half the energy of the corresponding cast magnets, but the technological advantages (absence of mechanical working, easy pressing of mounting details) lead to their wide application. Pressed magnets based on micropowders of Fe and Fe-Co have been developed (particle size about 0.02 mm). Their energy (particularly the anisotropic versions with elongated particles) is on the same level as that of the best magnets made of Alni with Co (up to $5 \cdot 10^6$ gauss-oe). In comparison with the latter, the pressed magnets have the advantages: 1) low specific weight (4-4.5 $g/cm^3$ in place of 6.9-7.3 $g/cm^3$ for Alni – – Alnico), which is important for moving magnet instruments; 2) lower radiation level after irradiation in the case of pressed magnets made from iron powders (important in atomic power applications); 3) higher electrical resistance (operation under conditions of imposition of alternating magnetic fields); 4) wide range of variation of the ratio of residual induction to coercive force. The favorable combination of properties and technological advantages makes the pressed powders very promising.

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B.G. Livshits, A.A. Yudin

PRESSED STEEL SHAPES — semifinished products with various cross-sectional shapes manufactured by hot pressing. Pressing has a number of advantages as a method for the pressure-working of metals: it is possible to fabricate a large number of standardized shapes on a small set of hydraulic presses of varying power with easily replaceable matrices, to produce shapes of very complex cross-sectional configuration, to fabricate finished shapes in a single pass of the press, to carry out deformation with the metal in its most favorable stressed state (omnidirectional nonuniform compression), which permits pressing of low-plasticity steels that cannot be rolled, and to manufacture shapes with thin flanges.

Pressed steel shapes are manufactured from structural, high-hot-strength, stainless, scale-resistant, and heat-resistant steels and from scale-resistant and high-hot-strength nickel-based alloys.

Pressed steel shapes are produced with cross-sectional areas of from 1 to 20 $cm^2$ and with maximum inscribed-circle diameters of 130 mm. The minimum flange thickness is 2 mm for structural steel, 3 mm for stainless steel, and 4 mm for heat-resistant steel. Shape lengths range up to 5-8 m for structural steel and 4-6 mm for stainless and heat-resistant steel. The minimum interflange radii are 4 mm (internal) and 1.5 mm (external) for structural steel, 5 mm (internal) and 2 mm (external) for stainless steel, and 6 mm (internal) and 2 mm (external) for heat-resistant steel.

The variety of pressed steel shapes now in production includes 600 standardized types. Angle pieces, which are produced with equal or un-

equal arms, have flanges 17-55 mm wide and 2-8.5 mm thick (with an interflange angle of 90-135°). T-pieces have flanges 30-85 mm wide and 2-11 mm thick (with an interflange angle of 90-120°). Shapes of the channel type have flanges 30-100 mm wide and 2.5-19 mm thick. Figure 1 shows certain of the more complex shapes presently being manufactured.

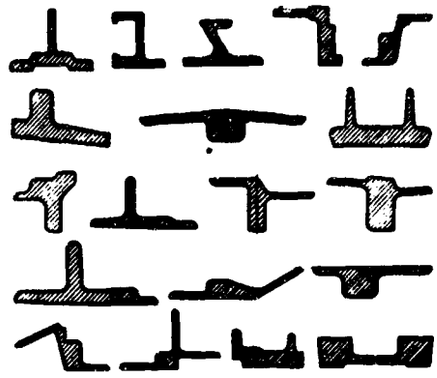


Fig. 1. Cross sections of certain pressed steel shapes.

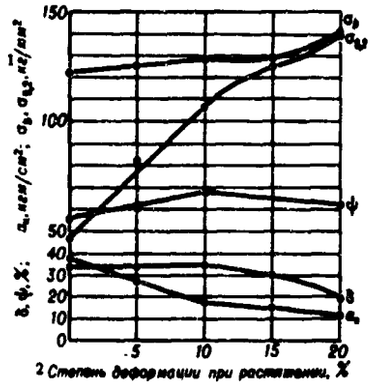



Fig. 2. Mechanical characteristics of Kh17N5M3 (SN-3) steel shapes as a function of degree of tensile deformation. Tempering at 500° for 1 hr. 1) kg/mm$^2$; 2) degree of tensile deformation, %.

The mechanical characteristics of pressed steel shapes correspond to the requirements imposed on hot-rolled bars or blanks. These shapes are delivered without heat treatment. When requested, shapes of stainless and acid-resistant steel (EI654, SN-2, SN-3, etc.) can be supplied in the cold-worked state, which provides substantially increased strength,

and a correspondingly reduced plasticity (Fig. 2). These shapes are hardened in hydraulic straightening machines during cold tensile deformation.

Techniques have been developed for the manufacture of standardized pressed steel shapes by drawing, employing more rigid dimensional tolerances; for example, the tolerance for flanges 2-10 mm thick can be reduced by a factor of 2.5-3.5, which substantially improves the surface quality of the shapes. Standardized shapes can be used in machine building without machining.

Steel shapes are pressed in horizontal hydraulic presses with a power that varies in accordance with the cross-sectional area and length of the finished product. The pressing rate is 0.1-0.2 m/sec or more, while the metal-flow rate is 2-10 m/sec or more; the blank is heated to 1150-1280°, depending on the type of steel, while the pressform is heated to 350-450°. The press-plate pressure in the pressform is 50-90 kg/mm$^2$ for structural steel and 60-110 kg/mm$^2$ for stainless and heat-resistant steel; the deformation ratio ranges from 5 to 30 (a ratio of 50 being permissible in exceptional cases).

One of the most important applications of pressed steel shapes is in the manufacture of annular welded components, since they provide a decrease by a factor of 1.5-2 in labor consumption and by a factor of 2-3 in metal consumption in comparison with rings produced from forgings or from thin-walled cast cylindrical blanks.

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N.D. Khabarov

PRESS EFFECT IN ALUMINUM ALLOYS – the higher tensile strength of pressed-aluminum-alloy components in the deformation direction in comparison with components produced by other types of pressure working, the heat-treatment regimes being identical. The press effect is sometimes evaluated from the difference in the strength of a pressed article with and across the deformation direction or from the ratio of the longitudinal alternate strength $\sigma_{bd}$ to the transverse ultimate strength $\sigma_{bt}$ (the coefficient V). This increase in $\sigma_b$ and $\sigma_{0.2}$ in pressed products is accompanied by a slight decrease in relative elongation and reduction in area. Hardness, shear resistance, and compressive strength remain virtually unaltered in the presence of the press effect, while long-term strength increases at low temperatures and decreases at elevated temperatures (200-300°). The press effect is observed in its clearest form in alloys of types D1, D16, AV, AK6, AK8, VD17, V92, V95, V96, and VAD23 after quenching and aging; it is sometimes seen in D20, D21, and AK2 alloys and extremely rarely observed in AK4, AK4-1, AK31, and AD33 alloys. Development of the press effect is facilitated by the presence of manganese, zirconium, chromium and other elements which, when alloyed with aluminum, yield phase diagrams with a very narrow crystallization range and a sharp drop in solid-state solubility at high temperatures. For D1, D16, and V95 alloys the difference in the ultimate strengths of pressed and forged or hot-rolled components (quenched and aged) reaches 15 $kg/mm^2$ and $V \approx 1.3$, i.e., the press effect is manifested in an increase of approximately 30% in ultimate strength. The technical specifications for semifinished products provide for a

higher ultimate strength and field strength for pressed bars and shapes than for forgings, castings, or plates. The press effect is also observed in certain transverse directions coinciding with the fiber orientation. Thus, increased strength is noted across pressed strips, the increase becoming more pronounced as the width-to-thickness ratio of the strip rises. By way of illustration, the table shows the characteristics of strips of D16 and AK4-1 alloys with cross sections of 30 × 170 mm. The results given indicate the presence of a press effect across strips of D16 alloy and also give some idea of the ratio of characteristics along and across the fiber direction in alloys in which the press effect does (D16) and does not (AK4-1) occur. As can be seen, only characteristics measured through the thickness of a strip or shape can be regarded as purely transverse characteristics.

| 1 Расположение образца | 2 Сплав Д16 | | 4 Сплав АК4-1 | |
|---|---|---|---|---|
| | 3 $\sigma_b$ (кг/мм²) | δ (%) | $\sigma_b$ (кг/мм²) | δ (%) |
| 5 По длине полосы | 52.6 | 14.5 | 42.9 | 13.2 |
| 6 По ширине полосы | 45.6 | 11 | 42.5 | 9.6 |
| 7 По толщине полосы | 38.9 | 5.4 | 40.9 | 6.1 |

1) Specimen position; 2) D16 alloy; 3) kg/mm$^2$; 4) AK4-1 alloy; 5) along strip; 6) across strip; 7) through thickness of strip.

Complete or partial disappearance of the press effect may be caused by the following factors (or combinations of these factors): a) an elevated ingot-homogenization temperature; b) a low metal temperature during pressing; c) a low pressed-product thickness; d) use of double pressing; e) use of cold deformation after pressing; f) extremely long holding during prequenching heating; g) an elevated aging temperature; h) a reduced manganese, chromium, and zirconium content.

The difference in the characteristics of pressed articles and other types of semifinished products is comparatively small after annealing

and is generally (although sometimes erroneously) neglected. After quenching the ratio $\sigma_{bd}/\sigma_{bp}$ rises to the level characteristic of the press effect, amounting to 1.2-1.3 for D16 alloy. The difference in ultimate strength along and across the fibers is increased by natural or artificial aging, although the ratio $\sigma_{bd}/\sigma_{bp}$ remains almost the same as after quenching or rises only slightly. An elevated aging temperature or prolonged holding time causes the coefficient V to drop almost to one. There is no unanimity of opinion regarding the nature of the press effect. The increased strength of pressed products is variously attributed to the influence of deformation texture, to the presence of finally dispersed particles of manganese or other phases in the alloy, to heterogenization of the alloy structure during crystallization and a continuous distribution of particles of intermetallic compounds along the grain boundaries, to the development of oriented stresses during quenching and aging, to supersaturation of the solid solution of manganese (chromium) in aluminum during crystallization and the influence of these elements on the decomposition of the solid solution when it is supersaturated with copper, zinc, or magnesium, and to refinement of the alloy structure and hardening of the grain and subgrain boundaries as a result of internal intercrystallite adsorption. Almost all researchers acknowledge that development of the press effect requires an unrecrystallized structure and various hypotheses differ in their explanations of the conditions for retention of the deformation texture and their definition of those elements of the unrecrystallized structure which are decisive in increasing strength.

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V.I. Dobatkin

PRESS EFFECT IN MAGNESIUM ALLOYS – the increased strength of pressed articles in comparison with semifinished products manufactured by other methods. The press effect is observed in products with an unrecrystallized or partially recrystallized structure, which in many cases is characteristic of pressed magnesium-alloy semifinished products at the pressing temperatures and rates generally employed in practice. This phenomenon is most marked in many aluminum alloys, in which the hardening caused by pressing is considerably intensified by heat treatment (see Press effect in aluminum alloys). The press effect in magnesium alloys is considerably less pronounced and is observed only in individual alloys. For example, pressed products of a magnesium alloy containing 3% Zn and 0.7% Zr have a minimum ultimate strength in the pressing direction of 28-31 $kg/mm^2$ and a yield strength of 19-22 $kg/mm^2$, while sheets of this alloy have a minimum ultimate strength of 25-26.5 $kg/mm^2$, a yield strength of 15.5-17 $kg/mm^2$, and precisely the same relative elongation. The minimum ultimate strength of bars of MA5 alloy is 30 $kg/mm^2$, while that of forgings and stampings is 27 $kg/mm^2$ at the same relative elongation. Increased strength is observed in the deformation direction in both aluminum and magnesium alloys. When pressed products are heated the strengths in the longitudinal and transverse directions are equalized and the press effect disappears. Bars pressed from unhomogenized ingots exhibit a more pronounced press effect than those pressed from homogenized ingots.

A.A. Kazakov

PRESSING OF PLASTICS – manufacture of finished products from plastics by hot pressure molding. This process is employed chiefly for reactive plastics (products are usually fabricated from thermoplastics by dye casting, extrusion, etc.). We can distinguish direct and casting molding. In the first case (Fig. 1) the press-material is loaded directly into the mold cavity, while in the second case it is first poured into an intermediate chamber (crucible), whence it passes through casting conduits to the mold cavity. In casting molding the hemimatrices can be arranged vertically (Fig. 2) or horizontally (Fig. 3) in the press form. Horizontally arrayed hemimatrices are more convenient, since it is not necessary to remove them from the press form and extract the finished product outside the press, which in most cases is a laborious and cumbersome operation.

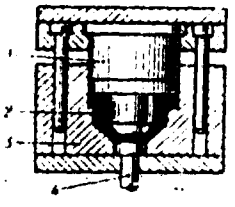


Fig. 1. Direct pressing: 1) Punch; 2) finished product; 3) matrix; 4) ejector.

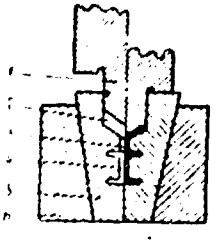


Fig. 2. Casting molding with vertical separation of hemimatrices (the beginning of the process is shown at the left and its end at the right): 1) Casting punch; 2) crucible; 3) pouring channel; 4) mold cavity; 5) two hemimatrices; 6) yoke.

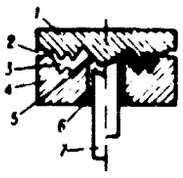


Fig. 3. Casting molding with horizontal separation of hemimatrices (the beginning of the process is shown on the left and its end on the right): 1) Upper hemimatrix; 2) discharge channel; 3) mold cavity; 4) lower hemimatrix; 5) pouring channel; 6) bushing; 7) piston.

Pressing Temperatures for Plastics

| 1 Материал | 2 Температура прессования (°С) | |
|---|---|---|
| | 3 без подогрева | 4 с подогревом |
| 5 Новолачные пресспорошки | 155—170 | 175—190 |
| 6 Резольные пресспорошки | 145—155 | 155—175 |
| 7 Волокнистые и слоистые фенольные прессмассы | 145—155 | 155—165 |
| 8 Аминопласты | 135—155 | 150—160 |

1) Material; 2) pressing temperature (°C); 3) without heating; 4) with heating; 5) lacquer-resin press-powders; 6) resol press-powders; 7) fibrous and laminated phenolic press-materials; 8) aminoplastics.

The press-material is selected in accordance with the product to be fabricated and the pressing method and regime, taking into account the bulk weight or specific volume, granulometric composition, flowability, setting rate, and shrinkage of the material. The pressing efficiency and the quality of the finished product depend to a large extent on the preliminary processing of the press-material, including Tableting and heating. Heating the press-material before loading makes it possible to reduce the time for which it must be held in the press form and the pressing pressure and aids in partial removal of moisture and volatile impurities. Heating of the material also results in a decrease in press form wear and an improvement in product quality. High-frequency electric heating is most frequently employed, since it heats the press-material uniformly and thus promotes more complete setting and reduces the possibility that internal stresses will develop within the finished

product. The heating time depends on the efficiency coefficient K, which is expressed by the formula K = 1/ε·tgδ, where ε is the dielectric permeability and tgδ is the tangent of the angle of dielectric loss of the press-material. The heating time also depends on the frequency and voltage, which can be raised only to a certain limiting value in order to avoid breakdown of the material being heated.

The pressing temperature depends on the character and type of the press-material (being higher for phenolic than for amino plastics and lower for laminated and fibrous than for powdered plastics), the preliminary treatment of the material, the size of the molds, and the thickness of the finished product. The table shows the pressing temperature as a function of the type of material and preliminary heating.

In pressing thin-walled components from lacquer-resin press-powders the temperature is raised to 200-210° and preheating is employed. The pressing time consists of the holding time and the time required for all auxiliary operations; the former can be reduced by preheating the press-material and raising the pressing temperature, while the latter can be shortened by mechanizing and automating the pressing process.

In direct pressing of plastics with [illegible] distinguish: 1) the molding pressure, which is applied to the press-material at the instant when it is deformed and spreads through the mold form and continues until the latter has completely closed; 2) the setting pressure, which is necessary in order that the press form remain closed after molding under the action of the elastic forces of deformation and the water vapor and gases liberated. It is impossible to differentiate these forces in practice. The minimum molding pressure is generally about 150 kg/cm$^2$, while the setting pressure does not exceed 20-50 kg/cm$^2$. In direct pressings the molding pressure reaches 500 kg/cm$^2$, depending on the press-material filler and the configuration of the finished product.



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The water vapor and gases formed are removed, since they would otherwise increase the holding time and reduce the structural quality of the product. For this purpose the punch is raised for 1-2 sec after the press form is closed and then reinserted into the mold. This operation is referred to as prepressing. Casting molding has a number of distinctive features in comparison with direct pressing: the flow of press-powder into the press form cavity is regulated automatically, so that the powder need not be tableted and preheating is more efficient. The pressure applied to the press-material in the crucible ranges from 800 to 1500 kg/cm$^2$, depending on the type of press-material, its flowability and other factors. The setting pressure (which holds the hemimatrices together) should not be more than 25% greater than the total force developed in the mold cavities of all the pressform recesses (which equals the specific pressure multiplied by the total area). The gases and water vapor liberated during casting molding move ahead of the material and are removed through slits or special narrow channels. This process can be used to fabricate products of complex configuration or with very fine metal reinforcing wires. Such products have virtually no burrs. Among the disadvantages of casting moldings in comparison with direct molding are the higher pressform cost and the press-material consumption.

M.G. Gurariy

PRESS-MATERIALS WITH CRUMBLED FILLERS – materials based on crumbled substances (textolite, wood, glass cloth, impregnated with synthetic resins. They are made into finished products by hot pressing and casting. Crumbled textolite is a press-material based on pieces of cotton cloth impregnated with resol resin. It is produced in type A, from belting and other fabrics weighing more than 300 g/m$^2$, and type B, from fabrics weighing less than 300 g/m$^2$. Finished products are pressed from crumbled textolite at a pressure of 400-800 kg/cm$^2$, a temperature of 160-170°, and a pressing time of 1.0-2.5 min per mm of product wall thickness. Preliminary heating permits a reduction in pressing pressure. Crumbled textolite is used in the manufacture of components with high mechanical and antifriction characteristics (hardware, packing glands, rollers, handles, gears, bushings, bearing linings, etc.). The table shows the physical, mechanical, and dielectric characteristics of press-materials with crumbled fillers.

TVFE-2 is a roll material impregnated with phenol-formaldehyde resin modified with a polysiloxane polymer. The material is cut into pieces of the requisite size before pressing. Finished products are fabricated from TVFE-2 by compression or molding pressing at a temperature of 140-150°, a pressure of 350-1200 kg/cm$^2$, and a pressing time of 1-2 min per mm of product wall thickness, but no less than 10-15 min for each article. Prolonged heating or a rise in temperature to above 200° reduces the ultimate bending strength, electric strength, and deep resistance. TVFE-2 is used in the manufacture of electronic components intended to operate under mechanical loads, at elevated temperatures

Physical, Mechanical, and Dielectric Characteristics of Press-Materials with Crumbled Fillers

| 1 Показатели | Текстолитовая крошка А | Текстолитовая крошка Б | 3 ТВФЭ-2 | 4 Древесная пресскрошка: 5 лигнофольная | 4 Древесная пресскрошка: 6 балинитовая |
|---|---|---|---|---|---|
| 7 Уд. вес | 1,35—1,40 | | 1,8—1,9 | 1,35—1,40 | 1,35—1,40 |
| 8 Ударная вязкость (кг·см/см²) | 9 | 12 | 25—80 | 10 | 12—19 |
| 9 Предел прочности (кг/см², не менее): | | | | | |
| 10 при изгибе | 500 | 600 | 900—1550 | 750 | 900—1000 |
| 11 при сжатии | 1400 | 2000 | — | 1200 | 900—1300 |
| 12 при растяжении | 400 | 500 | — | 550 | 550—650 |
| 13 Модуль упругости при растяжении (кг/см²) | 40—50·10³ | | — | — | — |
| 14 Теплостойкость по Мартенсу (°С) | 125 | | 150—180 | 140—170 | 140—170 |
| 15 Коэффициент линейного расширения | 3,0—3,4·10⁻⁵ | | — | — | — |
| 16 Удельная теплоемкость (кал/г °С) | 0,35 | | — | — | — |
| 17 Твердость по Бринеллю (кг/мм²) | 38 | | — | 30 | 30—40 |
| 18 Водопоглощение (%) | 0,3 | | — | 0,5—1,5 | 0,6—1,5 |
| 19 Маслостойкость (%) | — | | — | 0,01 | 0,01 |
| 20 Удельное объемное электросопротивление (ом·см) | 10⁷ | | 5,8·10¹³ | 2,4·10¹⁰ | 2·10⁹—1·10¹⁰ |
| 21 Удельное поверхностное электросопротивление (ом) | 10⁸—4·10¹⁰ | | 2,5·10¹¹ | 2·10⁹—1,4·10¹² | 2·10¹⁰ |
| 22 Электрич. прочность (кв/мм) | 12—16 | | 15 | 14 | — |
| 23 Тангенс угла диэлектрич. потерь: | | | | | |
| 24 при 50 гц | 0,22 | | 0,25 | 0,16 | — |
| 25 при 10⁶ гц | — | | 0,025 | — | — |
| 26 Диэлектрич. постоянная: | | | | | |
| 24 при 50 гц | — | | 10,8 | — | — |
| 25 при 10⁶ гц | 5—7 | | 7,6 | — | — |

1) Characteristic; 2) crumbled textolite; 3) TVFE-2; 4) crumbled-wood press materials; 5) lignofolic; 6) balinitic; 7) specific gravity; 8) impact strength (kg·cm/cm$^2$); 9) ultimate strength (kg/cm$^2$, no less than); 10) on bending; 11) on compression; 12) on extension; 13) modulus of elasticity on extension (kg/cm$^2$); 14) Martens thermostability (°C); 15) coefficient of linear expansion; 16) specific heat capacity; 17) Brinnel hardness; 18) water absorption (%); 19) oil resistance (%); 20) deep resistance (ohm·cm); 21) skin resistance (ohm·cm); 22) electric strength (kv/mm); 23) tangent of angle of dielectric loss; 24) at 50 cps; 25) at 10$^6$ cps; 26) dielectric constant.

(up to 200°), and in the presence of spark discharges.

Crumbled-wood press materials are produced in two types, lignofolic and balinitic; the former consists of pulverized veneer, usually birch, 0.35-0.55 mm thick impregnated with an alcohol-soluble (SBS) or water-soluble (SP-2 type) resol phenol-formaldehyde resin, the resin content amounting to 25-30% of the weight of the wood, while the latter consists of veneer treated with alkali before impregnation. Finished products are pressed from these materials at a pressure of 400 kg/cm$^2$ for articles with simple shapes and 600-800 kg/cm$^2$ for articles with complex shapes, a temperature of 150-160°, and a pressing time of 2 min per mm of product wall thickness. These products include bearing compon-

ents (bushings and sleeves), gears, cable junction boxes, electrical insulating components, caps for rectification columns, pinions for straightening machines, carrier bearings for textile machinery, etc., which require high mechanical strength, chemical stability and good antifriction characteristics. The coefficient of friction of these materials is 0.12-0.003 with water lubrication, 0.02-0.004 with machine-oil lubrication, and 0.01-0.006 with grease lubrication. Articles of crumbled-wood press-materials are resistant to acetic acid at temperatures of up to 120°, sulfuric and hydrochloric acids at up to 50°, dilute formic acid at up to 35°, tar water (liquor), ethyl acetate, and butyl acetate at up to 120°.

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M.S. Krol'

PRESSURE CASTING OF PLASTICS is a method of processing plastics into products, and is used for: polystyrene, polyvinyl chloride, polymethyl methacrylate, polyethylene, polypropylene, the polyamides, polycarbonate, polyformaldehyde, the etrols based on cellulose esters, and others. The method is highly productive, economical and permits complete automation of the production of plastic products. A feature of the method is the dimensional precision and the good finish of the resulting products, the possibility of the production of products of complex configuration, thinwall items, items with weak framework and with long generating lines. The pressure casting of plastics consists in the extrusion of the thermoplastic material preheated to a viscous-fluid condition by a plunger or screw at very high pressure (500-1500 $kg/cm^2$) into a cold closed form in which the plastic is converted into the corresponding product on cooling. The casting is performed on a machine shown schematically in Fig. 1. In order to obtain uniform heating of the polymer and to reduce the loss of pressure in the heating cylinder, on the casting machines wide use is made of preliminary plasticizing of the polymer using the piston or screw method. In machines with preliminary plasticizing the processes of heating the polymer and injection of the polymer into the forms are separate. In machines with piston plasticizing, use is made of the same heating cylinder as in the usual machines (Fig. 2). In machines with screw plasticizing the screw is used for the preliminary plasticizing and the transfer of the material (Fig. 3). The material is heated most uniformly in machines of this type. In addition to machines of these types, there

has been extensive development of casting machines of specialized design: high-speed, rotor, with several cylinders for two-color casting, vertical machines for casting products with a framework, etc.



Fig. 1. Schematic of casting machine. 1) Casting form; 2) nozzle; 3) heating cylinder; 4) splitter (torpedo); 5) heater elements; 6) feeder; 7) material plunger; 8) hydraulic cylinder.

A necessary part of the machine for pressure casting of the plastics is the casting form, whose design and dimensions depend on the product being produced. The form consists of two basic parts - the plunger and the die. In the die there is a conical opening (central pouring channel) which terminates externally in a spherical hole. This opening is intended for the filling of the form with the material. During casting the spherical

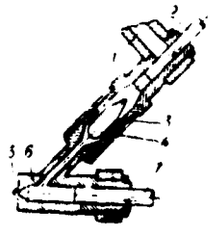


Fig. 2. Schematic of casting machine with piston plasticizing. 1) Feeder; 2) heating cylinder plunger; 3) heating cylinder for preliminary plasticizing; 4) splitter (torpedo); 5) nozzle; 6) injection cylinder; 7) injection cylinder plunger.

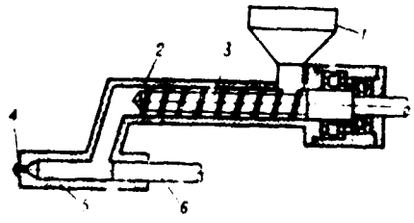


Fig. 3. Schematic of casting unit of machine with screw plasticizing. 1) Feeder; 2) cylinder for preliminary plasticizing; 3) screw of cylinder for preliminary plasticizing; 4) nozzle; 5) injection cylinder; 6) injection cylinder plunger.

hole is tightly pressed against the nozzle of the cylinder of the casting machine. In the form there is also one or more distributing pouring passages (the number of the latter is determined by the number of items being cast simultaneously). At the end of each passage there is an entry gate which usually has a considerably smaller cross section than the channel itself. This is necessary to facilitate the separation of the finished product from the pouring channel on termination of the process. The form is usually cooled by water which enters the plunger and the die through special passages.

In many form designs, depending on the plastic type and the form of the product, use is made of the so-called gateless casting. In this case the usual pouring channel is replaced by an elongated nozzle or heated channels with separate nozzles. The pressure casting process for the plastics can be regulated by the plunger pressure, the temperature of the heating cylinder and the form, the time the product is kept under pressure, the product cooling time, the magnitude of the delay between the casting cycles, the form closure force and the rate of movement of the plunger. Proper selection of these conditions and their observance during casting will provide for production of a high-quality product. The casting cycle is characterized by a curve similar to that shown in Fig. 4. It usually starts from the instant of closing the form (point 0). The movement of the plunger prior to initiation of polymer flow from the nozzle corresponds to the segment OA. The form cavity is filled in the course of the period AB under the action of the polymer pressure. After filling the form, in the course of the period BC the maximal pressure is created in the form. However, the pressure in the form is considerably less than the pressure on the piston because of the pressure losses in the cylinder and form. Then there is a densification of the polymer (segment CD) with a relatively fixed position of

the plunger. In this period the polymer flows into the form cavity at a comparatively low speed. After reversal of the plunger (point D), if the material has not hardened in the entry gate, it is possible that

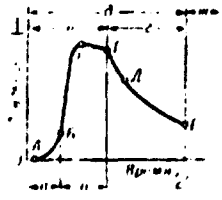


Fig. 4. Curve of pressure variation in the form in the course of the casting cycle: a) time for filling form; b) time for densification of polymer in form; c) time product is maintained under positive pressure; d) time for product cooling after reversal of plunger; e) time during which the form is closed; f) magnitude of delay between casting cycles. 1) Pressure; 2) time.

the polymer will flow out of the form in the direction of the sprue system. The pressure in the form corresponding to the instant of solidification in the entry gate is termed the shut-off pressure. The shut-off pressure and the temperature of the polymer corresponding to this pressure have a major influence on the process of the formation of the product. For example, product shrinkage, shrink holes on its surface or bubbles within the product, and also the behavior during ejection from the form are determined by this pressure and temperature. The segment DF corresponds to the period of cooling of the product; at the end of this period the form is opened at the residual pressure corresponding to the point F. Variation of the time under pressure leads to a variation of the shut-off pressure and the residual pressure. Increase of the residual pressure hinders removal of the product from the form. A deficiency of the process for pressure casting of plastics is the presence in the finished products of internal stresses, which is reflected in the mechanical properties of the products and their behavior during usage. The appearance of the internal stresses is associated with the nonuniform cooling of the polymer in the casting process. The molecular

orientation which occurs in the process of the polymer flow during filling of the form and during cooling has a major influence on the mechanical properties of the products. The internal stresses can be reduced to a considerable degree by means of proper casting conditions. The technological regime for casting depends on the type of polymer, the casting machine, the form design and the product being produced. It is advisable to preheat the thermoplastic material prior to casting to remove the moisture and the volatiles. Amorphous polymers (polystyrene, polymethyl methacrylate and others) are usually processed over a wide temperature range, for example, polystyrene at 170-200°. The shrinkage of these materials amounts to 0.4-0.6%. The crystalline polymers (polyethylene, polypropylene, polyamides and others) are processed in a narrower temperature range. The shrinkage of these materials can reach 5%.

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V.V. Lapshin

PRESSURE WORKING OF BERYLLIUM. Extrusion, rolling, forging, and stamping of three-dimensional shapes and sheets are employed in the production of various beryllium products.

Blocks manufactured by powder metallurgy or by casting are subjected to pressure working. The brittleness of such blocks at room tem-

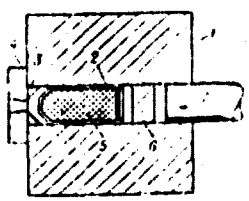


Fig. 1. General view of device for extrusion of beryllium rods: 1) heatable yoke; 2) steel casing (container); 3) conical insert; 4) die; 5) beryllium; 6) graphite plug; 7) punch.

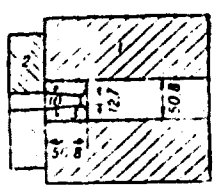


Fig. 2. Device with internal die for extrusion of tubes on small presses: 1) Pressform yoke; 2) die holder; 3) internal die.

perature and their transition to a viscous state at elevated temperatures places the lower limit of the pressure-working range at 400°. The oxidizability of Be becomes quite pronounced at 800° and this makes it necessary to use protective casings, which also create more favorable deformation conditions. The casing material is usually copper or low-carbon steel. Use of copper is limited to temperatures below 800°, while the upper limit of the range for steel is 1050°. The overall temperature range is thus restricted to 400-1050°. Be has a reduced $\sigma_b$ in

this region and fractures easily when subjected to tensile or shear stresses, but is deformed by compressive forces. The casings employed in pressure working are removed from the products by etching in nitric acid.

Extrusion is the most common pressure-working method, since compressive forces predominate. The extrusion scheme is shown in Figs. 1 and 2. A high-speed steel (18% W, 4% Cr, and 1% V) tool is used, the pressure reaching 14,000 kg/cm$^2$ during heating to 480-540°. The matrix has an inlet taper with an apical angle of 90°, which permits a reduction in pressure and passes smoothly into an elongated forming collar, the latter preventing transverse cracking caused by elastic stresses. Compound matrices are used (Fig. 1). A compound matrix is preferable for extrusion at the upper limit of the temperature range, where the taper reduces the cooling of the block, insulating it from the cooler cylindrical matrix and thus reducing the extrusion pressure. Hot extrusion is carried out above the recrystallization temperature. The block, encased in a steel shell, is heated to 1000-1060° and forced through the matrix at speeds of up to 50 mm/sec. The casing keeps the Be from sticking to the tool. The extrusion tool (container and matrix) is heated to 480-500°. This process is carried out at elongations of from 8 to 25 and produces round bars with diameters of 6.5-76 mm, square and rectangular shapes, and tubes with outside diameters of 25-100 mm, a minimum wall thickness of 2.5 mm, and length of approximately 4.5 m. Tubes with smaller diameters and thinner walls cannot be manufactured by extrusion. Special equipment is required for production of large tubes. Products fabricated from Be by hot pressing have an elongation of up to 25° in the extrusion direction and a very small elongation in the direction perpendicular to the extrusion axis. Hot-extruded rectangular strips are the starting material for manufacture of sheets. This

method can also be used to produce products with an elongation of 100 from pressed-powder briquets enclosed in steel shells. Compaction and extrusion are combined in this case and round bars with small cross-sections and comparatively high plasticity ($\delta$ = 20-25%) are produced. Any increase in the size of the briquets, whose density amounts to approximately 70% of the theoretical value, causes wrinkling of the casing and defects in the finished product. The surface finish of hot-extruded articles depends on the grain size. A rough, coarse surface is produced if the cast blank is large-grained, while extrusion of cermet blocks gives a smooth surface. Warm extrusion is carried out below the recrystallization temperature. Be has maximum plasticity at 400-450° and the blank and press-tool are consequently heated to this temperature. The press speed is lower than for hot extrusion (~10 mm/sec). The low oxidizability of Be at these temperatures makes it possible to extrude unprotected blanks. In order to keep the Be from sticking to the tool the blanks are coated with several layers of colloidal graphite or a mixture of colloidal graphite and molybdenum disulfide and a graphite taper is installed in the tool-steel matrix. The finished product is covered with a very thin graphite film. The high extrusion constant of beryllium (K = 5950 kg/cm$^2$ at 450° and 2,730 kg/cm$^2$ at 1066°) and the high maximum tool pressure (up to 14,000 kg/cm$^2$) limit the degree of elongation to 6-8. The press power required increases sharply as the cross-sectional area of the blank rises. The variety of products produced by warm extrusion is rather wide, including round bars, rectangular bars with rounded ribs, tubes, etc. Warm-extruded Be is very strong, but brittle. It acquires its best properties after annealing at 800-900°, but its plasticity is lower than that of hot-extruded beryllium. The finished products have good surface finishes and sufficiently precise dimensions, which often makes it possible to dispense with further

cutting. Extrusion is carried out at 730-820°, using a vitreous or salt lubricant. The extrusion constant is considerably lower in this case and the elongation reaches 8-16. The finished products have good mechanical properties.

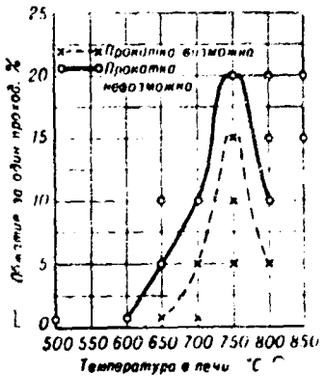



Fig. 3. Degree of reduction during one pass as a function of temperature in rolling of beryllium blanks 25.4 × 19.1 × 3.2 mm in size. 1) Reduction in area during one pass, %; 2) furnace temperature, °C; 3) rolling possible; 4) rolling impossible.

Little research has been done on the rolling of Be. Hot-pressed blocks or rectangular strips extruded from cast or cermet blocks are used as the blanks for rolling. Sheets rolled from coarse-grained extruded cast blanks have a poorer surface finish than those rolled from extruded cermet blanks. It is impossible to produce sheets by direct rolling of cast blanks. The blank is encased in a low-carbon-steel shell, which consists of a frame bearing two welded cover plates. This protects the metal against oxidation and provides a support that prevents cracking at the edges of the sheet under the action of the tensile stresses which develop during rolling. Stainless-steel casings make it possible to produce sheets with a better surface finish. Hot-pressed blocks are rolled in two mutually perpendicular directions, while rectangular extruded strips are rolled in one direction (perpendicular to the extrusion axis). Rolling is carried out in the same tem-

perature region as extrusion, the optimum temperature being 700-800°. Higher temperatures cause growth of the grains, which press against the casing and yield a sheet with a rough surface and poor mechanical properties. The rolling process involves a deformation of 5-10% per pass and no more than 20% in successive passes separated by intermediate heating. Figure 3 shows the degree of deformation per pass as a function of the rolling temperature. The total deformation between annealings increases with the rolling temperature, amounting to 50% at 500°. Rolling without casings at per-pass deformations of more than 1% causes formation of edge and surface cracks. The deformation during cold rolling is also very low, the total permissible deformation between annealings being approximately 2% for cold-pressed and sintered blocks. It is recommended that finish rolling be carried out at reduced temperatures (300-400°), where the metal does not adhere to the casing and the resultant sheet has a smooth finish. Sheets ranging in thickness from 0.5 to 25 mm and in area from 300 × 600 mm to 600 × 1200 mm and having standardized properties in the two directions of the sheet plane ($\sigma_b$ = = 50 kg/mm$^2$, $\sigma_{izg}$ = 38 kg/mm$^2$, and $\delta$ no less than 3%) are produced in the USA. It has been noted that it is difficult to achieve uniformity of characteristics within a single sheet or from sheet to sheet. Sheets with a $\delta$ of 30-40% in the sheet plane have been produced experimentally when the proper conditions for transverse rolling (temperature and degree of reduction) were carefully observed. Be powder is also rolled in steel shells under the aforementioned regimes, but the characteristics of such sheets are lower than for those rolled from preliminarily molded blanks.

Beryllium is forged in the form of blanks obtained by different methods. Cast blanks with a coarse columnar structure fracture during forging and, as a result, blocks obtained by cermet methods and prelim-

inarily extruded blanks are used for forging and hot stamping. Open forging requires the use of casings to prevent development of the tensile stresses at the lateral surfaces which cause cracking. These casings make it possible to conduct open forging at 1050° with large deformations over several low-power passes. It is possible to upset extruded blanks in a protective casing to 75% of their height. Forging in the direction perpendicular to the extrusion axis gives better results than forging along this axis. Isolated experiments have shown that it is possible to forge a blank without a casing in one stroke at 1150-1200°. Repeated passes lead to development of edge cracks. Both warm and hot forging can be carried out in dies, but small lateral deformations should be used in order to avoid development of lateral cracks. Use of small deformations permits forging in closed dies at 400°. The forces exerted in this case reach 14,000 kg/cm$^2$. It is recommended that they be applied slowly, pausing on reaching the maximum. Forging involving drawing of an extruded bar from 12.7 mm to 9.5 mm at 760° (in the same manner as for tungsten) causes intensive cracking. Forging is used for producing small articles: fluted washers, threaded components, etc.

Sheet stamping of rolled sheets is possible only when they are heated to 300-700°. In order to maintain minimum tensile stresses it is recommended that the temperature be held at 650° and that a low-carbon-steel casing be used to provide support. Such sheets fracture when subjected to marked deformation at room temperature.

Because of its low plasticity beryllium is not used for drawing.

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J., Metallurgical Reviews, 1958, Vol. 3, No. 9, pages 1-44; Darwin, G.E. and Budder, J.H., Beryllium, London, 1960; Stambler, I., Space Aeronautics,1959, Vol. 31, No. 2, pages 48-51; Jahnle, H.A., Prod. Engng, 1960, Vol. 31, No. 25, pages 72-75; Hill, N.A., Engineering Materials and Design, 1960, Vol. 3, No. 1, pages 26-30; Conference on the Metallurgy of Beryllium, The Institute of Metals, London, 1961.

N.M. Bogorad

PRESSURE WORKING OF MOLYBDENUM. Molybdenum has a body-centered-cubic lattice which is retained to a temperature of 2125°. The molybdenum monocrystal has a [112] cleavage plane at 200 and 300° and [110] at 1000°, the direction of cleavage for all three temperatures is [111]. With temperature reduction the plastic deformation of the monocrystal takes place primarily along the cleavage planes. Molybdenum oxidizes easily in the air (see Protective Coatings for Molybdenum), therefore heating prior to deformation must be performed in a reducing atmosphere (hydrogen) or in protective media (argon, helium). The plasticity and deformability of molybdenum and its alloys depend on the quality of the metal, which is determined by the melting method, the metal purity, and the degree of alloying. With the usual method of melting in electric-arc vacuum furnaces, the molybdenum ingots have a pronounced coarse dendritic structure with low reserve of plasticity, which hinders deformation of molybdenum ingots during hot pressure working. therefore deformation of molybdenum ingots must be performed by pressing on hydrostatic compression method of deformation is used which provides for satisfactory quality of the deformed material, even if this material has low plasticity. In pressing molybdenum, use of glass cloth lubricant with a coating of graphite lubricant is recommended. Use of high temperature lubricants reduces the contact friction between the ingot and the tool, and also provides thermal insulation of the ingots in the pressing process.

Molybdenum in the cast condition must be deformed by up to 85% by pressing, and in the pre-deformed condition it must be deformed up to

95%. These high degrees of deformation permit complete destruction of the coarse dendritic cast structure of the ingots and permit obtaining in the deformed mill products a uniform fine-grain structure with relatively uniform distribution of local inclusions.

Ingots of molybdenum and its alloys must be heated prior to pressing to 1600-1700° in electric resistance furnaces in a protective atmosphere. In the case of use of induction furnaces, ingot heating is carried out at temperatures to 1800° and higher. The neutral medium in the furnaces is argon. Heating of molybdenum and its alloys may be performed in salt deformed condition are usually subjected to subsequent hot pressure working at lower temperatures (1000-k400°) than in the cast condition. Rolling of thin sheet, fabrication of thin-wall tubing, and wire drawing operations are performed at low temmperatures in the range of 350-600°

The metal purity and degree of deoxidation are important factors which determine the plasticity of molybdenum during pressure working. The presence of oxygen causes a particularly sharp decrease of molybdenum plasticity. Thus, an oxygen content in the metal of more than 0.0025% significantly reduces the plasticity during hot pressure working as a result of the presence of oxides ($MoO_3$), which are located primarily along the grain boundaries. With 0.008-0.15% oxygen the metal becomes brittle and cannot be pressure worked. In purer molybdeum the thin interlayers of oxides improve hot working. Yielding of the metal during deformation in this case takes place along the grain boundaries. Carbon also reduces the plasticity and deformability of molybdenum. With more than 0.02% carbon in the alloy, the carbides formed aid in reducing the plasticity. Increasing the content of the other alloying elements also reduces the plasticity of molybdenum; this must be considered in the development of new molybdenum-base al-

loys.

References: Molybdenum, collection translated from English, M., 1959; Korneyev N.I., Skugarev I.G., Osnovy fiziko-khimicheskoy teorii obrabotki metallov davleniyem (Fundamentals of the Physico-chemical Theory of Pressure Working Metals), M., 1960; Probelmy sovremennoy metallurgii (Problems of Modern Metallurgy), 1961, No. 3 (57); Materials for Nuclear Reactors, translated from English, M., 1962; "Metal Progr.", 1955, v. 67, No. 5, p. 89-92; "Steel", 1956, v. 139, No 17, p. 80-82.

I.G. Skugarev

PRESSURE WORKING NIOBIUM. In contrast with the other refractory metals with body-centered cubic lattice (chromium, molybdenum, and tungsten), niobium has a very low temperature of transition from the plastic to brittle state. For high purity metal the transition temperature is below -196°. Niobium oxidizes intensively with heating above 400° in air. At 1370-1400° the oxide begins to evaporate. An essential deficiency of niobium is its ability to absorb certain gases on heating and its embrittlement with heating in air. Absorption of oxygen begins at temperatures near 200°.

The impurity content in the metal has a decisive effect on niobium plasticity and determines its behavior in the plastic deformation process. Small amounts of gaseous impurities – oxygen, nitrogen, hydrogen and others – which form interstitial solid solutions with niobium reduce the plasticity particularly markedly. With significant gaseous impurity content, niobium is not amenable to deformation even in the hot condition. Oxygen has the most harmful influence on the metal plasticity. Therefore metal which is intended for producing sheet, tubing and other mill products must not contain more than 0.03% oxygen. Alloying also reduces niobium plasticity. The plasticity of all the alloys which have been studied is lower than that of the pure metal. High-purity niobium is a very plastic metal and has only a slight tendency to work hardening, permitting deformation up to 90% in the cold condition without intermediate annealing. The low-alloy compositions can permit deformation up to 50-70% in the cold condition without intermediate annealing.

At the present time niobium is prepared in the compacted form either by the powder metallurgy method or by electric arc and electron beam melting. The sintered niobium bars are deformed in the cold condition by forging or rolling. The ingots prepared by electron beam melting are also deformed by forging in the cold condition. A salient feature of the ingots prepared by the electric arc method is the presence of a coarse-grained columnar structure. The low plasticity of the arc-melted metal leads to the need for the use of preheating of the ingots to high temperatures prior to deformation. Hot deformation of the ingots is performed by forging, rolling, or pressing (extrusion). Less-plastic (higher strength at high temperature) niobium alloys may be worked using the extrusion method with high compressive stresses. Therefore the alloys with low plasticity, which cause difficulty in pressure working, are deformed at the present time using only the extrusion method. The high strength and low plasticity of cast niobium and particularly niobium-base alloys lead to the requirement for performing the initial deformation of the ingots at high temperatures at which the alloy is weakened. Hot deformation facilitates breakdown of the coarse cast structure, as a result of which the metal plasticity increases by about a factor of 2 during forging on smooth dies. The ingots are turned prior to deformation in order to remove the contaminated surface layer. Forging ingots of pure niobium is performed at 1000-1500°; forging the alloys is done at 1400-1700°.

Extruding is performed at 1400-1550°. Above 1500° the extruding process is accompanied by severe wear of the tool as a result of the high activity of the niobium and particularly of its oxide ($t°_{pl}$ about 1450-1500°) which, solidifying on contact with the cooler tool, adheres to the surface of the die opening. Repeated pressure working of previously deformed metal is usually performed at lower temperatures (500-

700°) or in the cold condition. The ingots are subjected to vacuum furnace annealing between operations. The recrystallization temperature of pure nickel prepared by the arc melting method is about 1050-1075°. The recrystallization initiation temperature of electron-beam melted niobium after 75% deformation is 930-965°. Intermediate annealing of the work-hardened niobium and its alloys to restore plasticity is performed at temperatures above 1300°. However the temperature of the final anneal of deformed mill products made from niobium must not exceed 1300°, since there is a marked reduction of the impact strength of the alloys after annealing above 1300°.

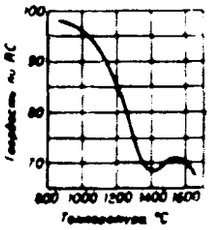
Heating facilities with neutral atmosphere (argon or helium) are used to protect niobium and its alloys from oxidation and embrittlement in the process of heating for deformation. Intermediate annealing of the deformed mill products is performed in vacuum furnaces. Coatings of heat-resistant enamels and shells made from plastic metals may be used in many cases. Multiple and extended heatings of niobium in the working process are very undesirable, since they lead to contamination and embrittlement of the metal to a considerable depth and the formation of cracks in the surface layer.

Chambers with neutral atmosphere with the complex of equipment required for pressure working installed inside are used to protect niobium from oxidation during the working process.

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I.G. Shugarev, Ye.I. Razuvayev

PRESSUREWORKING OF TANTALUM. Tantalum has a body-centered crystal lattice but, unlike a number of other metals, including certain refractory metals (Cr, Mo, W) with a similar lattice, it is characterized by a plastic state at low temperatures up to -196°. Tantalum is resistant in air up to 400°, however, an oxide film, which forms rapidly on machining and storage, is always present on its surface. At a temperature in excess of 400° tantalum starts to perceptibly oxidize. At the red heat temperature the oxide film is dissolved in the metal, tantalum loses its plasticity and becomes brittle. The tantalum-nitrogen reaction




Effect of the annealing temperature on the hardness of Ta with 10% W. 1) RC hardness; 2) temperature, °C.

is similar. In the 400-1000° interval, depending on the state of the metal's surface, hydrogen is absorbed, with the result that a brittle hydride of tantalum is formed. Thus, tantalum above 400° actively interacts with such interstitial elements as O, N, C and H and forms multivalent oxides, nitrides, carbides, hydrides, which, as a rule, are concentrated along the grain boundaries, thus sharply reducing its plasticity. In conjunction with this, tantalum and its alloys must be heated in a neutral or vacuum medium. The plasticity and shapability of tantalum and its alloys is determined by the degree of purity; a particulary

negative effect on the plasticity indicators is exerted by interstitial admixtures. Tantalum smelted by the electric arc method with a content of nonmetallic admixtures (O – 0.0042% and H – 0.0008%), is plastic.

Tantalum is freely forged and rolled into sheets at room temperature, and that smelted by the electron beam method is even more plastic and allows higher degrees of compression on shaping. It is hardened slowly in the process of plastic deformation, which makes it possible to shape with a high degree of compression ~90-95% without using intermediate annealing.

Hot pressureworking of tantalum is not effective, since the metal is oxidized to a substantial depth during shaping, which results in great losses due to the necessity of removing the oxidized layer by machining.

Alloying of tantalum with tungsten aids in strengthening the solid solution and results in reducing the plasticity and shapability of the alloy. A shaping alloy of the Ta-W system is an alloy the limiting W content of which is 15%. The alloy with 10% W has a good shapability. According to data published abroad, a high-purity alloy containing 90% of Ta and 10% of W is processed as follows: die forging at 1090°, annealing at 1205° and cold rolling. A tantalum alloy with 10% W, smelted by the electric arc method with a hardness of 229 kg/mm$^2$ (HB) is characterized by a high deformation resistance. Thus, in hot pressworking in the range of 1500-1600° with a 70% degree of compression, the specific pressures may be as high as 123-130 kg/mm$^2$.

After the cast structure is destroyed, the plasticity of the alloy is increased sharply and the metal is easily rolled into sheets at room temperature. According to foreign publications, the recrystallization temperature for tantalum is 1275° and for an alloy of 90% Ta + + 10% W, determined on a sheet which was rolled with a degree of com-

pression of 90% it is 1370° (Fig.). At 1200° and when held for 15 min. the alloy is only 50% recrystallized.

References: "Problemy sovremennoy metallurgii" [Problems of Modern Metallurgy"], No. 6, 1960; Svoystva i obrabotka tugoplavkikh metallov i splavov" ["Properties and Processing of Refractory Metals and Alloys"], Materialy Mezhdunarodnoy konferentsii po tugoplavkim metallam i splavam, sent. 1960, Sheffild [Materials of the International Conference on Refractory Metals and Alloys, Sheffield, 1960], Translated from English, Moscow, 1961; "Chem. and Engng. News," Vol. 38, No. 12, page 55, 1960; "Metalwork. Product," Vol. 104, No. 43, pages 27-29, 1960.

I.G. Skugarev and A.P. Zabavnova

PRESSURE WORKING OF TUNGSTEN. The susceptibility to oxidation at high temperatures exhibited by tungsten requires that it be heated before hot working in heating furnaces with a protective atmosphere.

The plasticity and deformability of tungsten are determined by its purity. A negligible content of interstitial impurities (primarily oxygen) highly reduces its plasticity. This is manifested in particular when the impurities precipitate along the grain boundaries. They weaken the intercrystalline bounds and in pressure working aid in the lamination of metal along the grain boundaries (Fig. 1). Cast tungsten ingots obtained by the electric arc method have a coarse columnar structure (Fig. 2) with a weak bound between the crystals for which reason they can be shaped only by pressure working. We know from data published abroad that high-purity tungsten obtained by various methods (electric arc, electron-beam) is plastic. Tungsten is pressure worked by pressing, forging, rolling, extrusion in the interval of 1650-2300° using high rates and high compression ratios.



Fig. 1. Lamination of metal along the grain boundaries.

The recommended optimum temperature interval for heating tungsten ingots before shaping is between the limits of 1700-1400°. After the rough cast structure is destroyed, the plasticity of the metal increases and secondary working by pressing can be performed at lower temperatures, but not below 1200°. Cast tungsten must be pressed with a degree of deformation of not less than 70-75% and tungsten which was previously deformed must be deformed by not less than 80%. Tungsten increases its

strength in the process of plastic deformation, which makes necessary intermediated annealings to remove the work hardness in the semifinished products. Deformed tungsten recrystallizes in the temperature interval of 1450-1600°. Cumulative recrystallization starts from 1700°. It is recommended that the tungsten ingots be heated to 1600° in electric resistance furnaces, and that heating to higher temperatures (2500°) be performed in induction furnaces with a protective atmosphere. A reducing atmosphere (hydrogen) is the one most favorable. Annealing of billets, particularly with a thin cross section, must be performed in vacuum furnaces or in furnaces with a protective atmosphere. To reduce the contact friction between the ingot and the tool when shaping tungsten by hot pressing and also to maintain the ingot at the proper temperature, it is recommended to use a combined high-temperature lubricant, that is, glass fabric together with a graphite lubricant.



Fig. 2. Coarse columnar structure of a cast tungsten ingot obtained by the electric arc method.

Tungsten heated to a high temperature cools rapidly and loses its plasticity. This circumstance requires that pressure working be performed at a high rate. A second factor which should be taken into account in pressure working of tungsten is the high temperature at which it passes from the brittle to the plastic state (Fig. 3). Hence the temperature at the end of the shaping process should be substantially higher (600-800°) than the brittleness threshold which is 300-400°. The tungsten article which is produced should be placed and removed from the tool in which it was worked before it had time to cool to a temperature below the brittleness threshold. In the opposite case brittle failure of the metal will take place.

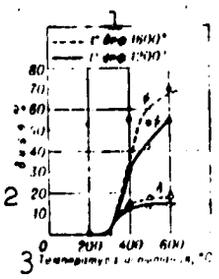



Fig. 3. Diagram for the transition of tungsten from the brittle to the plastic state. 1) Def; 2) δ and ψ in %; 3) test temperature, °C.

References: "Problemy sovremennoy metallurgii" [Problems of Modern Metallurgy]. No. 4 (28), 1956; Zelikman, A.N., Samsonov, G.V. and Kreym, O.Ye., Metallurgiya redkikh metalov [The Metallurgy of Rare Metals]. Moscow, 1954; "Dokl. AN SSSR" [Proc. of the Academy of Sciences of the USSR]. Vol. 140, No. 6, 1961; "Aviat. Week," Vol. 74, No. 2, page 63, 1961; "Precis. Metal Mold," Vol. 18, No. 7, page 14, 1960; "Iron Age," Vol. 181, No. 20, 1958.

I.G. Skugarev, A.P. Zabavnova

PRIMARY ALUMINUM ALLOYS – alloys prepared from primary metals (in ingots) and high-quality waste materials. In some cases primary aluminum alloys are prepared only from primary metals, using no waste material. These alloys are intended for production of shaped castings (see Aluminum casting alloys) and ingots, which are used to fabricate deformed semifinished products by pressure treatment (rolling, forging, drawing, etc.; see Aluminum shaping alloys).

References: Bochvar, A.A., Metallovedeniye [Metalworking], 5th edition, Moscow, 1956; Spravochnik po mashinostroitel'nym materialam [Hand of Machine Building Materials], Vol. 2, Moscow, 1959; Al'tman, M.B., et al., Playka i lit'ye legkikh splavov [Melting and Casting of Light Alloys], Moscow, 1956; Deformiruyemyye alyuminiyevyye splavy [Aluminum Shaping Alloys], collection of Articles edited by I.N. Fridlyander, et

V.V. Alt'man

PRIMER – is a varnish-and-paint material intended for smoothing the roughness of the surface before painting. The primer is composed of a film-forming material, a pigment and a filler. In contrast to other varnish-and-paint materials, the primer is characterized by a high content of mineral components (pigment + filler) which achieve 300-500 weight-% of the film forming material.

Types of Primers

| Тип шпатлевки | Вид пленкообразующего | Режим сушки (°С) | Область применения |
|---|---|---|---|
| Клеевая | Водный раствор мездрового клея + олифа или масляный лак | 15–60 | Для неответственных деталей, работающих в помещении |
| Масляная | Олифа | 15–150 | Для металлических и деревянных деталей, работающих в атмосферных условиях |
| Лаковая | Алкидные смолы | 15–150 | То же |
| Эпоксидная | Эпоксидная смола | 15–150 | » |
| Нитроцеллюлозная | Нитроцеллюлоза | 15–80 | » |
| Перхлорвиниловая | Перхлорвиниловая смола | 15–80 | » |
| Кремнийорганическая | Кремнийорганические смолы | 150–200 | Для металлических поверхностей, нагреваемых до 300–1000°, работающих в атмосферных условиях |
| Алкидностирольная | Алкидностирольный сополимер | 15–100 | То же |

1) Type of primer; 2) type of film-forming material; 3) drying conditions (°C); 4) field of application; 5) painting; 6) aqueous solution of hide glue + drying oil or oil varnish; 7) for low-duty objects used in rooms; 8) oily; 9) drying oil; 10) for metal and wood objects used in free atmosphere; 11) lacquer; 12) alkyd resins; 13) the same; 14) epoxy; 15) epoxy resins; 16) nitrocellulose; 17) nitrocellulose; 18) perchlorovinyl; 19) perchlorovinyl resin; 20) organosilicon; 21) organosilicon resins; 22) for metal surfaces heated up to 300-1000° working in free atmosphere; 23) alkyd-styrene; 24) alkyd-styrene copolymer.

The technological properties and the quality of the dried primer layer depend mainly on the type of the film-forming material and the quantity and quality of the filler (see Table).

The use of primers is inadequate for objects to be used in moist, tropical climates; epoxy primers are admissible as an exclusion. Perchlorovinyl and epoxy primers have a good resistance to acid and alkaline media. Epoxy primers are heat resistant up to 200°; organosilicon primers withstand a long-time service at 400°, and a short-time service at 1000°. All primers mentioned above are applied usually in combination with varnish-and-paint materials (first coats and enamels) with the same film-forming material or with materials which have a sufficient adhesion to the primer layer. The primer is applied to a previously primed surface, then, after drying and finishing, the corresponding enamel is laid on.

The thickness of the primer has a significant influence on the endurance and strength of the coating. The thicker the primer layer the higher is the probability of cracking. The maximum thickness of a single laid layer is 0.1-0.2 mm, a total thickness of 0.5-0.4 mm is admissible; epoxy primers may be laid on with a thickness of 0.8-1.0 mm. The drying conditions of the primer depend on the type of the film-forming material. Lacquer-and-oil, epoxy, oily and organosilicon primers must be dried at 80-200° to obtain a high-quality hardening; nitrocellulose, perchlorovinyl, alkyd-styrene and primers dry at room temperature.

References: Drinberg, A.Ya., Gurevich, Ye.S., Tikhomirov, A.V., Tekhnologiya nemetallicheskikh pokrytiy [Technology of Nonmetallic Coatings], Leningrad, 1957; Lyubimov, B.V., Spetsial'nyye lakokrasochnyye pokrytiya v mashinostroyenii [Special Paint-and-Varnish Coatings in Machine Building], Moscow-Leningrad, 1959; Organicheskiye

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zashchitnyye pokrytiya [Organic Protective Coatings], [a collection of papers], translated from English, Moscow-Leningrad, 1959.

V.V. Chebotarevskiy

PRIMING MATERIAL – painting material, intended for application as a first coat on a surface to be painted; a solution of a film-forming material with addition of pigments, etc.

For metals the priming material film should have inhibiting properties,i.e., the capacity of slow down corrosion processes and corrosion resistance; for timber it should be capable of filling pores and be impermeable to water, have excellent adhesion and high physiomechanical properties. The anticorrosion properties of priming materials are determined by the total of the properties of the coating among which a major role is played by the inhibiting properties. These properties depend on the kind and quantity of pigments which are contained in the priming material. Priming materials are divided into 4 groups which contain: 1) chromium pigments, 2) lead or iron minium, 3) zinc dust, 4) inert pigments. The following chromium priming materials are used: oil paint ALG-1, alkyd ALG-7 and ALG-8, phenolic-oil ALG-14, FL-0Zh, acrylic AG-3a and AG-10s, polyvinylbuteral VL-02 and epoxy EP-09T. Lead minium is added to priming materials (varnish, lacquer) directly before use in an amount of about 80% of the weight of the film-forming material, and zinc dust is added in an amount of about 90-95% of the weight of the film-forming material. The protective effect of priming materials containing inert pigments is based on their insulating property, i.e., on their capacity to interfere with the penetration of moisture to the metal surface. Such prming materials do not protect the metal for long periods of time, particularly under high humidity conditions. The selection of the priming material is determined by the kind

of the metal, the method by which it is prepared, property of the external enamel and the service conditions of the coatings. The industry produces about 30 brands of priming materials which, in combination with the corresponding enamels create protective coating systems. Only priming materials of the first group, that is, chromium [priming materials] produced with an alkaline resistant binder as a base, that is, with acrylic resin (the AG-10s priming material), epoxy resin (the EP-09T prming material) and alkyd resin (the AlG-7 priming material) are suitable for the protection of magnesium alloys. In addition to the above priming materials, prming materials with an oil paint binder as a base (AlG-1 and ALG-5), with a phenolic oil binder as a base (ALG-14, FL-03K), polyvinylbuteral binder as a base (VI-02) and others are suitable for the protection of aluminum alloys. Priming materials of all the three groups are suitable for the protection of steels. Proper selection of the external enamel layer is of importance.

References: Drinberg, A.Ya., Gurevich, Ye.S. and Tikhomirov, A.V., Tekhnologiya nemetallicheskikh pokrytiy [The Technology of Non-Metallic Coatings], Leningrad, 1957; Organichskiye zashchitnyye pokrytiya [Organic Protective Coatings]. Selection of articles, translated from English, Moscow-Leningrad, 1959.

V.V. Chebotarevskii

PROBABILITY OF FAILURE – a number which numerically characterizes the possibility of failure of a specimen or component. In the case of a normal distribution of properties the probability of failure is calculated from the normed Laplace function:

$$P(z_1) = 0{,}5 + \frac{1}{\sqrt{2\pi}} \cdot \int_0^{z_1} e^{-\frac{v^2}{2}} \cdot dv.$$

Here $z = \frac{x-a}{\sigma}$ and $z_1 = \frac{S-a}{\sigma}$ are the normed values of the random quantity $\underline{x}$. The distribution parameters $\underline{a}$ and $\sigma$ are the average values and root-mean-square deviation of the random quantity $\underline{x}$.

Example. On the basis of static tension tests of a large series of speciments made from the V95 aluminum alloy were obtained the average value of the actual breaking resistance $\overline{S}_k = \underline{a} = 75.0$ kg/mm$^2$ and the root-mean-square deviation $\sigma = 1.17$ kg/mm$^2$. It is required to determine the probability of failure of a speciment subjected to a tensile stress $S \leq 73.0$ kg/mm$^2$. In this case $\underline{z}_1 = (S - a)/\sigma = -1.71$, from the value of the Laplace function (from a table) we find the probability of failure: $P(z_1) = 0.5 - 0.4564 = 0.0436$ or $P(z_1) = 4.36\%$.

An experimental estimate of the probability of failure is the frequency $P = m/n$ where $\underline{n}$ is the number of specimens tested, and $\underline{m}$ is the number of specimens that failed at $x \leq x_m$.

References: see at the end of article Scattering of Mechanical Properties.

M.N. Stepnov

PROBLEM OF THE RELIABILITY OF MATERIALS — the aggregate of the technological, design, and operational questions that determine the capacity of a material to possess and retain throughout its service life characteristics governing the efficiency with which it functions under given conditions at the level of the requirements imposed during planning and calculation of the component for breakdown-free operation under normal conditions, as well as its ability to remain serviceable during possible deviation of working conditions from the norms set by plans, technological specifications, and operating instructions for components fabricated from it. In addition to the reliability of the material, the reliability of a system is governed by the characteristics of the components, their design, the operating conditions, the stability of the material, the Residual stresses, the presence of preset gaps, tolerances, and fits, and the change in the latter resulting from wear corrosion, lubrication, etc. This article deals with only some of the problems of reliability, which depends on the material.

For structural materials the principal value of reliability as an element of quality lies in preventing premature or unforeseen fracture of components.

Reliability became especially important in connection with the development of aviation, radio-electronics, automation, astronautics and nuclear engineering. In these fields of machine building the high requirements for light weight, small size, and efficiency do not permit the use of materials with a high reserve strength or other characteristics. The reserve strength of the materials employed in these fields

is very low (less than 1.2-1.5) and the probability of failure of reserve strength under actual production or operational conditions is consequently particularly high for metal alloys. The importance of reliability as an element of material quality increases with alloy working temperature, especially in the presence of sharp temperature gradients. The structure and properties of materials become quite unstable at elevated temperatures, since deformation is accompanied by gradual softening and aggregation of defects and the probability of unexpected deviations increases.

The measures taken to ensure reliability in contemporary designs have been radically altered.

Experience has shown that, despite the hundreds and thousands of components which perform their functions, there are those that break down before finishing out the service life provided by their plans or operational norms. The very small percentage of such components shows that the material selected satisfied design requirements and that the production technology and operational norms employed were worked out in conformity with the design characteristics and material parameters. In a sizeable portion of these cases breakdown results from various deviations from the production and operational conditions stipulated as normal for the component and its material. These include nonuniformity and instability of the material used. On the other hand, the reliability of the material is not the same as its uniformity and stability. In order to ensure reliability it is necessary that the entire volumn of material have a strength above the values assumed in planning and that it not not drop below a given level throughout the entire operational period. Very homogeneous and stable materials, such as glass, fracture under extremely small alternating stresses exceeding the calculated limits and consequently have a very low reliability. In order for a mater-

ial to be reliable it is therefore necessary that it have a low sensitivity to alternating loads.

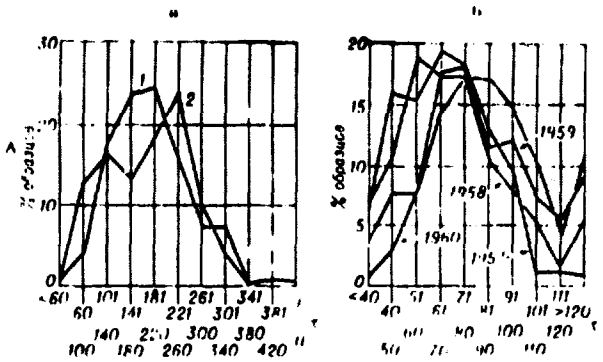


Fig. 1. Scattering of long-term strength (durability $\tau$ in hr) of typical high-hot-strength alloys delivered in different years. a) Kh77T7u alloy tested at 700° ($\sigma_b$ = 44 kg/mm$^2$); 1) 1959; 2) 1960; b) KhN70VMTTYu alloy tested at 850° ($\sigma_b$ = 20 kg/mm$^2$). A) % of specimens.

As a result of anisotropy of characteristics, the influence of surface condition after cold-working during machining, tensioning during assembly, and the residual stresses produced by welding, heat treatment, straightening, electrolytic plating, etc., stresses exceeding the calculated local stresses may develop as a result of impact and other accidental overloads during operation. A material incapable of eliminating stress concentration by plastic deformation cannot withstand excessive stresses and fractures. There is as yet no method for making a full evaluation of stress concentrations caused by random local technological and operational overloads. In planning a component these concentrations are usually taken into account by introducing the reserve strength, which generally includes the arbitrary ultimate strength rather than the fracture resistance of the material, particularly its resistance to brittle fracture. Moreover, when excessive local technological and operational stresses have a random character the calculated stresses may also be increased; when all these stresses are taken into

account the reserve strength proves to be far higher and the structure is made heavier. It should also be kept in mind that the stress ratio is not the sole criterion of nonfailure, since the deformation ratio can serve this purpose in such cases and energy criteria are often important.

The reliability of structural materials is governed both by their ability to withstand fracture as a disruption of continuity and by the manner in which the fracture process occurs. Local fracture (microcracking) may take place when the material contains an undetected defect or an unanticipated stress concentrator. In certain materials cracking occurs suddenly, while in others it is gradual or even arrested.

Local cracking is of varying during (lasting from seconds to thousands of hours) in different materials. If cracks propagate slowly they can be detected before they reach the failure point. Cracks can be detected visually, with the aid of special sensors, and by defectoscopy.

Nondestructive test methods, which permit detection of dangerous external and internal defects, are of great importance in ensuring reliability of material functioning. Internal cracks and separations can be detected by ultrasonic and acoustic methods, while internal flaws are shown up by x-ray- and gamma-defectoscopy. The uniformity of a metalic structure is determined with the aid of eddy currents and magnetic structurometry. Surface defects, including cracks and pores, can be reliably detected by magnetic-powder, ultrasonic, capillary, and electrostatic methods, as well as with eddy currents. There are also other nondestructive test methods for structural materials (see the appropriate articles on methods for defectoscopy of materials). A material which can function for a long enough period after development of

local cracks to permit their prompt detection is more reliable than a material in which cracks propagate rapidly. Determination of notch and crack sensitivity is consequently one method for evaluating reliability.

Reliability is a necessary qualitative factor for materials used in components intended for critical applications, where failure of any material percentage of components causes both delays for repair or replacement, i.e., economic losses, and possible severe breakdowns.

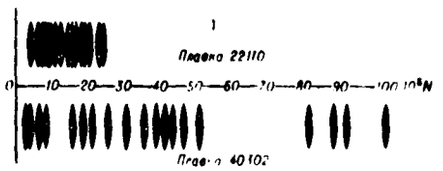



Fig. 2. Scattering of fatigue strength of different melts of KhN77TYuR alloy at 800° and an alternating-stress amplitude $\sigma = 27$ kg/mm$^2$. (Both melts satisfy technical specifications. The lenses indicate the number of cycles at which fracture occurred). 1) Melt.

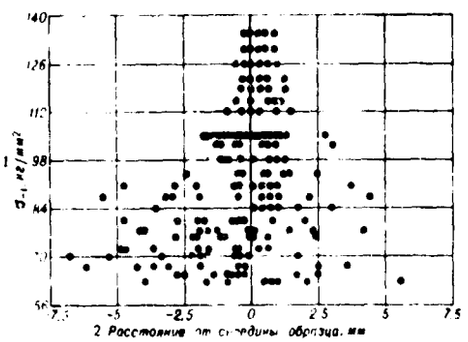



Fig. 3. Scattering of fatigue strength during bending of specimens of 4340 steel with varying cross sections; the specimens actually fractured at different distances from the center (at the points of least cross section) and thus at different values of $\sigma$. 1) $\sigma_{-1}$, kg/mm$^2$; 2) distance from center of specimen, mm.

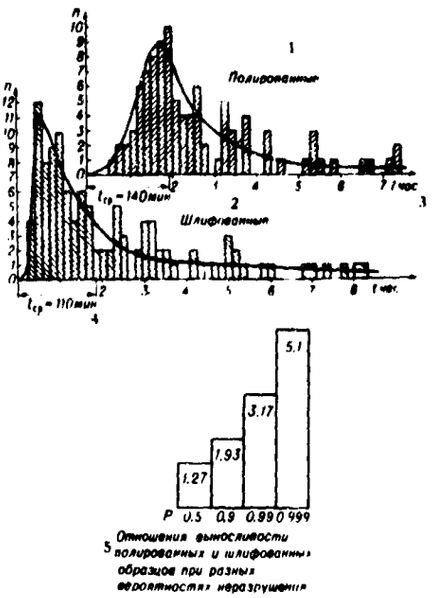



Fig. 4. Scattering of fatigue strength (durability t) of polish and ground specimens of KhN77TYuR alloy (it can be seen that the durability ratio of polished and ground specimens varies for different nonfailure probabilities, P = 0.5, 0.9, 0.99, and 0.999, and rises with increasing probability). 1) Polished; 2) ground; 3) hr; 4) min; 5) durability ratio of polished and ground specimens at different nonfailure probabilities.

Quantitative evaluation of reliability is hampered by the fact that the mechanical characteristics of materials subjected to fatigue testing are random quantities whose distribution about the typical or mean values is described statistically. Figure 1a and b shows frequency-durability curves for certain structural alloys, while Figs. 2 and 3 show the durability of steels and high-hot-strength alloys in a large number of tests.

Statistical processing of the results of a large number of tests makes it possible to evaluate the scattering of characteristics and to establish the maximum value that ensures a given nonfailure probability (90, 99, 99.9%, etc.), i.e., to determine the range of values within which it can be expected that the results of repeated testing of an arbitarily selected batch of material will fall with a predetermined probability (degree of statistical reliability); Figure 4 shows an ex-

ample of the location of reliability ranges with varying nonfailure reliabilities (90, 99, and 99.9%). (See Scattering of mechanical characteristics).

Reliability depends on the various conditions and factors acting on the material, on the size, shape, and surface condition of the component, on the mechanical and thermal stresses acting and their variations with time, and on environmental factors (physicochemical agents, irradiation, etc.). Quantitative criteria of reliability are therefore lacking or very arbitrary. Thus, reliability increases with: 1) the homogeneity of the material; 2) the stability of its structure and properties; 3) its insensitivity to stress concentration at notches and cracks; 4) its technical characteristics; 5) its insensitivity to overloads and to various external factors (corrosion, irradiation, thermal and magnetic fields, etc.).

Homogeneity. Complete homogeneity is impossible and the requirements imposed on uniformity of chemical composition, macrostructure, microstructure, and mechanical characteristics in testing by the methods prescribed by technical specifications mean only that the indices in question should correspond to those calculated or assumed in planning with a predetermined degree of reliability throughout the entire physical volume of the material. Required homogeneity does not mean that isotropy is obligatory in all cases.

A number of components are characterized by nonuniform stressing in different directions; for example, cylindrical tanks that function under internal pressure have a principal-stress ratio of 1:2. For such components it is best to use a material whose structure and characteristics are selected in such fashion that, in their anisotropy, they form a resistance field (the actual distribution of mechanical characteristics varying in accordance with location and direction) that coin-

cides with the stress field (see Anisotropic materials). For example, the most reliable material for tanks is a composite consisting of a metal shell, which resists the axial load, and a network of high-strength wire or uniformly oriented fiberglas, which resists the peripheral stresses. In such cases the requirement of homogeneity applies to each element of the composite material or to the mechanical characteristics obtained in a given direction.

Stability. By stability as an element of reliability we mean retention of the homogeneity stipulated by technical specifications throughout the entire service life of the material, as determined by operating conditions. It must be taken into account that, while the average indices of composition, structure, and properties remain stable, there may be local variations, e.g., in the surface layers. These variations are of special importance in some cases, giving rise to foci of failure that gradually propagate throughout the entire volume of the component. Included in this category are corrosion (see the appropriate articles on corrosion of metals), Erosion, sublimation, oxidation, carbonization, and the action of other environmental chemical, physical, physicochemical, and physicochemical-mechanical factors (see Gaseous corrosion of metals).

Insensitivity to stress concentration at notches and cracks. A material for which the ratio of the $\sigma_b$ of a specimen with a stress concentrator (e.g., a notch) to the $\sigma_b$ of a specimen without a stress concentrator is less than 1 cannot be regarded as reliable (see Concentration of stresses, Notch sensitivity).

In the general case the reliability of a material rises with increasing Plasticity ($\delta$ and $\psi$) and Impact strength. Since $\delta$ is composed of uniform and concentrated constituents, there may be cases in which the reliability of a material depends on whether elongation is uniform

or concentrated. The first case pertains to materials used in components that function under conditions of common deformation, e.g., a thin-walled cylindrical shell joined to a massive, rigid annular frame; the second case pertains to local overloads, e.g., those due to notches, sharp changes in cross section, hollows, etc.

Insensitivity to overloads must be evaluated (usually by natural and operational tests) in accordance with the service conditions under which the component in question is to operate; for example, multiple-action impact-ram machines are used for evaluating the ability of railroad components to withstand operational loads (during humping, etc.). Such tests have shown that this capacity varies considerably in different steels, despite the similarity of their standard mechanical characteristics.

Technological suitability. Technological suitability as a factor of reliability is determined by the probability that the chemical composition, structure, and properties stipulated by technical specifications will be obtained with the technology employed. It is associated with the number of operations, their complexity, and the permissible range of technological parameters that will ensure the required material quality, e.g., the smelting, casting, stamping, and heat-treatment temperatures, the degree of annealing, the degree of cold-working, etc.

A material with a narrow range of technological parameters, such as casting, pressure-working, and heat-treatment temperatures, degree of deformation, etc., will have a low technological suitability. Such a material is characterized by a high percentage of rejects and, with the existing culling methods, it is possible that individual blanks with nonuniform indices will be passed. Thus, a material with poor technological suitability may fail to satisfy the first requirement indicated in the definition of reliability and a formally conditional ma-

material may actually not possess the characteristics attributed to it by its technical specifications. Low technological suitability as a factor of reliability may also be due to other characteristics and properties of the material; for example, this phenomenon is observed in materials that have undergone substantial changes in volume during processing, which lead to considerable residual stresses. Such stresses are intensified when warping is eliminated by straightening. The low technological suitability of the material in cast components and welded joints can be attributed to its broad crystallization range, which promotes development of crystallization and liquation defects and hot cracking. Low technological suitability is manifested in the restrictions imposed on component design and technological operations. Thus, for example, high-strength steel ($\sigma_b \approx 200$ kg/mm$^2$) is a material of low technological suitability and requires far greater restrictions than medium-strength steel ($\sigma_b \approx 140$ kg/mm$^2$) on fillet radius, rigidity gradient, tensioning, straightening, and other operations during which stress concentration is possible; operations that leat to hydrogen absorption, carbonization, or cold-working or involve the action of other chemical or mechanical factors on the surface layer are excluded. Both the technological suitability and reliability of the material decrease as these restrictions become more severe.

Measures ensuring reliability can be taken during the following stages: a) production of materials and semifinished products; b) manufacture and assembly of products; c) operation.

Production of materials and semifinished products. The principal problem in increasing reliability during the production of alloys (by smelting or casting) lies in achieving maximum homogeneity and preventing liquation and crystallization defects and contamination of the metal by foreign impurities, especially gases and low-plasticity, brit-

tle, or low-melting inclusions. This problem can be solved by employing vacuum-smelting methods (vacuum induction smelting, vacuum arc remelting, crucibleless vacuum induction smelting), electron-beam and zone smelting, or electroslag remelting, by treating the liquid metal with synthetic slag, by vacuum-evaporating the molten metal in a ladle, by forcing gases (argon, hydrogen, etc.) through the molten metal, by using a direct-reducing charge in steel-smelting ladles, by various types of duplex processes, and by purifying the molten metal by filtration (for light alloys).

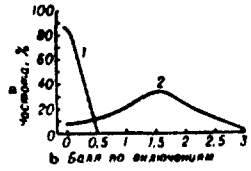



Fig. 5. Frequency distribution of nonmetallic inclusions (in arbitrary units) in metal produced by ordinary (atmospheric) smelting (2) and vacuum smelting (1). a) Frequency, %; b) inclusions, arbitrary units.

TABLE 1

Plasticity and Viscosity of Forged Compressor Disks of 1Kh12N2VMF(EI961) Steel as a Function of Smelting Method

| 1 Направление свойства | 2 Свойства | 3 Обычная выплавка | 4 Электрошлаковый переплав | 5 Вакуумная электродуговая выплавка |
|---|---|---|---|---|
| 6 В 3-м направлении | $\delta$ (%)<br>$\psi$ (%)<br>$a_н$ (кгм/см²) 8 | 2,6<br>11<br>1,7 | 13,5 (5)*<br>58 (4,5)*<br>3,6 (2)* | 15 (6)*<br>66 (6)*<br>11 (6,5)* |
| 7 Отношение показателей в 3-м направлении к показателям свойств в 1-м направлении | $\sigma_в$<br>$\delta$<br>$\psi$<br>$a_н$ | 0,91<br>0,2<br>0,19<br>0,16 | 0,99<br>0,9<br>0,72<br>0,3 | 0,96<br>0,98<br>0,98<br>0,75 |

*The figures in parentheses indicate the factor by which the characteristic in question exceeds that of metal smelted in the usual manner.

1) Direction of characteristics; 2) characteristics; 3) ordinary smelting; 4) electroslag remelting; 5) vacuum arc remelting; 6) in 3rd direction; 7) ratio of characteristics in 3rd direction to those in 1st direction; 8) kg-m/cm$^2$.

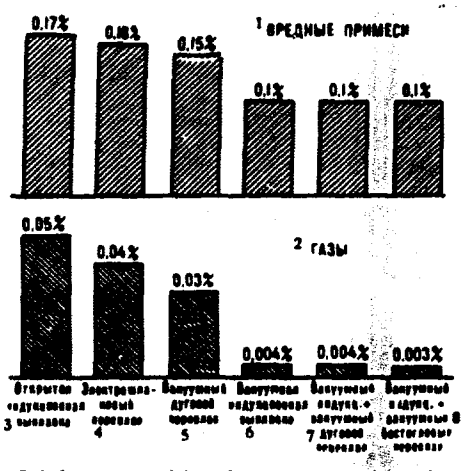



Fig. 6. Influence of smelting method on content of gases ($O_2$, $N_2$, $H_2$) and detrimental impurities (P, Pb, Sb, As, Bi, Sn, Cu, and S) in VKS-1 steel. 1) Detrimental impurities; 2) gases; 3) open induction smelting; 4) electroslag remelting; 5) vacuum arc remelting; 6) vacuum induction smelting; 7) vacuum induction and vacuum arc remelting; 8) vacuum induction and noncrucible vacuum remelting.

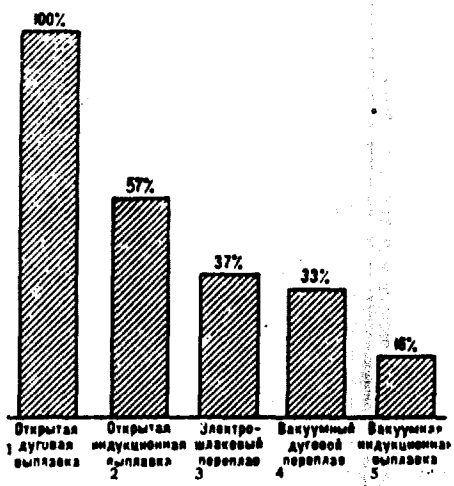



Fig. 7. Influence of smelting method on content of nonmetallic inclusions ($Al_2O_3$, $SiO_2$, $Fe_2O_3$, MgO, $Cr_2O_3$, MnO) in a high-hot-strength nickel alloy. 1) Open arc smelting; 2) open induction smelting; 3) electroslag remelting; 4) vacuum arc remelting; 5) vacuum induction smelting.

Remelting under vacuum conditions and in electroslag smelting equipment is of special value. These methods eliminate liquation and crystallization defects, refine the metal, reduce its content of gases and nonmetallic inclusions (Figs. 5, 6, and 7), raise its minimum ser-

vice life, heat resistance and durability, increase its technological plasticity, and ensure intensification of alloying and the highest degree of thermal and mechanical hardening. The principal advantage of vacuum smelting and electroslag remelting is the fact that they reduce the scattering of characteristics, cause a sharp decrease in anisotropy, and ensure uniformity of mechanical properties, especially plasticity and viscosity, in all three directions in forgings, stampings, and rolled shapes (Table 1, Fig. 8).

In order to ensure high reliability for components cast from alloys capable of forming stable oxide films when they react with atmospheric oxygen it is necessary to combine vacuum smelting with casting in a vacuum or neutral gas. High plasticity, high rupture resistance, and especially low sensitivity to stress concentrators are achieved by refinement of the structure of the cast metal, which requires addition of rare-earth metals, forcing of gases through the alloy in some cases, precise regulation of the sequence in which the alloying elements are added, intensive magnetic mixing of the molten metal (during induction smelting), etc. In certain cases, where it is possible to orient the structure of the alloy in the direction of the principal stresses, fusion crystallization is employed instead of refinement, producing crystals elongated in the direction of the tensile stresses, which substantially raises plasticity and impact strength and increases service life and durability.

Manufacture and assembly of components. Surface fineness is of decisive importance for the reliability of high-strength steels, titanium, aluminum, and magnesium alloys, and all structural alloys employed in the hardened state for components intended to function under alternating loads; scores, nicks, raised areas, hollows, and other surface defects are impermissible, as are sharp edges and corners, small radii

of curvature, sharp changes in cross-section, etc.

Among the most important measures taken to ensure reliability is

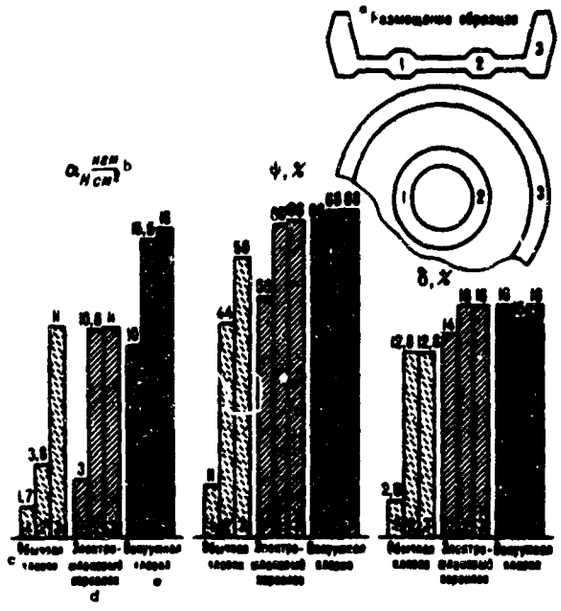


Fig. 8. Decrease in anisotropy of forged disks of 1Kh12N2VMF steel as a result of use of progressive smelting methods (specimen-cutting direction: 1) 3rd direction; 2) transverse; 3) per-unit). a) Specimen positioning; b) kg-m/cm$^2$; c) ordinary smelting; d) electroslag remelting; e) vacuum smelting.

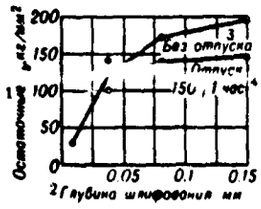


Fig. 9. Residual tensile stresses produced in 12Kh2N4A steel (cemented) during grinding as a function of grinding depth. 1) Residual $\sigma_b$, kg/mm$^2$; 2) grinding depth, mm; 3) without tempering; 4) tempering at 150° for 1 hr.

prevention of unplanned strains, especially in apertures, lugs, grooves, bushings, etc. All finish-machining operations should be strictly regulated, especially with respect to feed rate and cutting speed. In order to ensure reliability of high-strength steels and alloys it is very important to exclude or strictly limit grinding. Figure 9 shows the resid-

ual stresses produced by grinding. The scorching that occurs when there is a local increase in the feed rate or grinding depth is extremely dangerous. This phenomenon may produce residual stresses of such magnitude that they cannot be eliminated by tempering, especially when tempering high-strength steel at low temperatures and short holding times.

Prevention of embrittlement of the surface layers during heat treatment necessitates strict regulation of bath composition for operations such as bright quenching, bright tempering, etc., which utilize complex salt baths. Deoxidation of salt quenching baths with potassium ferrocyanide leads to severe embrittlement, since the surface layers become saturated with carbon and, particularly, with nitrogen, which raises their post-quenching hardness to 700 $kg/mm^2$. Technological operations such as acid tickling and degreasing may also lead to embrittlement and a considerable reduction in reliability. In ensuring reliability of soldered joints it must be ketp in mind that solder in the solid state generally has only a slight influence on strength and plasticity and thus on reliability; however, there may be a sharp, often catastrophic decrease in strength and plasticity and a corresponding drop in reliability during soldering when blanks having high residual stresses (after bending and straightening, especially at points where there are hollows, Brinnell indentations, core-sampling holes, etc.) come into contact with molten solder or when the joints are subjected to local overheating and, in general, in all cases where load-bearing metal comes into contact with a molten low-melting metal (tin, lead, zinc, mercury), e.g., during the melting-out of babbit-lined bearings, etc. It is consequently necessary to keep metal with rather high residual tensile stresses from coming into contact with molten active metals (see the appropriate articles on the soldering of various metals).

Among the techniques for increasing reliability are surface-hard-

ening methods, whose role is dictated by the condition of the surface layers, the importance of which was mentioned in discussing measures to prevent changes in the structure and properties of these layers during operation. Such methods include surface cold-working (shot-blasting, rolling, etc.), which raise fatigue resistance under alternating tensile and bending stresses by setting up compressive stresses in the surface layers and, as in the case of shot-blasting, by removing fine superficial stress concentrators (scores, microcracks, corroded grain-boundary segments, etc.), and application of various thermal-diffusion coatings, which increase the resistance of the metal to contact stresses, wear, erosion, etc. (cementation, cyaniding, nitriding, berylliza-tion, boriding, etc.).

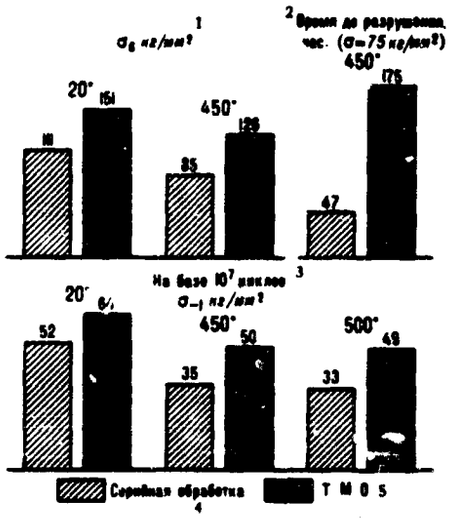



Fig. 10. Increase in the reserve strength of 1Kh12N2VMF steel components as a result of thermomechanical processing. 1) kg/mm$^2$; 2) time to fracture, hr ($\sigma$ = 75 kg/mm$^2$); 3) based on $10^7$ cycles; 4) serial processing; 5) thermomechanical processing.

Thermomechanical processing, which is a combination of heat treatment and plastic deformation, provides substantial opportunities for reinforcing and raising the reliability of steels and alloys with a sufficiently high degree of alloying. Such processing produces a finer structure (than ordinary heat treatment) and generally increases the

amount of hardening phase, which leads to a rise in $\sigma_{0.2}$, $\sigma_b$, long-term strength, and fatigue strength while only slightly altering plasticity and impact strength.

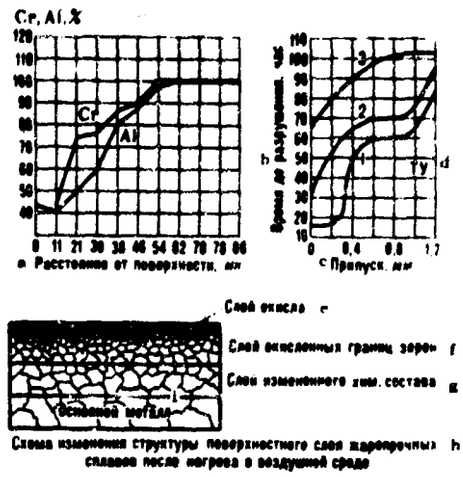



Fig. 11. Influence of heating atmosphere on the surface-layer composition and long-term strength of EI867 alloy (at varying machining tolerances): 1) Preforging heating and heat treatment in air; 2) preforging heating in air and heat treatment in argon; 3) preforging heating and heat treatment in argon. a) Distance from surface, μ; b) time to fracture, hr; c) allowance, mm; d) TU; e) oxide layer; f) layer of oxidized grain boundaries; g) layer of altered chemical composition; h) diagram showing structural changes in the surface layer of high-hot-strength alloys after heating in air; i) base metal.

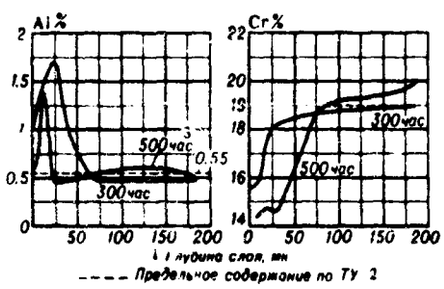



Fig. 12. Content of Al and Cr in the surface layers of EI437-alloy blad[illegible]perated for 300 and 500 hr. 1) Depth of layer, μ; 2) maximum conter[illegible] according to TU; 3) hr.

Figure 10 presents data showing a material rise in the characteristics of 1Kh2N2VMF (EI961) steel subjected to thermomechanical processing.

Operation. Measures which ensure stability of a material during

operation can be divided into groups in accordance with the charactor of the factors causing changes in composition, including: a) raising thermal stability by regulating phase composition through alloying and stabilizing heat treatment in cases where the material is to operate at temperatures sufficient to cause failure or embrittlement; increasing the content of alloying elements that form hardening phases; introducing elements that free the grain boundaries of low-melting or embrittling inclusions; regulating the size and total surface area of the crystallites by altering their block structure; setting up obstacles to dislocation migration and analogous measures in cases where reliability is determined by the creep rate, relaxation processes, equalization of the coefficient of linear expansion, and augmentation of reserve thermoplasticity under operational conditions in the presence of heat exchange, etc.; b) prevention of changes in the composition and structure of the surface layers during manufacture and operation. Figure 11 shows the change in the chemical composition of the surface layer of a high-hot-strength alloy used for gas-turbine blades during pre-pressure-working heating and heat treatment and the decrease in service life caused by combustion of the hardening components. Figure 12 shows the change in the alloying components of the surface layers of engine blades as a function of operational time.

Among the measures employed to prevent changes in surface-layer composition are heating in a neutral atmosphere or vacuum and protection of the surface layers by thermal-diffusion application of elements which retard corrosion, e.g., chromium-plating, lithium-plating, chromium-lithium-plating, etc., and thus rather effectively (Fig. 13) increase the reliability (reserve strength) of the blade material. Enameling also provides effective protection against oxidation, making it possible to increase the reliability (reserve strength) of high-hot-

strength and heat-resistant alloys, such as those used in jet-engine combustion chambers, by a factor of 2-2.5. Enameling is also used to prevent oxidation and oxygen-, nitrogen-, and hydrogen-saturation of semifinished sheets during pre-pressure working heating. In addition, enamel-fritt coatings can be used as a lubricant in hot rolling, reducing the rolling pressure, improving the surface condition of the finished sheets, and thus increasing their reliability. A combination of enameling and thermal-diffusion protection is of particular value for high-hot-strength alloys based on high-melting metals (Nb, Mo, W), since formation of only one thin surface layer, as of molybdenum disilicide, cannot reliably protect molybdenum components against oxidation at the working temperatures of gas-turbine engines and addition protection by enamelling is required. A complex procedure for increasing the reliability of materials intended to function under heat-exchange conditions is formation of thin (tenths or hundredths of a $\mu$) surface layers of high-temperature-resistant oxides of Al, Zr, etc. Such layers, which eliminate direct contant between the surface of the metal and the atmosphere, retard gaseous corrosion, reduce the heating and cooling rates and temperature drops, and cause a decrease in the loss of reliability due to brief rises in temperature.

An independent group of measures for preventing a drop in material reliability as the character of the surface layers changes during operation consists of techniques for protecting against corrosion in gaseous and protective media. It must be kept in mind, however, that corrosion-protection measures are sometimes associated with a loss of reliability: for example, galvanic plating entails absorption of hydrogen by the metal, which sharply reduces the structural factor in reliability. In such cases high reliability can be ensured by employing phosphating or cadmium-plating in an ammonium-chloride electrolyte, which makes it

possible to avoid hydrogen absorption, instead of zinc- or cadmium-plating in acid baths. The functional reliability of components of high-strength and structural steels with rigid tolerances is sharply in-

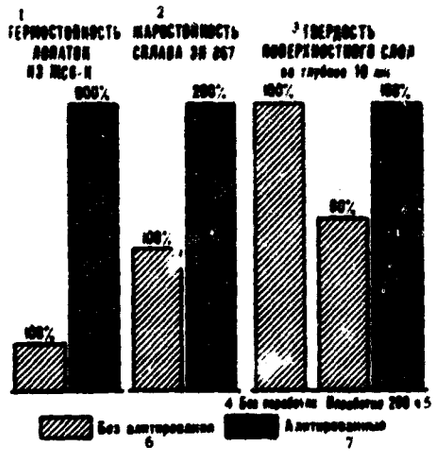



Fig. 13. Increase in the reserve strength of lithium-plated blades. 1) Thermostability of ZhS6-K blades; 2) hot strength of EI867 alloy; 3) hardness of surface layer at depth of 10 μ; 4) without processing; 5) processing for 200 hr; 6) without lithium plating; 7) lithium-plated.

creased by using oxide phosphating instead of blueing. The corrosion resistance of steel subjected to acid phosphating is more than 100 times that of blued steel and three times that of steel subjected to ordinary phosphating. The functional reliability of steel components can be raised by hydrophobization of their phosphate coatings through supplemental treatment with GKZh-94 silico organic fluid (ethylhydropolysiloxane). The molecules of this compound, which bond chemical with the phosphate coating, make it hydrophobic and intensify its protective properties by a factor of 10-20. Hydrophobization is employed for phosphated steel tanks, piping, etc.

Reliability of steel components intended to function at temperatures of up to 500° is ensured by use of nickel-cadmium plating instead of zinc- or cadmium-plating, which permit working temperatures of 350° and 250° respectively.

III-[illegible]

The problem of maintaining stability of characteristics during operation is especially acute for nonmetallic materials. Measures to increase the reliability of such materials are directed at maintaining stable characteristics or at least reducing the loss of strength and other properties under the action of environmental factors and operational conditions. The reliability of polymers and other nonmetallic materials can be raised in various ways, depending on their type, purpose, and operational conditions. Thus, for example, the characteristics of glass plastic can be stabilized by thermochemical treatment with silico organic products and compounds containing functional groups capable of interacting with glass or reacting with the binder, as well as by addition of active binder compounds, such as diethoxysilanes, which contain amino groups in the organic radical (product AM-2 or A-1100) and hydroxyl groups (product MR-1) (Table 2).

Binders containing no fatty acids and plastics containing minimal quantities of plasticizer are used to reduce the loss of reliability resulting from absorption of moisture. Use of chemically active compounds causes substantial stabilization of the properties of glass plastics employed in radio-engineering applications (Fig. 14) and raises the reliability of equipment functioning.

The reliability of rubber articles subjected to extension, which causes surface cracking, can be considerably increased by addition of ceraceous substance. (Table 3).

In order to prevent loss of reliability as a result of biological damage (see Biological stability) it is necessary to treat the material with antiseptics and chemical poisons. Depending on operational conditions, the antiseptic is applied to the surface, is used to impregnate the material, or is introduced into its composition. Wood is protected with creosotic acid, sodium chloride, or phenol compounds and rubber

with the zinc salt of salicylanilide; textiles are protected by soaking in 3% oxydiphenyl, which is also added in casein glue. Silicate optical glasses are protected by treatment with vinyltrichlorosilane and mer-

TABLE 2

Loss of Strength (%) in Glass Textolytes (After Boiling in Water for 2 hr)*

| 1 Свойства | 2 КАСТ-В | | 5 ФН | | 6 ВФТ | |
|---|---|---|---|---|---|---|
| | 3 без добавки | 4 с добавкой АМ-2 | без добавки | с добавкой АМ-2 | без добавки | с добавкой АМ-2 |
| 7 Предел прочности при растяжении (по основе) | 4 | 4 | 52 | 8 | 30 | 11 |
| 8 Предел прочности при изгибе (по основе) | 24 | 17 | 65 | 9 | 70 | 29 |
| 9 Предел прочности при сжатии (параллельно слоям) | 11 | 9 | 75 | 33 | 74 | 40 |
| 10 Модуль упругости (по основе) | - | — | 16 | 6 | 29 | 16 |

*Boiling in water for 2 hr is equivalent to two months at $\varphi$ = 98 ± 2% for one month in water at 20 ± 2°.

1) Characteristic; 2) KAST-V; 3) without additives; 4) with AM-2 added; 5) FN; 6) VFT; 7) ultimate tensile strength (along base); 8) ultimate bending strength (along base); 9) ultimate compressive strength (parallel to layers); 10) modulus of elasticity (along base).



Fig. 14. Change in the dielectric characteristics of VFT-S glass textolyte as a function of exposure time at high humidity ($\varphi$ = 98°, temperature — 30°): 1) VFT-S with 3% A-1100 added; 2) VFT-S with 3% AM-2 added; 3) VFT-S without active additives. a) Time, hr.

curic acetate. Protection against insects, particularly termites, which cause a great deal of damage to various materials (wood, paper, cardboard, textiles, leather) in southern climates, is provided by creosotic acid, arsenic compounds, chlorinated phenols, DDT, etc. (see Resistance to tropical conditions).

Antiseptic paints containing mercury and arsenic compounds prevent

any decrease in the reliability of the [illegible] ships, hydroplanes, etc. as a result of being overgrown with algae, crustaceans, fungi, molluscs, etc. The reliability of organic glass can be raised by the

TABLE 3

Time Required for Surface Cracking on Addition of Surfactaceous Substances to Rubber

| 1 Количество вводимой добавки | 2 Обычный состав | 3 1 вес. часть воска | 4 4 вес. части N, N'-дифторбутил-п-фенилдиамина |
|---|---|---|---|
| Время до появления первой трещины | 1 сутки 6 | 3 недели 7 | 2,5 года 8 |

1) Amount of additive; 2) ordinary composition; 3) 1 part by weight wax; 4) 4 parts by weight N, N'-difluorobutyl-n-phenyldiamine; 5) time to appearance of first crack; 6) 1 day; 7) 3 weeks; 8) 2.5 years.

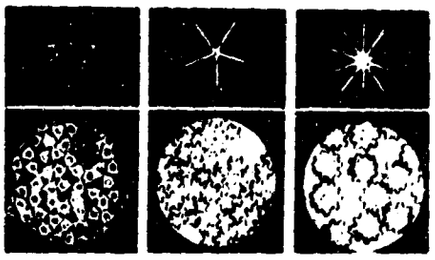
orientation method, which consists in tensioning it at a temperature above its softening point and fixing this stretched state during cooling. Orientation increases the cracking resistance of organic glass by a factor of more than 10 (see oriented Organic glass), its service life at 80° by two orders of magnitude (from 3 hr to 1000 hr under a stress of 175 kg/cm$^2$), and its plasticity, impact strength, and strength by a factor of 1.5-2.5.

Reliability of polymer materials exposed to ionizing radiation is ensured by addition of aromatic links to the chain molecules, by orientation (for example, orientation of ST-1 organic glass by 50% extension reduces its loss of strength after irradiation in a dose of ~20 Mrad by a factor of 10), by substitution of gums in rubber (polydimethylsiloxane gum for polyphenylsiloxane gum), or by use of special fillers, such as those which make it possible to reduce the loss of strenth of glass textolytes operating in the radioactive zone of a nuclear reactor by a factor of 5-6 (substituting quartzoid fiberglas for alcohol-free aluminoborosilicate fiberglas).

The reliability of many polymers can be materially raised by irradiation. Thus, supplemental radiation or electron-beam vulcanization of tire treads increases their reliability and running life by 20-30%. Use of irradiation during vulcanization increases the service life of rubber products at 300° by a factor of 30-40 in comparison with that of rubber produced by the usual method. The service life of polyethylene cable insulators at 150-200° can be greatly increased (from 10 to 5000 hr) by addition of special thermostabilizers and antioxidants and subsequent irradiation (radiation bonding). The reliability of VPM-1 and VEP-1 press-materials and VPS-2 glass textolyte is raised substantially (30-40%) by irradiation, which has a hardening effect. Irradiation of VS-350, VK-32-EM, and VK-6 glues in a dose of ~5 Mrad and of VK-2 glue in a dose of 140 Mrad produces an increase in reliability of the same order of magnitude. The decisive role in raising the reliability of components and materials is thus played by the optimum combination of design, experimental, technological, and operational measures. Especially important among these are: 1) operational observation and natural testing during polishing, start-up, and intermediate repair; 2) periodic defectoscopy when studying the operational regimes of entire units or pieces of equipment; 3) statistical processing of the results of testing and checking of materials and components.

A.T. Tumanov and N.M. Sklyarov

PROFILED FIBER – synthetic fiber with various cross sections (continuous or hollow), which has better service properties than smooth fibers with a round cross section (for example, polyamide or polyester). It is obtained by passing the raw material through spinnerets with profiled star-shaped holes (7 to 10 teeth for monofiber, 5 teeth for filament thread and staple fiber and 3 teeth for hollow monofiber, filament thread and staple fiber (figure). The cross sectional shape of profiled fibers is retained in drawing. The strength and elongation of profiled monofiber and filament threads are almost identical with those for standard fibers, the strength of profiled staple (hollow) fiber is insignificantly lower in comparison with polyamide staple fiber. With respect to resistance to multiple flexures and abrasion continuous profiled fiber is inferior to the standard fibers, while hollow profiled fiber exceeds them. Hollow profied fiber is characterized by high degree of twisting (by 50%), which increases the volume of finished products. The specific weight of hollow fibers is by 10% lower than that of continuous fibers. Profiled fibers have a high moisture absorption. Fabrics from profiled fibers are more permeable to air and water (by 20-45%) in comparison with fabrics from standard fibers. Products from profiled fibers are nontransparent and have a longer useful life than articles from standard fibers. The presence of voids in profiled fibers increases their porousness and specific volume, the consumption of material for making them is decreased at the same time. The fields of application of profiled fibers are the same as for standard fibers.



Standard types of spinneret holes and shapes of cross sections. a) Star with three teeth (for hollow profiled fiber); b) star with 5 teeth; c) star with 10 teeth.

References: Rogovin, Z.A., Osnovy khimii i tekhnologii proizvodstva khimicheskikh volokon [Fundamentals of the Chemistry and Technology of Chemical Fiber Production]. 2nd edition, Moscow, 1957; Böhringer, H., and Bolland, F., "Faserforsch. und Textiltechn." [Fiber Research and Textile Engineering], No. 5, pages 199-203, 1955; No. 10, page 405, 1958.

Z.A. Zazulina

PROFILED POLYAMIDE FIBER – synthetic fiber with different cross sections (continuous or hollow). It is produced in GDR in the form of monofiber, filament rayon and staple fiber.

The air permeability of fabrics made from profiled polyamide fiber made with No. 200 warp (12) and No. 600 woof (1) × 6 is 45% higher than that of fabrics from fibers with round cross sections. Products from profiled polyamide fibers have a better wearing ability than products from ordinary fibers.

References: Böhringer, H. and Bolland, F., "Faserforsch. und Textiltech." [Fiber Research and Textile Engineering], No. 10, page 405, 1958.

Z.A. Zazulina

PROTECTIVE COATINGS OF ALUMINUM ALLOYS – see Anodizing of Aluminum Alloys, Nickel-Plating of Aluminum Alloys, Chemical Oxidation of Aluminum Alloys, Chrome-Plating of Aluminum Alloys, Enameling of Aluminum Alloys, Varnish and Paint Coating of Aluminum Alloys.

PROTECTIVE COATINGS OF CHROMIUM – are surface coatings which protect chromium from saturation with gases (mainly nitrogen) at high temperature. Chromium is the only high-melting metallic element which proves a high corrosion resistance in oxidizing atmosphere. These properties of chromium are caused by the formation of a tight, nonvolatile oxide film with a high melting point (2200°). Chromium oxides do not dissolve in acids and alkalis when the metal is heated above 500-600°. Chromium, however, absorbs markedly nitrogen when heated in air (above 700°) and this fact results in brittleness. Different methods to protect the surface of pieces may be used in order to prevent the saturation of chromium and its low-alloys with nitrogen: a) diffusion coatings, coating with aluminum in furnaces with a neutral atmosphere by a mixture containing 98% powdered chrome-aluminum alloy (30% Al) and 2% ammonium chloride, for example. The pieces, set into tightly closed metal boxes with the above-mentioned mixture, are heated at 1200° for 5 hours. It must be taken into account that diffusion coatings raise the temperature at which chromium is converted from the brittle into the plastic state. b) electroplating or chemical plating with nickel, a nickel coating with a thickness of about 50 microns, for example, protects the pieces for a long time from reaction with aggressive gases which are present in the gas phase at temperatures up to 1200°. A previous heating in vacuum or in inert gas at 800-1000° for 1-3 hrs increases the resistance of the nickel coating. A supplementary aluminum plating of the nickel-plated parts increases markedly their resistance to corrosion. Diffusion coatings and electroplating prove to be highly

resistant to thermal shocks and to the erosion by the working medium. In cases when a high resistance of the protective coating to erosion by the working medium is not necessary, spraying of oxides (usually aluminum oxide) or of other corrosion-resistant chemical compounds may be utilized as a protective coating. Utilization of enamel coatings has given positive results in some cases.

I.O. Panasyuk

PROTECTIVE COATINGS OF MAGNESIUM ALLOYS – see Anodizing of Magnesium Alloys, Electroplating of Magnesium Alloys, Varnish and Paint Coating of Magnesium Alloys, Oxide Coating of Magnesium Alloys.

PROTECTIVE COATINGS OF MOLYBDENUM – are surface coatings which protect molybdenum from gas corrosion at high temperatures. Molybdenum is oxidized above 200°; Molybdenum oxide ($MoO_3$), formed on the surface, evaporizes at temperatures higher than 600°. Pieces from molybdenum, working in an oxidizing medium at high temperatures, must, therefore, be protected from oxidation.

The composition of the oxide film on the molybdenum surface, the oxidation rate of molybdenum, and the evaporation of its oxides change depending on the conditions (temperature, composition of the gas, flow velocity of the gas, pressure, etc.). It was found that molybdenum dioxide ($moO_2$) is formed on the surface of molybdenum, which further oxidizes to $MoO_3$. $MoO_2$ is a dark-brown or violet-colored oxide. The crystals are monoclinic with the following lattice constants: a = 5.110 A; b = 4.843 A; c = 5.526 A; $\beta$ = 119°37' ($MoO_2$ can be reduced by hydrogen to metal at 500°). Sublimated $MoO_3$ represents colorless crystals with an orthorhombic structure, the lattice constants being: a = 3.958 A; b = 13.820 A; c = 3.689 A, on the surface of the metal, however, it has a yellowish-white color. $MoO_3$ melts at 795° and forms an eutectic with $MoO_2$ at 777°. The appearance of a liquid layer on the surface facilitates the access of oxygen to the metal and lowers strongly the resistance to oxidation. In contrast to the oxidation mechanism of the majority of metals, the oxidation mechanism of molybdenum below the melting point consists in a diffusion of oxygen through the oxide; the oxidation develops on the metal – oxide interface. A number of molybdenum oxides is well-known: $MoO_2$ ($\delta$ oxide), $MoO_3$ ($\alpha$ oxide),

$Mo_9O_{26}$ ($\beta'$ oxide), $Mo_8O_{23}$ ($\beta$ oxide), $Mo_4O_{11}$ ($\gamma$ oxide), and others. The structure of these oxides is well-known. The rate of molybdenum oxidation at temperatures below 450° is low; the oxidation rate increases with rising temperature and with increased evaporation of the molybdenum trioxide (Fig.). The vapor pressure of $MoO_3$ reaches the atmospheric pressure (760 mm mercury column) at 1155°. Molybdenum and its low-alloys are usable without protective coatings for working at high temperature in vacuum, in an inert gas medium, and, for a short time, in air and other oxidizing media. A utilization of molybdenum and its alloys as heat-proof materials for a long working in oxidizing media and in air is only possible with surface protective coatings. The protective coatings of molybdenum must fulfill the following requirements: high heat resistance and thermal endurance, good resistance to erosion, strong adherence of the oxide to the metal, minimum of porosity, a thermal expansion coefficient near to the value of that of molybdenum, sufficient plasticity, low diffusion mobility of the atoms of the coating, etc.

The following methods of protective coating of molybdenum are developed: by thermal diffusion, with enamel, complex (thermal-diffusion -enamel, etc.), electrolytic, applied by spraying, ceramic, applied by plating, etc. A covering, able to secure molybdenum from oxidation on any working condition, does not exist to date. The existing coatings must be used selectively taking into account the specific properties of the coating, the working conditions and the shape of the piece.

-olybdenum with protective coatings is usable for engine parts exposed to an erosion in oxidating medium during some minutes at temperatures of the gas flow of 2000° and above; for blades of gas turbines, working in an oxidizing medium at 1100-1400°, for a relatively long time; as a facing sheet material working in oxidizing medium at temper-

atures up to 1500° during 1 hour; for parts of heating elements working on air at temperatures about 1500°; for protecting tubes of thermocouples working at high temperatures (1700°), etc.

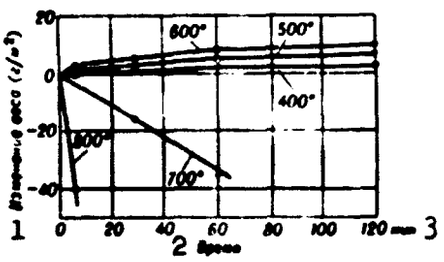



Fig. Isotherms of the molybdenum oxidation in air. 1) Change in weight ($g/m^2$); 2) time; 3) min.

Thermodiffusion coatings on molybdenum are formed by saturation the surface layers of the piece with different elements which diffuse from the surrounding medium into the metal. The depth of the most thermodiffusion coatings does not exceed 0.15 mm. Cracking along the edges of the piece occurs when the layer is thicker. Molybdenum disilicide ($MoSi_2$) is the most heatproof coating of all known diffusion coatings. This coating can be applied by the method of thermodiffusion using silicon powder in presence of ammonium chloride, or from the gas phase, using $SiCl_4$ and hydrogen. The $MoSi_2$ coating is stable in oxidizing medium up to 1700°. The low plasticity of the $MoSi_2$ at temperatures up to 1000°, and the high sensibility to thermal shocks result in the formation of cracks through which the oxidation of molybdenum and the evaporation of its oxides ("burning out") may occur. $MoSi_2$ coatings are capable of "self-sealing" resulting in a stop of the begun "burning out" when the defects of the coating are insignificant. Coatings from $MoSi_2$ can be used for the protection of molybdenum pieces working at a low number of thermal shocks (inserts into the critical cross section of nozzles, hoods of thermocouples, etc.). The properties of $MoSi_2$ can be significantly improved by alloying with Cr, Al, Ti, Zr, W, etc. The former elements diminish intensely the grain of $MoSi_2$ and increase in this way the plasticity and heat resistance; W and Zr increase the strength of $MoSi_2$. The existing thermodiffusion coatings (Cr-Al-Si; Ti-Si, and Zr-Si) withstand up to 1000 thermal shocks at the

following temperature conditions: 200-1200-200°, and more than 500 thermal shocks at 100-1500-100°. These coatings protect molybdenum from oxidation in still air at 1200° for 1000 hrs, at 1500° for more than 50 hrs, and at 1700° for more than 5 hrs. The coatings are resistant to erosion and possess at high temperatures a margin of plasticity sufficient for most designs (2.2%). The hardness of the coating, determined by the PMT-3 apparatus with a load of 100 g, is equal to 1200-1300 $kg/mm^2$, the radiation factor increases from 0.54 (at 150°) to 0.94% (at 1000-1200°) and does not change up to 1600° (investigations in neutral medium). The W-Si coating is less heat resistant, but the specimens protected by it have proved to be more stable in long-time tests at high temperatures than specimens with other coatings. Thermodiffusion coatings can be utilized for protection of antennae, inserts into critical cross section of nozzles, protecting tubes of thermocouples, filters, rudders, industrial holders and fasteners, etc. Thermodiffusion coatings are known, obtained by saturation in a vacuum, immersion into liquid metal, etc. Chromium and titanium give good layers by saturation in vacuum. Coatings from $Mo_3Al$ and $Al_2O_3$ are obtainable by immersion into a liquid aluminum bath and subsequent oxidation of the formed layer.

Enamel is a silicate coating formed after sintering. 2 types of this coating are the most widely used: a frit without metallic filler (glass-like coating), and a mixture of high-dispersed powders of chromium, frit and porcelain (glass-chromium coating, pseudo-enamel). According to the working conditions of the piece, the thickness of the enamel layer may attain 150 microns. The following method is used for the preparation of the enamel. The batch, composed from previously ground raw material, is mixed, melted, granulated, certain quantities of clay and water are added, and grinding is carried out in ball mills to obtain a

suspension (slip). The slip is applied to the piece with a brush, by pouring over, immersion, spraying, or electrostatic coating, and the piece is fired after drying in hydrogen, argon or vacuum. Certain ingredients melt during the firing, and glassy enamels are obtained. The firing temperature is, as a rule, by 150-200° higher than the working temperature of the enamel. Glass-chromium coatings prove a higher heat resistance than glassy coatings. The surface of the piece has a dark-gray color after the enamel is applied; enamels containing chromium become dark-green (due to the oxidation of chromium) after heating on air. The radiation factor of the enamel is equal to 0.8 at 1150-1200°. In order to obtain thin-layer coatings (5-10 microns), true solutions of compounds soluble in water are used, for example, nitrates of chromium, aluminum, calcium and other metals, which decompose by heating forming volatile and solid compounds. Silica, the main component of the silicate coating, is present in the true nitrate solutions in form of suspended particles. Tetraethoxysilane is also used as a component; it gives semicolloidal solution with nitrates, from which a solid phase is formed after heating. The nigh-dispersed phase precipitates on the surface and forms the protective coating after heat treatment. This method is known as the method of dissolved ceramic. The use of enamels for protection from oxidation is limited. They are utilized for the short-time working of parts, and, mainly, in complex coatings.

Complex coatings of molybdenum consist of two or more layers different in their nature, a thermodiffusion- and an enamel-layer, for example. The total thickness of a complex coating is 0.25-0.3 mm. Such coatings are recommended for protection of long-time working parts. The properties of the thermodiffusion coating remain considerably longer preserved under the enamel. The depth of the thermo-diffusion layer does not change after a test at 1200° during 1000 hrs, and the phase

composition changes only insignificantly. Moreover, the reliability of the protection of the piece is increased because the possible microdefects in the thermodiffusion coating become considerably more harmless when they are coated with enamel. The enamel protects the thermodiffusion coating from mechanical impacts and is sufficiently resistant to erosion at a given temperature. It is expedient to degasify the pieces protected with a thermodiffusion coating in a $1 \cdot 10^{-4}$ mm mercury column vacuum in $MoSi_2$ powder at 1200° before the enamel is applied. This ecludes a blistering of the enamel caused by liberation of gases during the firing process. Complex coatings are used for the protection of molybdenum pieces in the same cases as the thermodiffusion coatings.

Electrolytic coatings of molybdenum are obtained by electrolysis of aqueous solutions or molten salts in order to produce a metallic layer on the molybdenum which protects it from oxidation. Cr-Ni coating with a total depth of the layer equal to 0.3-0.6 mm is the most thoroughly investigated of all electrolytic coatings which protect from oxidation for 100 hrs at 100° and for a longer time at 1000° and below. This coating is plastic. The microhardness in the depth of the nickel layer, measured by the PMT-3 apparatus with a load of 50 g, lies within 160 and 320 $kg/mm^2$ (150-200 $kg/mm^2$ before firing). The Cr-Ni coating is applied subsequently, Cr at first, and then Ni. In order to secure a strong adhesion to the molybdenum, anode pickling of the cleaned molybdenum pieces is carried out in a mixture of $H_2SO_4$ + $H_3PO_4$ (volume ratio 1:1) during 2-3 min at a current density of 2-10 $amp/dm^2$. The coated specimens are fired in $H_2$ or in an atmosphere of inert gases in order to improve the adhesion of the coating to molybdenum and to increase the heat resistance. The Cr-Ni coating has light-gray color and becomes greenish-black after heating at high temperatures. The Cr-Ni coating is usable to protect simply-shaped molybdenum pieces from temperatures up

to 1100°. The diadvantages of electrolytic coatings are: difficult depostion of the coatings on edges and corners of the pieces, and difficult protection in points with electrical contact. In order to increase the resistance to oxidation of the nickel layer, an aluminum layer (0.05-0.07 mm thick) may be applied on the nickel layer (0.17 mm thick) by electrolytic deposition from melted cryolite at 1000°.

Ceramic coatings consist of oxides applied usually with plasma or other burners. These coatings are also appliable by melting, immersion in liquid baths, electrostatic deposition from suspensions, etc. All these methods give coatings whose properties are lower than these of coatings obtained with burners, therefore they are not used in practice.

Protective spray coatings are obtained by spraying different materials in liquid state (or near to it) with oxyacetylene, plasma, and other torches. The materials for the spraying are used in form of powders, flexible or rigid rods and also in form of wires. The flexible rods (cores) of the materials to be sprayed are prepared by mixing the powders with plasticizers (polyethylene, polyisobutylene) and subsequent extrusion through a mouth piece; the rigid ones by the same method but fired additionally in order to burn out the plasticizer and to sinter the powder particles. The materials to be sprayed must melt in the flame without decomposition and volatilization, and the melted material must disperse in drops and not form threads. Aluminum oxide, zirconium dioxide and zirconium coatings are applied by this method to protect molybdenum from oxidation. These coatings are heatproof at temperatures >2000°, they are resistant to erosion in gas flow, are characterized by a low thermal expansion coefficient and a low heat conductivity. They are, however, brittle, porous and insufficiently heat resistant. The porosity may range within 0.4 and 12%, depending on the material used and the conditions of the spraying. The compression strength of

these coatings is approximately 10 times higher than the tensile strength. Coatings from other ceramic materials: mullite ($3Al_2O_3 \cdot 2SiO_2$), forsterite ($2MgO \cdot SiO_2$), spinel ($MgO \cdot Al_2O_3$), chromium oxide ($Cr_2O_3$), cerium dioxide ($CeO_2$), titanium dioxide ($TiO_2$), etc. and also of metals, alloys and cermets may be deposited by spraying methods $MoSi_2$, sprayed with a plasma torch, is the most promising and easily realizable in technology coating at temperatures up to 1700°. Coatings obtained by spraying methods are usable for protection of constructions (mainly of laminated ones) working at 1200-2500°.

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Ye.V. Sivakova, N.A. Gasnikova

PROTECTIVE COATINGS OF NIOBIUM – are surface coatings protecting niobium from oxidation and saturation with gases (nitrogen, hydrogen) when heated in a wide temperature range. Niobium, beginning with a temperature of 200°, combines easily with oxygen and absorbs hydrogen and nitrogen considerably beginning with 250° forming hydrides or nitrides, respectively. A dark, tight oxide film with a good adhesion to the metal basis forms on the surface of niobium heated in air within 200-400°. The structural components of this film are lower niobium oxides: niobium oxide (NbO) and niobium dioxide ($NbO_2$). Niobium oxide has a face-centered cubic lattice of the sodium chloride (NaCl) type with the lattice constant a = 4.2018 A. The melting point of niobium oxide is 1945°, the specific gravity ~ 7.26 $g/cm^3$. Niobium dioxide ($NbO_2$) is a dark-blue crystalline substance with the specific gravity of 6.3 $g/cm^3$ and a melting point of 1915°. $NbO_2$ has a hexagonal crystalline structure, analogous to the structure of rutile ($TiO_2$), with a somewhat distorted lattice (the lattice constants are a = 4.844 A; c = 2.99 A; and c/a = = 0.618).

The oxidation rate of niobium obeys a parabolic law in the 200-400° temperature range. A rise of the temperature above 400° accelerates the oxidation rate of niobium, and beginning with 700° its oxidation is a linear function of the time. A porous oxidized layer of niobium pentoxide ($Nb_2O_5$) is formed on the niobium surface at these temperatures, which separates easily from the metallic basis and which does not protect the metal from further oxidation. The ratio of the oxide volume to the metal volume is equal to 2.69. Niobium pentoxide is a white crystal-

line substance with the specific gravity of 4.53-5.02 g/cm$^3$ and a melting point of 1510°. According to different authors, niobium pentoxide exists in four modifications with limited regions of homogeneity. The low-temperature modification of niobium pentoxide ($\alpha$ $Nb_2O_5$) forms at temperatures below 800° and has an orthorhombic crystalline structure with the following lattice constances: a = 6.16 A; b = 3.65 A, and c = 3.94 A. It is irreversibly converted at temperatures above 800° into the $\beta$ modification which is stable up to 1060°. Above this temperature, the conversion of the $\beta$ modification into the high-temperature $\gamma$ modification of niobium pentoxide occurs. The latter, heated at 1285°, undergoes a reversible conversion into the $\gamma'$ modification of niobium pentoxide which melts without decomposition at 1510°. The high-temperature $\gamma\gamma$ modification of niobium pentoxide has a monoclinic lattice with the constants a = 19.63 A; b = 3.835 A; c = 20.93 A, and $\beta$ = 120°. Niobium pentoxide is completely soluble in oxalic and tartaric acid at room temperature, and in 80% sulfuric acid at 180-200°. All niobium oxides are nonvolatile up to their melting point due to the low pressure of their vapors. The reaction of niobium with hydrogen begins above 250°, the compounds NbH and $NbH_2$ may be formed. According to the data of different authors, their crystalline structure is identical and may be body-centered cubic, rhombic or tetragonal with somewhat distorted constants. The solubility of niobium in nitrogen increases from 0.005% to 0.7% (by weight), respectively, when temperature rises from 300° to 1500°. Two compounds, NbN and $Nb_2N$ are formed in the niobium-nitrogen system. The crystalline structure of NbN is face-centered cubic, and that of $Nb_2N$ is hexagonal.

The ability of niobium to absorb gases and to react with them at high temperatures does not permit one to use high-heatproof alloys on its basis for working in air during a long time. Special coatings pro-

tecting these alloys from oxidation and gas diffusion are indispensable for their utilization. In principle, the preparation of niobium alloys with a high resistance to oxidation is possible.

The diversity of the working conditions of the pieces does not permit the development of a universal protective coating. The requirements put up to ideal coatings as follows: the coating must protect the alloy from gas diffusion not lessening the properties of the basic material; it must resist well to alternating temperature changes, it must not decompose during cold and hot deformation, it must possess the ability of self-sealing when damaged; the layer of the coating must be thin, tightly adherent and uniform in thickness.

The protective coatings may be made from metals, cermets and ceramics. Several methods of deposition of coatings are known, depending on the purpose of the working piece, its shape, and the composition of the protective coating; plating with heatproof materials; spraying of oxides, intermetallic compounds, and alloys with a gas-or a plasma torch; saturation by thermodiffusion, precipitation from a gas phase, enameling and electrolytic precipitation from solutions or melted salts or oxides. The coatings can be a single-layer, a multilayer, combined and a complex one. Independent of the composition of the coating and the method of its deposition, the mechanism of protection of the alloy by the coating results in the fact that tight oxide films are formed during heating which protect the basic material from saturation with gases.

Cr-Al-Si coating, deposed by the method of thermaldiffusion saturation or spraying, can be used for protecting niobium and its heatproof alloys from oxidation and saturation with gases when heated in air for 300 hrs at 800° and for 10 hrs at 1450°. Coatings from alloyed (with boron, chromium or aluminum) molybdenum or niobium silicides, from high-heatproof alloys on niobium basis (Nb-Ta-W-Zr) applied by spraying

with a plasma torch, and also non-fired enamels containing high-melting oxides of zirconium, beryllium, yttrium or intermetallic compounds, may be most promising for long-time working at temperatures up to 1500°.

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Ye.L. Zarubina

PROTECTIVE COATINGS OF STEEL – see Bluing of Steel; Electroplated Coatings of Steel; Varnish and Paint Coating of Steel; Chrome Plating of Steel.

**PROTECTIVE COATINGS OF TANTALUM** – are surface coatings which protect tantalum from oxidation and saturation with gases (nitrogen, hydrogen) when heated in a wide temperature range. Tantalum undergoes almost no gas corrosion when heated in air up to 300°. It begins to oxidize noticeably at higher temperatures, an oxide film forms on the surface. This film is dark, tight and well adherent to the metallic basis at temperatures up to 500°. The structural components of the film are mainly $Ta_2O_5$ and, hypothetically, traces of $Ta_2O_3$. The oxidation rate increases at higher temperatures, and a bright porous $Ta_2O_5$ is formed on the surface which easily separates from the metallic basis without exerting protective properties. The reaction of tantalum with nitrogen begins markedly at 700°. A layer of tantalum nitride (TaN) is formed on the surface of tantalum whose thickness grows with rising temperature. Tantalum begins to react with hydrogen even at room temperature. The rate of hydrogen absorption by tantalum increases at 500-600° and falls again when the temperature rises further. A relived pressure during the heating reduces the hydrogen absorption rate. At a temperature about 1000° and a pressure of $10^{-4}$ mm mercury column, the hydrogen can be totally given off from tantalum.

Owing to its low resistance to gas corrosion, tantalum may be used as a heatproof material only when effective methods of protection from oxidation are provided. The methods recommended for the protection of other high-melting metals, Nb, Mo, and W, can also be used for the protection of tantalum from oxidation at high temperatures. It is known, for example, that tantalum disilicide is a very heatproof material. It

withstands a heating at 1500° for 1 hour. A tight glassy protective film compose from a solution of the oxides $Ta_2O_5$ and $SiO_2$ (the melting points of these oxides are 1890 and 1728°, respectively) is formed on the surface of tantalum disilicide when it is heated in an oxidizing medium. The tight layer of tantalum disilicide obtained on tantalum by the thermal diffusion method, possesses a good resistance to oxidation up to 1700°. Crystallizable glassy coverings, containing the high-melting oxides $ZrO_2$, BeO, $HfO_2$, etc., are most promising for a short-time protection of tantalum from oxidation at 1800-2500°.

References: Gebhart E., Preisendanz H., "Z. Metallkunde," 1955, Vol. 6, No. 8, pages 560-568; Gebhart E., Seghezzi H. D., Item 1959, Vol. 50, No. 5, pages 248-257; Niobiy i tantal [Niobium and Tantalum], a collection of translations, 2nd part, Moscow, 1946.

Ye. N. Novikova

PROTECTIVE COATINGS OF TITANIUM ALLOYS – see Anodizing of Titanium Alloys; Varnish and Paint Coating of Titanium Alloys; Brass Plating of Titanium Alloys; Copper Plating of Titanium Alloys; Molybdenum Plating of Titanium Alloys; Nickel Plating of Titanium Alloys; Chrome Plating of Titanium Alloys.

PROTECTIVE COATINGS OF TUNGSTEN – are surface coatings which protect tungsten from gas corrosion at high temperatures. Tungsten is a metal very resistant to oxidation when heated in air up to 700°. The oxidation rate increases at higher temperatures (Fig.), and a yellow powderlike oxide is formed on the surface, which begins to evaporate noticeably above 800°. Three stable oxygen compounds of tungsten are known: $WO_3$ (α-phase); $W_4O_{11}$ (γ-phase), and $WO_2$ (δ-phase). The compound $WO_3$ is formed in a surplus of oxygen; it is a yellow colored oxide with a triclinic (pseudoorthorhombic) crystalline structure. The compound $WO_2$, with a monoclinic crystalline structure, is formed in presence of smaller oxygen quantities. This compound is observable in the deepest part of the oxide layer obtained on tungsten after heating to about 700°. The intermediate compound $W_4O_{11}$ is a blue-violet colored oxide with a monoclinic crystalline structure. The low protective properties of the oxide film on tungsten are due to the friability of the cinder, the weak adhesion of the oxide to the metal, and the volatility of $WO_3$. Owing to the low resistance to oxidation at high temperatures, tungsten can be used as a high heatproof material only when the surface of the working piece is reliably protected from a reaction with the oxidizing medium or when working in a neutral medium and in a vacuum.

The development of protective coatings for tungsten has not passed over the first stage of investigation. A multilayer coating which protects tungsten from oxidation at a temperature of 1650° for 20 minutes is well-known. The coating is composed from successively applied chromium (5 microns), silicon (12.5 microns), chromium (12.5 microns), and

rhodium (12.5 microns). The first chromium layer and the last rhodium layer are applied by electroplating. The silicon and the chromium layer are applied by precipitation from the gas phase. The latter process results in a reduction of the chlorides of the corresponding metals by hydrogen, and precipitation of the reduced metal on the hot surface of the piece.

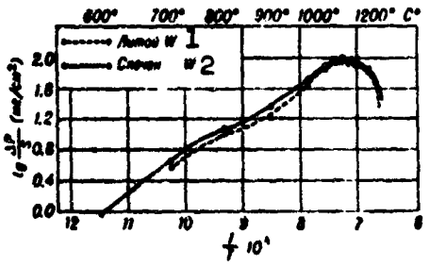



Fig. The logarithm of the increase in weight ($mg/cm^2$) of the specimen as a function of the temperature, oxidation time 1 hour. 1) Cast tungsten; 2) sintered tungsten.

For more high temperatures, silicide coating by diffusion is used, which resists heating to 1815° in oxidizing medium during 10 hrs.

The siliconizing is carried out in silicon powder with additions of NaF and $NH_4Fl$ at a temperature of 1050° and a holding time of 4-8 hrs. The protective properties of the silicide coating in oxidizing atmosphere at 1815° are explained by the formation of a thin, $SiO_2$ containing, glassy oxide film on the surface. Such a tight film is not formed at temperatures lower than 1400°, and the coating does not protect tungsten from oxidation.

For a short-time protection from oxidation of tungsten at temperatures of 2000-3000°, enamel-like ceramic coatings are in development, containing high-melting compounds (oxides, borides, carbides) as a basic filler, and a high-melting glass as a binder which thermal expansion coefficient is near to that of tungsten.

Ceramic coatings may be applied by immersion, laying on or spraying an emulsion with an atomizer and subsequent heating, and also by spraying the materials in form of powders or rods with an adequate composition by means of gas or plasma burners (see Protective Coatings of Molybdenum).

References: Arkharov V.I., and Kozmanov Yu.D., K voprosu o vysokotemperaturnom okislenii vol'frame [On the Problem of the High-Temperature Oxidation of Tungsten] "Fizika metallov i metalovedeniye," 1956, Vol. 2, No. 2, page 361; Planseeber. Pulvermetallurgie [Plansee Reports on Powder Metallurgy], 1961, Vol. 9, No. 1/2, pages 36-38.

Ye.N. Novikova

**PROTECTIVE (PRESERVATIVE) LUBRICANTS** – lubricants used to protect metals, mechanisms, and machinery against corrosion. The majority of protective lubricants are mineral oils thickened with paraffin and ceresin and can can be called vasolines. Certain special types of vasolines are produced under the names gun grease, composition No. 5/5, etc. Additive-containing liquid oils used to protect the internal cavities of internal-combustion engines are often included in this group of lubricants. There are also special soap-containing protective lubricants. Greases such as ammunition grease (GOST 2649-52) are used to protect leather products against deterioration. Technical vasoline (GOST 782-59), PVK (GOST 10586-63), and gun grease (GOST 3005-51) are general-purpose protective lubricants with virtually identical compositions and characteristics. They are generally used to coat all unpainted portions of machine tools, industrial equipment, instruments, tools, metal containers (tin cans), etc. when they are shipped from the factory. These lubricants have good protective properties as a result of their water resistance and chemical stability. Cases are known in which they have protected metal articles from corrosion for 10 or more years. Their use at low temperatures is hampered by their high viscosity. The melting point of hydrocarbon protective lubricants is 50-60°, which facilitates their application to the surfaces to be protected in molten form but makes it impossible to use them at high temperatures. AMS lubricant (produced in types AMS-1 and AMS-3, GOST 2712-52), which consists of viscous steam-engine cylinder oil thickened with aluminum soaps, provides good corrosion protection for metal pro-

ducts, even when they are exposed to salt water. These lubricants undergo severe thicknening at low temperatures, a phenomenon especially pronounced in AMS-3. Their melting point is 85-90°; they cannot be used in the molten state, since their properties are altered at temperatures above their melting point. Jet and piston engines are preserved with K-15 liquid lubricant (GOST 9185-59), a mixture of MS-20 and transformer oils with additions of approximately 1% of TsIATIM-339 additive, gum rubber, and the lithium soap of oxidized petrolatum. This lubricant can retain its protective properties for several years, depending on the type of engine and the storage conditions. It need not be removed from the engine before start-up.

The new lubricants K-17 and K-19 (TU76-60) differ in composition from K-15 in the fact that they contain additives - calcium sulphinate and diphenylamine; K-19 also contains a corrosion inhibitor, sodium nitrite. NG-203 (MRTU 12 N No. 78-64) and NG-204 (MRTU 12 N 69-63) lubricants are also produced commercially. All these lubricants are intended for preserving engines to be operated and stored at elevated humidities; they afford better corrosion resistance for ferrous-metal components than K-15.

In addition to the aforementioned lubricants, many plastic antifriction lubricants, such as lubricant greases, TsIATIM-203, etc., can be used for protecting machinery and mechanisms (see Plastic lubricants).

V.V. Sinitsyn

**PROTEIN FIBER** – artificial fiber from natural proteins (high-molecular compounds which are formed from α amino acids by biochemical synthesis). Fibers are produced from casein (milk protein) base proteins of animal origin under the name Wipolan (Poland), Aralac (USA), VH Fibrolane and VS Fibrolane (England), Merinova (Italy); and also from wastes of the meat and fishing industries and from natural proteins with zein (corn protein) as a base under the name Vicara (USA), from soya and peanut proteins under the name Ardil (England).

Protein fibers are primarily formed from alkaline solutions and are produced in the form of cord fibers and short-fiber staple ($N_m$ el. from 300 to 3000, length of sections from 27 to 150 mm). They are obtained as shiny, mat and colored fibers. Protein fibers are close to wool by their properties. They are characterized by high resistance to acids, peroxides, many organic solvents, micro-organisms and moths, by low electrifiableness, but also by low heat resistance (the fiber becomes brittle at a temperature above 100°) and low resistance to alkalis; the fibers are inflammable. The specific weight of protein fibers is lower than that of cellulose fibers and comprises 1.25-1.3. The moisture content under standard conditions for various kinds of fibers is within the limits of 10-15% (it is 14% for wool). The thermal conductivity coefficient of protein fibers is higher than that of wool, the wetting heat is 27.4 cal/g (it is 27 cal/g for wool). Protein fibers are sufficiently weather resistant (slow aging, accompanied by slow breakdown and fading), this is particularly true of VS Fibrolane. Protein fibers have a homogeneous structure throughout the thickness; to

strengthen the structure and reduce loss of strength in the wet state, the fiber is treated by formaldehyde and mineral salts (aluminum and chromium alums). Protein fibers do not dissolve in acetone, benzol, gasoline, glacial acetic acid, formic acid, phenol, dimethylformamide; they swell in water (34-35%) and in weak alkalis (40-42%); are dyeable by acidic, direct, basic and dispersion dyes, however, the dyes are not color-fast in washing. Faster dyes are obtained by using certain types of mordant dyes. Protein fibers have a low felting ability.

The initial modulus of protein fibers (at 1% elongation) is 2.2-3.6 kg/mm$^2$ (Vicara), while this modulus for wool is 2.2-2.8 kg/mm$^2$. The elasticity of protein fibers (reversible deformations) attendant to 2% elongation comprises 100% (it is 99.0% for wool and 74.0% for cotton). The fibers have a low wear resistance (when mixed with wool in 1:1 pro-

Physicomechanical Properties of Protein Fibers and Wool (for Comparison

| Свойства 1 | Волокно 2 | | | | | | |
|---|---|---|---|---|---|---|---|
| | казеиновое 3 | казеиновое мериноса 4 | винара 5 | ардила 6 | из белка сои 7 | из белка регенер. шерсти 8 | шерсть 9 |
| Разрывная длина (км) . 10 | 7.2–9.0 | 9.9 | 9.9–13 | 7.2 | 7.2 | 9.0 | 10.8–13.5 |
| Потери прочности в мокром состоянии (%) . . . . 11 | 62.5–60 | 45.5 | 43.5–51.5 | 39 | 69 | 70 | 35–30 |
| Временное сопротивление разрыву (кг/мм²) 12 | 9.3–11.6 | 12.77 | 12.4–16.3 | 9.36 | 9.45 | 11.7 | 15–18 |
| Удлинение (%) 13 | | | | | | | |
| в сухом состоянии . . 14 | 30–50 | 50 | 32–40 | 50 | 30–50 | 30 | 25–30 |
| в мокром состоянии 15 . . | 50–70 | 60 | 37–50 | 60 | 60–70 | 33 | 25–35 |

1) Properties; 2) fiber; 3) casein; 4) Merinova-casein; 5) Vicara; 6) Ardil; 7) from soya protein; 8) from regenerated wool protein; 9) wool; 10) rupture length (km); 11) wet strength loss (%); 12) ultimate tensile strength (kg/mm$^2$); 13) elongation (%); 14) in the dry state; 15) in the wet state.

portion the abrasion and wear resistance increase), are little susceptible to electrification. Protein fibers are used in the textile and knitwear industry primarily together with wool, cotton, synthetic viscose and acetate staple fibers (from 20 to 50%). In the pure form they are used as a substitute for wool stockinet. Protein fibers together with

viscose staple fiber improve the softness of fabrics and articles; mixed with cotton they improve the flexibility and elasticity of fabrics; mixed with synthetic fibers they increase the moisture absorbing capacity of products.

References: Rogovin, Z.A. Osnovy khimii i tekhnologii proizvodstva khimicheskikh volokon [Fundamentals of the Chemistry and Technology of Chemical Fibers Production]. 2nd edition, pages 561-72, Moscow, 1957; Monkriff, R.W. Chemical Fibers [translated from English], pages 237-68, Moscow, 1961.

V.M. Bukhman

PULSATING STRESS CYCLE – an alternating stress cycle varying from zero to a maximum ($\sigma_{min} = 0$) or from zero to a minimum ($2_{maks} = 0$); in both cases the mean stress and amplitude have the same value.

G.T. Ivanov

**PUMICE** – a porous variety of volcanic glass. Its structural and textural characteristics depend on the size and shape of the pores and the character of the partitions between them. Pumice may be fibrous, cellular, vesicular, fibrous-acicular, or foamy in texture and fine-pored, coarse-pored, etc., in structure. Pumice containing 68-74% $SiO_2$ is used commercially. Depending on its iron content and the valence of this element, pumice varies from white and blue to yellow, brown, and black in color. Its specific gravity is 1.9-2.3, its bulk weight is 0.3-0.9 $g/cm^3$, and its total porosity is 60-80%; the partitions between pores are thin (0.1-0.001 mm) plates of glass with sharp cutting edges. The Moos hardness of this rock is 5-6.5 and the crushing resistance of dry specimens is 7-285 $kg/cm^2$. Pumice is characterized by low thermal and acoustical conductivity and good gas permeability; it combines a high coefficient of moisture saturation with sufficiently good frost resistance. Pumice is a refractory material, has a softening range of 1300-1400°, and is chemically inert. High grades of this rock (in the 65-mm size group) are used principally as abrasives in the wood- and metal-working industries, in tanning, and for grinding and polishing marble, bone, and lithographic stones. Polishing blocks and papers are manufactured from pumice. Low grades of pumice (in the 5-65 mm groups) and pumice gravel (punicite) are employed in construction. In the chemical industry pumice is used in the manufacture of filters and drying equipment and as an inert base for various catalysts. It is employed for purifying oils in the petroleum and foodstuffs industries. Addition

of pumice to nitroglycerin explosives increases their detonation sensitivity. Low grades of pumice are employed as a raw material in glass manufacture. This material can be used to produce inexpensive glazes for conduit pipe and similar products.

References: Tatarinov, P.M., Malyavkin, S.F., and Geysler, A.N., Kurs nerudnykh mestorozhdeniy [Course in Non-Ore-Bearing Deposits], Pt. 2, Leningrad-Moscow, 1935; Yeremeyev, V.P. and Petrov, V.P., Nerudnyye iskopayemyye Kabardino-Balkarii [Non-Ore-Bearing Minerals of the Cabardine-Balkan Region], in collection: Kabardino-Balkarskaya ASSR [The Cabardine-Balkan ASSR], Nal'chik, 1957.

V.V. Nasedkin

PUNCH-CARD PAPER – a paper manufactured from 100% unbleached cellulose, which is left the natural fiber color or slightly stained in light hues. The weight of 1 $m^2$ of this paper, which is 175 μ thick, is 170 g; it is used in the manufacture of punch-cards for computers. Punch-card paper has a rather high mechanical strength, with a tearing length (average in two directions) of no less than 3, 600 m. Its surface is smooth and is not highly lustrous; the average smoothness for the face and screen sides, as determined in a B-1 apparatus, is no less than 45 sec; the degree of sizing is no less than 1.0 mm, as determined by the hatch method. Punch-card paper has a moisture content of 7 ± 1%. It is produced in rolls 683, 600, and 518 ± 2 mm wide. Sheets of punch-card paper are highly stable with respect to shape and integrity, so that they can be passed 50 times through a sorting machine without crumpling or tearing their edges.

Z. I. Gruzdeva

**PUNCHING TEST** – is a technological trial for the relative evaluation of the plasticity of sheet material destined for cold pressing. The mostly used punching is the Ericsson test consisting in the punching of a specimen (a card) of the sheet metal with a spherical punch through a die with a round hole until the first visually perceptible crack appears in the specimen. The depth of the impression of the punch when the crack is formed decreases with increasing thickness of the tested material and serves as an index of the plasticity. The tests are carried out on a press (Fig. 1) with a hand-driven worm gear and a micrometer dial for the measurement of the impression depth. The results of the tests of diverse materials are usually graphed as curves in "thickness v.s. impression depth" coordinates (Fig. 2).

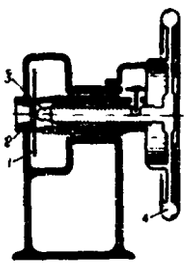


Fig. 1. Scheme of an Ericsson press: 1) Sheet specimen; 2) die; 3) punch; 4) hand wheel.

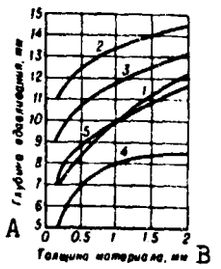



Fig. 2. Curves of the depth of impression on an Ericsson press: 1) Low-carbon steel; 2) brass; 3) copper; 4) zinc; 5) aluminum. A) Depth of impression, in mm; B) thickness of the material, in mm.

References: Shaposhnikov N.A., Mekhanicheskiye ispytaniya metallov [Mechanical Tests of Metals], 2nd edition, Moscow-Leningrad, 1954; Issledovaniya v oblasti obrabotki metallov davleniyem [Investigations on the Field of Metal Treatment by Pressing] [Collection of Papers], Moscow, 1960.

I.V. Kudryavtsev, D.M. Shur

PURE COPPER is grade M0 copper containing 99.95% Cu and no more than 0.05% impurities (GOST 859-41). Several grades of especially pure oxygen-free and vacuum copper used in the electroyacuum industry (see table) are produced in accordance with special TU. The series A and B oxygen-free coppers are used to produce ribbon, strip, rod and tubing; vacuum pure copper is used to produce rod and strip; pure copper which has been deoxidized using manganese is used to produce rod. All these mill products are used in the electrovacuum industry. Pure oxygen-free copper has a low recrystallization temperature (about 100°).

Chemical Composition of Various Grades of Pure Copper

| 1 Медь | 2 Cu (%, не менее) | 3 Примеси (%, не более) | | | | | | | | | | | | 4 сумма примесей |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mn | Bi | Sb | As | Fe | Ni | Pb | Sn | Zn | S | P | C | |
| 5 Медь бескислородн. серии А (ЦМТУ 3302-53, 3303-53, 3304-53) | 99,97 | – | 0,002 | 0,002 | 0,002 | 0,005 | 0,002 | 0,005 | 0,002 | 0,004 | 0,005 | 0,003 | – | 0,03 |
| 6 Медь бескислородн. серии Б (ЦМТУ 3302-53, 3303-53, 3304-53) | 99,95 | – | 0,002 | 0,002 | 0,002 | 0,005 | 0,002 | 0,005 | 0,002 | 0,003 | 0,005 | 0,003 | – | 0,05 |
| 7 Медь вакуумная (ЦМТУ 3205-52, 3206-52) | 99,9 | – | – | – | – | – | – | – | – | – | – | – | – | 0,01 |
| 8 Медь, раскисленная марганцем (ЦМТУ 3204-52) | 99,96 | 0,1–0,3 | 0,002 | 0,002 | 0,002 | 0,05 | 0,005 | 0,007 | 0,002 | 0,007 | 0,005 | 0,003 | 0,02 | 0,1 |

1) Copper; 2) Cu (%, no less than); 3) impurities (%, no more than); 4) total impurities; 5) oxygen-free copper, series A (TsMTU ); 6) oxygen-free copper series B (TsMTU ); 7) vacuum copper (TsMTU ); 8) copper deoxidized by manganese (TsMTU ).

O. Ye. Kestner

**PURE MAGNESIUM** is magnesium containing total impurities of less than 0.02%. Pure magnesium may be produced by refining raw magnesium (electrolytic or produced by a metallothermic method), by volatilization in a vacuum or in an inert gas atmosphere. Thanks to the high vapor pressure of magnesium, it volatilizes away from the impurities, which have lower volatility. We differentiate between volatilization by sublimation (vaporization from the solid state) and by distillation (vaporization from the molten metal). Volatilization by sublimation is preferable since in this case we obtain magnesium contaning less than 0.005% Al, 0.002% Mn, 0.004% Ca, 0.002% Fe, 0.004% si, 0.001% Cu, 0.004% Ph. The purity of the magnesium may be increased by repeated volatilization. To avoid contamination of the magnesium by chloride and other impurities, remelting of the sublimate is performed in argon at normal pressure. Pure magnesium has higher corrosion resistance in comparison with industrial magnesium of normal purity. Magnesium alloys of high corrosion resistance are produced on the basis of pure magnesium.

A.A. Lebedev

PYROGRAPHITE – graphite obtained by surface deposition of carbon by precipitation from a dissociated gas (usually methane). This material is generally manufactured with a definite crystallographic orientation; its superficial thermal conductivity is higher than that of copper or silver. According to foreign data, this material retains its characteristics after heating to 2500° and cooling, even when the coating is only several tenths of an mm thick. The electrical resistance in the layers parallel to the surface is substantially lower than in technical graphite, while that in the direction perpendicular to the surface is many times higher. The density of pyrographite is 2.22 $g/cm^3$, while that of technical graphite is 1.6-1.7 $g/cm^3$. This material has a high specific strength in the longitudinal direction, being 4-5 times stronger than technical graphite at temperatures above 2000°. Pyrographite is distinguished by a high erosion resistance at high gas-flow rates and temperatures. In order to increase its erosivity and oxidation resistance pyrographite is alloyed with boron, silicon, niobium, etc.

The higher hardness and finer structure of alloyed pyrographite insures an elevated oxidation resistance. According to foreign sources, its ultimate bending strength is approximately 38 $kg/mm^2$, as compared with 22.5 $kg/mm^2$ for unalloyed pyrographite and 2.4 $kg/mm^2$ for technical graphite. This material is not widely used commercially, but as a result of foreign tests it can be recommended as a promising material, e.g., for various rocket components.

D.K. Ablov

PYROELECTRICS – dielectric materials whose surface becomes electrified as a result of changes in temperature through additional polarization along the so-called electrical axis. This effect occurs in anisotropic crystals having no center of symmetry; its magnitude is characterized by the pyroelectric constant, $\gamma = \Delta e/\Delta t^{\circ}$, where $\Delta e$ is the quantity of electricity produced per unit surface area perpendicular to the electrical axis of the crystal when the temperature is raised by $\Delta t^{\circ}$. In the majority of pyroelectrics $\gamma$ is of the order of 1 (in the CGSE system). These materials include tourmaline, quartz, topaz, tartaric and zirconic acids, and certain of their salts. An inverse electrocaloric effect is observed when pyroelectrics are electrified; in tourmaline, for example, this effect is of the order of $10^{-5}$°C per CGSE unit. Pyroelectrics can be employed for studying thermal effects by electrostatic methods, since such processes in these materials are not accompanied by passage of an electric current.

References: Khvol'son, O.D., Kurs fiziki [Course in Physics], 3rd Edition, Vol. 4, Berlin, 1923, page 215, Zhdanov, G.S., Fizika tverdogo tela [Physics of Solids], Moscow, 1962, page 247.

M.M. Gorshkov

PYROLUSITE – manganese dioxide with the composition 63.2% Mn and 36.8% O and containing impurities of $Fe_2O_3$, $SiO_2$, $H_2O$, etc. It exhibits tetragonal syngony and is opaque and black or steel-gray in color. Its luster is semimetallic. This material has a reflectivity of 27.5% for red, 32.5% for orange, and 34% for green. The Moos hardness of crystal-

| Свойства пиролюзита 1 | 2 Температура (°С) | | | | |
|---|---|---|---|---|---|
| | 0 | 45 | 60 | 80 | 90 |
| Диэлектрич. постоянная . . . . 3 | $4 \cdot 10^3$ | $17 \cdot 10^3$ | $15 \cdot 10^3$ | — | $3 \cdot 10^3$ |
| Тангенс угла диэлектрич. потерь 4 | $8 \cdot 10^{13}$ | $32 \cdot 10^{13}$ | — | $10 \cdot 10^{13}$ | $14,5 \cdot 10^{13}$ |

1) Characteristics of pyrolusite; 2) temperature (°C); 3) dielectric constant; 4) tangent of angle of dielectric loss.

line pyrolusite is 5-6, while that of porous pyrolusite is 2. This mineral is brittle and exhibits complete cleavage along the {110} plane. Its specific gravity is 4.7-5. Pyrolusite exhibits semiconductive and piezoelectric characteristics. It is ferroelectric at temperatures below 50°. Its electrical conductivity (for alternating and direct current) ranges from $10^{-1}$ to $10^{-3}$ $ohm^{-1} \cdot cm^{-1}$. Pyrolusite has a specific resistance of 6-100 ohm·cm (1.34-4.84 ohm·cm at a voltage of 0.1-15 v) and a magnetic permeability of $14.6 \cdot 10^6$ at 14°. At temperatures of 550-650° it dissociates to form β-braunite; at 940-1100° β-braunite becomes hausmannite. Pyrolusite dissolves in hydrochloric acid, literating chlorine. It is used in the production of dry-electrolyte batteries and activated products used for the same purpose. The high oxidizing capacity of pyrolusite is employed in leaching Weltz oxides and in the production of catalysts of the hopcalite type to be used in special gas-

masks for protection against CO. Potassium permanganate and other manganese salts are manufactured from this mineral. Pyrolusite is employed in the glass industry for decolorizing green glasses, in the paint industry for producing vehicles and oils and as a pigment, and in the tanning industry for dressing crowned hides.

References: Betekhtin, A.G., Kurs mineralogii [Course in Mineralogy], 3rd Edition, Moscow, 1961; Gryaznov, V.I., DAN SSSR [Proceedings of the Academy of Sciences USSR], 1958, Vol. 121, No. 1; Bhide, V.G., Damle, R.V., Physica, 1960, Vol. 26, No. 1.

V.V. Nasedkin

PYROPHYLLITE – a mineral of the silicate class with the formula $Al_2[Si_4O_{10}]\cdot[OH]_2$ or $Al_2O_3\cdot 4SiO_2\cdot H_2O$. Its principal impurities are $Fe_2O_3$, MgO, CaO, and FeO and it exhibits monoclinic syngony.

Crystals of this mineral are lamellar or laminar-radial. It exhibits complete cleavage along the {001} plane; it fractures unevenly and is white in color with a yellowish or greenish tint. Its luster is mother-of-pearl. Pyrophyllite is optically negative ($N_g$ = 1.600, $N_m$ = = 1.588, and $N_p$ = 1.552), greasy to the touch, and hydrophobic. Its specific gravity is 2.66-2.9 and its Moos hardness is 1-2. It is a poor thermal and electrical conductor. This mineral does not react with HCl or $HNO_3$, but decomposes when subjected to intensive heating in $H_2SO_4$. It is very similar to talc in its crystal structure, appearance, and physical and technical characteristics, but contains aluminum as well as magnesium. Pyrophyllite occurs relatively widely in nature, but large monomineral deposits are rare. Rocks containing no less than 50-75% phyophyllite are of practical interest.

Pyrophyllite is used: 1) in technical, structural, and household ceramics, in the form of integrally lathed products (gas burners, laboratory crucibles and boats) and as a ceramic component (in the production of insulators, wall panels, dishware, etc.); 2) as a refractory material (in the form of lumps for fire brick) for heat insulation; 3) in enamels; 4) as a filler for paper, rubber, dyes, and dusts; 5) in the applied arts and decorative sculpture.

References: Betekhtin, A.G., Kurs mineralogii [Course in Mineralogy], 3rd Edition, Moscow, 1961; Trebovaniya promyshlennosti k kach-

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estvu mineral'nogo syr'ya [Industrial Specifications for Mineral Raw Materials], No. 1 – Chernosvitov, Yu.L., Tal'k i pirofillit [Talc and Pyrophyllite], Moscow, 1961.

Yu.L. Chernosvitov

QUARTZ – is one of the modifications of $SiO_2$ with crystalline structure which is widespread in nature. Fused quartz, quartz glass, is obtained by rapid quenching of a quartz smelt. The α-quartz is stable at temperatures below 573°, the hexagonal modification of $SiO_2$ is stable (high-temperature quartz or β-quartz). β-quartz occurs relatively rarely and does not form large deposits. The colorless, transparent variation of the α-quartz is termed rock crystal, the violet variation is the amethyst, the smoky-gray – the smoky topaz, the black – the morion, and the lemon-yellow – the citrine. Rocks, containing not more than 0.001-15% impurities, on the premises that enrichment is possible, serve as a raw material for the industrial mining of quartz. Such minerals are quartz sand, quartz sandstone; quartzite, and vein quartz. Quartz has a glassy glance. The (Mohs) hardness is 7. The specific gravity is 2.5-2.8. Quartz is optically monoaxial and positive, $N_g$ = 1.553, $N_p$ = 1.544, it proves a piezoelectrical and pyroelectrical effect and is transparent for ultraviolet rays.

The heat conductivity (cal/sec·cm·degree) in the direction parallel to the c axis is 22.5 at 100°, 15.8 at 200°, and 10.8 at 400°; the values for the direction perpendicular to this axis are 13.9, 10.1, and 7.8, respectively.

The dielectric constant at a wavelength of $10^{-3}$ is 4.27 perpendicular to the c axis, and 4.34 parallel to the c axis. The specific resistance of the venin quartz is $10^6$-$10^7$ ohm·cm. Quartz is a chemically stable material. It is almost insoluble in water and acids: HCl, $HNO_3$, or $H_2SO_4$ at 25°; it is somewhat less resistant to alkalis, especially

when heated.

Quartz is most widely used in the glass industry. The low coefficient of thermal expansion, the transparency and the acidproofness of the quartz have the greatest importance for the glass industry. Quartz is one of the main components of the glass batch when special glass grades or melted quartz (PK) are produced. Quartz is widely used in the production of acids. It is applied in the form of great lumps for packings in columns and towers, and in ground state for the production of acidproof linings. The high hardness of the quartz makes it possible to use it in the production of abrasives and in metal working in the form of grindstones, polishing discs, and in sandblasting. Its refractoriness and its ability to form chemical compounds with basic elements is utilized in metallurgy. Quartz additions increase the strength and heatproofness of porcelain in the ceramics industry. The transparent quartz varieties are widely used in electric and radio engineering. PK has a Mohs hardness of 4.9-7.0. Its density ($g/cm^3$) is 2.202 at -200°, 2.203 at 0°, 2.202 at +200°, and 1.198 at 1000°. The index of refraction is N = 1.46. The crushing strength is $19.5 \cdot 10^9$ dyne/$cm^2$, the tensile strength $3\text{-}8 \cdot 10^9$ dyne/$cm^2$. The modulus of compression is $317\text{-}425 \cdot 10^9$ dyne/$cm^2$, the modulus of the linear elasticity is 600-699 dyne/$cm^2$, the modulus of torsion is 238-308 dyne/$cm^2$. The compressibility of the β-quartz is $3.2\ 10^{-6}$ at 1960 Mbar and $3.16 \cdot 10^{-6}$ at 7840 Mbar. The resistance to compression at an omnidirectional pressure of 25,000 kg/$cm^2$ is equal to 39,600 kg/$cm^2$. The melting point is 1713°, the evaporation temperature is 2100°. The viscosity changes from $10^{13}$ to $10^6$ poises within the temperature interval from 1100 to 1900°.

The transmissivity is 77% for the light with a wavelength (in millimicrons) of 218, 81% for 240; and 90% for 312. The dielectric constant is 3.58-3.80. The breakdown voltage (kv/cm) is 150-400 at room tempera-

ture and 40-50 at 500°. The specific resistance (ohm·cm) is $1 \cdot 10^{18}$ at 0°; $0.3 \cdot 10^{9}$ at 500°, and $0.5 \cdot 10^{6}$ at 1200°. The specific conductivity in

TABLE

The Thermal Properties of Fused Quartz

| 1 Показатели | 2 Температура (°C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | −250 | −100 | 0 | 100 | 250 | 500 | 1000 | 1700 |
| 3 Средний коэфф. линейного расширения, $\alpha \cdot 10^{8}$ | 35.5 | 14.4 | 38.2 | 50.6 | 54.3 | 56.7 | 52 | – |
| 4 Теплоемкость, $c_p \cdot 10^{3}$ (дж/г) | 7.7 | – | 165.7 | – | 23.6 | – | 292 | 352 |
| 5 Теплопроводность (кал/см²·сек·°C·10⁻³) | 1.3 | 2.5 | 3.0 | 3.38 | 3.64 | – | – | – |

1) Characteristics; 2) temperature (°C); 3) mean coefficient of linear expansion, $\alpha \cdot 10^{8}$; 4) heat capacity, $c_p$ $10^{3}$ (joules/g); 5) heat conductivity (cal/cm$^2$·sec·°C·$10^{-3}$).

the temperature range 1000-1400° in vacuum is $10^{-4}$ ohm $^{-1} \cdot$ cm$^{-1}$. PK maintains the vacuum at a pressure of $10^{-5} \cdot 10^{-6}$ mm mercury column. It is characterized by chemical stability and does dissolve only in HF.

The highest grades of quartz glass are used for the production of optical lenses, of many kinds of lamps and radiation tubes, including quartz lamps for ultraviolet radiation. The high electric strength, the insignificant dielectric losses, the excellent mechanical properties and the absence of reaction to arc discharges has permitted the use of PK for the production of high-frequency and high-voltage insulators, of variable capacitors, insulators for electric filters, and sparkplugs. PK is used in the production of concentrated acids and other chemical materials, including chlorine, in chlorination and bromination of organic substances, etc., owing to its acidproofness and the inertness to thermal shocks. Crucibles, protecting tubes for thermocouples, and vacuum pumps made from PK are used in laboratory practice. Wool and fibers with a diameter $\leq 7$ microns are manufactured from fused quartz. Low grade PK is used for the lining of tank furnaces.

References: Berch F., Sherer D., Spicer G., Spravochnik dlya geo-

logov po fizicheskim konstantam [Handbook on Physical Constants for Geologists], translated from English, Moscow, 1949; Pryanishnikov V.P., Kvartsevoye steklo [Quartz Glass], Moscow, 1956; Shubnikov A.V., Kvarts i yego primeneniye [Quartz and Its Application], Moscow-Leningrad, 1940; Shlain I.B., Mineral'noye syr'ye dlya steklovareniya [Mineral Raw Materials for Glass Manufacture].

V.V. Nasedkin

QUARTZ GLASS – silicon dioxide ($SiO_2$); it is obtained in the vitreous state by fusion of extremely pure natural varieties of crystalline quartz (rock crystal, vein quartz, or pure quartz sand) at temperatures above 1700°. We can distinguish two types of commercial quartz glass, nontransparent and transparent. Nontransparent quartz glass is more commonly used and is cheaper; it is fused from pure quartz sand. It is made nontransparent by a large number of small gas bubbles (ranging from 0.003 to 0.3 mm in diameter), which are distributed throughout the glass and disperse light. Optically transparent quartz glass, which is obtained by fusion of rock crystal, is completely uniform, contains no visible bubbles or waviness, and has the lowest index of refraction of any silicate glass ($n_D$ = 1.4584). Tables 1-5 show the most important characteristics of quartz glass.

TABLE 1

Physical and Mechanical Characteristics of Quartz Glass

| Свойства 1 | Вид стекла 2 | |
|---|---|---|
| | непрозрачное 3 | прозрачное 4 |
| Удельный вес 5 | 2,02—2,15 | 2,20 |
| Общая пористость (%) 6 | 3,0—7,5 | ~0 |
| Модуль упругости 7 (кг/мм²) | ~6000 | 6500—7000 |
| 8 Коэффициент Пуассона | — | 0,26 |
| 9 Предел прочности (кг/см²) (при 20°): | | |
| при сжатии 10 | 3500 | 6500 |
| 11 при изгибе | 450 | 1100 |
| при растяжении 12 | 400 | 600 |
| 13 Ударная вязкость (кг·см/см²) | 0,85 | 1,1 |
| 14 Микротвердость (кг/мм²) | — | 1200 |

1) Characteristic; 2) type of glass; 3) nontransparent; 4) transparent; 5) specific gravity; 6) total porosity (%); 7) modulus of elasticity ($kg/mm^2$); 8) Poisson's ratio; 9) ultimate strength ($kg/cm^2$) (at 20°); 10) on compression; 11) on bending: 12) on extension; 13) impact strength ($kg \cdot cm/cm^2$); 14) microhardness ($kg/mm^2$).

TABLE 2

Thermal Characteristics of Quartz Glass

| Температура (°C) 1 | Средняя теплоемкость стекла (кал/кг·°C) 2 | | Коэфф. теплопроводности стекла (ккал/м·час·°C) 5 | | Средний коэфф. линейного расширения α·10⁷ (1/°C) 6 |
|---|---|---|---|---|---|
| | прозрачного 3 | непрозрачного 4 | прозрачного | непрозрачного 4 | |
| 20 | 0.213 | 0.205 | 1.19 | 1.07 | - |
| 50 | — | — | — | — | 4.48 |
| 100 | — | — | 1.32 | 1.24 | 5.06 |
| 200 | 0.213 | 0.205 | 1.42 | 1.39 | 5.33 |
| 300 | 0.220 | 0.218 | — | — | 5.57 |
| 400 | 0.230 | 0.228 | 1.61 | 1.63 | 5.67 |
| 500 | 0.224 | 0.237 | — | — | 5.67 |
| 600 | 0.240 | 0.242 | 1.74 | 1.81 | 5.60 |
| 700 | 0.250 | 0.247 | — | — | - |
| 800 | 0.260 | — | 1.85 | 1.92 | 5.40 |
| 1000 | 0.273 | — | 1.97 | 1.98 | 5.20 |
| 1200 | — | — | 2.09 | 2.05 | — |

1) Temperature (°C); 2) average heat capacity (kcal/kg·°C); 3) transparent; 4) nontransparent; 5) coefficient of thermal conductivity (kcal/m·hr·°C); 6) average coefficient of linear expansion $\alpha \cdot 10^7$ (1/°C).

The mechanical strength of quartz glass rises steadily on heating and exceeds its strength at room temperature by 50-60% at 1200°. Gases diffuse through this glass only at high temperatures: hydrogen chloride at 1400° or more and methane, oxygen, and carbon dioxide at 1300°. The gases with the lowest atomic weights (helium, hydrogen) readily diffuse at 500°. For transparent quartz glass at 700° the diffusion coefficient for helium is $2.1 \cdot 10^{-8}$, that for hydrogen and deuterium is (2.1 and 1.7)$\cdot 10^{-9}$, that for neon is $4.2 \cdot 10^{-10}$, and that for argon, oxygen, and nitrogen is less than $10^{-15}$. Quartz glass occupies a special place among the inorganic glasses with respect to thermal characteristics; it has an extremely high thermal conductivity and a very low coefficient of thermal expansion, so that it is distinguished by an exceptionally high heat resistance.

Thin-walled articles of transparent quartz glass (dishes, crucibles, and flasks) heated to 1000° can withstand severe cooling in water without any damage whatsoever; when heated to 1300° they can withstand rapid cooling in air. Large articles of nontransparent quartz glass

heated to 1000° can withstand cooling in air at any rate; they also permit rapid, nonuniform heating. The state and characteristics of quartz glass are materially altered only at comparatively high temperatures (above 1100°). At 1200° this glass begins to soften, gradually losing its elasticity and becoming plastic; its viscosity decreases, but remains many times higher than that of ordinary commercial glasses at equivalent temperatures. (The viscosity of quartz glass is approximately $10^{12}$ poises at 1200° and $10^{11}$ poises at 1300°). Noticeable crystallization begins at 1200° for nontransparent quartz glass and at 1300° for transparent quartz glass; the maximum crystallization rate occurs at 1520° and 1630° respectively. If the crystallized glass is cooled to 180-230° there is a considerable reduction in its volume and it breaks. Quartz-glass vessels can be used for prolonged heating of various substances at temperatures of up to 1100° and for brief heating at temperatures of up to 1300-1400°. Crystallized quartz glass is stable at temperatures of up to 1700°. This glass is extremely inert with respect to the majority of chemical reagents and is an excellent acid-resistant material, especially under the action of concentrated organic and mineral acids at high temperatures. Hydrofluoric and phosphoric acids constitute the only exception; the former causes marked erosion at normal temperatures, while the latter attacks quartz glass at temperatures above 300°. Among the mineral acids, hydrochloric acid has a comparatively strong erosive action, particularly on nontransparent quartz glass. The inside of chemical apparatus of nontransparent glass is often protected with a fused-on layer of transparent glass. Use of quartz glass in strongly alkaline media is not recommended. This glass exhibits virtually no reaction with the metal oxides CaO, MgO, ZnO, $Fe_2O_3$, and $Al_2O_3$ at temperatures below 800°. Molten tin, zinc, and lead do not react at all with quartz glass, but copper, aluminum, and

silver intensively decompose it.

TABLE 3

Chemical Stability of Quartz Glass

| Реагенты 1 | Условия обработки стекла 2 | | Потери в весе (г/м²) поверхности стекла 5 | |
|---|---|---|---|---|
| | продолжительность (час.) 3 | температура (°С) 4 | прозрачного 6 | непрозрачного 7 |
| 8 Серная кислота (уд. в. 1,84) | 24 | 205 | 0,06 | 0,13 |
| 9 Азотная кислота (уд. в. 1,40) | 24 | 115 | 0,11 | 0,15 |
| 10 Соляная кислота (уд. в. 1,19) | 24 | 86 | 0,14 | 0,33 |
| 11 Уксусная кислота (70%-ная) | 24 | 108 | 0,01 | 0,03 |
| 12 Натр едкий (1%-ный) | 2 | 101 | 1,66 | 15,20 |
| 13 Кали едкое (1%-ное) | 2 | 98 | 0,68 | 4,63 |
| 14 Аммиак водный (25%-ный) | 2 | 65 | 0,09 | 0,33 |
| 15 Хлористый натрий (10%-ный) | 2 | 102 | 0,14 | 0,34 |
| 16 Натрий углекислый (10%-ный) | 2 | 102 | 1,20 | 4,99 |
| 17 Медь сернокислая (10%-ная) | 24 | 102 | 0,29 | 0,70 |

1) Reagent; 2) exposure conditions; 3) time (hr); 4) temperature (°C); 5) loss in weight ($g/m^2$) of surface; 6) transparent; 7) nontransparent; 8) sulfuric acid (specific gravity – 1.84); 9) nitric acid (specific gravity – 1.40); 10) hydrochloric acid (specific gravity – 1.19); 11) acetic acid (70%); 12) sodium hydroxide (1%); 13) potassium hydroxide (1%); 14) aqueous ammonia (25%); 15) sodium chloride (10%); 16) sodium carbonate (10%); 17) copper sulfate (10%).

TABLE 4

Electrical Characteristics of Quartz Glass

| Температура (°С) 1 | Пробивная напряженность стекла (кв/мм) 2 | | Объемное удельное сопротивление стекла (ом·см) 5 | | Тангенс угла диэлектрич. потерь стекла при частоте 50 гц 6 | |
|---|---|---|---|---|---|---|
| | прозрачного 3 | непрозрачного 4 | прозрачного | непрозрачного | прозрачного | непрозрачного |
| 20 | 43,0 | 32,0 | — | — | — | — |
| 100 | 37,0 | 26,5 | — | — | — | — |
| 150 | — | — | $>10^{16}$ | $2\cdot10^{14}$ | 0 | 0,0030 |
| 175 | — | — | $>10^{15}$ | $3\cdot10^{14}$ | 0 | 0,0060 |
| 200 | 32,0 | 21,0 | $3\cdot10^{15}$ | $3\cdot10^{13}$ | 0,0015 | 0,0120 |
| 225 | — | — | $8\cdot10^{14}$ | $8\cdot10^{12}$ | 0,0030 | 0,0250 |
| 250 | — | — | $9\cdot10^{13}$ | $2\cdot10^{12}$ | 0,0060 | 0,0500 |
| 275 | — | — | $1,3\cdot10^{13}$ | $5\cdot10^{11}$ | 0,0100 | 0,1000 |
| 300 | 28,0 | 16,0 | $7,4\cdot10^{12}$ | $2\cdot10^{11}$ | 0,0220 | 0,2200 |
| 325 | — | — | $1,2\cdot10^{12}$ | $6\cdot10^{10}$ | 0,0450 | 0,4500 |
| 400 | 17,0 | 12,0 | — | — | — | — |
| 500 | 10,0 | 7,0 | — | — | — | — |
| 600 | 5,2 | 3,2 | — | — | — | — |

1) Temperature (°C); 2) breakdown voltage (kv/mm); 3) transparent; 4) nontransparent; 5) deep resistance (ohm·cm); 6) tangent of angle of dielectric loss at 50 cps.

TABLE 5

Transparency of Quartz Glass to Ultraviolet Rays (for sheet 13 mm thick)

| Длина волны (мμ) 1 | Светопропускание (%) 2 | Длина волны (мμ) | Светопропускание (%) | Длина волны (мμ) | Светопропускание (%) |
|---|---|---|---|---|---|
| 217 | 6.0 | 226 | 41.9 | 260 | 82.0 |
| 220 | 10.1 | 248 | 50.9 | 268 | 90.0 |
| 226 | 28.0 | 252 | 62.0 | 290 | 92.0 |
| 230 | 38.0 | 256 | 73.0 | 400 | 92.4 |

1) Wavelength (mμ); 2) transmissivity (%).

Quartz glass is a good dielectric, being distinguished by negligible electrical conductivity, a very high breakdown voltage (dielectric strength), and virtually no dielectric losses.

The deep resistance of transparent quartz glass at room temperature is $10^{-18}$ $ohm^{-1} \cdot cm^{-1}$, while that of nontransparent glass is $10^{-16}$ $ohm^{-1} \cdot cm^{-1}$.

The tangent of the angle of dielectric loss of transparent quartz glass is almost zero at a field frequency of $10^6$ cps and 0.0006 at a frequency of $2 \cdot 10^6$ cps; that of nontransparent quartz glass is 0.0003 and 0.0025 respectively.

The dielectric permeability of quartz glass is 3.7 at low frequencies (50 cps) and 4.3 at a field frequency of $2 \cdot 10^6$ cps; in contrast to ordinary commercial silicate glasses, this factor is independent of temperature. Optically transparent quartz glass has a very high transmissivity (in contrast to silicate glass), especially with respect to ultraviolet light. In the infrared portion of the spectrum quartz glass passes approximately 90% of all radiation with a wavelength of 4 μ or less; it is of low transparency (40-25%) with respect to waves 6 μ or more long, only very thin sheets being transparent.

The mean white-light absorption factor of this glass does not ex-

ceed 0.002. Its mean dispersion ($n_F$-$n_C$) amounts to 0.006756, while its dispersion coefficient (Abbe number) is 67.8. The applications and purposes of quartz glass are very diverse. In chemical machine building it is employed in the manufacture of chemically stable apparatus, tubing, condenser coils, concentrating-tower components, dishes, baths, cells, reaction vessels, retorts, pumps, valves, etc. Chemical laboratory vessels and apparatus and instruments for chemical research (crucibles, dishes, flasks, dilatometers, distillation apparatus, Dewar flasks, ignition tubes, thermometers, inspection glasses, etc.) are also produced from quartz glass. This material is used in the manufacture of thermocouple jackets, tubes for ignition furnaces, flue muffles for gas and electric furnaces, crucibles and housings for high-frequency induction furnaces, quartz burners, electric heaters, dishes, crucibles, and retorts for sublimating low-melting metals, refining tubes for aluminum production, blocks for lining glass furnaces, and crucibles (with capacities of up to 400 liters) for compounding glass. In the electronics, radio, and vacuum-tube industries quartz glass is employed in the production of tubular, supporting, through, and other insulators for electric gas-purification installations and high-voltage transmission lines, cathode insulators for mercury rectifiers, various components of ac capacitors, self-induction coils, cathode and generator lamps, lamps, instruments, and apparatus relating to ultraviolet radiation (mercury lamps, spectral-analysis tubes, submersible dischargers, Geissler tubes, etc.), and various types of vacuum equipment which must operate reliably at high temperatures under a residual pressure of $10^{-5}$-$10^{-6}$ mm Hg.

Quartz glass is used to produce fine thread, the horizontal and vertical bearings required by precision instruments, various standards, mirrors for projectors and astronomical instruments, and illuminators for deep-water and high-altitude equipment.

S.I. Sil'vestrovich

QUARTZITE – see Natural Acidproof Materials.

RADIOACTIVE ISOTOPES – unstable, spontaneously decaying isotopes of the chemical elements. During radioactive decay the atoms of radioactive isotopes are converted to atoms of one (single decay) or more (multiple decay) other chemical elements. The following types of radioactive decay are known: α- and β-decay, K-capture, and nuclear fission. Isotopes exhibiting the first three types of decay (principally β-decay) are used in nonnuclear technology. Approximately 50 natural radioactive isotopes exist, while about 1000 artificial radioisotopes have been produced through nuclear reactions. Only certain of the artificial isotopes are used technologically – those which are the least expensive and have sufficiently long half-lives and easily recorded radiation. The principal quantitative index of a radioactive isotope is its activity, which is defined as the number of radioactive decays occuring in a given amount of isotope per unit time. The basic unit of radioactivity, the curie, corresponds to $3.7 \cdot 10^{10}$ decays per sec. The cheif qualitative indices of a radioisotope are its half-life (the time required for its activity to be halved) and the type and energy ("hardness") of its radiation. Radioisotopes are widely used as radioactive tracers and radiation sources in science and technology. Their most important applications are in radiation chemistry and in studying the processes which take place in blast and open-hearth furnaces, the crystallization of ingots, the wearing of machine components and cutting tools, and diffusion and self-diffusion in metals and alloys. In mensuration technology radioisotopes are employed for contactless measurement of parameters such as density, the chemical compositions

of various materials, gas-flow rates, etc. In Gamma-defectoscopy radioisotopes emitting γ-radiation are used to fluoroscope products and materials in order to detect internal defects (see Tagged-atom method).

L.K. Tatochenko

RADIOTRANSPARENT MATERIAL – dielectric or semiconductor materials with a high permeability to guided beams of radiowaves. Radiotransparency depends not only on the properties of the material, but also on the beam-incidence angle, the shape of the component, and the ratio of component thickness to wavelength. It is determined to a substantial extent by the loss factor, $K_\delta = \varepsilon tg\delta$, where $\varepsilon$ is the dielectric permeability and $tg\delta$ the angle of dielectric loss (see Dielectric losses). The $K_\delta$ of radiotransparent materials should be as low as possible, no more than 0.1, and they should exhibit minimum reflection and scattering of electromagnetic waves, i.e., $\varepsilon/\varepsilon_0 \approx 1$, where $\varepsilon_0$ is the dielectric permeability of the space surrounding the material. Their reflection should be low even when they form thick barriers. For example, if a material has an $\varepsilon = 1.7\ \varepsilon_0$ the maximum reflectivity for a perpendicular beam amounts to only 6.7% of the total incident power; reflectivity is greater for an obliquely incident beam.

The radiotransparent materials used in the deflectors of aircraft and rocket antennas must satisfy a complex set of radio-engineering, mechanical, and aerodynamic requirements. Their radio-engineering properties should ensure a maximum coefficient of energy transfer. The loss of amplitude should be of the order of 5% or less of the gradient in degrees and should be accompanied by minimal distortion of the directivity graph (a minimum error gradient). Under operational conditions their radio-engineering, mechanical, and aerodynamic characteristics should be maintained for long periods at temperatures of the order of 200-450° and briefly at temperatures of up to 1000° when the

deflectors are of substantial size (≈200-3000 mm in diameter). An important requirement for radiotransparent materials is stability of $\varepsilon$ over the entire working-temperature range (a $\Delta\varepsilon \leq 5\%$ is usually permissible). It is also desirable that tg$\delta$ vary little with temperature (a $\Delta$tg$\delta$ = 100% is usually permissible).

Radiotransparent materials are produced in single layers with a thickness $\delta \leq 0.01\text{-}0.04\lambda_0$ or (more frequently) in half-wave layers with a thickness equal to a whole number of half-waves, as well as in multilayers. The most common of the latter are three-layer materials consisting of outer load-bearing layers and an internal filler, which is usually discontinuous. Asbestos- and glass-based plastics with polyester, phenolic, and silico-organic binders, which provide the requisite mechanical strength and thermal stability, are widely employed for single-layer materials and the outer portions of multilayer materials. Many foam and cellular materials with poor sizes of substantially less than one wave length are excellent radiotransparent materials; these include Polystyrene plastic foam, Polyurethane foam, Silico-organic plastic foam, Glass foam, Ceramic foam, and stekloplast cellular filler. As a result of their considerable gas content these materials have very low dielectric losses (tg$\delta \approx 10^{-4}\text{-}10^{-3}$, $\varepsilon \approx 1.05\text{-}2.0$) and are widely used as deflectors for aircraft and rocket antennas, for hermetic sealing of waveguide systems at horn-type antennas, etc. The polystyrene foam PS-1 is used for work over the temperature range ±60°, while the polyurethane foam TU-101A is used at up to 170° and the phenol-formaldehyde foams FK-20-A-20 and FK-40 are used at up to 200-350° (for the physical and mechanical characteristics of these materials see the appropriate articles). Deflectors which must function over a range of 500° or more are made of ceramic foam, which has the following dielectric characteristics over the range 20-500° at $\gamma$ = 0.6 g/cm$^3$

and a frequency of $10^{10}$ cps: tgδ = 0.0015, ε ≈ 1.8, and $\sigma_{1z}$ = 50-40 kg/cm$^2$.

The nose-cone effectors of modern rockets should have good resistance to high temperatures, thermal shock, vibration, and erosion. Foam materials are not always sufficiently strong under such complex operational conditions. According to foreign data, pyroceram (a molded alkali-free vitreous material, which is converted by annealing to a high-strength crystalline material with low dielectric losses) exhibits a combination of good radiotransparency and sufficiently high mechanical strength. At $10^{10}$ cps and 25, 30, and 500° tgδ = 0.0003, 0.0008, and 0.0015 respectively, while ε ≈ 5.5. The specific gravity of pyroceram is approximately 2.6, while the strength of certain brands is equivalent to that of structural steel. This material can briefly withstand temperatures of the order of 1200°.

Ferrites are a special type of radiotransparent material; they are gyrotropic, rotating the plane of radio-wave polarization when magnetized, and exhibit selective absorption under certain resonance conditions. They are used for switching, decouplers in feeder circuits, etc.

Sh.Ya. Korovskiy

RAIL STEEL – open-hearth or Bessemer carbon steel used in the manufacture of railroad, trolley, and crane rails and for arrow points. The table shows the chemical composition and mechanical characteristics of these steels.

The same steel is used for arrow points (GOST 6421-52) as for broad-gauge rails. The normal length of broad-gauge railroad rails is 25 or 12.5 m, while that of narrow-gauge rails is 10 m.

Various defects, primarily accumulations of nonmetallic inclusions and contaminants, lead to formation of chinks and scale during operation, these causing splitting and transverse cracking of the head of the rail.

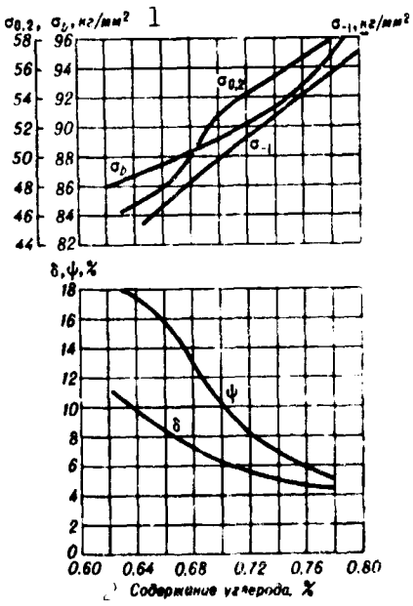



Fig. 1. Mechanical characteristics of rail steel as a function of carbon content. 1) kg/mm$^2$; 2) carbon content, %.

Formation of Floccules in open-hearth metal is not permissible. The

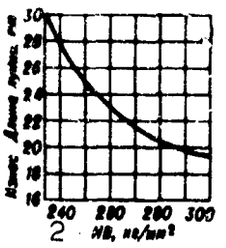



Fig. 2. Wearing of rail steel as a function of hardness. 1) Wear, length of hole, mm; 2) HB, kg/mm$^2$.

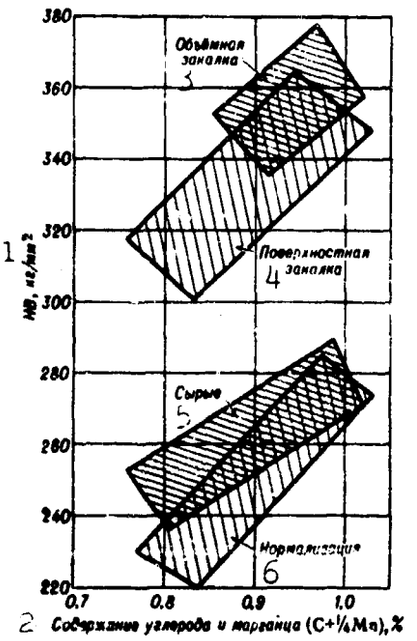



Fig. 3. Hardness of heat-treated rail steel as a function of C and Mn contents. 1) HB, kg/mm$^2$; 2) carbon and manganese content (C + 1/4 Mn), %; 3) through quenching; 4) surface quenching; 5) raw; 6) normalization.

principal requirements imposed on rail steel are high strength and durability and absence of local stress concentrators of metallurgical origin. The rail surface should be smooth and clean, without flaws, scabs, or cracks; isolated hairline cracks and burrs are permissible if they are no more than 1 mm deep (0.3-0.5 mm deep in the middle third of the rail). As the carbon content is raised $\sigma_{0.2}$, $\sigma_b$, and $\sigma_{-1}$ increase, while plasticity decreases (Fig. 1). Higher alloying of rail steel with carbon and manganese causes an increase in hardness and thus in wear resistance (Fig. 2). The ends of the rail head are surface quenched for

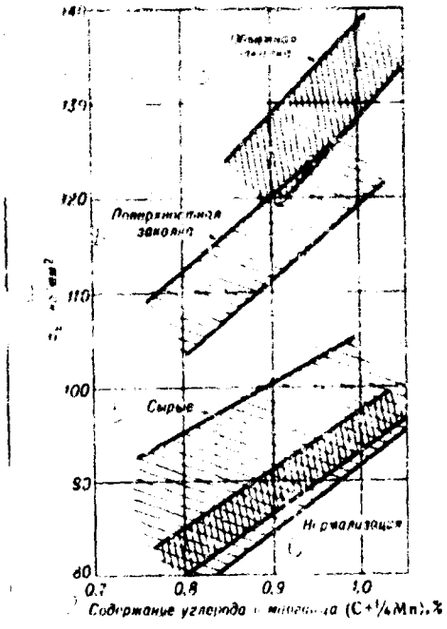



Fig. 4. Graph of $\sigma_b$ of heat-treated rail steel as a function of C and Mn contents. 1) $\sigma_b$, kg/mm$^2$; 2) carbon and manganese content (C + 1/4 Mn), %; 3) through quenching; 4) surface quenching; 5) raw; 6) normalization.

Chemical Composition and Mechanical Characteristics of Rail Steel

| Тип рельсов по ГОСТ и назначение 1 | 2 Содержание элементов (%) | | | | | 4 $\sigma_b$ (кг/мм$^2$), не менее |
|---|---|---|---|---|---|---|
| | C | Mn | Si | P | S | |
| | | | | 3 не более | | |
| 5 Мартеновская сталь | | | | | | |
| 7 Рельсы широкой колеи типов Р75 (ТУ) и Р65 (ГОСТ 8160–56) | 0,69–0,82 | 0,7–1,0 | 0,17–0,28 | 0,04 | 0,05 | 80 |
| 8 Рельсы широкой колеи типа Р50 (ГОСТ 6944–54) | 0,67–0,8 | 0,7–1,0 | 0,17–0,28 | 0,04 | 0,05 | 80 |
| 9 Рельсы широкой колеи типа Р38 и Р43 (ГОСТ 4224–54) | 0,64–0,77 | 0,7–1,0 | 0,17–0,28 | 0,04 | 0,05 | 80 |
| 10 Рельсы трамвайные желобчатые (ГОСТ 8544–57) | 0,4–0,55 | 1,2–1,6 | 0,15–0,35 | 0,04 | 0,04 | 80 |
| То же | 0,67–0,8 | 0,7–1,0 | 0,17–0,28 | 0,04 | 0,04 | 80 |
| 11 Рельсы узкой колеи типа Р8, Р11, Р15, Р18 и Р24 (ГОСТ 5876–57) | 0,4–0,7 | – | – | 0,05 | 0,055 | – |
| 12 6 Бессемеровская сталь | | | | | | |
| 13 Рельсы широкой колеи типа Р38 (ГОСТ 5633–51) | 0,48–0,67 | 0,6–1,0 | 0,15–0,3 | 0,07 | 0,06 | 75 |
| 14 Рельсы широкой колеи типа Р43 (ГОСТ 5633–51) | 0,5–0,7 | 0,6–1,0 | 0,15–0,3 | 0,07 | 0,07 | 75 |
| 15 Рельсы крановые (ГОСТ 4121–57) | 0,5–0,7 | 0,6–1,0 | 0,15–0,3 | 0,075 | 0,06 | 75 |
| 16 Рельсы широкой колеи типа Р33 (ГОСТ 7521–55) | 0,4–0,65 | 0,6–1,0 | 0,15–0,3 | 0,07 | 0,06 | 70 |
| 17 Рельсы узкой колеи типа Р8, Р11, Р15, Р18, Р24 (ГОСТ 5876–57) | 0,35–0,6 | – | – | 0,085 | 0,085 | – |

Note: An As content of no more than 0.15% is permissible in rails of types R38, R43, R50, and R65, while a content of no more than 0.16% is permissible in rails of type R33.

1) Type of rail (according to GOST) and purpose; 2) content of elements (%); 3) no more than; 4) $\sigma_b$ (kg/mm$^2$), no less than; 5) open-hearth steel; 6) Bessemer steel; 7) broad-gauge rails of types R75 (TU) and R65 (GOST 8160-56); 8) broad-gauge rails of type R50 (GOST 6944-54);

9) broad-gauge rails of types R38 and R43 (GOST 4224-54); 10) grooved trolley rails (GOST 6544-53); 11) the same; 12) narrow-gauge rails of types R8, R11, R15, R18, and R24 (GOST 5876-53); 13) broad-gauge rails of type R38 (GOST 5633-51); 14) broad-gauge rails of type R43 (GOST 5633-51); 15) crane rails (GOST 4121-52); 16) broad-gauge rails of type R33 (GOST 7521-55); 17) narrow-gauge rails of types R8, R11, R15, R18, and R24 (GOST 5876-53).

a distance of 80-200 mm (HB = 300-401 kg/mm$^2$) to prevent premature wear. Quenching from the temperatures produced by rolling heating or by high-frequency electric heating should ensure a gradual transition from the quenched to the unquenched layer, prevent overheating, and ensure that no cracks or other defects are present. Especially heavily loaded areas subject to intensive wear are hardened by heat treatment in the form of through quenching in oil, surface quenching with high-frequency electric heating, or through recrystallization heating and subsequent intermittent spray cooling in water. Figures 3 and 4 show the variation in the HB and $\sigma_b$ of heat-treated rail steel as a function of carbon and manganese content. The hardness (HB) of quenched rails should be 100 kg/mm$^2$ or more higher than that of non-heat-treated rails.

L.M. Shkol'nik

RARE EARTH CERAMICS – are ceramics made from oxides of rare-earth elements and used for the production of refractories. Only cerium cioxide, $CeO_2$ is of practical interest. The refractoriness of $CeO_2$ is 2600-2800°; the density is 7.13 $g/cm^3$; the specific heat is 233.4 kcal/ /mole at 25°. $CeO_2$ becomes readily reduced to $Ce_2O_3$ which has a refractoriness of 1600°. The electric conductivity of $CeO_2$ is significantly higher than that of the other pure oxides; $CeO_2$ is therefore used as a heater and as a light source. The specific volume resistance of $CeO_2$ is $6.5 \cdot 10^4$ at 800°, and $3.4 \cdot 10^2$ at 1200°. Strongly calcinated $CeO_2$ is insoluble in HCl and $HNO_3$, but soluble in hot concentrated $H_2SO_4 \cdot CeO_2$ becomes easily hydrated, a fact which limits its application.

V.L. Balkevich

RARE-EARTH METALS (lanthanides) – 14 elements in addition to lanthanum located in Group III of the periodic table, called the lanthanides, which are isolated in a separate series of the Mendeleyevian system. These elements have atomic numbers of from 58 to 71 inclusive (cerium, praseodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutecium).

TABLE 1

Content of Rare-Earth Metals in the Earth's Crust

| 1 Элемент | 2 По А. Е. Ферсману | | По А. П. Виноградову* | | По В. М. Гольдшмидту | |
|---|---|---|---|---|---|---|
| | 3 вес. % | в %, по отношению к сумме | вес. % | в %, по отношению к сумме | г на тонну | в %, по отношению к сумме |
| Y | $5\cdot10^{-3}$ | 33.79 | $2.8\cdot10^{-3}$ | 17.78 | 31 | 20.66 |
| La | $6.5\cdot10^{-3}$ | 4.38 | $1.8\cdot10^{-3}$ | 11.43 | 19 | 12.65 |
| Ce | $2.9\cdot10^{-2}$ | 19.55 | $4.5\cdot10^{-3}$ | 28.59 | 44 | 29.31 |
| Pr | $6.5\cdot10^{-4}$ | 3.03 | $7\cdot10^{-4}$ | 4.44 | 5.6 | 3.72 |
| Nd | $1.7\cdot10^{-2}$ | 11.45 | $2.5\cdot10^{-3}$ | 15.87 | 23 | 13.9 |
| Sm | $7\cdot10^{-4}$ | 4.71 | $7\cdot10^{-4}$ | 4.44 | 6.5 | 4.33 |
| Eu | $2\cdot10^{-4}$ | 0.13 | $1.2\cdot10^{-4}$ | 0.76 | 1.0 | 0.67 |
| Gd | $7.5\cdot10^{-4}$ | 5.05 | $1\cdot10^{-4}$ | 6.35 | 6.3 | 4.19 |
| Tb | $1\cdot10^{-4}$ | 0.67 | $1.5\cdot10^{-4}$ | 0.95 | 1.0 | 0.66 |
| Dy | $7.5\cdot10^{-4}$ | 5.05 | $4.5\cdot10^{-4}$ | 2.85 | 4.1 | 2.86 |
| Ho | $1\cdot10^{-4}$ | 0.67 | $1.3\cdot10^{-4}$ | 0.83 | 1.2 | 0.80 |
| Er | $3.5\cdot10^{-4}$ | 4.38 | $4\cdot10^{-4}$ | 2.55 | 2.4 | 1.60 |
| Tu | $1\cdot10^{-4}$ | 0.67 | $8\cdot10^{-5}$ | 0.51 | 0.3 | 0.26 |
| Yb | $8\cdot10^{-4}$ | 5.41 | $3\cdot10^{-4}$ | 1.91 | 2.6 | 1.73 |
| Lu | $1.7\cdot10^{-4}$ | 1.14 | $1\cdot10^{-4}$ | 0.65 | 0.7 | 0.46 |

*A.P. Vinogradov's data do not include the content of rare-earth metals in the hydrosphere and atmosphere.

1) Element; 2) according to A.Ye. Fersman; 3) % by weight; 4) % of total; 5) acccrding to A.P. Vinogradov; 6) according to V.M. Gol'dshmidt; 7) g per ton.

The term "rare-earth elements" dates historically to the end of the 18th and the beginning of the 19th Centuries, when it was erroneously thought that minerals containing elements of two subgroups, the cerium (La, Ce, Pr, Nd, Pm, Sm, Eu) and ytterbium (Gd, Tt, Dy, Ho, Er, Tu, Yb, Lu) groups, are rarely encountered in the earth's crust. How-

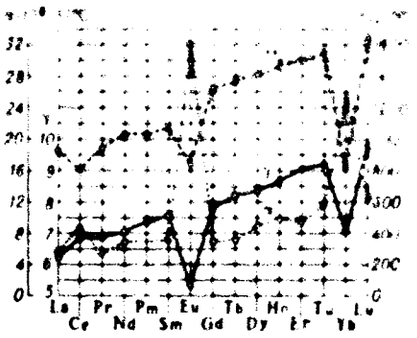



Fig. 1. Graph of $\gamma$, a, and $t^{\circ}_{pl}$ of the rare-earth metals as functions of atomic number.

over, in terms of raw-material reserves these elements are not rare at all, since their total content (approximately 0.016%) is greater than that of lead by a factor of 10, than that of molybdenum by a factor of 50, and than that of tungsten by a factor of 165. Table 1 shows the occurrence of individual rare-earth metals in the earth's crust. These elements are very similar chemically and in certain of their physical properties, this being due to the structure of their electron shells. The lanthanides belong to the transition group, but, in contrast to the other transition metals, which have complete de-levels, in the rare-earth metals the deeper 4 f orbital is filled. Table 2 shows the crystal structure and lattice parameters of these elements. The lanthanides are characterized by a valence of +3, although certain of them also exhibit other valences, e.g., +2 for Sm, Eu, and Yb and +4 for Ce, Pr, and Tb. The standard electrode potential $R^{\circ} \rightarrow R^{3+}$ varies from −2.4 to −2.1 over the series La-Lu, while the ionic radius $R^{3+}$ drops from 1.22 to 0.99 A (according to Goldschmidt) and the mean "metallic radius" also decreases from 1.87A to 1.73A. In this case Eu and Yb are anomalous, since their "metallic radii" do not obey the aforementioned rule, but are maximal (2.04 and 1.94A). A similar anomaly is also observed for certain other properties of the rare-element

(Fig. 1); for example, density increases from 6.18 to 9.79 g/cm$^3$ over the series La-Lu, but the densities of Eu and Yb are 5.30 and 7.02 g/cm$^3$ respectively, a phenomenon resulting from the comparatively large atomic volumes and atomic radii of Eu and Yb and the structure of their crystal lattices.

The rare-earth metals are obtained by reduction of the corresponding oxides, by calcium thermal reduction of dehydrated fluorides, by electrolysis of annydrous salts, and by other methods.

The rare-earth metals are paramagnetic: Gd and Dy exhibit ferromagnetic properties, while Ho displays one of three types of magnetism (ferromagnetism, antiferromagnetism, or paramagnetism), depending on its temperature.

The lanthanides are chemically the most active of all the transition elements. They corrode at room temperature when dry and especially when wet. Their corrosion resitance increases over the series La-Lu, La, Ce, Nd, and Pr being more intensively oxidized and Ho, Er, and Yb having a higher corrosion resistance at room and elevated temperatures.

The element with atomic number 61 (promethium) has not as yet been detected in nature; it is produced artificially and many of its properties have not been sufficiently well studied. The density of Pn is 7.26 g/cm$^3$, while its $t^{\circ}_{pl}$ is 1035 ± 10°; its physical and mechanical properties are intermediate between those of Nd and Sm.

Tables 3-5 show the physical, nuclear, and mechanical properties of the rare-earth metals. Analysis of the data on mechanical properties indicate that strength increases with the atomic number of the element.

The mechanical properties of Eu, Tb, Tu, and Lu have been the subject of little research and there are only isolated data on the proper-

TABLE 2

Crystal Structure and Lattice Parameters of Rare-Earth Metals

| Элемент 1 | Модификация 2 | Кристаллич. структура 3) | 4 Параметры решетки | |
|---|---|---|---|---|
| | | | a (Å) | c (Å) |
| La | α—La<br>β—La*)<br>γ—La | ГПУ<br>ГЦК<br>ОЦК | 3,770±0,002<br>5,304±0,003<br>4,26±0,01 | 12,159±0,008 |
| Ce | α—Ce<br>β—Ce<br>γ—Ce<br>δ—Ce | ГЦК<br>ГПУ<br>ГЦК<br>ОЦК | 4,85±0,01<br>3,68<br>5,1612±0,0005<br>4,11±0,01 | 11,92 |
| Pr | α—Pr<br>β—Pr | ГПУ<br>ОЦК | 3,6725±0,0007<br>4,11±0,01 | 11,8354±0,0012 |
| Nd | α—Nd<br>β—Nd | ГПУ<br>ОЦК | 3,6579±0,0003<br>4,13±0,01 | 11,7992±0,0005 |
| Sm | α—Sm<br>β—Sm | Ромбоэдрич.<br>ОЦК | 8,966<br>4,070 | α =23°13' |
| Eu | — | ОЦК | 4,5820±0,0004 | — |
| Gd | α—Gd<br>β—Gd | ГПУ<br>ЦК | 3,6360±0,0009<br>4,06 | 5,7826±0,0006 |
| Tb | α—Tb | ГПУ | 3,6010±0,0003 | 5,6936±0,0002 |
| Dy | — | ГПУ | 3,5903±0,0001 | 5,6475±0,0002 |
| Ho | — | ГПУ | 3,5773±0,0001 | 5,6158±0,0002 |
| Er | — | ГПУ | 3,5888±0,0003 | 5,5874±0,0002 |
| Tu | — | ГПУ | 3,5375±0,0001 | 5,5546±0,0004 |
| Yb | α—Yb<br>β—Yb | ГПУ<br>ОЦК | 5,4862±0,0004<br>4,45 | — |
| Lu | — | ГПУ | 3,5091±0,0004 | 5,5509±0,0004 |

*GPU — Hexagonal tightly-packed lattice, GPK — face-centered cubic lattice, OTsK — body-centered cubic lattice.
**Observed on production of metal by electrolysis.

1) Element; 2) modifications; 3) crystal structure; 4) lattice parameters; 5) GPU; 6) GTsK; 7) OTsK; 8) rhombohedral.

ties of Yb. The ultimate strength of Yb is virtually the same at 20 and 205°, amounting to 7.2-7.3 kg/mm$^2$; its plasticity is less than 1% at room temperature and 10.8% at 205°.

The rare-earth metals and alloys based on them are used in the manufacture of various semifinished and finished products by casting, hot pressure working (pressing, rolling), and powder metallurgy.

When reacted with metalloids (B, C, N, O, H, Si, P, and S) the lanthanides form borides, carbides, nitrides, oxides, hydrides, sili-

TABLE 3

Physical Properties of the Rare-Earth Metals

| Свойство 1 | La | Ce | Pr | Nd | Sm | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 Атомный номер | 57 | 58 | 59 | 60 | 62 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 |
| 3 Атомный вес | 138,91 | 140,12 | 140,907 | 144,24 | 150,35 | 157,25 | 158,924 | 162,50 | 164,930 | 167,26 | 168,934 | 173,04 | 174,97 |
| 4 $\gamma$ (г/см$^3$) | 6,16 | 6,79 | 6,71 | 6,96 | 7,50 | 7,90 | 8,19 | 8,45 | 8,63 | 9,01 | 9,20 | 7,02 | 9,74 |
| 5 $t°_{кип}$ (°С, грубые данные) | 920±5 | 787±3 | 935±5 | 1024±5 | 1072±5 | 1426±20 | 1412±5 | 1384±5 | 1407±5 | 1461±5 | 1547±5 | 1454±5 | 1926±5 |
| $t°_{пл}$ (°С, грубые данные) | 3470 | 3470 | 3017 | 3210 | 1670 | 1630 | 2830 | 2680 | 2330 | 2380 | 2396 | 1720 | 3180 |
| Теплота плавления $\Delta H$ (ккал/моль) 6 | 1.8 | 1,238±0,004 | 1.650 | 1,765±0,019 | 2,061±0,015 | 2.0 | 2.1 | 2.2 | 4.8 | 4.1 | 4.2 | 1.3 | 1.8 | 4.7 |
| 7 Темп-ра полиморфного превращения (°С) $\alpha \rightarrow \beta$ (для Ce $\alpha \rightarrow \gamma$) | 310±5 | 113±5 | 791 | 862 | 917 | 21 нет | 1264 | 1426 | — | — | — | — | 796 | — |
| 8 Теплота полиморфного превращения $\Delta H$ (ккал/моль) | 0,895 | 0,88±0,04 | 0,760 | 0,713±0,015 | 0,744±0,036 | — | 1,02 | 1,06 | — | — | — | — | 0,125 | — |
| Теплота испарения 9 $\Delta H_{исп}$ (ккал/моль) | 93,8 (1387—1744°) | 92,9±0,4 (1238—1765°) | 79,5±1,1 (1150—1420°) | 76,6±2,0 (1075°) | 48,1±0,8 (930°) | 81,1±0,1 (460—630°) | 77,5±3,1 (1275°) | — | 68,2±6,9 (542°) | — | 54,7±2,3 (1100—1300°) | 37,5±0,2 (730—950°) | 90,1±1,1 (2040°) | — |
| 10 $c_{при\ 0°K}$ (ккал/моль·°С) | 0,05 | 0,09 | 0,45 | 7,20 | 0,69 | 6,60 | 11,20 | 6,34 | 6,72 | 6,55 | 6,05 | 6,57 | 6,06 | 6,72 |
| 11 $\alpha \cdot 10^6$ (1/°С), при 25° | 4,9±0,1 | 8,5 ±2 | 6,5±0,6 | 6,7±0,6 | — | 32,0 | 6,4±0,3 | 7,0±0,3 | 8,2—8,9 | 9,5 | 9,2±0,3 | 11,0 | 10,0 | 9,9 |
| 12 среднее значение (1/°С) | 3,2 (от —173 до 310°) | 7,1 (от —25 до 725°) | 6,5 (от —173 до 800°) | 8,6 (от —173 до 800°) | — | 26±4 (от —200 до 760°) | 9,7 (от 25 до 950°) | 11,8 (от 25 до 950°) | 11,4 (от —96 до 1000°) | — | 12 (от —173 до 950°) | — | 10,4 (от 25 до 950°) | — |
| 13 $\lambda$ (кал/см·сек·°С) | 0,033±0,003 | 0,026±0,00 | 0,028±0,003 | 0,031±0,003 | — | — | — | — | 0,024± 0,002 | — | 0,027± 0,002 | — | — | — |
| 14 $\rho \cdot 10^6$ (ом·см) | α 84,8 (25°) β 96 (360°) γ 120 (800°) | α 74 (240°) β 78,3 (25°) γ 123 (770°) | α 69 (25°) β 132 (820°) | α 64 (25°) β 57 (890°) | 88 (25°) | 81,3 (25°) | 140,5 (25°) | 135 (18°) | 56 (25°) | 87 (.5°) | 107 (25°) | 29 (25°) | 27 (25°) | 79 (25°) |
| 15 Термич. коэфф. электросопрот. ($\rho_{25}/\rho_{-196}$) | 2,18 | 0,57 | 1,71 | 1,64 | 1,48 | 4,80 | 1,76 | 0,81 | 1,19 | 1,71 | 2,01 | 1,95 | 1,70 | 1,5 |
| 16 Магнитная восприимчивость при 25°·$10^{-12}$ | 101 | 2430 | 5320 | 5650 | 1275±25 | 33100 | 356000 | 183000 | ≠9800 | 70200 | 44100 | 262000±100 | 71 | 17,9 |
| 17 Постоянная Холла при 25°·$10^{-12}$ (см/а·э) | —0,8 | +4,4 | +0,709 | +0,971 | —0,2 | — | —4,48 | — | —27 | — | —0,341 | —1,8 | —27 | —0,735 |
| 18 Работа выхода электронов (эв) | 3,33 | 2,84 | 2,7 | 3,3 | 3,2 | 2,56 | 3,07 | 3,09 | 3,00 | 3,12 | 3,12 | 2,60 | 3,14 | 3,14 |

1) Property; 2) atomic number; 3) atomic weight; 4) $\gamma$ (g/cm$^3$); 5) $t°_{kip}$ (°C, rough data); 6) heat of fusion $\Delta H$(kcal/mole); 7) temperature of polymorphous transformation $\alpha \rightarrow \beta$($\alpha \rightarrow \gamma$ for Ce) (°C); 8) heat of polymorphous transformation $\Delta H$(kcal/mole); 9) heat of vaporization $\Delta H_{isp}$ (kcal/mole); 10) c at 0°K(kcal/mole·°C); 11) $\alpha \cdot 10^6$(1/°C) at 25°; 12) $\alpha$, mean value (1/°C); 13) $\lambda$ (cal/cm·sec·°C); 14) $\rho \cdot 10^6$(ohm·cm); 15) thermal coefficient of electrical resistance (degrees$^{-1} \cdot 10^3$); 16) magnetic susceptibility at 25°·$10^{-12}$; 17) Hall's constant at 25°·$10^{-12}$ (cm/amp·oersted); 18) electron work function (ev); 19) from; 20) to; 21) none.

cides, phosphides, and sulfides, while with Se and Te they form selenides and tellurides. All these compounds have very important properties. The most stable of lanthanide borides are the hexaborides ($MeB_6$).

The carbides of the rare-earth elements decompose in air, producing hydrocarbons. Their nitrides are stable in dry air, but rapidly break down in moist air to form hydroxides and release ammonia; they are soluble in hydrocloric, nitric, and sulfuric acids. Table 6 shows the characteristics of certain carbides and nitrides of the rare-earth metals.

TABLE 4

Nuclear Properties of Rare-Earth Metals

| 1 Элемент | 2 Массовые числа природных изотопов и их содержание в % (в скобках) | 3 Число ядер $\times 10^{24}$ | 4 Микроскопич. сечения для нейтронов 2200 м/сек, барн * $\sigma_a$ | $\sigma_s$ | 5 Макроскопич. сечения для нейтронов 2200 м/сек·см$^{-1}$ $\Sigma_a$ | $\Sigma_s$ | 6 Коэфф. рассеяния γ-лучей с энергией 3 мэв см$^{-1}$ | 7 Коэфф. поглощения γ-лучей с энергией 3 мэв см$^{-1}$ | 8 Резонансный интеграл поглощения (барн) |
|---|---|---|---|---|---|---|---|---|---|
| La | 138 (0,089), 139 (99,11) | 0,0267 | 9,3±0,3 | — | 0,237 | — | 0,229 | 0,154 | 11 |
| Ce | 136 (0,193), 138 (0,250), 140 (88,48), 142 (11,07) | 0,0297 | 0,73±0,08 | — | 0,0217 | — | 0,260 | 0,177 | 3,7 |
| Pr | 141 (100) | 0,0277 | 11,6±0,6 | — | 0,313 | — | 0,249 | 0,166 | 7 |
| Nd | 142 (27,09), 143 (12,14), 144 (23,83), 145 (8,29), 146 (17,26), 148 (5,74), 150 (5,63) | 0,0291 | 46±2 | — | 1,35 | — | 0,267 | 0,182 | 40 |
| Pm | 147 (не стабилен) 9 | — | 150 | — | — | — | — | — | — |
| Sm | 144 (3,16), 147 (15,07), 148 (11,27), 149 (13,84), 150 (7,47), 152 (26,63), 154 (22,53) | 0,0311 | 5600±200 | — | 181,3 | — | 0,298 | 0,205 | 1790 |
| Eu | 151 (47,77), 153 (52,26) | 0,0207 | 4300±100 | 8±1 | 91,20 | 0,166 | 0,204 | 0,140 | 5080 |
| Gd | 152 (0,20), 154 (2,15), 155 (14,73), 156 (20,47), 157 (15,68), 158 (24,87), 160 (21,90) | 0,0305 | 46000±1000 | — | 142* | — | 0,307 | 0,212 | 67 |
| Tb | 159 (100) | 0,0316 | 46±4 | — | 1,45 | — | 0,324 | 0,223 | — |
| Dy | 150 (0,052), 158 (0,090), 160 (2,29), 161 (18,88), 162 (25,53), 163 (24,97), 164 (28,18) | 0,0317 | 950±50 | 100 | 29,67 | 3,17 | 0,334 | 0,230 | — |
| Ho | 165 (100) | 0,0320 | 65±3 | — | 2,08 | — | 0,343 | 0,238 | — |
| Er | 162 (0,136), 164 (1,56), 166 (32,3), 167 (22,9), 168 (27,1), 170 (14,9) | 0,0172 | 173±17 | — | 2,97 | — | 0,188 | 0,131 | — |
| Tu | 169 (100) | 0,0333 | 127±4 | 7 | 4,23 | 0,233 | 0,372 | 0,260 | — |
| Yb | 168 (0,14), 170 (3,03), 171 (14,31), 172 (21,82), 173 (16,13), 174 (31,84), 176 (12,73) | 0,0244 | 37±4 | 12 | 0,903 | 0,293 | 0,280 | 0,197 | — |
| Lu | 175 (97,4), 176 (2,6) | 0,0335 | 112±5 | — | 3,76 | — | 0,393 | 0,275 | 720 |

*For natural isotopic mixture.

1) Element; 2) mass numbers of natural isotopes and contents in % (in parentheses); 3) nuclear number·cm$^3$·$10^{24}$; 4) microscopic neutron cross-section, 2200 m/sec, barns; 5) macroscopic neutron cross-section, 2200 m/sec, cm$^{-1}$; 6) scattering factor for γ-rays with energy of 3 mev, cm$^{-1}$; 7) absorption factor for γ-rays with energy of 3 mev, cm$^{-1}$; 8) absorption resonance integral (barns); 9) unstable.

The lanthanide oxides are high-melting compounds and are more widely used in technology than the oxygen-free high-melting compounds of the rare-earth metals. Their melting temperatures range from 2000 to 2600°. These oxides are less strong and have a lower α and ρ than high-melting metalloid compounds, but are generally exceptionally resistant to oxidizing atmospheres.

The oxides of the rare-earth metals have a high heat of formation. They vary in their thermostability, tendency toward hydration, reduction, and vaporization at high temperatures. Thus, for example, cerium

TABLE 5

Mechanical Properties of Certain Rare-Earth Metals at Room and Elevated Temperatures

| Свойства 1 | Состояние металла и темп-ра 2 | La | Ce | Pr | Nd | Sm | Gd | Dy | Ho | Er |
|---|---|---|---|---|---|---|---|---|---|---|
| $\sigma_b$ | Литой при 20° 4 | 13,3 | 10,5 | 11,2 | 17,4 | 12,7 | — | 25,1 | 26,4 | 29,8 |
| $\sigma_{0,2}$ | | 12,8 | 9,3 | 10,3 | 16,8 | 11,4 | — | 22,9 | 22,6 | 29,7 |
| $\delta$ | | 8,0 | 24,0 | 10,0 | 11,0 | 3 | | 6 | 5 | 4 |
| $\sigma_b$ | Кованый при 20° | 19,0 | 11,2 | 20,2 | — | 18,5 | 27,4 | 33,0 | — | 28,8 |
| $\sigma_{0,2}$ | | 22,5 | 15,4 | 21,9 | 21,9 | 19,4 | 39,7 | 43,6 | — | 32,0 |
| $\delta$ | | 4 | 17,0 | 7,0 | 2,0 | 8,0 | 7,0 | 3,0 | — | 7,0 |
| $\sigma_b$ | Литой при 205° | 10,8 | 4,6 | 14,1 | — | 14,8 | 12,6 | 21,6 | 21,6 | 24,4 |
| $\sigma_{0,2}$ | | 8,7 | 3,3 | 10,3 | — | 12,6 | 11,0 | 14,6 | 17,3 | 20,8 |
| $\delta$ | | 9,4 | 21,4 | 15,8 | — | 10,4 | 6,8 | 8,3 | 6,0 | 5,5 |
| $\sigma_b$ | Литой при 425° | 4,7 | — | 4,7 | 4,2 | 8,4 | 9,8 | — | — | 17,6 |
| $\sigma_{0,2}$ | | 2,6 | — | 4,1 | 4,0 | 7,7 | 8,5 | — | — | 20,2 |
| $\delta$ | | 21,0 | — | 29,0 | 13,0 | 5,6 | 11,3 | — | — | 6,8 |
| $\sigma_b$ | Кованый при 205° | 18,3 | 9,6 | 18,6 | 14,0 | 17,4 | 29,0 | 33,7 | — | 29,0 |
| $\sigma_{0,2}$ | | 2,0 | 7,9 | 17,8 | 12,4 | 13,5 | 21,9 | 25,7 | — | 32,3 |
| $\delta$ | | 8,6 | 9,5 | 11,7 | 10,3 | 14,5 | 4,2 | 12,0 | — | 4,6 |
| $\sigma_b$ | Кованый при 425° | 3,0 | 3,6 | 4,3 | 8,9 | 10,2 | 13,5 | 20,4 | — | 15,8 |
| $\sigma_{0,2}$ | | 2,9 | 1,4 | 3,8 | 8,4 | 9,1 | 10,0 | 18,8 | — | 13,4 |
| $\delta$ | | 27,0 | 8,0 | 47,5 | 8,0 | 12,5 | 12,0 | 4,2 | — | 4,6 |
| $E$ | 20° | 7031—7734 | 4429 | 4922—9843 | — | 5625 | 5625—9843 | 7031—9843 | — | 11600 |
| $G$ | 20° | 1518 | 1223 | 1378 | 1476 | 1286 | 2278 | 2587 | — | 3046 |
| $\mu$ | 20° | 0,228 | 0,248 | 0,305 | 0,306 | 0,352 | 0,259 | 0,243 | — | 0,238 |
| $HB$ | 20° | 35—40 | 25—30 | 35—50 | 35—45 | 45—65 | 55—70 | 55—105 | 50—125 | 60—95 |

Note: The dimension of $\sigma_b$, $\sigma_{0.2}$, E, G, and HB is $kg/mm^2$, while that of $\delta$ is %.

1) Property; 2) state of metal and temperature; 3) cast at; 4) forged at.

TABLE 6

Properties of Carbides and Nitrides of Lanthanium and Cerium

| 1 Соединение | 2 $\gamma$ (г/см³ рентг.) | $t_{пл}$ (°С) | 3 $\rho$ (мком·см) | Теплота образования $\Delta H_{298}$ (ккал/моль) 4 | Тип кристаллической структуры* 5 | $\alpha \cdot 10^6$ (1/°С) |
|---|---|---|---|---|---|---|
| $LaC_2$ | 5,35 | 2000 | 68 | — | ОЦТ 6 | 12,1 |
| $CeC_2$ | 5,56 | 2540 | 58,8 | — | ОЦТ | 10,1 |
| LaN | 6,90 | — | — | 72 | ГЦК 7 | 9,0 |
| CeN | 8,09 | — | — | 78,2 | ГЦК | 30,9 |

*OTsT — body-centered tetragonal lattice, GTsK — face-centered cubic lattice.

1) Compound; 2) $\gamma$(g/cm³, roentgenographically); 3) $\rho$(μohm·cm); 4) heat of formation $\Delta H_{298}$ (kcal/mole); 5) type of crystal structure; 6) OTsT; 7) TTsK.

dioxide ($t^{\circ}_{pl}$ = 2600°) is stable in air, but can be reduced to the sesquioxide by heating in a nonoxidizing atmosphere. Table 7 shows the most important properties of the lanthanide oxides.

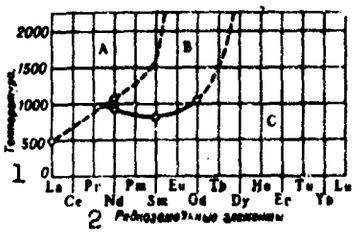



Fig. 2. Variation in the structure of lanthanide sesquioxides as a function of temperature and atomic number. A) Hexagonal; B) triangular (rhombic or monoclinic); C) cubic. 1) Temperature; 2) rare-earth elements.

All the lanthanide oxides are capable of absorbing moisture at room and elevated temperatures, forming hydroxides. Moisture absorption occurs more rapidly and reaches a higher level as the relative humidity rises. Of all the lanthanide sesquioxides $La_2O_3$ reacts most vigorously with water at room temperature, a process accompanied by evolution of heat. The reactivity of these oxides with water decreases as the atomic number of the metallic element increases. The behavior of the lanthanide oxides in boiling water is of great technological importance. Their solubility in boiling water depends on the method by which they are produced and the type of crystal lattice involved. For example, when powdered Sm, Eu, Gd, and Dy oxides are boiled they partially dissolve, the majority of the loss of weight occuring during the first 10-20 hr. Disprozium oxide is the least soluble in boiling water of the oxides with a cubic modification, while europium oxide is the least soluble of the oxides with a monoclinic modification. The reactivity of these oxides with water decreases as their calcination temperature increases.

Attempts have been made in the literature to clasify the struc-

ture of the rare-earth-metal sesquioxides ($R_2O_3$) in accordance with three modifications (Fig. 2), high-temperature (A, B) and low-temperature (C). The rough data given in this Figure on the polymorphism of the lanthanide sesquioxides as a function of atomic number pertain either to equilibrium or to near-equilibrium conditions. The cubic modification, C, is characteristic of elements with atomic numbers above 67.

The rare-earth metals form hydrides with hydrogen, the density of these compounds being less than that of the corresponding metals.

The simplest method for producing hydrides is direct reaction of hydrogen (purified of water vapor and other impurities) with rare-earth metals. The resultant compounds have a face-centered cubic lattice of the $CaF_2$ type.

Table 8 shows the characteristics of certain lanthanide dihydrides.

In constrast to the other rare-earth elements, saturation of Eu and Yb with hydrogen is accompanied by considerable compression and a consequent increase of 12.5-13.5% in density over the base metal. The composition of the lanthanide hydrides varies with temperature; for example, lanthanium forms the hydride $LaH_3$ at temperatures of up to 300°, a solid solution of hydrogen in La dihydride between 300 and 600°, and the dihydride $LaH_2$ at 600-1000°.

These hydrides vary in thermochemical stability. Cerium hydride reacts with nitrogen at room temperature and is converted to the nitride on heating to 800-900°. This hydride burns in air to form a mixture of cerium oxide and cerium nitride. In order to prevent such decomposition of cerium hydride it is treated with dry carbon dioxide. $CeH_3$ begins to break down at a temperature of ~200°, while $CeH_2$ is stable to 800°. Pr and Nd are inert with respect to hydrogen at room temperature and begin to absorb this element actively only at 300-400°.

Table 9 shows the characteristics of the rare-earth metal silicides (compounds of the lanthanides and silicon).

Phosphides of the rare-earth elements are obtained by reacting phosphine ($PH_3$) with the appropriate metal. Lanthanum monophosphide (LaP) is formed after phosphidization of lanthanum oxide at 1300° for 3-5 hr. LaP has a face-centered cubic lattic of the NaCl type with a lattice constant a = 6.016A; its density is 5.18 $g/cm^3$ and its microhardness 158 $kg/mm^2$. LaP is insoluble in water and cold or hot alkalis, slightly soluble in $H_2SO_4$ of any concentration, and highly soluble in dilute and concentrated $HNO_3$; it dissolves slowly in dilute and concentrated HCl and aqua regia.

The rare-earth metals form sulphides with sulfur. These are high-melting, stable compounds and are resistant to most liquid metals at temperatures of up to 1800°.

The majority of the lanthanide sulfides have crystal lattices of the cubic type. The sesquisulphides of the rare-earth elements are decomposed by acids (especially nitric acid), chlorine, carbon dioxide, and aqua regia; hydrogen, nitrogen, gaseous ammonia, and many molten chlorides have no effect on them. The properties of certain monosulphides and sesquisulphides are shown in Table 10.

Scandium and yttrium are also included among the rare-earth metals, since they have certain properties similar to those of the latter and are found together with the lanthanides in nature. Sc is a high-melting, corrosion-resistant metal which remains almost unoxidized when stored in air for prolonged periods (at temperatures of up to 300°). Y is similar to the lanthanides in physicochemical properties and occupies a position intermediate between titanium and aluminum with respect to strength and elasticity. Sc and Y form appropriate compounds (nitrides, carbides, borides, etc.) when reacted with metal-

loids (N, C, B, etc.). Table 11 shows the characteristics of Sc and Y.

TABLE 7

Properties of Rare-Earth-Metal Oxides

| Оксиды 1 | Молекулярный вес 2 | Цвет 3 | γ (г/см³) 4 | Тип кристаллич. решетки 5 | $t°_{пл}$ (°C) | $t°_{кип}$ (°C) | Теплота образования (ккал/моль) 6 | c (кал/г·°C) 7 | Удельная магнитная восприимчивость $10^6$ CGS 8 | Растворимость** в воде при 100° г на 100 г 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| $La_2O_3$ | 325,82 | Белый 10 | 6,51 | Гексагональная кубическая 20 | 2315 | 4200 | 458,0 | 0,0749 | −78 (20°) | 4·10⁻³ |
| $Ce_2O_3$ | 328,24 | Серо-зеленый 11 | 6,9–7,0 | » | 1692 | – | 448,0 | – | – | н. р. |
| $CeO_2$ | 172,12 | Желтый | 7,3 | Кубическая | 2600 | – | 233,0 | 0,0877 (0–100°) | +26 (20°) | н. р. |
| $Pr_2O_3$ | 329,81 | Желто-зеленый 13 | 6,87–7,07 | Гексагональная кубическая | разл. | – | 422,0 | – | +8994,0 (21°) | 2) н. р. |
| $PrO_2$ | 172,91 | Сине-коричневый 14 | 6,82 | Кубическая 21 | перех. при 350° в $Pr_6O_{11}$ 24 | – | – | – | – | – |
| $Pr_6O_{11}$ | 675,68 | Серый 15 | 6,81 | » | – | – | – | – | – | – |
| $Nd_2O_3$ | 336,48 | Светло-синий 16 | 7,24 | Гексагональная кубическая | 1900 | – | 425,0 | – | +10200,0 (19°) | 1 · 10⁻³ |
| $Sm_2O_3$ | 348,70 | Желтый 12 | 7,43 | Моноклинная кубическая 22 | 2300 ± 50 | – | 433,0 | 0,0962 (0–100°) | +1260,0 (19°) | н. р. |
| $Eu_2O_3$ | 351,91 | Бледно-розовый 17 | 7,42; 6,55* | » | 2050 ± 50 | – | 415,6 | 0,0956 (0–100°) | +1000,0 (22°) | н. р. |
| $Gd_2O_3$ | 362,50 | Белый | 7,407 | » | 2420 ± 20 | – | 439,2 | 0,0842 (0–100°) | +332,0 (20°) | 1 · 10⁻³ |
| $Tb_4O_7$ | 365,50 | Белый | 7,81 | Кубическая | – | – | 441,0 | – | +58,5 (0–15°) | 25) н. р. |
| $Dy_2O_3$ | 373,00 | Желтый | 7,81 | » | 2340 ± 10 | – | 455,8 | – | +226,0 (15°) | н. р. |
| $Ho_2O_3$ | 377,83 | Желтый 18 | 8,36 | » | – | – | 449,4 | – | +97,0 (15°) | – |
| $Er_2O_3$ | 382,52 | Розовый | 8,64 | » | – | 3000 | 452,0 | 0,065 (0–100°) | +120,0 (15°) | 1 · 10⁻³ |
| $Tm_2O_3$ | 385,86 | Светло-зеленый | 8,60 | » | – | – | 453,0 | – | +114,0 (15°) | – |
| $Yb_2O_3$ | 394,08 | Белый 19 | 9,17 | » | 2346 | – | 458,0 | 0,0656 | – | – |
| $Lu_2O_3$ | 397,94 | Белый | 9,49 | » | – | – | 461,0 | – | – | – |

*7.42 – $Eu_2O_3$ obtained from nitrates, 6.55 – $Eu_2O_3$ obtained from oxalates.
**n.r.– insoluble, sl.r. – slightly soluble.

1) Oxide; 2) molecular weight; 3) color; 4) γ(g/cm³); 5) type of crystal lattice; 6) heat of formation (kcal/mole); 7) c(cal/g·°C); 8) specific magnetic susceptibility, $10^6$, CGS; 9) solubility in cold water in g per 100 g; 10) white; 11) grey-green; 12) yellow; 13) yellow-green; 14) blue-brown; 15) gray; 16) light blue; 17) light rose; 18) rose; 19) light green; 20) hexagonal cubic; 21) cubic; 22) monoclinic cubic; 23) varies; 24) changes to $Pr_6O_{11}$ at 350°; 25) n.r.; 26) sl.r.

TABLE 8

Characteristics of Rare-Earth-Metal Dihydrides

| Гидрид 1 | γ (г/см³) 2 | Теплота образования (ккал/моль) 3 | Период решетки (Å) 4 |
|---|---|---|---|
| $LaH_2$ | 5,63 | [illegible] | [illegible] |
| $CeH_2$ | 5,14 | [illegible] | [illegible] |
| $PrH_2$ | 5,65 | [illegible] | [illegible] |
| $NdH_2$ | 5,94 | [illegible] | [illegible] |
| $SmH_2$ | 6,32 | [illegible] | [illegible] |
| $GdH_2$ | 7,08 | [illegible] | [illegible] |

1) Hydride; 2) γ(g/cm³); 3) heat of formation (kcal/mole); 4) lattice constant (A).

| | | | | | | |
|---|---|---|---|---|---|---|
| $LaSi_2$ | 5.0 | 1520 | 236 ± 20 | Тетрагональная | [illegible] | 27.2 |
| $CeSi_2$ | 5.45 | | 408 ± 20 | Ромбическая | 565 | – |
| $NdSi_2$ | 5.7 | 1525 | 349 | α-ромбич.<br>β-тетраго-нальная | | – |
| $EuSi_2$ | 5.5 | 1500 | – | Тетрагональ-ная | – | – |
| $GdSi_2$ | 6.4 | 1540 | 267 | α-ромбич.<br>β-тетраго-нальная | – | –<br>4.4 |
| $DySi_2$ | 6.8 | 1550 | 3020 | α-ромбич.<br>β-тетраго-нальная | –<br>– | –<br>6.8 |

1) Silicide; 2) $\gamma(g/cm^3)$; 3) $\rho(\mu ohm \cdot cm)$; 4) crystal structure; 5) $kg/mm^2$; 6) tetragonal; 7) rhombic; 8) α-rhombic; 9) β-tetragonal.

TABLE 10

Properties of Rare-Earth-Metal Monosulphides and Sesquisulphides

| Сульфид<br>1 | γ (г/см³)<br>2 | $t^\circ_{пл}$ (°C) | Коэфф. термич. расширения $\cdot 10^6$ при 20–1000° (1/°C)<br>3 | ρ·10 (ом·см) при 20° | ρ·10 (ом·см) при 1000° | Абсолютный коэфф. термоэдс при 0° (мв/град)<br>5 | Работа выхода для электронов (эв)<br>6 | | Ширина запрещенной зоны (эв)<br>7 | Магнитная восприимчивость $H_a \cdot 10^6$, CGSM<br>8 | Константа Ричардсона (а/см²·град²)<br>9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1200°K | 1700°K | | | |
| LaS<br>$La_2S_3$ | 5.75<br>4.99 | 1970<br>2100 | 11.62±0.27<br>9.9±0.67 | 92<br>1.5 | –<br>90 | –11.6A<br>+154.0 | 3.10<br>3.15 | 3.15<br>3.16 | 17.7±0.1<br>2.29±0.01 | +52<br>–12.2 | – |
| CeS<br>$Ce_2S_3$ | 5.88<br>5.2 | 2100<br>1890±50 | 12.37±0.12<br>10.65±0.67 | 170<br>1.19 | –<br>87 | –9.58<br>+574.0 | 3.02<br>3.05 | 3.05<br>3.08 | 3.18±0.5<br>3.19±0.02 | 220м<br>26м | – |
| PrS<br>$Pr_2S_3$ | 6.03<br>– | –<br>2100 | 14.3±0.2<br>11.28±0.4 | 260<br>1.1 | –<br>65 | –10.3<br>– | 3.10<br>3.08 | 3.09<br>3.06 | –<br>2.6±0.02 | 679м<br>56м | [illegible] |
| NdS<br>$Nd_2S_3$ | 6.24<br>5.38 | 2140<br>2010 | 15.75±0.14<br>12.90±0.5 | 262<br>0.7 | –<br>15 | –21.8<br>– | 3.09<br>3.04 | 3.09<br>3.01 | –<br>3.46±0.01 | 660м<br>55м | [illegible] |

*Reduced to the International System of Units (SI), 1 cal/sec = 4.186 watts.

1) Sulphide; 2) $\gamma(g/cm^3)$; 3) coefficient of thermal expansion $\times 10^3$, at 20-1000° (1/°C); 4) ohm·cm; 5) absolute coefficient of thermal emf at 20° (μv·°); 6) electron work function (ev); 7) $\lambda \cdot 10^2$ (watts/cm·degree); 8) magnetic susceptibility $H_a \cdot 10^6$, CGSM; 9) Richardson's constant (amp/$cm^2$·$degrees^2$).

The rare-earth elements have come into use in various br[illegible] of technology. They have important physical and mechanical [illegible]operti[illegible]

and are consequently widely utilized in electronics, instrument building, nuclear engineering, machine building, the chemical industry, metallurgy, etc.

In electronics lanthanium ethyl sulphate and gadolinium ethyl sulphate are used with additives of cerium in producing molecular (quantum) generators, the so-called masers and lasers. Ce, La, and other rare-earth metals are employed as gas absorbers (getters in vacuum tubes), emitters (cathode coatings), incandescend-bulb filaments, etc. Cathodes of La boride are successfully used in synchrophasotrons, while cathodes coated with lanthanum hexaboride are employed in ion engines. The oxides of Ce, Nd, etc. are used in the manufacture of capacitors and insulators, while those of Pr, Ce, and La are employed in thermal batteries.

The lanthanides are widely used in illumination engineering (for the fuses of carbon electrodes, luminophores, etc.). Carbon electrodes are employed in high-power zenith projectors, movie-making and movie-projection apparatus, television, and especially in color cinematography (increasing image brightness and thus improving color transfer). Ce, Pr, Nd, Sm, Eu, Dy, Tb, Er, Tu and Yb are used as activators in commercial luminophores.

Those rare-earth elements with large thermal-neutron cross sections (Sm, Eu, Gd, and Dy) are employed in nuclear engineering. They are used in the form of metals, oxides, or metal-oxide alloys as neutron absorbers in nuclear-reactor controls.

The radioactive isotopes of La, Ce, Nd, Pm, Sm, Eu, and Tu are of practical value for radiography and gammagraphy in medicine, instrument building, etc. The most important of these elements are $Tu^{170}$, which emits stable soft $\gamma$-radiation similar to the rays produced by x-ray tubes, and $Pm^{147}$, which is used for miniature atomic batteries.

$Tu^{170}$ is employed for x-raying sheet materials and for defectoscopy of welds and castings. A very important use of thulium is in portable fluoroscope units for technical purposes and for field surgery.

La, Ce, Nd, and Pr are very widely used in the glass industry in the form of oxides and other compounds. These elements decolorize glass and increase its transparency. Rare-earth metals are used in special-purpose glasses for transmition of infrared light and absorption of ultraviolet light, in acid- and heat-resistant glasses, and in glasses with special optical properties. The lanthanides and their compounds are of especially great importance in the chemical industry (e.g., in the production of pigments, lacquers, and paints) and in the petroleum industry (e.g., in catalytic processes and the oxidation of organic substances). The rare-earth metals are employed in the manufacture of explosives, etc.

The alloying ability of the lanthanides is utilized in metallurgy to improve the technological, physical, and mechanical properties of pig iron, steel, and other alloys. Small additions (0.05-0.5%) of La, Ce, Pr, Nd, etc. have a modifying action on high-strength pig iron and refine structural steels and alloys as a result of their high affinity for oxygen and sulfur. They improve the temperability of steel, increase its reserve viscosity, and reduce its tendency toward temper brittleness.

Alloying of aluminum and magnesium alloys with Ce, Nd, Pr, etc. in quantities of 5% or more increases their high-temperature strength.

The sulphides, phosphides, selinides, and tellurides of the rare-earth metals are used in semiconductor technology. Sc is employed in electronics and metallurgy.

Yttrium is the most common of the lanthanides in the earth's crust and is widely used in technology. Addition of 1-2% Y to stainless

TABLE 11

Properties of Scandium and Yttrium

| 1 Элемент | 2 Атомный номер | 3 Атомный вес | 4 Атомный объем | 5 Структура кристалл. решет. | 6 γ (г/см³), рентг. | 7 t°пл (°C) | t°кип (°C) | λ (кал/см·сек·°C) | 8 c при 25° (ккал/моль °C) | 9 ρ·10⁶ (ом·см) | α·10⁶ (1/°C) | 10 σв (кг/мм²) | σ-в | δ (%) | 11 Упругие свойства E (кг/мм²) | G (кг/мм²) | μ | 12 НВ (кг/мм²) | 13 t° полиморф. превращ. (°C) | 14 Теплота образования (ккал/моль) | 15 Теплота плавления (ккал/моль) | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sc | 21 | 44.956 | 15.061 | гпу ВОЦК | 2.992 | 1535±5 | 2727 | — | — | 66 | — | 41.6 | 100 | — | — | — | | 50—60 | 1150 | 1450 | | — |
| Y | 39 | 88.905 | 19.886 | гпу ВОЦК | 4.472 | 1502 | 2630 | 0.035 | 6.50 | 65 | 7.6 (25—300°) 10.1 (25—1000°) | 22.8—31.5 | — | 3.8—9.0 | 6630 | 2671 | 0.26 | 45—90 | 1473 | | | 3.2 |

1) Element; 2) atomic number; 3) atomic weight; 4) atomic volume; 5) structure of crystal lattice; 6) γ(g/cm³), roentgenographically; 7) λ(cal/cm·sec·°C); 8) c at 25° (kcal/mole·°C); 9) ρ·10⁶ (ohm·cm); 10) kg/mm²; 11) elastic properties; 12) kg/mm²; 13) HB(kg/mm²); 14) t° of polymorphous transformation α → β (°C); 15) heat of formation (kcal/mole); 16) heat of fusion (kcal/mole); 17) α-GPU; 18) β-OTsK.

steel containing 25% chromium increases its hot strength to 1370°. Y bonds nitrogen and oxygen into an insoluble phase in chromium and chromium-based alloys, breaking up the structure of the alloy and increasing its strength. Alloying of vanadium with yttrium (0.5-2.0%) increases its plasticity during rolling. This is due to the fact that Y removes detrimental impurities, nitrogen and oxygen, from molten vanadium.

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Ekonomicheskiye ocherki po redkim zemlyam [Economic Outline of the Rare Earths], Moscow, 1961; Redkozemel'nyye elementy [Rare-Earth Elements], collection of articles, Moscow, 1958; Samsonov, G.V. et al., in collection: Redkozemel'nyye elementy [Rare-Earth Elements], Moscow, 1963; Zelikman, A.N., in book: Kratkaya khimicheskaya entsiklopediya [Brief Chemical Encyclopedia], Vol. 2, Moscow, 1963; Gshneyder, K.A., Probl. sovrem. metallurgii [Problems of Contemporary Metallurgy], 1960, No. 2; Trifonov, D.N., Problema redkikh zemel' [The Problem of the Rare Earths], Moscow, 1962; Mikheyeva, V.I., Gidridy perekhodnykh metallov [Hydrides of the Transition Metals], Moscow, 1960; Portnoy, K.I., Fadeyeva, V.I., Timofeyeva, N.I., Atomnaya energiya [Atomic Energy], 1963, Vol. 14, No. 6; Filyand, M.A., Semenova, Ye.I., Svoystva redkikh elementov [Properties of the Rare Earths], Moscow, 1964; Nucleonics, 1962, Vol. 20, No. 8; Karl, A., in collection: The Rare Earths, New York – London, 1961; Rare Metals Handbook, ed. Clifford A. Hampel, 2nd Edition, New York, 1961; Handbook of Chemistry and Physics, Cleveland, 1962.

K.I. Portnoy

**RASCHIG FLUIDITY** – indicator of the capability of thermosetting molding compositions to fill the mold upon reprocessing. It is determined (GOST 5689-60) in a special mold into which 7.5 or 10 g of the material is loaded and compressed at 150 ± 2° and a pressure of 300 ± ± 5 kg/cm$^2$ for 3 minutes. The measure of fluidity is the length of a densely pressed rod, expressed in mm.

M.S. Krol'

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[Transliterated Symbols]

3352 ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = All-Union State Standard

RAY-PATH DIFFERENCE – the difference in the optical lengths of the paths (the products of the path lengths by the corresponding indices of refraction for the media traversed) of two light rays with the same points of origin and termination.

L.S. Priss

REALGAR – a mineral of the sulfide class, arsenic monosulfide, AsS (70.08% As). It has a specific gravity of 3.24-3.56 and a Moos hardness of 1.5-2 (can be cut with a knife) and is brittle and toxic. Realgar varies in color from flame-red to orange-yellow; it becomes orange after ultraviolet irradiation for 20 hr and carmine-red after radium irradiation (14 days). This mineral is transparent and has a resinous to greasy lustre. It is usually encountered in crystals (monoclinically syngonic), granular and compact aggregates, incrustations, impregnations, and powdery accumulations. Realgar breaks down under the action of sunlight or atmospheric oxygen, being converted to an orange powder; it is stable at temperatures of up to 200-250° in darkness when no air is supplied, but decomposes at 300°. This mineral has a melting point of 307-314-320°, can be completely volitalized, and has a boiling point of 565-760°; its heat of formation is 40.3 kcal (80 kilojoules). Realgar is electrically nonconductive (in light and darkness). Its comparative photoelectric capacity is as follows:

| Wave length of light (μ) | 440 | 480 | 520 | 550 | 560 | 580 | 600 |
|---|---|---|---|---|---|---|---|
| Photoelectric capacity | 0 | 15 | 840 | 1360 | 1260 | 575 | 200 |

Realgar has a dielectric constant of 7.6. Its vapor density at different temperatures is 19.6 (450°), 18.5 (503°), 15.9 (513°), 13.89 (574°), 7.51 (100°), and 6.95 (2000°).

Realgar does not luminesce in cathode rays, but pulse conductivity is excited when it is subjected to α-irradiation. This material is

stable at temperatures of up to 70° in pure distilled water. It decomposes and releases sulfur when treated with $HNO_3$ or aqua regia, does not wholly dissolve in heated alkalies (leaving a dark brown residue), and is slightly soluble in carbon bisulfide and benzine, especially at high temperatures. Realgar is resistant to KCN, HCl, $FeCl_3$, and $HgCl_2$. When exposed to chlorine it forms a yellow (low % of chlorine) or brownish (high % of chlorine) liquid; aqueous bromine solutions oxidize this mineral to arsenic acid. Realgar is produced synthetically by melting together As and S in a ratio of 1:1.

Realgar is an important raw material for the production of $As_2O_3$ and metallic arsenic and is used as an additive to increase the hot strength of copper and in the manufacture of lead shot, certain typographic alloys, and arsenic-cadmium babbitt. $As_2O_3$ is used in photocells, as a decolorizing agent in the glass industry, in the dyestuffs industry (for cotton dyes), in pyrotechnics, as a depilatory (hair remover) in the leather industry, as a preservative in the manufacture of leather and furs and in taxidermy, and as an agricultural pesticide (to combat insects and rodents).

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V.I. Magidovich

REBINDER EFFECT – the physicochemical influence of media on the mechanical properties of materials, independent of corrosion, dissolution, and other chemical processes. This effect takes the form of a decrease in strength and facilitation of elastic and plastic deformation under the influence of adsorption (absorption of molecules from the surrounding medium by the surfaces produced in the deformed body). The Rebinder effect occurs in metallic monocrystals and polycrystals, semiconductors, ionic crystals, concretes, glass, rocks, etc. Its magnitude depends on the temperature, stress, loading method, composition and structure of the material and, to a large extent, the loading time. This phenomenon is most manifest when the new surfaces produced during prefracture deformation are covered with adsorption layers, which occurs during Creep under prolonged static stress and during Fatigue. The Rebinder effect is considerably attenuated when we move from monocrystalline to polycrystalline metals, since the facilitation of deformation is concentrated in the superficial layers and does not extend into the depth of the body. Molten media with a molecular structure similar to that of the deformed body cause the greatest decrease in the surface energy of a material; this occurs, for example, if high-melting metals and alloys are stressed in a medium consisting of molten lower-melting metals (specifically, the presence of a mercury film on zinc monocrystals reduces their strength and plasticity by a factor of several tens). The Rebinder effect is offten detrimental to structural materials, since it lowers their strength and plasticity. This phenomenon is useful for facilitating cutting and for accelerating and

improving running-in under friction. Protecting the surface of a component from the action of the surrounding medium (e.g., with organic coatings) may increase its strength.

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Ya.B. Fridman

THE RECOVERY PHENOMENON IN ALUMINUM ALLOYS – see Aging of Aluminum Alloys.

RED COPPER are alloys of copper containing tin, zinc and lead, having a characteristic red color, and also the cast tin brozes ("red casting") containing no less than 78% Cu, 4 – 10% Sn, to 10% Zn, to 5% Pb and no more than 2% other additives. With regard to usage, the red coppers have been divided into chemical bronze (decorative), mechanical-technological (gun), acoustic (bell), and optical (mirror). Today copper is used inelectrical engineering and for decorative casting.

O.K. Kestner

**REFINING OF ALUMINUM ALLOYS** – removal of metallic or nonmetallic inclusions during smelting of the metal. Gaseous and solid inclusions (see Aluminum) are removed by treatment with special fluxes, chlorine (see Chlorination of aluminum alloys), or nitrogen (see Nitriding of aluminum alloys) or by addition of zinc or manganese chloride or other halides. All these methods are absorptive in character. Vacuum refining for 5-10 min (P = 0.1-0.5 mm Hg) is a very promising technique, while treatment of the molten metal with ultrasound is highly effective. In contrast to the absorptive methods, in vacuum and ultrasonic refining the equilibrium of the metal-gas-oxide system is disrupted throughout the entire melt volume, a process facilitated by the fact that nonabsor ed metals are more active than adsorbed metals. Refining efficiency can be increased by combining two methods, e.g., the vacuum technique and simultaneous superficial application of an active refining flux. Iron is removed by permitting the molten metal to stand in the presence of manganese at a temperature 20-30° above the melting point. Vacuum sublimation is employed for removal of zinc.

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licheskikh vklyucheniy iz alyuminiyevykh splavov [Methods for Removing Gases and Solid Nonmetallic Inclusions from Aluminum Alloys], Moscow, 1959.

M.B. Al'tman

REFINING OF BRASS – removal of detrimental metallic and nonmetallic impurities during smelting of the metal. Brass cannot be refined by oxidation of detrimental impurities, since it contains zinc, which has a greater affinity for oxygen than the impurities. The detrimental effect of low-melting impurities (Pb, Bi), which reduce the plasticity of hot brass, can be attenuated or neutralized by introduction of special additives (Ca, Ce, Li) that form high-melting compounds with the impurities and remove impurities from the grain boundaries. During the most common smelting procedure, smelting in low-frequency iron-core furnaces, brass is freed of gaseous impurities (hydrogen) by superheating the molten metal in the furnace channel, which is accompanied by release of zinc vapor from the melt.

A decrease in the zinc content of brass reduces its vapor tension, so that, in order to remove dissolved gases and to curtail somewhat the smelting time, the zinc should be introduced at the beginning of the smelting process, after the molten metal has cooled slightly; this is done by adding part of the brass scrap.

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A.V. Bobylev

REFINING OF BRONZE – removal or reduction in content of detrimental nonmetallic and metallic impurities during smelting of the metal.

The most detrimental and readily oxidized impurities in tin bronzes, aluminum and silicon, are removed by oxidative smelting (in reverberatory furnaces) or by addition of oxidizing agents (oxides of copper, lead and zinc, manganese peroxide, sodium and potassium nitrates, etc.) to the charge. The oxidized impurities are extracted from the molten metal by treatment with fluxes (borax, a glass-borax mixture, soda ash, fluorspar, etc.). Aluminum is removed from tin-lead bronzes with cupric oxide, 4% of which is added for each 1% of aluminum; cupric oxide mixed with sodium chloride (50:50) is used to extract silicon. When zinc oxide is used for this purpose 6% is added for each 1% of aluminum and mixed with the metal for 3-5 min at a temperature of 1200°. After the impurities have been oxidized a slagging flux (soda ash) is added to a total of 0.5% of the charge weight and thoroughly mixed with the metal. The slag is removed after 10-15 min and the alloy is acidified with copper phosphide added to a total of ~0.3% of the charge weight. Only phosphorus forms liquid products during the reduction of bronze, readily floats on the surface of the melt, and can be completely removed from the alloy.

Sulfur impurities are easily extracted with sodium carbonate. Cover fluxes, which keep the metal from burning off, make it possible to remove certain impurities simultaneously. Thus, a flux consisting of 40% fluorspar, 40% dry quartz sand, and 20% soda ash removes sulfur and, to some extent, iron from bronze. This flux is added to a total

of 1% of the charge weight and keeps zince, copper, etc. from burning off. When remelting chips the flux should be introduced at the same time as the charge, this facilitating rapid melting and partial removal of detrimental impurities. Mixtures of sand, soda, and calcium fluoride (e.g., 645 g of sand, 420 g of soda, and 100 g of $CaF_2$), of broken glass and sodium chloride (50:50), or of soda and calcium fluoride (50:50), as well as borax, cryolite, etc. are used as cover fluxes.

Oxides can also be removed by adding purifiers – salts which form gases in the molten metal; these are most frequently chlorides. Solid oxide films are removed by the floatation method. Thus, in order to free aluminum bronze of excess aluminum oxides moisture-free zince chloride is added to a total of 0.05% of the charge weight. The action of this compound on aluminum bronzes is similar to its action on aluminum alloys.

Dissolved gases can also be removed from the metal (de-gasification) with chlorides ($ZnCl_2$, $MnCl_2$) or by creating a vacuum (1-20 mm Hg) over the molten metal.

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O.Ye. Kestner

REFINING OF MAGNESIUM ALLOYS – removal of detrimental nonmetallic and metallic impurities during smelting of the metal. Nonmetallic impurities (oxides, nitrides, etc.) are removed by treatment with fluxes; as a result of the difference in specific gravities the impurities settle to the bottom of the bath when the molten metal is permitted to stand. Flux treatment is carried out at 720°. Fluxes are selected in such fashion that nonmetallic inclusions are better wetted by the flux than the metal, i.e., the interphase tension at the metal-oxide boundary should be higher than that at the flux-oxide boundary. The interphase tension at the metal-flux boundary should be reduced to the limit below which the flux adheres to the alloy and contaminates castings with flux inclusions. Refining can be carried out with a single flux in a smelting furnace, applying to the surface of the molten metal a flux such as BI2, which contains 38-46% $MgCl_2$, 32-40% KCl, 5-8% $BaCl_2$, 3-5% $CaF_2$, no more than 10% $CaCl_2$ + NaCl, and 3% $H_2O$. The cover flux has a composition such as 29.5% $MgCl_2$, 26.8% KCl, 2.5% NaCl, 7.6% $CaCl_2$, 19.4% $CaF_2$, 6.4% MgO, and 7.8% $H_2O$. The higher the specific gravity of the flux, the lower its surface activity with respect to the alloy, the higher the melting temperature, and the longer the settling time, the more completely are suspended chlorides and oxides removed from the molten metal. The flux consumption amounts to 1-1.5% of the weight of the moleten metal.

Magnesium alloys are freed of gases (degasified) by treatment with inert gases, nitrogen, or chlorine in order to reduce the formation of micropores in the castings and to curtail the loss of zircon-

ium during alloying.

Magnesium near its melting point dissolves 18-20 $cm^3$ of hydrogen per 100 g of metal. Solubility increases with temperature, following the equation

$$\lg S = -631\,T^{-1} + 2{,}390 + \tfrac{1}{2}\lg P.$$

The solubility of hydrogen in the liquid metal varies from 20 to 40 $cm^3$, depending on the composition of the magnesium alloy; thus, for example, the amount of hydrogen which dissolves in 100 g of molten ML5 alloy is determined from the equation: $\lg S = -680T^{-1} + 2.388 + \frac{1}{2}\lg P$. Hydrogen forms a solid solution of the intersticial type with magnesium and magnesium alloys. The solubility of hydrogen in commercial magnesium alloys depends on their phase composition. It is less soluble in nonheat-treated or aged multiphase alloys than in quenched monophase alloys. Under certain conditions hydrogen dissolved in the molten metal increases the microporosity of castings, while, when present in large quantities, it increases the zirconium wastage in magnesium-zirconium alloys. When an inert gas is passed through the molten metal the gases dissolved in the alloy diffuse into the inert gas and are released into the atmosphere. The amount of inert gas needed for degasification depends on the depth of the bath and the hydrogen content of the alloy. The inert gas is forced through the alloy at 740-750°; the flow rate should be such as to provide intensive aggitation without spattering the alloy onto the walls and lid of the furnace, while the flow time should be no more than 30 min, since prolonged degasification causes a slight increase in the grain size of the alloy and a decrease in its mechanical properties. Good results are obtained by passing an inert gas mixed with carbon tetrachloride ($CCl_4$) through the molten metal, using 80-100 $cm^3$ of $CCl_4$ for each 200-300 kg of alloy. Passage of active gases (nitrogen and chlorine) through the metal pro-

duces magnesium nitrides and chlorides. Nitrogen is forced through the melt at 660-680°. The alloy is refined and modified after degasification. Formation of magnesium chloride (which is solid below 715° and liquid at higher temperatures) leads to dilution of the flux and increases the danger of flux inclusions in the castings. Treatment with chlorine is carried out at 740-760°; varying the rate at which the gas is forced through the molten metal from 2.5 to 8 liters/min has no noticeable effect on the grain size or mechanical properties of the alloy, provided that the chlorine content does not exceed 3% of the weight of the molten metal. Degasification and modification can be combined by treating the metal with a mixture of chlorine and carbon tetrachloride (1-1.5% Cl + 0.25% $CCl_4$, with respect to melt weight). In some cases degasification is replaced by addition of calcium to bond the hydrogen. The calcium does not reduce the hydrogen content of the alloy, but apparently forms stable hydrides; this process increases the density of the castings.

Magnesium alloys are freed of metallic impurities (iron) by precipitation in the presence of manganese. For this purpose manganese is added to the molten magnesium or alloy at 800° in the maximum quantity soluble at this temperature (4.5% for magnesium) and the melt is held at 700° for 20-30 min (until the solubility of the manganese decreases). As a result, the excess manganese, first crystallized and extracted by specific gravity, removes the iron. This type of refining may reduce the iron content to thousandths of a per cent, thus substantially increasing the corosion resistance of the alloy. Addition of zirconium or cerium has a similar effect on impurities of iron and silicon. Alloys containing zirconium are consequently not refined to free them of iron and silicon. Alkali metals (potassium, sodium) and calcium are removed by a bulk reaction with magnesium chloride ($2K + MgCl_2 = 2KCl +$

+ Mg), which is added to the molten metal in the flux.

A.A. Lebedev

REFRACTORY COMPOUNDS – compounds of metals with boron (see Borides), carbon (see Carbide), nitrogen (see Nitride), silicon (see Silicates), with oxygen (see Refractory Oxides). Refractory compounds are divided into two basic groups: metallic and nonmetallic. Refractory compounds in their turn are divided into oxygen and oxygen-less.

The first group includes refractory compounds of transition metals (titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten, manganese, rhenium, metals of the iron group, platinoids, rare-earth and actinium metals) and alkaline earth metals. All of them have a high thermal and electrical conductivity, have hardness, high melting temperatures (up to 3900°), weak paramagnetic properties. The thermal expansion coefficients of these compounds are lower than of the corresponding metals. All the metallic refractory compounds are highly resistant to oxides, heated aggressive gases, molten metals and salts. Metallic carbides are by many of their properties similar to metals: they have a simple crystal lattice, in a majority of cases similar to that of solid interstitial solutions, for which reason they are called interstitial phases.

Nonmetallic, nonoxygen refractory compounds, i.e., boron and silicon carbides and nitrides, boron-silicon alloys, have, in the overwhelming number of cases, a complex crystal lattice with melting temperatures up to 3000°. Below the melting temperature they usually decompose or melt with attendant decomposition, have a high thermal stability, low thermal expansion coefficients, high electrical resistivity, which is characteristic of semiconductors. Certain nonmetallic re-

fractory compounds (boron and silicon nitrides) have dielectric properties. Silicon nitride, boron and silicon carbides have a quite high hardness while boron nitride has a very low hardness. Nonmetallic refractory compounds also resist the effect of molten chemical reagents, molten salts and metals.

Refractory compounds, in addition to the two main groups, also include certain intermetalloids, sulfides, phosphides, as well as chemical compounds of beryllium, aluminum and magnesium with boron, carbon, nitrogen and silicon, which have a melting temperature up to 2500°.

References: Samsonov, G.V. and Umanskiy, Ya.S., Tverdyye soyedineniya tugoplavkikh metallov [Solid Compounds of Refractory Metals], Moscow, 1957; Samsonov, G.V. and Portnoy, K.I., Splavy na osnove tugoplavkikh soyedineniy [Refractory-Compound-Based Alloys], Moscow, 1961.

K.I. Portnoy

REFRACTORY METALS – transition metals of the V and VI group of Mendeleyev's periodic table, having the maximum melting temperature (within their periods). Metals with particularly high melting temperatures are W (3410°), Ta (2996°), Mo (2622°) and Nb (2500°). These metals are extensively used and form the so-called "big four." Refractory metals also include Re, which is a metal of the VII group of the periodic system with $t°_{pl}$ of 3160° and Cr (1910°). Metals in the V and VI periods with a very high $t°_{pl}$ are those of the VIII group, Ru (2250°), Rh (1960°), Pd (1552°), Os (3000°), Ir (2410°) and Pt (1769°). These metals are called the platinum metal group.

A.S. Stroyev

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[Transliterated Symbols]

3371 пл = pl = plavleniye = melting

REFRACTORY OXIDES – high-temperature metal-oxygen compounds. Oxygen refractory compounds differ from refractory metal type (oxygenless) compounds by the kind of the bound, higher chemical resistance and high-temperature corrosion resistance in a wide temperature range, lower values of thermal and electrical conductivity and other properties. Refractory oxides are the subject of attention of designers, since these

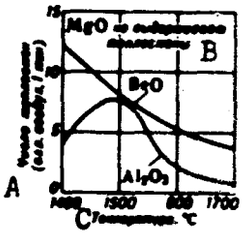



Fig. 1. Temperature dependence of the thermal stability of refractory oxides. A) Number of heat changes (cooling air, 1 min); B) cannot withstand heat changes; C) temperature, °C.

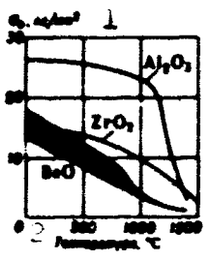



Fig. 2. Change in the rupture strength as a function of the test temperature. 1) kg/mm$^2$; 2) temperature, °C.

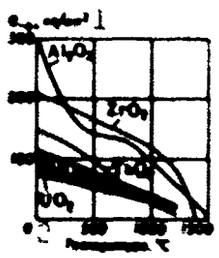



Fig. 3. Change in the compression strength as a function of the test temperature. 1) kg/mm$^2$; 2) temperature, °C.

materials possess a set of properties of importance for modern technology, which are retained to relatively high temperatures.

TABLE 1

Physical Properties of Refractory Oxides*

| 1 Свойства | $Al_2O_3$ | BeO | $HfO_2$ | MgO | ThO | $UO_2$ | $ZrO_2$ |
|---|---|---|---|---|---|---|---|
| 2 Молекулярный вес | 101,96 | 25,01 | 210,59 | 40,31 | 264,06 | 270,03 | 123 |
| 3 Кристаллическая структура | Ромбоэдрическая Гексагональная Кубич. | Гексагональная | Моноклинная Тетрагональная Гексагональная Кубич. | Кубич | Кубич | Кубич | Моноклинная Тетрагональная Кубич. |
| 4 Плотность | 3,97 | 3,025 | 9,68 | | | | |
| 5 | 2050±5 | 2550 | 2850 | 2800 | | | |
| 6 | 2568 | 4200 | | 3500 | 4400 | 4100 | 5100 |
| 7 | 8,5 (20–1000°) 0,0723 | 10,6 (20–1700°) | 6,65 (20–1700°) 0,0839 | 13,5 (20–1700°) 0,086 1,736 | 10,2 (25–1700°) 0,0826 2,15 | 9,2 (27–1000°) 0,0819 | 7,7 (20–1000°) 0,0864 2,152 |
| 8 | $N_g$=1,768 $N_p$=1,760 | $N_g$=1,719 $N_p$=1,717 | | | | | |
| 9 | 9·10 (700°) 9·10⁻¹ (1000°) 9·10⁻¹ (1200°) 1·10⁻¹ (1600°) | 2·10⁻¹ (20°) 6·10⁻² (1000°) 7·10⁻² (1200°) 3·10⁻² (1600°) 2·10⁻² (2000°) | 1·10⁻¹ (70°) 1·10⁻¹ (900°) 1·10⁻¹ (1100°) 1·10⁻¹ (1300°) | 1·10⁻¹ (70°) 6·10⁻² (1300°) 6·10⁻² (1500°) 1·10⁻² (1900°) 2·10⁻² (2100°) | 2·10⁻¹ (1000°) 7·10⁻² (1220°) 1·10⁻² (2700°) | 3·10⁻² (20°) 1·10⁻² (1300°) 7·10⁻³ (1600°) 2·10⁻³ (2000°) 2·10⁻³ (2600°) | 1·10⁻² (900°) 2·10⁻³ (1100°) 1·10⁻³ (1300°) 1·10⁻³ (2100°) |
| 10 Давление паров (мм рт. ст.) | 6·10⁻⁷ (1900°) 3·10⁻⁶ (2000°) 3·10⁻⁵ (2200°) 2·10⁻⁴ (2300°) | 1·10⁻⁷ (1900°) 1·10⁻⁶ (2000°) 1·10⁻⁵ (2100°) | | | | | |

*The $t^\circ_{pl}$ given here are the most reliable.

**For a temperature of 200°.

***With an admixture of 4-13% MgO.

1) Properties; 2) molecular weight; 3) crystalline structure; 4) rhombohedral; 5) monoclinic; 6) cubic; 7) hexagonal; 8) tetragonal; 9) face centered; 10) density (g/cm³); 11) pl; 12) kip; 13) cal/cm-sec-°C; 14) refraction index; 15) (ρ ohm-cm); 16) vapor pressure (mm of Hg).

TABLE 2

Change in the Thermal Conductivity of Oxides as a Function of Density and Temperature

| 1 Оксид | 2 Плотность (г/см³) | 3 Пористость (%) | 4 λ (кал/см·сек·°С) 100° | 200° | 400° | 600° | 800° | 1000° | 1200° | 1400° | 1600° |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Al_2O_3$ | 5 Теорет. 3,97 6 Опыты 3,69–3,79 | 6,5–7,3 | 0,0224 0,0690 | 0,0338 0,0508 | 0,0316 0,0308 | 0,0218 0,0208 | 0,0172 0,0166 | 0,0145 0,0140 | 0,0132 0,0126 | 0,0121 0,0125 | 0,0163 0,0136 |
| BeO | Теорет. 3,01 Опыты 2,7–2,96 | 1,67–6,95 | 0,525 0,350 | 0,417 0,298 | 0,222 0,211 | 0,152 0,107 | 0,0665 0,0615 | 0,0585 0,0462 | 0,0512 0,0393 | 0,0471 0,0372 | 0,0362 0,0316 |
| MgO | Теорет. 3,58 Опыты 3,55–3,48 | 0,8–8,1 | 0,0823 | 0,0671 0,0465 | 0,0396 0,0377 | 0,0275 0,0263 | 0,0203 0,0194 | 0,0187 0,0160 | 0,0166 0,0160 | 0,0164 0,0156 | 0,0166 0,0172 |
| $UO_2$ | Теорет. 10,96 Опыты 10,7 | 0,7 | | 0,0191 0,0142 | 0,0138 0,0103 | 0,0105 0,0079 | 0,0088 0,0066 | 0,0081 0,0061 | – | – | – |
| $ThO_2$ | Теорет. 9,99 Опыты 9,32 | 6,75 | 0,0265 0,0246 | 0,0204 0,0164 | 0,0143 0,0112 | 0,0114 0,0087 | 0,0081 0,0068 | 0,0073 0,0061 | 0,0059 0,0050 | – | – |
| $ZrO_2$ | Теорет. 6,1 Опыты 5,22–5,35 | 12,9–14,4 | 0,0168 0,0161 | 0,0146 0,0141 | 0,0069 0,0062 | 0,0053 0,0043 | 0,0052 0,0045 | 0,0054 0,0047 | 0,0052 0,0049 | – | – |

1) Oxide; 2) density (g/cm³); 3) porosity (%); 4) λ (cal/cm-sec-°C); 5) theoretical; 6) experimental.

In modern designs operating under high dynamic and thermal loads, refractory oxides are used in a number of cases in limited quantities,

due to the low values of impact ductility (0.03-0.08 kgm/cm$^2$) and low thermal stability.

In addition to simple refractory oxides (formed by one metal), use is made in equipment of compound oxides, consisting of two different metal oxides in the form of solid solutions or chemical compounds (aluminates, chromites, phosphates, silicates, titanates and zirconates).

TABLE 3

Thermodynamic Properties of Refractory Oxides

| Окисел 1 | Теплота образования 2 | Энтропия 3 | Теплоемкость $c = a + b \cdot T \cdot 10^{-3} + c \cdot T^{-2} \cdot 10^{5}$ (кал/моль·град) 4 | | | | $c_{298.15}$ (кал/моль·град) 7 |
|---|---|---|---|---|---|---|---|
| | $-\Delta H$ (ккал/моль) 5 | $S^\circ$ (кал/моль·град) 6 | a | b | c | °K | |
| $Al_2O_3$ | 400.4 | 12.2 | 27.38 | 3.08 | −8.20 | 298–1800 | 17.98 |
| BeO | 143.1 | 3.37 | 8.45 | 4.00 | −3.17 | 298–1200 | 6.08 |
| $HfO_2$ | 266.0 | 14.2 | 17.39 | 2.08 | −3.48 | 298–1800 | 14.09 |
| MgO | 143.7 | 6.44 | 10.18 | 1.74 | −1.48 | 298–2100 | 9.04 |
| $ThO_2$ | 293.2 | 15.6 | 15.84 | 2.88 | −1.60 | 298–1800 | 14.90 |
| $UO_2$ | 259.2 | 18.63 | 19.20 | 1.62 | −3.96 | 298–1500 | 15.23 |
| $ZrO_2$ | 259.5 | 12.1 | 16.64 | 1.80 | −3.36 | 298–1478 | 13.39 |

1) Oxide; 2) formation temperature; 3) entropy; 4) specific heat (cal/mole-degree); 5) $-\Delta H$ (kcal/mole,; 6) $S^\circ$ (cal/mole-degree); 7) $c_{298.15}$ (cal/mole-degree).

Refractory oxides are successfully used in very critical designs, where the main importance is taken on by refractoriness, chemical inertness, structural stability, and the existing metals cannot be used. To ensure rupture strength of these materials under thermal loads, and

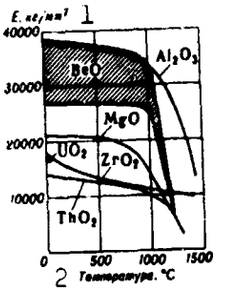



Fig. 4. Change in the modulus of elasticity as a function of the temperature. 1) kg/mm$^2$; 2) temperature, °C.

also under a large temperature gradient along the product thickness, it

is necessary to select refractory oxides with a low modulus of elasticity, low thermal expansion and, as far as possible, with high thermal conductivity and strength.

Thermal stability is a very important characteristic of a material, determining the feasibility of using it in designs. This is particularly true with respect to brittle refractory compounds (oxides, borides, carbides, etc.)

Thermal stability depends on the strength, elasticity, thermal conductivity, etc., and also on the shape and dimensions of components and on the temperature gradient. It can be seen from Fig. 1 that BeO is the most thermally resistant oxide.

The more important properties of refractory oxides are presented in Tables 1-3 and Figs. 1-4.

The majority of refractory oxides belongs to the insulator class, while $UO_2$ is a semiconductor with a mixed conductivity. Oxides have a high electrical resistance and have a high compatibility with many materials at high temperatures (up to the melting temperature). Together with this, each refractory oxide has its own peculiar features.

$\alpha$-$Al_2O_3$ has a rhombohedral lattice. Another form – $\gamma$-$Al_2O_3$ with a spinel-type lattice, etc., is also known, but they are not theremodynamically stable and can exist in a limited temperature range. As a result of heating to 1500-1600° $\gamma$-$Al_2O_3$ is transformed into the $\alpha$ form.

The melting temperature of $Al_2O_3$ varies within the limits of 2000-2050°* $Al_2O_3$ belongs among the most chemically resistant oxides, has higher strength properties than other oxides (Figs. 2-4). $Al_2O_3$ has a low vaporization rate, is resistant in air up to 2000°, but slowly dissociated in vacuum at a temperature of ~1800° and above. Products from $Al_2O_3$ can be made with various porosities. Foam corundum, i.e., porous sintered $Al_2O_3$, which is obtained by adding foam-forming agents into

pure $Al_2O_3$ dross, has acquired importance in the last few years.

Properties of this foam corundum with a density of 0.66-0.74 $g/cm^3$ are as follows: total porosity 81.83%, pore size 1.2-4.5 microns, compression strength 63-68 $kg/cm^2$, working temperature up to 18 0°. At low temperatures and a pore volume of 83% the thermal conductivity of foam corundum is several-fold lower than that of dense $Al_2O_3$. $\lambda$ for foam corundum comprises 0.008 cal/cm-sec-°C, while $\lambda$ for densely sintered corundum is ~0.062 cal/cm-sec-°C. This material is used as refractory (nonconsumable) heat insulation and is good electrical insulation material at high temperatures. $Al_2O_3$ is used in making insulators for aircraft engine spark plugs, chemical apparatus, as cores for hollow blades of jet engines, in the production of gages and cutting tools, etc.

BeO has a hexagonal structure. Unlike other refractory oxides it is a good heat conductor and electrical insulator. BeO at low temperatures exceeds all the oxides and the majority of metal by its thermal conductivity, while at high temperatures its thermal conductivity drops sharply (Table 2). A perceptible vaporization in a vacuum starts with 2100°. Above 1650° it is unstable in water vapor. BeO is toxic. The high melting temperature (2450-2570°), chemical inertness and high-temperature corrosion resistance, relatively high thermal stability, small cross section of thermal neutron capture, and other properties have made BeO one of the few very effective neutron moderators for power-producing nuclear reactors operating at high temperatures in an oxidizing atmosphere.

The properties of BeO and other refractory oxides depend to a substantial extent on the density. In Figs. 2-4 the mechanical properties of BeO are represented by the cross-hatched area. The minimum values of $\sigma_b$ and E pertain to a density of 2.7 $g/cm^3$, while the maximum values

are for a density of 3.0 $g/cm^3$.

$HfO_2$ exists in three crystalline forms: with a monoclinic structure, which is stable up to 1700°, with a tetragonal structure which forms upon heating to 1700-1865° as a result of a irreversible polymorphous transformation, and with a face-centered cubic lattice which crystallizes upon adding moderate quantities of oxides (Mg, Ca, Mn, etc.) at above 1500°. The melting temperature is 2810-2900°. $HfO_2$ is a strong refractory compound and is used as a refractory and wear-resistant material in metallurgy and radioelectronics. The ability of hafnium to produce decay-product isotopes makes it possible to use $HfO_2$ as a slowly-consumed neutron absorber for high-temperature operation.

MgO has a cubic structure, does not undergo crystalline transformations and belongs to the most extensively prevalent refractory oxides. The melting temperature is 2800-2950°. The vapor pressure becomes perceptible at above 1600-1700°, for which reason products from MgO cannot be used under a vacuum above the aforementioned temperature. It is used in a reducing atmosphere up to 1700°.

The feature distinguishing MgO from other refractory oxides is the fact that its thermal expansion is the greatest, which is used in electronic vacuum instruments.

$ThO_2$ has a cubic structures, does not undergo crystalline transformations on heating. It is the most refractory oxide ($t°_{pl}$ = 3050-3300°) and the most chemically stable when reacting with other minerals at high temperatures. $ThO_2$ is used as a material for crucibles used in induction melting of refractory and rare metals, it is distinguished by a high thermal expansion coefficient and, in comparison with other refractory oxides, by a lower thermal conductivity, which makes it exceptionally sensitive to thermal stresses. From among all the refractory oxides $ThO_2$ has the poorest thermal stability, its thermal conductivity

at 100° and 1200°, respectively, comprises ~0.02 and 0.005 cal/cm-sec-°C. Thorium dioxide is not oxidized in air. To obtain dense products they are sintered in an air medium at ~1800° for 2 hours. $ThO_2$ has a low vapor pressure, perceptible vaporization in vacuum starts at temperatures in excess of 2300°, it is toxic. Its inertness to many metals at high temperatures and other properties makes it an indispensable material in high-vacuum special apparatus. It is used not only as an intermediate product in the production of metallic thorium, but also as a nuclear fuel.

$UO_2$ has a cubic structure, $t°_{pl}$ = 2760-2880°. Products from $UO_2$ can operate in neutral and reducing atmospheres. For example, uranium dioxide is stable in a hydrogen atmosphere up to the melting temperature. Compact $UO_2$ specimens are compatible with other oxides ($Al_2O_3$, MgO, BeO) up to 1800° and have a low oxidation rate in air at room temperature and in water with high parameters (degassed water). The thermal conductivity of $UO_2$ is lower than that of other refractory oxides (with the exception of $ZrO_2$) and to a substantial extent depends on the material's porosity; $UO_2$ is toxic.

The high chemical and structural stability of $UO_2$ as well as the feasibility of obtaining higher operating temperatures of the heat generating elements in nuclear reactors when using $UO_2$ (in comparison with metallic uranium) have served as the cause for the extensive use of $UO_2$ in nuclear engineering.

$ZrO_2$ exists in three crystalline forms: cubic, tetragonal and monoclinic, $t°_{pl}$ of zirconium dioxide is 2600-2850°.

When heated, $ZrO_2$ undergoes polymorphic transformations. Its monoclinic form is stable up to 1000°, while at higher temperatures it is transformed into the tetragonal form which is stable up to 1900°. This transformation involves volume changes and destruction of products.

Hence stabilized $ZrO_2$ of the cubic form is used in equipment.

$ZrO_2$ is chemically resistant, inert to many metals at high temperatures, has comparatively high mechanical properties and resistance to oxidizing atmospheres. $ZrO_2$ belongs to semiconductor materials and is a good insulator at high temperatures and an electric current conductor at high temperatures. The thermal conductivity depends to a substantial extent on the density. For example, with a porosity of 7-10% and temperatures of 500, 700 and 1000° the thermal conductivity is, respectively: 0.0042, 0.0044 and 0.0047 cal/cm-sec-°C, while for a porosity of 28% the thermal conductivity is reduced substantially and for the same temperatures it is equal, respectively, to 0.00175, 0.0018 and 0.0020 cal/cm-sec-°C.

Porous foamy $ZrO_2$ has high heat insulating characteristics. The specific weight comprises 1.35 g/cm$^3$ with the thermal conductivity equal to 0.0007-0.0014 cal/cm-sec-°C. With respect to insulating properties it is better than foamy $Al_2O_3$ and can operate at 2200° and above. $ZrO_2$ is used in furnaces for melting heat-resistant glass, in the production of glass fiber, in the metallurgical industry for lining reverberatory and high-temperature induction and gas furnaces, as well as for making crucibles for melting chromium and noble metals.

Refractory oxides are most extensively used in radio equipment, metallurgical, chemical, nuclear and other branches of industry, as well as for rockets and space vehicles.

For properties of BeO see Beryllium Oxide.

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[Footnotes]

Limits of the melting temperature of refractory oxides characterize the admixture content.

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[Transliterated Symbols]

3373 пл = pl = plavleniye = melting

3373 кип = kip = kipeniye = boiling

REFRAKTALOY – see Nickel-iron-cobalt-chromium shaping alloys.

REINFORCED LINEN – cut and ruled fabric (GOST 2198-43) manufactured from brass wire and coarse asbestos linen, twisting the two into a thread. It is used in the production of motors for packings which must function at temperatures of up to 150°. The linen is 0.6, 0.7, and 1.1 mm thick and no less than 500 mm wide; each piece is no less than 1500 mm long. Its distendability when soaked at 20° for 24 hr is no more than 30% in water, 32% in type C machine oil, and 22% in "kalosh" gasoline. According to the data of VNII [All-Union Scientific Research Institute for Asbestos Technical Products, the tearing strength of this linen is 70 $kg/cm^2$ along the warp and 200 $kg/cm^2$ along the woof. The residual shrinkage along the thickness of the cloth is ~17% under a load of 250 $kg/cm^2$ and ~27% under a load of 500 $kg/cm^2$. The loss when the fabric is roasted at 700° is ~20%. Packings of reinforced linen should be elastic; they do not cause corrosion when they come into contact with aluminum alloys, steel, or cast iron. When corrosion occurs the thickened area is easily removed and does not exfoliate.

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REINFORCED PLASTIC FOAMS – load-bearing structural materials consisting of alternate layers of plastic foam and plywood, plastic, or metal reinforcement.

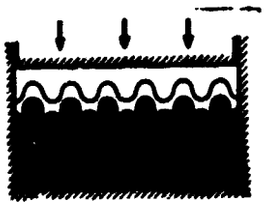


Fig. 1. Arrangement of corrugated material and plastic foam in the manufacture of reinforced plastic foam of the honeycomb type.



Fig. 2. Arrangement of sheet reinforcing material and plastic foam before pressing: 1) Sheet reinforcing material; 2) plastic-foam slab.

The following types of reinforced plastic foam are produced: honeycomb, in which the reinforcing walls of the cells, joined to one another to form a rigid framework, are filled with plastic foam (Fig. 1); laminar, in which the sheet reinforcing elements are glued to the foam (Fig. 2); wire-reinforced, in which the reinforcing wires are arranged in a definite geometric pattern to increase the rigidity and strength of the material (Fig. 3). In the honeycomb and laminar arrangements the foam and reinforcing sheets support one another, increasing the rigidity of the system and giving it characteristics not inherent in either of the initial materials. In order to make reinforced foams of the honeycomb type convenient for use in production processes, they are manufactured in large-size blocks, from which blanks for all types of components and structures are cut. The size of the rough block depends on the equipment at hand, the number of blanks required, and the requisite east of turning the block during lay-out and machining. Blocks of this type consist of corrugated plywood, textolite, getinaks, etc., produced by pressing or other methods and plas-



Fig. 3. Bundle before gluing to form blank: 1) Reinforcing wire; 2) plastic foam.

tic-foam blanks. The blocks are glued with VIAM B-3 glue under a pressure of 1-2 kg/cm$^2$. The holding time is 6-8 hr at room temperature and 2-3 hr at 50°. Blocks for reinforced foams of the laminar type consist of plastic-foam slabs (equal in thickness to the reinforcement spacing to be used) and sheets of reinforcing material. The resultant block is glued and subjected to the necessary machining (cut into sheets). Reinforced plastics are machined on ordinary wood-working equipment.

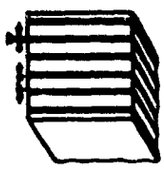


Fig. 4. Basic parameters of reinforced plastic foam: b) Thickness of reinforcing material; c) spacing of reinforcement.

The strength and rigidity of reinforced foams can vary in wide limits, depending on the reinforcement coefficient, K = b/c for reinforcement with plywood, delta-wood, glass textolite, or dural, where b is the thickness of the reinforcing material and c is the reinforcement spacing, or K = d/D for reinforcement with wire, where d is the diameter of the wire and D is the diameter of the foam surrounding it. Figure 4 shows the principal parameters of reinforced foams. Figure 5 shows the reinforcement systems used and the formulas employed to calculate the characteristics of reinforced foams.

The possibility of strengthening plastic foams by this material can be employed both to reinforce sheet facings applied to a filler and to create the internal sheet or wire framework necessary to give a product uniform load-bearing characteristics. The ability of sheets and wire embedded in plastic foam to function effectively under extension and compression makes it possible to produce rational designs with low weight and high strength and rigidity. Reinforced plastic foams used as fillers serve both as a load-bearing support for sheet facing materials and as an internal structural framework, performing a binding function.

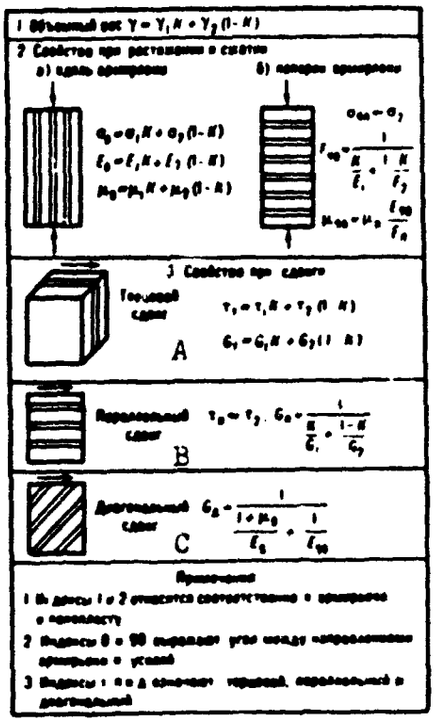


Fig. 5. Reinforcement of plastic foams and formulas for calculating the principal physicomechanical characteristics of reinforced foams. 1) Bulk weight; 2) characteristics on extension and compression; a) along reinforcement; b) across reinforcement; 3) characteristics on shearing; A) edgewise shear; B) parallel shear; C) diagonal shear.

Notes: 1) The subscripts 1 and 2 designate the reinforcement and foam respectively; 2) the subscripts 0 and 90 indicate the angle between the direction of the reinforcement and that of the forces; 3) the subscripts t, p, and d designate edgewise, parallel, and diagonal shear.

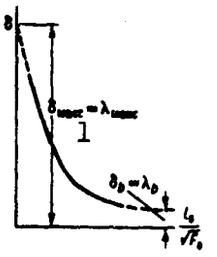
Reinforced plastic foams are widely employed as fillers for sandwich structures in aviation, ship building, construction, and other fields of technology.

M.Ts. Sikally

RELATIVE DEFORMATION – magnitude of deformation referred to a certain characteristic dimension, the initial (conventional deformation) or current (true deformation) [dimension].

N. V. Kadobnova

RELATIVE ELONGATION – one of the principal characteristics of plasticity of metals and alloys, which is obtained in tensile test; is designated by δ. It is defined as the ratio of the absolute residual elongation $\Delta l$ of the test part of a specimen after rupture to its original test length $l_0$ and is expressed in %. Relative elongation is a sum of two elongations – uniform and concentrated. As tht test length of a specimen is reduced the relative elongation increases, since the effect of concentrated deformation is increased (see figure). Hence the magnitude of relative elongation is always accompanied by a subscript, which indicates over which test length, a multiple of $\sqrt{F_0}$ ($F_0$ is the initial cross-sectional area of the specimen) the measurements are taken. Usu-




The relative elongation in tension δ as a function of $\frac{l_0}{\sqrt{F_0}}$.
1) Maks.

ally relative elongation is determined on test lengths of $l_0 = 10d_0$ and $l_0 = 5d_0$ for cylindrical specimens from 3 mm and more in diameter and $l_0 = 11,3\sqrt{F_0}$ and $l_0 = 5,65\sqrt{F_0}$ for flat specimens with a thickness from 0.5 mm and more (GOST 1497-61). Tests for cast specimens and from brittle metals may be performed over a test length of $l_0 = 2,82\sqrt{F_0}$. It is frequent practice abroad to determine the elongation over a test length of 50.8 mm (two inches).

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

Yu.S. Danilov.

Manuscript Page No.

[Transliterated Symbols]

3387 ГОСТ = GOST = Gosudarstvenny obshchesoyuznyy standart = All-Union State Standard

RELATIVE NECKING – the ratio of the decrease in specimen cross-sectional area to the initial cross-sectional area, usually expressed as a percentage: $\psi = \frac{F_0 - F_1}{F_0} \cdot 100\%$, , where $F_0$ is the pretest cross-sectional area and $F_1$ is the cross-sectional area at the test time under consideration. The final (terminal) relative necking $\psi_k = \frac{F_0 - F_k}{F_0}$ , or the greatest necking over the least neck area $F_k$ after fracture, characterizes the maximum tensile plasticity of the material. On true-stress curves the relative necking $\psi_k$ is the abscissa of the terminal point corresponding to the fracture resistance $S_k$. The final relative necking ($\psi_k$) is easy to determine for round specimens and very difficult to determine for rectangular specimens. As a rule, for rectangular specimens of plastic materials the value of $\psi_k$ (just as that of the elongation $\delta$) is somewhat less than for round specimens of equal cross-section; this difference increases with the ratio b/a, where b and a are the initial width and thickness of the specimen. The relative concentrated necking (see Concentrated necking) and uniform necking (see Uniform necking) are also determined during tensile tests.

N.V. Kadobnova

**RELAXATION** – in the broad sense, the approximation of physical or physicochemical systems to static equilibrium. In this case the macrocharacteristics of the system (e.g., degree of structural ordering, etc.) approach their equilibrium values. In the narrow sense, relaxation of stress, this term refers to a gradual reduction in stress, the total (i.e., plastic and elastic) deformation of the body remaining constant, as in the loosening of tightened bolts or springs. Relaxation of stress is closely associated with and calculated together with creep, since it results from a general decrease in the proportion of elastic deformation and an increase in the proportion of residual deformation; however, relaxation takes place in the presence of regularly decreasing stresses, rather than the constant stress associated with creep. This explains the differences between relaxation and creep: 1) the lower (by a factor of 10–100 in some cases) plastic deformation during relaxation than during creep; 2) the varying rates of aging and other structural processes during relaxation (with decreasing stress) and creep (with a virtually constant mean stress). The relaxation rate is characterized by the time required for the quantity undergoing relaxation to decrease by a factor of $e(\cong 2.7)$. A single body may be subject to relaxation of several physical and physicochemical characteristics simulatneously (depending on the composition and structure of the body, the thermal, magnetic, and electrical fields acting, etc.). For example, in a body exhibiting nonuniform elastic deformation relaxation may be due to a decrease in the temperature nonuniformity (which arises when the extended areas are cooled and the compressed areas

heated), diffusion of the larger atoms into the extended areas and smaller atoms into the compressed areas, etc. The aggregate of the relaxation times (or their reciprocals) forms the relaxation spectrum of the material in question. Relaxation in polycrystals and in granular materials in general usually proceeds more actively along surfaces of separation (grains, mosaic blocks, dislocations, etc.). We can consequently distinguish boundary and volumetric relaxation, just as for diffusion. Since structural regularity generally decreases from the center of a grain to its boundary, the degree of disorder is higher in areas near the boundary than in the internal zone and the activation energy is correspondingly lower. Viscous boundary flow also occurs near the grain boundaries, causing relaxation of stress. The diffusion rate rises and the coefficient of viscosity drops as the temperature increases, thus greatly increasing the relaxation rate (reducing the resistance to relaxation). While a test time of thousands of hours is required to detect relaxation in steel at 20°, it becomes noticeable within minutes or sooner at high temperatures. If the body is regarded as being in equilibrium before loading, the nonequilibrium state of the specimen and the relaxation rate increase with the applied stress. The higher the test temperature, the more rapidly the relaxation rate rises as the initial stress increases. As a rule, the relaxation rate gradually decreases with time, this corresponding to the similar decrease in the creep rate during the transition from nonsteady to steady creep (or from period I to period II). As for period III (the accelerated period), which is observed during creep resulting from cracking and the consequent increase in local stresses, the relaxation rate generally exhibits a gradual drop as the average stress decreases. However, in certain cases, as during intensive phase transformations in some austenitic steels exhibiting severe structural in-

stability, where large spheroidized σ-phase particles are segregated at 650-700°, the relaxation rate may rise after a considerable time, behaving like period III. Thus, period III (the accelerated period) of relaxation is a special case, unlike period III of creep, which is observed in most instances. Relaxation is greatly affected by both the initial structure and that which develops during the relaxation process, under the joint action of stress, temperature, and the surrounding medium. The more rapidly the structural changes (heterogenization, etc.) take place in the specimen or component undergoing relaxation, the less is its resistance to relaxation, and vice versa. In tests at rather high temperatures resistance to creep increases with grain size, just as resistance to creep; fine-grained structures are more resistant to creep and relaxation at low temperatures. Cold working has a similar influence: resistance to relaxation and creep usually increases at low temperatures and rather short holding times and decreases at higher temperatures and longer loading times. All other conditions being equal, resistance to relaxation increases with melting temperature; as a result, aluminum alloys undergoing relaxation are not used at temperatures above 200-250°, while steels can be used up to 800-850°, chromium, molybdenum, and tungsten alloys at still higher temperatures, etc. Alloying may materially increase resistance to relaxation, as when bismuth, sulfur, cadmium, or antimony is added to tin alloys, magnesium, calcium, or tin is added to lead alloys, titanium, niobium, molybdenum, tantalum, or tungsten is carbidized (which strengthens the solid solution), or steels are dispersion hardened. Many of these additives also increase resistance to creep.

Relaxation reaches especially high values in polymers (most plastics, rubbers, fibers, leathers, etc.), which consist of long flexible chain molecules that are in turn built up of smaller elements, the

links of the chain. As a result of this "two-stage" structure (the chain and its links) relaxation of the relative positioning of the chains and their links, structural elements with considerable length, requires a substantial period of time, while the shape of the chains themselves is altered considerably more rapidly. In deformed and stressed polymers the extended and stress-oriented bundles of molecules gradually bend and twist, which causes deformation to lag behind the change in stress and leads to relaxation phenomena. The relaxation of polymers depends to a great extent on temperature, decreasing both when the temperature increases (culminating in a highly elastic state) and at very low temperatures (in the vitrified state); relaxation is most manifest in polymers between these two temperature ranges.

Relaxation tests are generally conducted either in special relaxation machines or on models, such as those consisting of a tube and a bolt, a stressed plate, or a spring and a clamp. A constant total elastic and residual deformation, a necessary condition for relaxation, is achieved automatically or, less frequently, by manual adjustment. I.A. Oding's test method is widely employed. In this technique a wedge is driven into a split ring with a uniform bending resistance; the wedge determines the total deformation. After the wedge has been driven into the slit in the ring the latter is held at a given temperature and then relieved; the plastic deformation is measured from marks made beforehand on the side of the ring. Relaxation tests are also conducted under torsion. The temperature range, the initial stress, the test time, the specimen size, shape, composition, processing, and structure, and the loading mode (tension, bending, torsion, or complex stressing) are selected in accordance with the purpose of the test. The degree of relaxation (decrease in stress) is evaluated directly

from a graph or by calculating the stresses from the measured elastic deformation or from the measured frequency of dying oscillations (dynamic method). In the latter case longitudinal or transverse oscillations are set up in bars or strings by mechanical or electromagnetic excitation. Considering the need to conduct tests at varying temperatures and stresses, a series of 10-20 specimens is usually investigated. In automatic relaxation-testing devices the deformation-measuring instrument (tensometer) adjusts the decrease in stress (through a photocell, electric contact, or other device) so that the total deformation remains constant.

When the component in question has a short service life the relaxation of stress can be evaluated experimentally under laboratory conditions. Prolonged relaxation tests (tens and hundreds of thousands of hours) are difficult and it is often necessary to use graphic or analytic extrapolation to make the conversion to service conditions in such cases. Extrapolation is reliable only when there is a more or less linear relationship between some of the stress functions and the elapsed time over the entire extrapolated interval; the existence of such a relationship can be assumed only on the basis of analysis of a large number of long-term tests. Relaxation curves with logarithmic coordinates are often used for such extrapolation.

In calculations for components undergoing relaxation, such as bolted joints, vessels, piping, flanges, etc., one usually knows the minimum stress necessary to ensure a tight joint over a definite service period at a given temperature. The composition and processing of the material and the dimensions of the component are usually selected on the basis of the stress. Resistance to relaxation can be increased by altering the composition, structure, or processing of the material or by changing the loading regime. Such a change can be effected by

preliminary Acclimatization (single or repeated loadings) or by repeated "tightening" of components subject to relaxation. Thus, bolted joints and springs are acclimatized before assembly or during experimental operation. Tightening is generally carried out periodically during service. The changes in the size of bolts, springs, and other components during acclimatization or tightening must be taken into account by making appropriate corrections in their initial dimensions.

References: Relaksatsionnyye yavleniya v metallakh i splavakh. Tr. mezhvuzovskogo soveshchaniya [Relaxation Phenemena in Metals and Alloys. Transactions of an Inter-University Conference], edited by B.N. Finkel'shteyn, Moscow, 1960; Kachanov, L.M., Teoriya polzuchesti [Theory of Creep], Moscow, 1960; Oding, I.A., et al., Teoriya polzuchesti i dlitel'noy prochnosti metallov [Theory of Creep and the Long-Term Strength of Metals], Moscow, 1959; Relaksatsiya i polzuchest' metallov [Relaxation and Creep of Metals], collection of articles, Moscow, 1952; Gintsburg, Ya.S., Relaksatsiya napryazheniy v metallakh [Relaxation of Stresses in Metals], Moscow-Leningrad, 1957.

Ya.B. Fridman

**RELIEVING NOTCH** is an additional notch made near a basic notch which cannot be avoided in the structure in order to increase the strength of the part as a whole. The relieving notch leads to an increase of the strength as a result of favorable redistribution and some additional concentration of the stresses outside the zone of maximal stresses, which leads to reduction of the concentration in the most highly loaded spot – near the peak of the basic notch. To achieve the strengthening effect the relieving notches must be more gentle than the primary (relieved) notches and must be made at an optimal (usually small) distance from the latter. It is convenient to characterize this distance by the ratio b/t, where b is the distance of the relieving notch from the primary notch, t is the depth of the relieving notch. With b/t = 10 there is practically no strength increase, with b/t = 1 the strength increase of the brittle materials may reach 250% of the strength of the specimen without the relieving notch. The use of relieving notches is usually not advisable for the plastic condition of materials when the stress concentration sensitivity is low. Care must also be taken to avoid a weakening, rather than strengthening, action of the additional notches. The degree of increase of the static strength resulting from introducing relieving notches ranges up to a factor of 2-2.5 for the brittle materials, and 20-30% for the plastic materials. The fatigue strength is increased by 20-30% by the relieving notches; certain alterations of the shape of parts (relief at the end of bolt threads, additional grooves in nuts, undercutting, etc.) which are successfully used to increase the structural strength of articles may also be considered as relieving notches.

Ya.B. Fridman

RESIDUAL STRESS is the elastic deformation and the corresponding stress which is in equilibrium within a body in the absence of external forces. In contrast with the transient stresses (internal stress) the residual stresses are retained in time. Depending on the degree of localization, we differentiate: residual stresses of the 1st kind (macroscopic) which equalize themselves over volumes of the same order as the dimensions of the entire body, existing methods evaluate primarily residual stresses of the 1st kind; residual stresses of the 2nd kind (microscopic) which equalize themselves over volumes of the same order as the grain dimensions, they are determined by X-ray methods; residual stresses of the 3rd kind (submicroscopic distortions) which equalize themselves in volumes of the same order as the dimensions of the atomic crystalline lattice, reliable methods for determining residual stresses of the 3rd kind have not yet been sufficiently developed. The primary cause for the occurrence of the residual stresses is the nonuniformity of the deformed state in view of the differing variation of the length (volume) in different zones of the body. The cause of the appearance of this nonuniformity may be: thermal gradient, for example, with abrupt heating or cooling (thermal or temperature stresses); nonuniformity of the thermal expansion of different structural or constructional components of the body (heterogeneous structures, bimetals, and others); phase transformations (phase stresses); nonuniformity of plastic deformation (residual stresses after surface strain hardening).

Residual stresses may be both harmful (leading to the appearance of inadmissible residual deformations, buckling, cracks, complete fail-

ure, accelerating corrosion, etc.), and useful (increasing the elastic limit of the system, increasing the fatigue strength, corrosion-mechanical and corrosion resistance, etc.). Tensile residual stresses are generally harmful, particularly in the biaxed and triaxed stress state, while compressive residual stresses are generally useful. As a rule, embrittling factors (temperature reduction, presence of bulk elongation, abrupt increase of deformation rate) amplify the effect of the residual stresses and, on the other hand, the more plastic the material condition the more rapidly and completely the residual stress may be relieved. In the most highly stressed surface layers (near notch peaks, etc.) there is a tendency for the creation of local compressive residual stresses of high magnitude. These residual stresses are equalized in the internal zones by tensile residual stresses which are distributed over large sections and which are therefore lower in magnitude and less critical.

There are methods for creating useful residual stresses (surface strain hardening, cementation, nitriding, combined methods, and others) and means for reducing and eliminating the harmful residual stresses (primarily by heating, which causes relaxation of the residual stresses, sometimes by means of plastic deformation, vibration, etc.). We must take into account the fact that initial deformations and fracture depend strongly on the residual stresses of the 2nd kind, therefore an analysis of the residual stresses of the 1st kind alone is inadequate.

A large part of the existing so-called mechanical measuring methods evaluate the magnitude of the residual stresses of 1st kind from a measurement of the elastic deformations which occur during disturbance of the integrity of the body (as a result of cutting, drilling, etching, etc.). The residual stresses which were in equilibrium prior to cutting cease to be in equilibrium after the cut is made. Measuring the elastic

deformations and assuming validity of Hooke's law, we compute the magnitude and distribution of the residual stresses. These methods were first suggested by the Russian metallurgist Kalakutskiy (see Kalakutskiy Method). The nondestructive methoss of measuring the residual stresses are usually less reliable and are used much less frequently than the mechanical methods. The methods for measuring the residual stresses depend on the shape of the body: for bodies of simple and symmetric shape (disc, cylinder, pipe, rectangular prism) the distribution of the residual stresses may be determined with adequate accuracy; for bodies of complex form (and nonsymmetrical distributions of the residual stresses) it is usually only possible to make an approximate estimate of the magnitude and distribution of the residual stresses, in particular from measurements of deformation by sectioning of the article or by cutting elements of simple form from the article. The bodies of simple form include discs (thickness $\leq 1/5$ the diameter), solid and hollow cylinders with ratio of length to diameter $\geq 2$, thin-wall tubing, prismatic beams, etc. The methods of Kalakutskiy and Davidenkov are used for determining the residual stresses in discs.

For cylinders of small diameter, when primary importance lies in evaluating only the axial stresses, we remove sequentially the outer layers and measure the length of the remaining part (Hein-Bauer method), neglecting the transverse stresses, i.e., considering approximately that the stress state is uniform. More exact is the Sachs methos, which accounts for the three-dimensional stressed state which is always present. A complete picture of the residual stresses is obtained from a s single cylinder (disc) by first turning down the diameter and then by performing a cutoff.

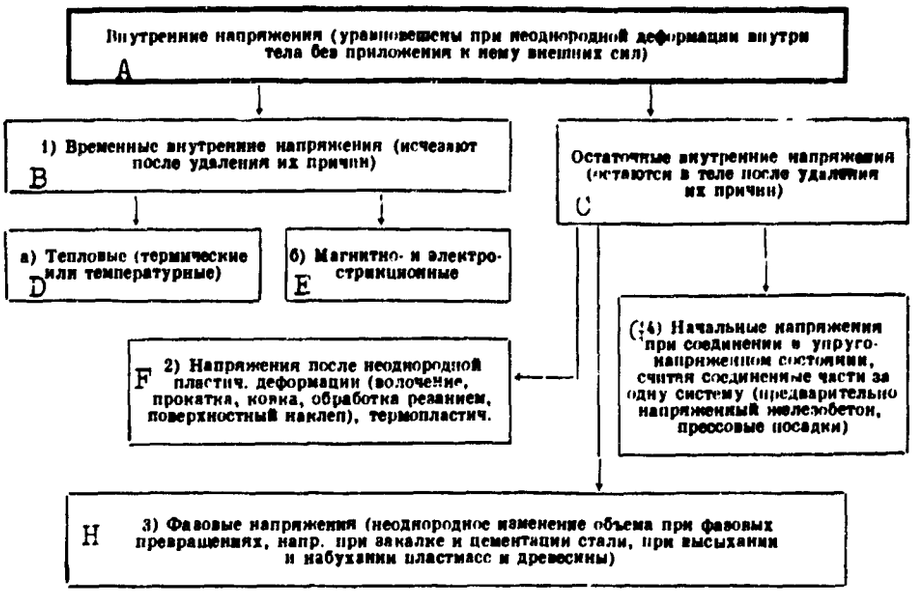
The Davidenkov method is used to determine the residual stresses in thin-wall tubing. The Davidenkov method may also be applied for non-

rectangular sections, tee-sections for example, and others. If in beams there exists a plane (biaxed) stress state where the two stresses are close in magnitude and have the same sign, then the stress values are multiplied by the quantity $1/1-\mu$, where $\mu$ is the Poisson factor.

Combined methods of measuring the residual stress are used when sectioning or excision can reduce complex bodies to simple bodies or can reduce complex stresses to more simple stresses. In thin-walled tubes which have been butt welded, with severely nonuniform stress distribution along the length, the tube is sectioned into individual rings in which the change of diameter before and after cutoff is measured. The magnitude of the circumferential stress is evaluated from the diameter change. In shafts and discs of large dimensions (diameter 500 mm and more, length more than 1500 mm) for which the accuracy of the Sachs method is inadequate in view of the small deformations, in order to determine the residual stress sequential measurements are made of the deformations of individual elements cut from the shaft or rotor (for example, rings, and then discs). Discs of variable thickness may be studied by the Davidenkov method separately for the disc and the hub; if the thickness in the hub is commensurate with the diameter, the axial stresses are also measured. Articles of complex form are studied using the Glikman method. For this, a small segment of the surface to which electrical strain gages have first been bonded is separated by means of cuts which relieve this segment of the residual stresses. It is convenient to perform the relieving by excision of a 15-20-mm-diam column by a special milling cutter to a depth of 0.7 times the column diameter. After excision the deformation is again measured by the sensors bonded to the end of the column. Use is also made of the technique of boring holes of diameter about 10 mm to a depth of 1.5-2 diameters with measurement of the deformation using electrical or wire strain

gages or using the photoelastic lacquer method.

Primary Forms of Internal Stresses




A) Internal stresses (equalized with nonuniform deformation within body without application of external forces to the body); B1) transient internal stresses (disappear after removal of their cause); C) residual internal stresses (remain in body after removal of their causes); Da) heat (thermal or temperature); Eb) magneto- and electrostrictional; F2) stresses after nonuniform plastic deformation (drawing rolling, forging, machining, surface strain hardening), and thermoplastic; G4) initial stresses with joining in the elastically-strained condition, considering the joined parts as a single system (prestressed reinforced concrete, press fits); H3) phase stresses (nonuniform variation of volume during phase transformations, for example, during quenching and case hardening of steel, during dessication and swelling of plastics and wood).

The chemical methods of measuring the residual stresses are based on surface cracking under combined action of tensile stresses and an a aggressive medium. On the basis of the appearance of such cracking under the action of a known medium we can approximately evaluate the magnitude of the residual stresses, for example, for the brasses in ammonia vapors, in a 2% solution of mercuric chloride and a 2% solution of nitrate of nercury with 2% nitric acid; for the high-chrome steels in a 50% solution of hydrochloric acid with the addition of 1% $SeO_2$. During sectioning and turning operations heating and relaxation of the residual stresses must be avoided. During removal of layers by etching it is

necessary to obtain a smooth surface. During measurement of small deformations using the sectioning method, account must be taken of the effect of thermal expansion, particularly over long lengths, and this effect must be eliminated. For articles of irregular and complex section the majority of the above methods of measuring the residual stresses are not suitable and use must be made of the approximate combined methods, and also the Glikman excision method. At the same time the residual stresses are of primary practical importance precisely for complex articles. Residual stresses of the 2nd kind are determined by the X-ray methods. Since plastic deformation takes place primarily within the grains, and the X-ray methods evaluate primarily the state within the grains, in the plastic state these method determine a lower value of the residual stress than the mechanical methods. In the elastic condition the X-ray and mechanical estimation of the residual stress are in agreement.

References: Glikman L.A., Metody opredeleniya ostatochnykh napryazheniy (Methods od Determining Residual Stresses), Tr. Leningr. inzh.-ekon. in-ta (Transactions of the Leningrad Engineering-Economics Institute), 1960, No. 30; Birger I.A., Ostatochnyye napryazheniya v drevesine pri yeye sushke (Inaernal Stresses in Wood During Drying), Moscow-Leningrad, 1959; Vasil'yev D.M., Dobrodeyeva N.M., Fizika tverdogo tela (Solid State Physics), 1962, Vol. 4, No. 1, pages 140-147.

Ya.B. Fridman

RESISTANCE TO EXFOLIATION – see Exfoliation strength.

RESISTANCE TO PLASTIC DEFORMATION – the resistance of a material to development of plastic deformation, measured in $kg/mm^2$ or $kg/cm^2$. At low temperatures (usually below the recrystallization temperature) resistance to plastic deformation increases with the total deformation; this is the phenomenon known as cold working. We can consequently distinguish resistance to plastic deformation at small deformations (limits of elasticity and flow), moderate deformations (Brinell, Rockwell, and Vickers hardness, microhardness), and at large deformations (near fracture). When the specimen under tension is necked the ultimate strength $\sigma_b$ also characterizes the resistance to plastic deformation, while when necking is absent $\sigma_b$ characterizes the Rupture strength.

Ya.B. Fridman

RESITE – see Phenolic plastics.

RESITOL – see Phenolic plastics.

RESOL – see Phenolic plastics.

RETINAKS – a heat-resistant friction material with good technical characteristics, which enable it to be hot-molded into articles from 3 to 40 mm thick. Types FK-16ℓ and FK-24a are produced commercially. Table 1 shows the physical and mechanical characteristics of retinaks.

TABLE 1

Physical and Mechanical Characteristics of Retinaks

| 1 Показатели | 2 ФК-24а | 3 ФК-16л |
|---|---|---|
| 4 Предел прочности при сжатии (кг/см², не менее) | 900 | 1000 |
| 5 Предел прочности на срез (кг/см², не менее) | 480 | 250 |
| 6 Твердость по Бринеллю (кг/мм², не менее) | 21 | 30 |
| 7 Теплопроводность (ккал/м·час·°С) | 0,32 | 0,4 |
| 8 Теплоемкость (кал/ч·°С) | 0,23 | 0,20 |
| 9 Плотность (г/см³) | 2,41 | 2,44 |

1) Characteristic; 2) FK-24a; 3) FK-16ℓ; 4) ultimate compressive strength ($kg/cm^2$, no less than); 5) ultimate sheer strength ($kg/cm^2$, no less than); 6) Brinell hardness ($kg/mm^2$, no less than); 7) thermal conductivity (kcal/m.hr.°C); 8) heat capacity (cal/hr.°C); 9) density ($g/cm^3$).

TABLE 2

Coefficient of Friction and Operational Coefficient of Friction of FK-16ℓ

| 1 Темп-ра (°С) | 2 Коэфф. трения | 3 Коэфф. трения эксплуатационный |
|---|---|---|
| 200–300 | 0,30–0,41 | 0,30–0,4 |
| 400–500 | 0,13–0,25 | 0,25–0,32 |
| 1000 | 0,22 | 0,16–0,17 |

1) Temperature (°C); 2) coefficient of friction; 3) operational coefficient of friction.

FK-24a retinaks is a good dielectric and is resistant to concentrated acids.

TABLE 3

Operational Coefficients of Friction of FK-16ℓ and FK-24a as a Function of Pressure

| 1 Уд. давление (кг/см²) | 2 Коэф. трения | |
|---|---|---|
| | 3 ФК-16ℓ | 4 ФК-24а |
| 10 | 0.304 | 0.463 |
| 15 | 0.253 | 0.297 |
| 25 | 0.202 | 0.252 |
| 35 | 0.208 | 0.195 |
| 50 | 0.155 | 0.172 |

1) Pressure (kg/cm$^2$); 2) coefficient of friction; 3) FK-16ℓ; 4) FK-24a.

Table 2 shows the coefficient of friction of FK-16ℓ before heat treatment, as determined in an I-47 K-54 friction machine, as well as its operational coefficient of friction after processing at high temperatures.

Table 3 shows the operational coefficients of friction of FK-16ℓ and FK-24a as a function of pressure.

The coefficient of friction of retinaks depends to a considerable extent on the overlap of the elements of the friction pair, i.e., the ratio of the dimensions of the pair.

The coefficient of friction of FK-16ℓ is 0.18 at a temperature of 350° and an overlap of 0.75, while at an overlap of 0.25 it increases to 0.35. Articles are manufactured from retinaks by mechanical processing. Brake shoes, disks, and linings of retinaks can function at specific pressures of up to 60 kg/cm$^2$, sliding speeds of up to 60 m/sec, and surface temperatures of up to 1000°. Components of FK-24a are used in the brake units of walking excavators (at a friction-surface temperature of 400°) and in the brakes of oil-drilling winches (at a friction-surface temperature of 600°). Components of FK-16ℓ are employed in brake units operating under severe conditions, at friction-surface temperatures of 1000-1200°, as in the brake units of aircraft, in the

friction clutches of heavy presses, etc.

G.A. Georgiyevskiy

RHEOLOGY – a branch of mechanics devoted to studying the flow and deformation of viscous liquids and colloids. Models (a spring as an elastic element, a piston as a viscous element, etc.) and calculation of the behavior of combinations of different elements are widely employed in rheology. It is difficult to demarcate rheology from a number of branches of plasticity theory, but this discipline properly reflects the inadequacy of a purely statistical approach and the need to take into account the rate of a process and the elements of flow; on the other hand, rheology suffers from a certain tendency toward oversimplification and arbitrariness.

References: Reiner, M., Desyat' lektsiy po teoreticheskoy reologii [Ten Lectures on Theoretical Rheology], translated from English, Moscow-Leningrad, 1947; Reologiya [Rheology], edited by F. Eirich, translated from English, Moscow, 1962; Reiner, M., Rheology, in book: Handbuch der Physik [Handbook of Physics], Vol. 6, Berlin, 1958.

Ya.B. Fridman

**RHODIUM**, Rh – a chemical element in group VIII of the Mendeleyevian periodic system, with an atomic number of 45 and an atomic weight of 102.95; it has the stable isotope $Rh^{103}$. Rhodium is a metal of the platinum group; its content in the earth's crust amounts to $1 \cdot 10^{-7}$% by weight. It has a density of 12.44 g/cm$^3$, a $t^{\circ}_{pl}$ of 1960°, and a $t^{\circ}_{kip}$ of ~450°.

Rhodium is a silvery-blue metal resembling aluminum; it is harder and higher-melting than Pt or Pd and is incredibly difficult to work. Very pure rhodium is quite flexible when hot and less flexible when cooled. The most important characteristics of rhodium are its high melting point, chemical stability, nonoxidizability at high temperatures and high reflective capacity. See Precious metals.

O.Ye. Zvyagintsev

RIL'SAN – a synthetic heterogenous-chain fiber, the polycondensation product of aminoundecanic acid. It is produced on a commercial scale in France and Italy, in the form of monofilament fiber and bristles; the production technology of a fiber of the ril'san type (known as undecane) has been mastered in the USSR. The physical and mechanical characteristics of ril'san are as follows: specific gravity – 1.04, moisture content under standard conditions – 1.0-1.5%, melting point – 189°, frost resistance – from –70° to –55°, deep resistance – $10^{14}$ ohm·cm (dropping to $10^{13}$ ohm·cm after soaking in water for 24 hr), thermal conductivity – $5.7 \cdot 10^{-4}$ cal/cm·sec·°C, heat capacity – 0.5 cal/g·°C, coefficient of linear expansion (by 1%) – $9.9 \cdot 10^{-5}$, skin resistance – $2\text{-}3 \cdot 10^{14}$ ohm at 18° and 80% relative humidity, dielectric permeability – 3.5, tangent of angle of dielectric loss – 0.02-0.03 at 100 cps and 0.01 at $10^6$ cps, and breakdown voltage – 40 kv/mm (for a film 0.5 mm thick). Ril'san is insoluble in hydrocarbons, oils, fats, toluol, ether, acetone, and trichloroethylene and soluble in phenols. It is resistant to dilute acids (sulfuric, hydrochloric, nitric, and phosphoric), alkalies (sodium hydroxide, potassium hydroxide, and ammonia), and oxidizing agents at room temperature (hypochlorite, permanganate, etc.). Ril'san cloth can withstand repeated laundering. The principal shortcomings of this material are its poor dyeability and low thermostability. Ril'san has a tearing length of 50 km and is equally strong when wet or dry; its elongation when dry amounts to 25%. This material exhibits an elasticity of 100% (on elongation by 6%) and a modulus of elasticity of 450 kg/mm$^2$ (on elongation by 1%).

Its durability and bending resistance are the same as for caprone and nylon 66. Ril'san is used as an electrical-insulating and upholstery material; like nylon 610 and perlon V it is used in the form of bristles in the manufacture of various brushes.

References: Floyd, D.E., Poliamidy [Polyamides], translated from English, Moscow, 1960; Hopff, G., Mueller, A., Wenger, F., Poliamidy [Polyamides], translated from German, Moscow, 1958; Itogi nauki [Progress in Science], edited by V.V. Korshak, Vol. 7, Moscow, 1961.

E.M. Ayzenshteyn

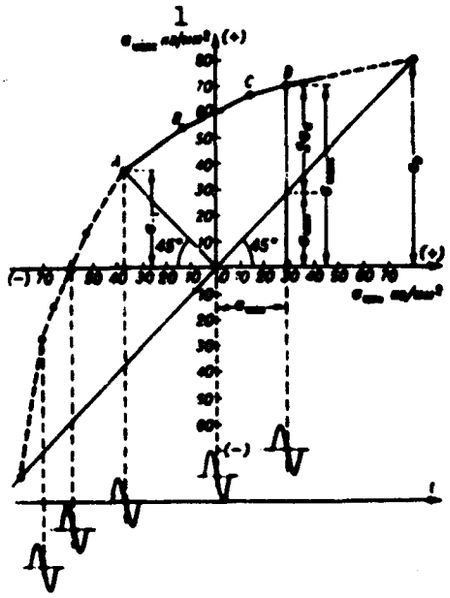
RIVET BRASS is brass used for making rivet wire. Rivet wire made from L62 brass with diameter from 1 to 10 mm is produced in accordance with the specifications TsTU 18-58 (see Wrought Bras). The wire is produced in the annealed condition with tensile strength of no less than 38 kg/mm$^2$ and relative elongation of no less than 18%. In order to avoid spontaneous corrosion cracking the riveted details or products must be subjected to low-temperature annealing at 250-300°.

Ye.S. Shpichinetskiy

**RIVET STEEL** – is a Martin steel with an increased plasticity for the production of rivets. The rivet-steel grades M12kp and M18kp, containing not more than 0.05% of sulfur and phosphorus together, are the most widespread ones. Rivet steel is delivered in rods with a diameter from 8 to 40 mm, and in bundles with a diameter of 14 mm St3 with a relative elongation of not less than 24% and a shortening during shrinkage of not less than 40% may also be used as a rivet steel. The relative elongation of rivet steel with a diameter of less than 8 mm reduces by approximately 1% for each mm the diameter is diminished. In building of special machines, where the weight of the units and the firmness of the rivet joint are especially important, rivets are made from rods (wires) of the alloyed 20KhMA and 20GA steels stipulating for a shearing strength of not less than 50 $kg/mm^2$ (after heat treatment) as a special condition.

M.L. Bernshteyn, I.N. Kidin

ROCHE DIAGRAM – a graph characterizing the relationship between the maximum and minimum stresses of a cycle (Fig.). A Roche diagram




1) $kg/mm^2$.

is constructed with the aid of Fatigue curves obtained from tests on 3–4 series of identical specimens at different (for each series) mean cyclic stresses. The values of the mean cyclic stresses and amplitudes lie at points AD (see Fig. 2 in the article entitled Smith diagram); these points correspond to the total durability (base) and are used to calculate the maximum and minimum cyclic stresses, which are the coordinates of the analogous points in the Roche diagram. Each durability (base) corresponds to a Roche diagram.

G.T. Ivanov

ROCK CRYSTAL – mineral, a form of colorless, transparent quartz, one of the crystalline variations of silica ($SiO_2$). Rock crystal exists in two polymorphic forms: the hexagonal α-form (high-temperature) which is stable in the interval of 573-870°, and the triangular β-form (low temperature), which is stable below 573°. Specific weight 2.65, Mohs hardness 7, brittle, not cleavageable or very incomplete cleavageability along the rhombohedral; conchoidal fraction, has the piezoelectric property; electrical charges arise due to mechanical stresses, optically single axis, positive; passes ultraviolet rays up to wavelengths of 1800-2000 A, rotates the polarization plane. $t^{\circ}_{pl}$ 1713°, from the melt it crystallizes into glass. Natural crystals of rock crystal are usually elongated prismatic or dipiramidal. Rock crystal can have mechanical admixtures in various quantities in the form of gaseous, liquid or solid substances ($CO_2$, $H_2O$, Ca, hydrocarbons, minute crystals of rutile, actinolite, etc.). Pure homogeneous crystals of rock crystal are encountered rarely, crystals with a minimum size of 3-5 cm are those which are of practical importance, large pure crystals of rock crystal are encountered infrequently. Deposits of rock crystal in the USSR are in the Ural, Ukraine, Pamir, Aldan, overseas they are in Brazil and Madagascar.

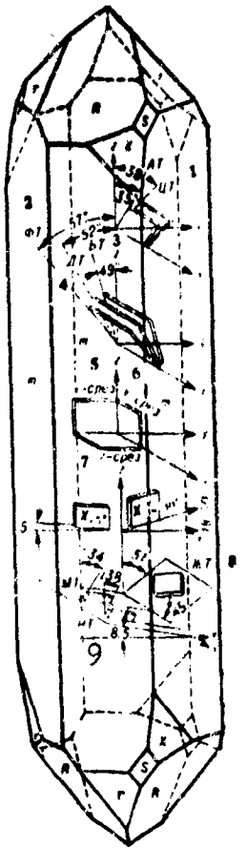
Monocrystals of rock crystal are grown in autoclaves by the temperature gradient method in a wide range of pressures (300-2000 $kg/cm^2$) and temperatures (300-450°) by dissolving vein quartz in water solutions of $Na_2CO_3$ or NaOH and using monocrystalline plates and natural or artificial rock crystal as seeds. The introduction of various admix-

tures in the process of artificial rock crystal growing changes the properties of the crystals; for example, Ge increases, while Al decreases the refraction indices, $Fe^{2+}$ gives green color, $Fe^{3+}$ gives brown color, while Co gives blue color.

Rock crystal is used extensively in radio engineering for frequency stabilization. Piezoelectric resonators (plates) from rock crystal ensure the required service activity, monofrequency and stability of frequency with respect to time. To obtain the necessary piezoelectric characteristics, the plates are cut with a high precision of orientation with respect to the crystallographic axes of the crystal (Fig.). In the frequency range of 0.5-50 megacycles use is made of plates with shear vibrations along the thickness (cuts: AT, BT, NT, MT), while plates with shear vibrations along the contour and bars (rods) which vibrate along the length or width (cuts: GT, FT, CT, X+5°, X = 18°30') are used in the frequency range below 0.5 megacycles. Rock crystal plates also serve for obtaining ultrasonic vibrations, pressure measurement, etc. Rock crystals are used for making spectrograph prisms, ultraviolet optical lenses, wedges of polarizing microscopes; semiprecious stones are obtained from colored crystals of artificial rock crystal.

References: Shubnikov, A. V., Kvarts i yego primeneniye [Quartz and its Uses], Moscow-Leningrad, 1940; Tyul'panov, A.A., Tekhnologiya proizvodstva kvartsevykh plastin [Quartz Plate Production Technology], Moscow-Leningrad, 1955; Betekhtin, A.G., Kurs mineralogii [A Course in Mineralogy], 3rd edition, Moscow, 1961.

V.P. Butuzov



Orientation of the most commonly employed resonators with respect to the crystallographic axes of the right-hand crystal in rock crystal. 1) TsT; 2) FT; 3) BT; 4) DT; 5) x-axis; 6) y-axis; 7) z-axis; 8) ZhT; 9) NT.

ROCKWELL HARDNESS – standard physicomechanical characteristic of a material, which determines its ability to resist local plastic deformation which is produced by statically forcing into the specimen or product surface a diamond cone with a 120° generating vertex angle, or a hardened steel ball 1/16 inch (1.588 mm) in diameter). The methods for determining Rockwell hardness are presented in GOST 9013-59. The Rockewell hardness (or hardness number) HR is defined as the difference between the depth of penetration h of the cone or ball under total load P and the depth of penetration $h_0$ produced by a preliminary load of $P_0$ = 10 kg. The hardness number Hr is expressed in arbitrary dimensionless units and is determined from the following formulas: when measuring on the A and C scales (diamond cone, loads, respectively, 60 and 150 kg) – HR = 100 – e, when measuring on the B scale (steel ball, load 100 kg) – HR = 130 – e. Here $e = h - h_0/0.002$ is the depth of penetration of the indenter, expressed in Rockwell hardness units. The Rockwell hardness numbers RA, RB and RC are not equal to one another even for the same material. In addition to the standard ball 1/16 inches in diameter (B scale) use is sometimes made of balls 1/8, 1/4 and 1/2 inches in diameter (the RE, RM, RS, etc., scales). The Rockwell hardness can be related to the Brinell Hardness by empirical formulas. For example, for the C scale

$$HB = \frac{25000 - 10\,(57 - RC)^2}{100 - RC}.$$

References: Shaposhnikov, N.A., Mekhanicheskiye ispytaniya metallov [Mechanical Testing of Metals], 2nd Edition, Moscow-Leningrad,

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1954.

I.V. Kudryatsev and D.M. Shur

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[Transliterated Symbols]

3421 ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart =
All-Union State Standard

ROCKWELL METHOD – determination of the hardness of metallic materials by pressing a conical diamond indicator with an apical angle of 120° (scales A and C) or a quenched steel spear with d = 1/16 inch (1.588 mm) (scale B) into the surface of the specimen or component under the action of two successively applied loads, the preliminary load $P_0$ and the basic load $P_1$, so that the total load $P = P_0 + P_1$. The uni- of hardness is assumed to be a quantity corresponding to axial displacement of the tip by 0.002 mm. The hardness number is determined from the following equations:

for measurement on scales A and C

$$HR = 100 - e;$$

for measurement on scale B

$$HR = 130 - e,$$

where e is the axial displacement of the tip under the action of the basic load ($P_1$), expressed in Rockwell hardness units ($e = h - h_0/0.002$). GOST 9013-59 sets the conditions for Rockwell hardness tests. The Table shows the loads $P_0$, $P_1$, and $P_{obshch}$ for measurement of hardness on scales A, B, and C.

A basic load of 100 kg is applied over a period of 3-6 sec with the instrument initially at no load. The Rockwell metnod is used for testing soft (scale B), hard (scale C), and very hard (scale A) materials. The minimum specimen thickness depends on the hardness of the material. Special instruments - hardness gauges (Fig.) – are used to deatermine Rockwell hardness. These devices make it possible to produce

Loads for Measurement of Rockwell Hardness

| 1 Шкала | 2 Нагрузка (кг) $P_0$ | $P_1$ | $P_{общ.}$ | 3 Пределы изменения твердости H | 4 Твердость по Бринеллю (кг/мм²) |
|---|---|---|---|---|---|
| A | 10 | 50 | 60 | RA = 70—85 | >700 |
| B | 10 | 90 | 100 | RB = 25—100 | 60—230 |
| C | 10 | 140 | 150 | RC = 20—67 | 230—700 |

1) Scale; 2) load (kg); 3) limits of change in hardness H; 4) Brinell hardness ($kg/mm^2$).

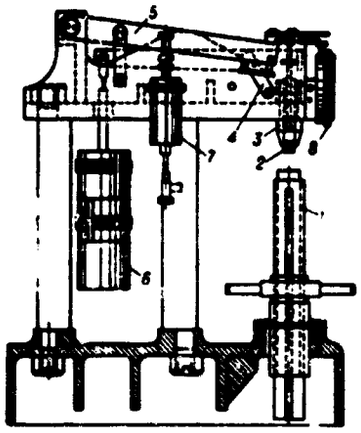



Diagram of TK apparatus (Soviet-designed) for measuring Rockwell hardness: 1) Support column (base); 2) indentor; 3) spring for preliminary loading; 4) lever; 5) weight-bearing arm; 6) weight; 7) oil shock absorber; 8) indicator with dial and pointer.

indentations with a conical or spherical tip and to measure the depth of the indentation with the aid of an indicator divided at 0.002 mm intervals, its scale being graduated directly in Rockwell hardness units. The "Super-Rockwell" apparatus is used to measure the hardness of very thin sheets; this device is distinguished by greater indicator accuracy (0.001 mm), more precise geometric dimensioning of the conical and spherical tips, and reduced loads (3, 15, 30, and 45 kg).

References: Avdeyev, B.A., Ispytatel'nyye mashiny i pribory [Test Machines and Instruments], Moscow, 1957.

I.V. Kudryavtsev and D.M. Shur

ROCK WOOL – loose-fiber mass of randomly located and entangled cotton, wool, mineral, glass and other fibers; is used as heat and sound insulating material. The following kinds are produced: 1) Cotton with a fireproof impregnation – it is made from low-quality cotton, contains, after impregnation in a water extract 0.5% of boron, not more than 3% of phosphorus and 0.3% of $SO_4$ ions. 2) Glass wool is used for thermal insulation of industrial equipment and pipelines in the temperature interval from –60° to +450°. 3) Glass wool from extra-thin fibers is used for light thermal insulation and sound-absorbing materials and for air purification filters, serves as the raw material for the production of mats, canopies, tile and paper. 4) Mineral wool (slag, rock), approximate composition (by %) is: $SiO_2$ – 42, $Al_2O_3$ – 7, CaO – 32, MgO – 7, and S – 1; it is produced as brands "100," "150" and "200" (the brand number corresponds to the specific weight of the wool). Increasing the silicon content increases the temperature resistance of mineral wool, increasing the ferrous oxide content reduces it. Aluminum oxide improves the chemical and biological resistance of mineral wool while ferrous oxide improves its corrosion properties; the thermal conductivity coefficient for a specific weight of 120-300 $kg/m^3$ and temperature of 0° varies in the interval of 0.0420-0.0575 kcal/m × hour·°C, the sulfur content in all the brands should not exceed 1.5%, and the acidity modulus (ratio of the total weight of silicon and aluminum to the total weight of calcium and magnesium) should be not lower than 1.2, it is heat resistant up to 600°. 5) Kaolin (ceramic) wool consists of refractory $Al_2O_3$ and $SiO_2$ in the form of thin fibers with an average

diameter of 6 microns and nonfibrous inclusions ("beads" up to 10% by weight), the thermal conductivity coefficient for a specific weight of 100 kg/m$^3$ in the temperature interval 100-1000° varies within the limits of 0.04-0.32 kcal/m·hour·°C; it is used as a filler for thermal insulation of high-temperature units. 6) Asbestos wool is a product of mechanical processing of asbestos; is used up to 600° as thermal insulation of instruments and machinery; at a higher temperature it loses its mechanical strength due to evaporation of its constituting water. The thermal conductivity coefficient depends on the specific weight and at a temperature of 50° it is 0.08-0.13 kcal/m × hour·°C.

V.G. Nabatov

ROOFING CAST IRON – is a plastic sheet material (0.5-1.5 mm) employed in roofing, and manufactured by graphitizing or decarbonizing tempering of sheets obtained by continuous rolling of cast iron. Roofing cast iron is a cast iron alloyed with a small quantity of copper in order to improve the corrosion resistance and containing 3.0-3.4% C, 1.4-1.7% Si (0.5-0.8% Si in the case of decarbonizing tempering); 0.4-0.7% Mn, up to 0.12% P; up to 0.1% S, up to 0.05% Cr, and 0.15-0.20% Cu. Roofing cast iron is melted in cupola furnaces, the copper is added into the ladle. The pouring temperature is 1260-1280°.

The graphitizing tempering is carried out under the same conditions as the tempering of malleable ferritic cast iron (see Malleable cast iron), and the decarbonizing tempering is performed at 1000° for 6 hrs in a gaseous or solid medium. The carbon content lowers to 0.15% after the decarbonizing tempering, i.e., in essence, the cast iron is transformed into a low-carbon steel.

The mechanical properties of 0.65-0.75 mm thick sheets of roofing iron submitted to decarbonizing tempering are as follows: a) $\sigma_b$ = 25-30 kg/mm$^2$ after the tempering; $\delta$ = 4% (in this state the roofing iron withstands a bending of 180° about a mandrel with a radius of 8 mm without forming cracks); b) after rolling with a 30% deformation: $\sigma_b$ = = 38-42 kg/mm$^2$, $\delta$ = 14-18%. The sheets of roofing iron are weldable with cast-iron and steel sheets by point or seam welding. The sheets of roofing iron are used mainly as a roofing material, but architectonic and machine-building parts may also be made of it by cutting or bending, and also by punching under a low drawing.

References: Nikolayenko, Ye.G., Yassikiy, D.I. and Burov, S.L., Proizvodstvo chugunnogo lista [Manufacture of Sheet Iron], in the book Spravochnik po chugunnomu lit'yu [Handbook on Iron Casting], Moscow-Leningrad, 1960.

A.A. Simkin

ROPE - see Twisted Objects.

ROSTERITE – see Beryl.

ROVIL' – see Polyvinylchloride fiber.

RUBBER – an elastic material, a complex composition of caoutchouc (gum rubber) and various ingredients. The most important property of rubber is its elasticity, which is improved by vulcanization. Rubber is classified as soft, semi-hard or hard (ebonite), in accordance with its degree of vulcanization.

The characteristics of rubber (elasticity, strength, low gas- and water-permeability, low electrical conductivity, high resistance to various aggressive media, ozone-, heat-, and frost-resistance, and comparatively low modulus) make it an important, often irreplaceable structural material for various products. The list of technical rubber products numbers more than 30,000 items (tires, drive belts, conveyor belts, shock absorbers, rubber tubing, flexible piping, hoses, packing components, anticorrosion coatings, electronic components, sanitary and hygienic products, etc.).

Principal Physical and Mechanical Properties of Soft Rubber

| Показатели 1 | Единица измерения 2 | Величина 3 | Примечание 4 |
|---|---|---|---|
| 5 Предел прочности при разрыве | кг/см² | 50—300 | Пределы величин зависят от типа каучука и количества усиливающего наполнителя 13 |
| 6 Относительное удлинение | % | 100—700 | |
| 7 Остаточное удлинение | % | 0—40 | |
| 8 Условно-равновесный высокоэластический модуль (модуль упругости | кг/см² | 10—200 | 14 В зависимости от числа связей между молекулами каучука, образующихся в процессе вулканизации (т. е. от температуры и продолжительности вулканизации, количества вулканизирующих агентов, типа и количества наполнителя) |
| 9 Твердость по ТМ-2 | — | 40—95 | 15 В зависимости от количества наполнителей, а также числа связей между молекулами каучука |
| 10 Морозостойкость (по температуре хрупкости) | °С | —20...70 | |
| 11 Теплостойкость | °С | 50÷300 | 16 В зависимости от типа каучука |

1) Characteristic; 2) unit of measurement; 3) value; 4) notes; 5) alternate tensile strength; 6) relative elongation; 7) residual elongation; 8) arbitrary high-elasticity equilibrium modulus (modulus of

elasticity); 9) hardness in TM-2 apparatus; 10) frost resistance (embrittlement temperature); 11) thermal stability; 12) kg/cm$^2$; 13) the maximum and minimum values depend on the type of rubber and the amount of reinforcing filler; 14) depending on the number of bonds formed between the rubber molecules during vulcanization (i.e., on the vulcanization temperature and time, the amount of vulcanizing agents, and the type and quantity of filler); 15) depending on the quantity of filler and the number of bonds between the rubber molecules; 16) depending on the type of rubber.

As a result of its elasticity, strength, and low modulus of elasticity, which ensure good contact at low loads, rubber is widely used as a sealing and packing material. The Table shows the principal physical and mechanical properties of soft rubber.

The principal constituent of any rubber mixture is caoutchouc, on which the specific properties of the rubber essentially depend. The caoutchouc content of rubber mixtures varies from 5 to 98%. In addition to caoutchouc, such mixtures contain fillers, vulcanizing agents, accelerators, antiaging agents, and softeners. Some rubber mixtures also include dyes, pore-forming agents, and substances to increase frost resistance, thermal stability, etc.

Fillers can be divided into reinforcing and inert, depending on their action on caoutchouc. Reinforcing fillers (different types of carbonaceous soot, powdered silica gel, etc.) increase the mechanical characteristics (strength, modulus of elasticity, hardness) of the rubber. Many types of synthetic rubber have a very low strength (10-30 kg/cm$^2$), even when vulcanized, and acquire high strength (100-250 kg/cm$^2$) only when mixed with reinforcing fillers.

Inert fillers (chaulk, kaolin, barium sulphate, asbestos dust, etc.) have virtually no reinforcing effect and are added to rubber mixtures to reduce their cost or to give them special properties; for example, asbestos dust increases durability and thermostability, barium sulphate increases acid resistance, etc.

Vulcanizing agents, principally sulfur and organic peroxides, are intended to vulcanize gum rubber, i.e., to join it into three-dimensional molecules with the aid of sulfur or peroxide atoms, so that the raw rubber mixture is converted from a viscous plastic mass to a highly elastic, strong material. Vulcanization extends the temperature range over which the rubber can be used, makes it resistant to the reaction of heat, light, and various aggressive media (oxidizing agents, fuels, etc.), increases its durability, and improves a number of its other properties. Certain types of synthetic rubber can be vulcanized without sulfur at high temperatures; the rubbers thus obtained are called thermal vulcanizates. The overwhelming majority of rubber products are vulcanized, only a few being used in raw form in the manufacture of cements, sealers, insulating tape, etc.

Vulcanization accelerators [tetramethylthiuram disulphide (thiram), mercaptobenzothiazole (captax), diphenylguanidine (DFC), dibenzothiazolyl disulphide (altax), benzothiazolyl sulfenediethylamide (sulfenamide BT), etc.] reduce the vulcanization time and, in some cases, the vulcanization temperature.

Antiaging agents [antioxidents — phenyl-β-naphthylamine (neozon-D), aldol-α-naphthylamine (aldol), etc.] protect rubbers from oxidation (aging), which causes their operational characteristics to deteriorate with time. The protective action of antiaging agents substantially prolongs the service life of rubber products.

Softeners (stearic and oleic acids, pine tar, paraffin, vasoline oil, etc.) promote a more homogeneous distribution of the ingredients of the rubber mixture and improve the technological characteristics of raw mixtures, facilitating calendering, extrusion, and molding.

Special substances none as plasticizers or antifreezes [synthetics, chiefly complex esters of various organic acids, e.g., the di-

butyl ester of phthalic acid (DBF), the dibutyl ester of sebacic acid (DBS), the dioctyl ester of sebacic acid (DOS), etc.] are added to certain rubber mixtures in order to increase their frost resistance. Antifreezes lower the freezing temperature of rubber, thus expanding the temperature range over which it can be used. In addition, antifreezes, being plasticizers (softeners), improve the technological characteristics of raw rubber mixtures. Powdered substances are added to rubber mixtures to produce porous or sponge rubbers.

The manufacture of rubber products consists of the following basic operations: 1) plasticization of the gum rubber; 2) preparation of ingredients for mixing (pulverization, drying, sizing, filtration, etc.); 3) mixing of the gum rubber and ingredients; 4) production of intermediate products from the raw mixture by calendering, extrusion, or molding; 5) piecing together of individual components to produce the desired article. Complex products including rubberized cloth, metal, and other materials, such as tires and shoes, and large-size articles are manufactured by assembly on templates, lasts, or special machine tools. In this technique it is important that the raw rubber intermediate products used for assembly be self-adhesive. Synthetic rubbers are usually less adhesive than natural rubber; 6) vulcanization of molded rubber products in press forms in hydraulic vulcanization presses; tubes, cords of various shapes, and flexible piping are vulcanized on trays in boilers with steam supplied to the boiler jacket; rubber shoes are vulcanized on lasts in hot-air boilers in order to preserve the luster of the lacquer film; rubber products with complex shapes assembled from separate components (tires, fuel containers) are vulcanized in press forms or on templates in autoclaves or boilers. It is very important to observe the proper temperature, press form pressure, and vulcanization time in order to maintain the quality and durability

of the product; 7) finishing of the final product – removal by cutting or polishing of the fin (or rib) formed when excess rubber is forced into the gap where the press form separates; 8) inspection of the products for external appearance (presence of pores, bubbles, and blisters), size, etc.

Certain critical rubber components (e.g., sliding packing components) are measured and rejected when they fail to meet the appropriate dimensional requirements.

References: Koshelev, F.F., Klimov, N.S., Obshchaya tekhnologiya resiny [General Technology of Rubber], 2nd Edition, Moscow, 1978; Dogadkin, B.A., Khimiya i fizika kauchuka [Chemistry and Physics of Rubber], Moscow-Leningrad, 1947; Borodina, I.V., Nikitin, A.K., Tekhnicheskiye svoystva sovetskikh sinteticheskikh kauchukov [Technical Characteristics of Soviet Synthetic Rubbers], Leningrad-Moscow, 1952; Zakharov, N.D., Novyye tipy kauchukov i oblasti ikh prakticheskogo ispol'zovaniya [New Types of Rubber and Areas for Their Practical Application], Handbook of Data, Yaroslavl, 1962; Kauchuki spetsial'nogo naznacheniya [Special-Purpose Rubbers], collection of survey articles, edited by I.V. Garmonov, Moscow, 1961; Novyye kauchuki [New Rubbers], collection of translations, edited by V.F. Yevstratov and F.I. Yashunskiy, Moscow, 1958; Sinteticheskiy kauchuk [Synthetic Rubber], edited by G.S. Whitby, translated from English, Leningrad, 1957; Ketton, N.L., Neopreny [Neoprenes], translated from English, Leningrad, 1958; Lepetov, V.A., Resinovyye tekhnicheskiye izdeliya [Technical Rubber Products], Leningrad, 1959.

F.Ye. Fradkina

RUBBER ADHESIVE – is a solution of natural rubber or of a rubber blend in an organic solvent. Dependent upon their purpose, the rubber adhesives are subdivided into: 1) assembling adhesives, used to piece together rubber articles and rubber-fabric products (rubber footgear, tire treads, hoses, and tanks) with a subsequent vulcanization; 2) self-vulcanizing glues used to bond products made from vulcanized rubbers and rubberized fabrics, and to repair such products; 3) glues for the fabrication of rubberized fabrics; 4) glues for the production of seamless thin-walled objects, and 5) rubbers based on rubber derivatives, which are used to bond rubber with metals. The assembling and the self-vulcanizing adhesives are commercial grades. The adhesives for the production of rubberized fabrics and thin-walled seamless objects (rubber nipples, surgical gloves, etc.) are used only in the plants which produce these objects.

Rubber adhesives must possess good adhesion and viscosity, and must ensure a high strength of the joints after vulcanization (in the case of assembling adhesives), or after bonding (in the case of self-vulcanizing adhesives) and sufficient stability during transport and storage. The adhesive solvents must be as less toxic as possible chemically inert to the rubbers and the components of rubber compounds, must not have an unpleasant odor, must be as little inflammable as possible and must have a boiling point between 70° and 120°. A gasoline solvent (the so-called "galosh" gasoline, GOST 443-56) boiling at 80-120°, with a specific gravity of 0.72 and containing not more than 3% armatic hydrocarbons, is used in the USSR as a basic solvent for rubber adhesives.

The application of toxic solvents (benzene, dichloroethane, etc.) is permitted only in exceptional cases in the USSR.

The working properties of rubber adhesives are evaluated on the basis of the following characteristics: 1) the concentration of the adhesive (the dry residue); 2) the viscosity determined by Svetlov's funnel (the outflow time of a fixed volume through a standardized opening) or by the Lepetov – Konstantinov viscosimeter (fall of a standardized size ball through an adhesive layer of a fixed depth); 3) the bonding strength (kg/cm), determined by the strength of the joint of two bonded fabric strips when they are separated on a dynamometer with a fixed velocity, 10-12 hours after the bonding was carried out. The assembled objects are vulcanized by saturated steam, heated air or water at 120--150°. The commercial rubber adhesive delivered according to GOST 2199--43, a solution of NK in gasoline, is the most widespread type of assembling adhesives. Solutions of chloroprene rubbers (Nairit in the USSR, Neoprene abroad) are used as assembling adhesives. Self-vulcanizing adhesives are used in the assembling of boats, balloons, clothes and footwear, and also in their repair. Self-vulcanizing adhesives and pastes are used in the repair of automobile, motorcycle and bicycle tires, and in joining and repairing conveyor and driving belts. The vulcanization of the glue films occurs at normal temperature in a short time by means of special vulcanizers (ultra-accelerants). The adhesive joints have a high strength. The adhesives are delivered in two solutions in order to avoid a premature vulcanization: the one solution contains the rubber or rubber blend and the ultra-accelerant, and the other contains the sulfur and the promoter of the vulcanization. Both solutions are mixed before being used. Rubber adhesive grades delivered in two solutions are: 3125, 3126, SV-1, SV-2, and SV-3. The selection of a rubber adhesive for any object depends on the object's shape, on the

working conditions, on the rubber compound, etc. Rubber adhesives must be stored at 5-20° in tightly closed containers: large quantities in tin-plate or aluminum containers, small quantities in cans from the same material or in glass jars. Rubber adhesives are stable when correctly sealed and stored. The shelf life of rubber adhesives lies between 3 months and 2 years.

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S.K. Zherebkov

**RUBBER CONTAINING RECLAIM** – a vulcanized rubber mixture in which part (less frequently all) of the gum and part of the soot, mineral ingredients, and softeners are replaced by reclaim. The advantages of rubber containing reclaim are its reduced cost and the savings in hard-to-obtain raw materials. Thus, for example, use of one ton of such rubber in tire production yields a savings of 400-450 kg of gum rubber.

High-quality reclaim improves the technical characteristics of rubber mixtures. Mixtures containing reclaim have good plastic properties, which facilitates their subsequent processing and permits a substantial increase in the rates at which they are extruded and calendered. Such mixtures can be calendered in thicker linen without formation of air bubbles. Reclaim also facilitates and accelerates the rubberizing (impregnation and facing) of cloth. Rubber mixtures containing reclaim are more moldable, since, in addition to having good flowability and a certain surface roughness, they readily fill the press forms, forcing out the air which they contain. Rubber and ebonite mixtures containing reclaim are characterized by an elevated vulcanization rate. Reclaim somewhat reduces the elasticity, tensile strength, and durability of rubbers, as well as their serviceability under repeated high-frequency deformation. It improves the rigidity, hardness, and thermostability of rubbers, increases their adhesion to metals, and improves their resistance to thermal and atmospheric aging, which is of great importance in certain areas where rubbers containing reclaim are employed. Such rubbers have high dielectric characteristics in the absence of metallic inclusions, which are removed from the reclaim during

manufacture by magnetic separation and straining.

In selecting the types of articles which can be fabricated from rubbers containing reclaim and determining the permissible quantities of reclaim in rubber mixtures it is necessary to take into account the requirements imposed on the finished products, the production conditions, and the operational conditions. This approach to the application of reclaim-containing rubbers makes it economically and technologically efficient.

Reclaim is produced commercially from whole tires, treads, inner tubes, and casings, as well as from the colored strap yielded by the manufacture of toys and sanitary and hygienic products. Whole-tire reclaim is widely used in the manufacture of circular belts, technical sheets for various purposes, ebonite articles, hoses, single-piece micropore shoe soles, and other products. Whole-tire reclaim is the simplest and cheapest to produce, but is less uniform than the other types, since it contains large quantities of inclusions (so-called grit). Tread reclaim, which has an elevated rigidity and strength as a result of its high active-soot content, is used in tread rubbers and in a number of molded rubber products. Inner-tube reclaim is used principally in the production of inner tubes. Soft, plastic casing reclaim is used in casing mixtures in the tire industry, as well as in mixtures for the manufacture of technical rubber products and rubber shoes. Reclaimed strap from the production of toys and sanitary and hygienic products is used in the manufacture of articles of the same type. In different nations the consumption of reclaim-containing rubber ranges from 12% to 18% of the gum-rubber consumption.

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I.A. Shokhin

RUBBER FOR ANTIFRICTION COATINGS – rubber with an increased resistance to liquid and gaseous corrosive and aggresive media, particularly those with an acid reaction. The chemical and thermal stability of such rubbers is due primarily to the properties of the initial gum rubber. They are used in anticorrosion engineering chiefly for coatings to protect against corrosion, erosion, alternating deformation, fluctuations in temperature, and other detrimental factors. Rubberizing prolongs the service life of metal equipment and makes it possible to replace expensive nonferrous metals with ferrous metals.

Technical Characteristics of Antifriction Coatings Based on Synthetic Rubbers

| Каучуки 1 | 2 Температура вулканизации, °С | 3 Эластические свойства | 4 Устойчивость к истиранию | 5 Устойчивость к | 6 минеральным кислотам | 7 щелочам | 8 окислителям | 9 минеральным маслам | 10 Сопротивление тепловому старению | 11 Верхний температурный предел эксплуатации, °С | 12 Вид защиты | 13 Способы склеивания и сварки |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Натрийдивинильный (СКБ) | 100–142 | 3 | 3 | 2 | 3 | 1 | 1 | 2 | 75 | ОБ | СКН |
| Дивинилстирольный (СКС) | 100–142 | 3 | 3 | 2 | 3 | 1 | 1 | 2 | 75 | ОБ | СКН |
| Дивинилнитрильный (СКН) | 142 | 3 | 3 | 2 | 3 | 1 | 3 | 2 | 86 | ОБ | СКН |
| Бутилкаучук | 130–142 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 100 | ОБ | СКН-СВ |
| Полиизобутилен | — | 1 | 1 | 3 | 3 | 2 | 1 | 3 | 100 | ОБ | СВ-СКН |
| Хлорсульфированный полиэтилен | 125–150 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 100 | ОБ | СКН |
| Хлоропреновый | 80–140 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 90 | ОБ | СКН |
| Жидкий наирит | 80–140 | 2 | 3 | 2 | 3 | 1 | 3 | 2 | 90 | ПР | — |
| Жидкий диметилсилоксановый | 20 | 2 | 2 | 1 | 1 | 2 | 1 | 3 | 250 | ПР | — |
| Жидкий тиокол | 20 | 2 | 1 | 1 | 1 | 1 | 3 | 2 | 100 | ПП | — |
| Порошкообразный тиокол | — | 1 | 2 | 1 | 1 | 1 | 3 | 2 | 70 | ПГ | — |

Symbols: 3) High; 2) satisfactory; 1) low. OB) Sheet facing; PR) coatings deposited from solution; PP) coatings applied in paste form; PG) coatings applied by the gas-flame method; SKL) cementing; SV) welding.

1) Rubber; 2) vulcanization temperature, °C; 3) elastic properties, 4) durability; 5) resistance to; 6) mineral acids; 7) alkalis; 8) oxidizing agents; 9) mineral oils; 10) resistance to thermal aging; 11) maximum operating temperature, °C; 12) type of protection; 13) joining method; 14) sodium divinyl (SKB); 15) divinyl styrene (SKS); 16) divinyl nitrile (SKN); 17) butyl; 18) polyisobutylene; 19) fluorsulphated polyethylene; 20) chloroprene; 21) liquid nairit; 22) liquid dimethyl siloxane; 23) liquid thiocol; 24) powdered thiocol; 25) OB;

26) PR; 27) PP; 28) PG; 29) SKL; 30) SKL-SB; 31) SV-SKL.

Rubberizing is carried out by lining the equipment with sheets of "raw" rubber and then vulcanizing them, by cementing on or inserting a prepared vulcanized facing or lining, by applying solutions or pastes which are then subjected to thermal or cold vulcanization, by applying latex mixtures or other gum-rubber dispersions, or by gas-flame deposition of gum rubber. Lining with sheets is the most common procedure and is employed to protect chemical, galvanic, etc. equipment against corrosion. Cementing-on of a prepared lining is employed for rubbers which do not bond reliably to metal, e.g., those with fluorine bases, which have an exceptionally high chemical stability. Lining with solutions and pastes (liquid nairit, thiocol paste) applied by painting has come to be quite important. This technique makes it possible to line products with complex shapes directly at chemical, machine building, etc. plants. Latexes (e.g., chloroprene latex) can be applied by various special procedures, including electrodeposition. Lining with latex is not widely employed, because of the difficulties arising from the colloid nature of this material. Gas-flame deposition (e.g., of powdered thiokol) with special torches of the autogenous type permits rubberizing of metal articles without cements, solvents, or vulcanization. The type of rubber to be used is selected on the basis of the conditions under which the protected equipment will operate and its size and shape. Natural-gum, sodium divinyl, and divinyl styrene rubbers are used as acid-resistant coatings with moderate thermostability. Compositions based on divinynitrile and chloroprene are employed when resistance to oils and certain other organic products is also required. Thiocol rubbers provide coatings with a high resistance to organic solvents but with a low acid resistance. Acid-

resistant coatings with an elevated thermostability are obtained from butyl rubber and polyisobutylene, while coatings with a high resistance to oxidizing agents are produced from khaypalon.

The Table shows the characteristics of anticorrosion coatings of various types of polymers. It can be seen from the data in the Table that there are no general-purpose rubbers for anticorrosion coatings. The range of anticorrosion rubbers is, however, broad enough to solve many practical problems. The protective properties of anticorrosion coatings as a whole also depend on the chemical stability of the cemented seams, so that, all other conditions being equal, it is necessary to select those types of rubber which can be joined to give seams with physical and mechanical properties and a chemical stability equivalent to those of the base material (butyl rubber, polyisobutylene). Protective coatings with completely uniform characteristics are obtained from solutions or pastes, since they have no seams. When a primer is used such coatings are so strongly bonded to the metal that equipment lined in this manner can be used both under pressure and in a vacuum. The drawbacks of anticorrosion rubbers include low thermostability, lack of thermal conductivity, and susceptibility to aging, the intensity of the latter depending on the temperature and aggresiveness of the medium to which the rubber is exposed. Rubber coatings lose their protective properties after 1-2 years under severe conditions, but can function for 3-4 years under normal conditions and for up to 10-15 years under especially favorable conditions (low temperatures, absence of oxygen).

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A.L. Labutin

RUBBER RESISTANT TO HYDRAULIC FLUIDS – rubber used for packing movable and stationary joints in hydraulic systems, in the manufacture of hoses for transferring hydraulic fluid and in the production of pump diaphragms.

In developing rubbers of this type it is necessary to take into account the aggressiveness of the hydraulic fluid, the purpose of the rubber component, and the requirements imposed on it.

Hydraulic-fluid-resistant rubbers which will be exposed to AU oil in hydraulic systems are produced from SKN-26 gum rubber or a combination of SKN-26 and SKN-18 gums. In order to produce siding packing components 110-150 parts by weight of chimney soot or lamp black are added to the rubber mixture, giving it the requisite hardness and durability; small quantities of SKN-40 gum or fluoroplast-4 are also added to reduce the coefficient of friction. Increasing the content of SKN-40 gum reduces the frost resistance of the rubber. The approximate physical and mechanical characteristics of AU hydraulic-fluid-resistant rubber are as follows: tensile strength – 100-150 $kg/cm^2$, relative elongation – 150-200%, hardness in TM-2 apparatus – 75-85, short-term high-elasticity equilibrium modulus – 80-150 $kg/cm^2$, embrittlement temperature – −30° to −40°, degree of distension – −2.0 to +15% by weight, and residual deformation after compression by 20% for 1 day at +70° – 10-25%.

AU hydraulic-fluid-resistant rubber for hoses, containers, and diaphragms has a TM-2 hardness of 50-65, which is achieved by adding lamp black, chalk, barium oxide, etc. In order to ensure high resist-

ance to diffusion of hydraulic fluid large quantities of softeners should not be added to the mixture. Diffusion can also be reduced by employing antidiffusion barriers of polyamide films and other materials in the structure of rubber products.

MVP and AMG-10 hydraulic-fluid-resistant rubbers are manufactured from SKN-18 gum. In view of the tendency of chloroprene gum to crystallize it is used only as an additive. Addition of plasticizers redues the minimum operating temperature of MVB and ANG-10 rubbers to −60° and also lowers their degree of distension. The approximate physical and mechanical characteristics of MVP and AMG-10 hydraulic-fluid-resistant rubbers for packing components are as follows: tensile strength − 100-150 kg/cm$^2$, relative elongation − 150-250%, hardness in TM-2 apparatus − 75-90, degree of distension − 1-4% by weight, short-term high-elasticity equilibrium modulus − 100-200 kg/cm$^2$, embrittlement temperature − −45° to −60°, and residual deformation after compression by 20% for 1 day at +70° − 15-30%.

AGM hydraulic fluid is more aggresive than AMG-10 or MVP fluid. Rubbers for AGM are produced from SKN-26 gum, SKN-18 gum being insufficiently resistant to this fluid. In order to increase the frost resistance of SKN-26-based rubber 30 parts by weight of plasticizer or antifreeze, are added for each 100 parts by weight of gum. It is also advisable to add 25-40 parts by weight of chloroprene or SKN-18 gum to improve the frost resistance and maximum distension of the rubber. The basic physical and mechanical properties of AGM hydraulic-fluid-resistant rubber are analogous to those given above for AMG-10 and MBP rubbers, except for its embrittlement temperature, which is −40° to −50°.

The physical and mechanical characteristics of rubbers drop by 20-30% on exposure (for up to 5 years) to AU, AGM, MVP, or AMG-10 fluid at 20°. Technical rubber products intended for operation in alcohol-

glycerin fluids manufactured from nonpolar frost-resistant NK, butyl, SKBM, and SKMS-10 gums. Rubbers intended for operation in pure silicoorganic fluids are produced from the nonpolar frost-resistant gums NK, SKMS-10, etc. Rubber mixtures to be used in silicoorganic fluids containing naphthene oil are prepared from SKN-18 gum or chloroprene to which small quantities (10-20 parts by weight) of nonpolar gums are added. The remaining requirements imposed on the rubber mixtures and the principals of their compounding are analogous to those discussed above. The gum used for hydraulic-fluid-resistant rubbers depends on the composition and structure of the synthetic fluid: siloxane and butyl rubber are used for phosphoric-acid products, Vayton's fluorocarbon polymer for organic diesters, and the methylvinylpyridine gum filprene VP-5 for ethers that are mixtures of the reaction products of monoatomic alcohols and organic acids.

Methylvinylpyridine-based rubbers retain their high strength after exposure to complex ethers for 72 and 240 hr at a temperature of 150°, while divinylnitrile rubbers lose 75-80% of their strength after exposure to ethers at 70° for 24 hr.

Siloxane rubbers are used as packings for fixed and flexible joints, membranes, etc. in hydraulic systems using phosphoric-acid products for fluid.

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F.Ye. Fradkina

RUBBER RESISTANT TO STRONG OXIDIZING AGENTS (and other highly aggressive media) – rubber which remains serviceable in machinery and equipment using concentrated nitric acid (up to 98%), nitric acid containing dissolved nitrogen oxides, concentrated hydrogen peroxide, and other highly aggresive media. Rubbers intended to function under such conditions are used in the manufacture of packing components, diaphragms, hoses, hermetic seals, etc. The operational characteristics of rubbers resistant to strong oxidizing agents depend on the character of the aggressive medium, the temperature, the component's operating regime, etc. Thus, the maximum service life of rubber components in fuming red nitric acid does not exceed 2-3 months, while that of components in concentrated hydrogen peroxide is 6 or more months.

TABLE 1

| 1 Среда | 2 Набухание (объемн. %) при 20° за время в сутках | | |
|---|---|---|---|
| | 1 | 2 | 27 |
| 3 Белая дымящая азотная кислота . . . . | 12 | 22 | 24 |
| 4 Красная дымящая азотная кислота . . | 9 | 15 | 24 |

1) Medium; 2) distension (% by volume) at 20° over (days); 3) fuming white nitric acid; 4) fuming red nitric acid.

In the majority of cases the service life of rubber components in highly aggressive media is prolonged by use of special structural techniques; for example, rings with round cross-sections are installed in special wedge-shaped fittings rather than in flat flanges or rectangular grooves. This reduces the surface area of the ring in contact with the aggressive medium and creates conditions for self-pack-

TABLE 2

| 1 Показатели | 2 Выдержка при 20° | | | | | |
|---|---|---|---|---|---|---|
| | 3 Красная дымящая азотная кислота | | | 7 Перекись водорода (90%) | | |
| | 4 До выдерживания | 5 через 6 час | | 4 До выдерживания | 5 через 6 час | |
| 8 Предел прочности при разрыве (кг/см²) | 130 | 115 | 92 | 130 | 125 | 125 |
| 9 Твердость по ТМ-2 | 58 | 52 | 48 | 56 | 55 | 57 |
| 10 Относительное удлинение (%) | 630 | 610 | 57 | 700 | 665 | 700 |

1) Index; 2) soaking at 20°; 3) fuming red nitric acid; 4) before immersion; 5) after; 6) hr; 7) hydrogen peroxide (90°); 8) ultimate tensile strength (kg/cm²); 9) hardness in TM-2 apparatus; 10) relative elongation (%).

ing; the working pressure of the product forces the ring into the narrow portion of the wedge, facilitating hermetic sealing. The decrease in the area of contact between the ring and the product makes it possible to use less stable rubbers. In such cases gums with high chemical stability (e.g., those containing fluorine) are usually combined with gums that are frost-resistant but not resistant to strong oxidizing agents (e.g., SKMS-10 divinylstyrene). This expands the component's working-temperature range. In addition to changing the fittings in fixed packing systems, the axial compression of the rubber component can be increased; a ring with a round cross section is compressed by 35-50% when working with strong oxidizing agents and by 15-30% when working with mild media. The maximum service life of fixed rubber packing components and hoses does not exceed 2-3 months in oxidizing agent.

In designing the rubber-metal components of packing valves the oxidation-resistant rubber is fastened to the metal framework by rolling or molding. The service life of rubber gaskets used to pack to rotating rollers drops to 10-15 days, since high temperatures develop where the rubber is in contact with the roller and the distension of

the rubber in the aggressive medium causes a decrease in thermal stability and durability.

Rubbers resistant to strong oxidizing agents are manufactured from Kel'-F and Vayton fluorine-containing polymers, chlorsulphated polyethylene (KhP), nitrosyl gum (N), and ethylene-propylene gum (EK).

Rubbers based on the fluorine-containing gum Kel'-F have an exceptionally high resistance to strongly oxidizing mineral acids, peroxides, and alkalies. The most chemically stable Kel'-F rubbers are obtained with organic peroxides and contain fillers (dispersed silica gel or calcium fluoride). Vulcanizates with high chemical stability can be produced by using salts of certain amines or a combination of carbon black and silica, but these have a lower residual compression than peroxide vulcanizates.

In the majority of cases addition of softeners and plasticizers is formation of bubbles in the rubber; the aggressive media act on these bubbles, leaching out the softeners and plasticizers.

Tables 1 and 2 shows the chemical stability of Kel'-F rubbers produced with benzoyl peroxide.

Immersion of Kel'-F products in fuming nitric acid at 58° for 1 week has virtually no effect on their relative elongation or hardness, even when they are subjected to dynamic deformation.

Kel'-F rubber is fastened to metals with epoxy glues.

Special structural techniques are employed to ensure that components will remain serviceable in highly aggresive media at temperatures down to −40°. For example, double reinforced cups, one of rubber resistant to strong oxidizing agents and the other of frost-resistant rubber, which is less resistant to the medium, are used to pack rotating rollers.

Rubbers based on Vayton gum have a frost resistance similar to

that of Kel'-F rubbers, but are more heat-resistant; the former can function at 250° for up to 50 days, while the latter can do so for no more than 3 days. Vayton rubbers have a lower chemical stability than Kel'-F rubbers (Table 3).

Rubber based on nitrosyl gum is a clear polymer of trifluoronitrosomethane and tetrafluoroethylene and has a molecular weight of more than one million. N-based rubbers are completely inflammable and exceptionally resistant to various solvents (except freons), ozone, and natural aging; its distension after 2 days in fuming nitric acid at room temperature amounts to 20% by volume (compared with 70% for Vayton rubbers).

N-based rubbers are vulcanized by amines. A combination of triethylene tetraamine and hexamethylene diamine carbamate is the most effective vulcanizer. Finally-dispersed silica gel is the best filler. N-based rubbers are frost-resistant to −40° and the polymer itself has a vitrification temperature of −51°. The principal drawback of these rubbers is their low tensile strength (no more than 50 kg/cm$^2$).

TABLE 3

| 1 Среда | 2 Температура (°С) | 3 Продолжительность контакта (сутки) | 4 Набухание: объемн. % | 4 Набухание: по весу % | 5 Сохраняется: прочности при растяжении (%) | 5 Сохраняется: относительного удлинения (%) | 10 Изменение твердости по ТМ-2 |
|---|---|---|---|---|---|---|---|
| 11 Безводный фтористый водород | 20 | 3 | — | 31 | 12 Сильно набухает, крошится | | |
| Царская водка 12 | 20 | 7 | 197 | — | 12 Сильно набухает, крошится | | |
| Дымящая серная кислота 13 | 20<br>70 | 7<br>3 | 4,8<br>51 | —<br>69 | 58<br>7 | 69<br>10 | −4<br>−6 |
| Азотная кислота (уд. 14 | 20<br>20<br>70 | 7<br>30<br>7 | 24,5<br>4,5<br>250 | 17,5<br>1,1<br>19,2 | 85<br>— | 95<br>94<br>15 Набухает | 13<br>25 |
| Царская дымящая азотная кислота 17 | 20<br>70 | 7<br>3 | 122 | 96 | 19 Разрушается | | 20 |

1) Medium; 2) temperature (°C); 3) contact time (days); 4) distension; 5) % by volume; 6) % by weight; 7) maintenance of; 8) ultimate tensile strength (%); 9) relative elongation (%); 10) change in TM-2 hardness; 11) anhydrous hydrogen fluoride; 12) aqua regia; 13) fuming sulfuric

acid; 14) 60° nitric acid; 15) fuming red nitric acid; 16) intensive bubble formation; 17) specimens very soft; 18) soft; 19) decomposes.

KhP-based rubbers are vulcanized with magnesium oxide (20-40 parts by weight per 100 parts by weight of gum). Rubbers vulcanized with lead oxide function better in dilute oxidizing agents. The type of filler used has little effect on the stability of KhP rubbers. A large amount of filler reduces the distension of of these rubbers; use of zince oxide or precipitated calcium carbonate is not recommended. If possible, use of softeners should be avoided. A high degree of vulcanization promotes a decrease in distension. KhP rubbers are less resistant to strong oxidizing agents than fluorocarbon polymers; they can function for prolonged periods in 50% chromic acid at 93°, 70% nitric acid at room temperature, 50% hydrogen peroxide, and concentrated sulfuric acid and briefly (for approximately 1 day) in fuming red nitric acid. Distension after three months in 80-85% hydrogen peroxide amounts to no more than 10% by weight. KhP rubbers are widely employed in the manufacture of articles which must be exposed to liquid peroxides.

EK-based rubbers have a high durability and chemical stability and are frost-resistant to -35 or 40°; they are used in the manufacture of sliding packings which must function in liquid peroxides. There are indications that EK rubbers are more resistant to concentrated hydrogen peroxide than KhP vulcanizates and can function in this medium for up to 1 year.

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V.S. Yurovskiy

RUBBEROID – see Bituminous materials.

RUPTURE – fracture due to tensile stresses, generally occurring after low-magnitude plastic deformation. The condition for brittle rupture is that the tensile stresses equal the rupture resistance before the tangential stresses exceed the yield strength. If the yield strength rises more rapidly than the rupture resistance when the test temperature decreases the tendency toward brittleness and fracture by rupture is enhanced. Rupture usually occurs in metals that have undergone slight prior plastic deformation. Brittle (elastic) rupture is observed in ceramics, glass, and many plastics. Intercrystalline rupture may occur when brittle or weak phases precipitate along the grain boundaries. In many instances brittle fracture under service conditions (see Reserve elastic energy) occurs by rupture, especially in steel, and it is consequently necessary to attempt to raise rupture resistance by all possible means. See Rupture resistance and Fracture by rupture.

Ya.B. Fridman

RUPTURE LENGTH – a characteristic of the strength of materials, which is numerically equal to the greatest length of a specimen with a constant cross section, freely suspended from one end, at which it does not break due to its own weight (when subjected to a short-duration load). The rupture length is identical with the indicator of the specific tensile strength of the material. It is used in testing threads, fabrics, and similar materials, for which it is impossible to accurately determine the cross section. It is calculated from one of the following formulas:

$$L_p = P_p N_m \qquad (1)$$

$$L_p = P_p \frac{l}{Q} \qquad (2)$$

$$L_p = \frac{P_p}{l \cdot b} \qquad (3)$$

where $L_r$ is the rupture length in km (m), $P_r$ is the rupture load in kg (g), $N_m$ is the metric number; Q is the weight of the specimen (between clamps) in g; g is the weight of a $m^2$ of the material in g, $\ell$ and b are the length and width of the specimen (between clamps) in m. Formulas (1) and (2) are used for fibers, threads and other twisted products; Formulas (2) and (3) are used for paper, cardboard, fabrics, films.

B.I. Panshin

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[Transliterated Symbols]

3459 p = r = razryvnaya = rupture

RUPTURE STRENGTH OF FIBERS – a quantity characterizing the ability of fibers to withstand failure under the action of the stresses produced by a single extension. The rupture strength of fibers and threads depends on the structure of the fibers themselves and on that of the finished product. In connection with the difficulties involved in measuring the cross-sectional area of a fiber, rupture strength is determined from the applied force required to cause failure of the fiber or thread. Multiplying the rupture force by the metric number of the fiber gives its so-called tearing length. This is the length (expressed in km) at which the fiber or thread fails under its own weight. Knowing the tearing length of a fiber or thread it is simple to determine the tensile stress necessary to cause it to fail. For this purpose the tearing length is multiplied by the specific weight of the fiber. The resultant quantity is the so-called short-term rupture resistance and is expressed in $kg/mm^2$. In using the weight characteristics of a fiber, including its titer (weight in g per 9000 m) or greks (weight in g per 10,000 m), to determine its rupture strength it is necessary to employ the relative rupture load, which equals the rupture force in g divided by the titer or greks and is expressed in g/denier or g/greks, respectively. In order to convert the relative fiber strength in g/denier or g/greks to the tearing length in km the number of g/denier must be multiplied by 9 and the number of g/greks by 10. The rupture strength and tearing length are determined on different breaking machines, in which the fiber is tensioned at a definite rate under a given loading regime. Rupture strength depends on the test temperature and loading time.

V.A. Berestnev

RUTHENIUM, Ru – a chemical element in group VIII of the Mendeleyevian periodic system, with an atomic number of 44 and an atomic weight of 101.07; it has the stable isotopes $Ru^{96}$ (5.51%), $Ru^{98}$ (1.87%), $Ru^{99}$ (12.72%), $Ru^{100}$ (12.62%), $Ru^{101}$ (17.07%), $Ru^{102}$ (31.61%), and $Ru^{104}$ (18.58%) and the radioactive isotopes $Ru^{103}$ and $Ru^{106}$.

Ruthenium is a metal of the platinum family; its content in the earth's crust is $5 \cdot 10^{-7}$% by weight. It has a density of 12.4 g/cm$^3$, a $t^{\circ}_{pl}$ of 2250°, and a $t^{\circ}_{kip}$ of ~4900°. Ruthenium is a silvery-white metal similar to platinum and is high-melting and very hard even at high temperatures. The most important properties of ruthenium are its high melting point, hardness, chemical stability, and ability to accelerate certain chemical reactions. It forms the volatile oxide $RuO_4$. See Precious metals.

O.Ye. Zvyagintsev

RUTILE – a mineral with the chemical formula $TiO_2$, the most stable modification of $TiO_2$ at both high and low temperatures. The specific gravity of the pure mineral is 4.2-4.3, while that of varieties containing niobium and tantalum ranges up to 5.6. It is brittle, exhibiting complete cleavage in the {101} direction and moderate cleavage in the {100} direction; its Moos hardness is 6. It is usually dark yellow, brown, red, or black in color; colorless or light-hued varieties are extremely rare. Rutile is tetragonally syngonic, having the elementary-cell dimensions a = 4.58A and c = 2.95A. It differs from the other modifications of $TiO_2$ (brookite and anatase) in structure. Rutile crystals have a high index of refraction, a higher birefringence than calcite crystals, high dispersion, and high dielectric permeability. In nature rutile is formed under various conditions, most frequently during metamorphic transformation of titanium-containing minerals, being isolated in individual grains in gneisses, mica schists, amphiboles, and other rocks. Natural rutile is used for smelting ferrotitanium and in the manufacture of titanium oxide, components with high dielectric permeability, etc.

Crystals of artificial rutile can be obtained by Verneyl's method or by hydrothermy; such crystals are used in the manufacture of high-temperature rectifiers. Artificially faceted rutile crystals are used as imitation diamonds. Pure rutile crystals with impurities such as rubin can be used in light quantum generators.

References: Betekhtin, A.G., Jurs mineralogii [Course in Mineralogy], 3rd Edition, Moscow, 1961.

V.P. Butuzov

SAND (natural) – a loose sedimentary rock consisting of unbound grains of various minerals; it is a product of the natural physical and chemical breakdown of rocks.

Depending on which mineral or group of minerals predominates, we can distinguish the following types of sand: quartz, quartz-feldspar, quartz-mica (these being the varieties most frequently encountered), glauconite, carbonate, titanite, ilmenite, magnetite, zirconium, monazite, etc. The granulometric composition of sand is characterized by great diversity. Sands of varying grain size with a more or less uniform content of individual fractions are generally encountered. Depending on the predominant grain size (mm), sands can be classified as: coarse-grained (1-2), large-grained (0.5-1), medium-grained (0.25-0.5), small-grained (0.1-0.25), fine-grained (0.05-0.1), and dusty (0.01-0.05). Clay is usually present as an impurity. The porosity of dry sand ranges from 30.2 to 63.2%, depending on the grain size. Its bulk weight is 1.47-1.81 when dry and 1.91-2.14 when water-saturated. The thermal conductivity of quartz-feldspar sand is 2.7 watts/cm·degree·$10^3$, that of fine-grained quartz sand is 1.67 watts/cm·degree·$10^3$, and that of coarse-grained quartz sand is 3.8 watts/cm·degree·$10^3$. The specific resistance of quartz-feldspar sand is $10^5$-$10^6$ ohm·cm when dry, $8.3 \cdot 10^{-4}$ ohm·cm at a water content of 0.16%, $3.8 \cdot 10^{-4}$ ohm·cm at a water content of 1.52%, $1.2 \cdot 10^{-4}$ ohm·cm at a water content of 5.8%, and $0.95 \cdot 10^{-4}$ ohm·cm at a water content of 9.5%. The speed of sound in medium-grained sand is 1400-2600 m/sec. The compressibility of dry fine- and medium-grained sands is 2.6-13 kg/cm$^2$.

Sands are classified commercially as structural or industrial. In construction sand (quartz and quartz-feldspar) is employed principally as an inert additive. This material is widely used in the glass-making industry, primarily in the form of quartz sand containing no less than 98% $SiO_2$. Quartz sand containing no more than 0.012% $Fe_2O_3$ (the total content of $Fe_2O_3$, $Cr_2O_3$, $Al_2O_3$, and other impurities should not exceed 0.2%) is used in the manufacture of optical glass, crystal, mirrors, and radio-tube glass. Electrovacuum glass is produced from dusty quartz sand. In the casting industry molds are fabricated from quartz sand with acute-angled grains. Coarse-grained sand is employed for heavy castings and small- and fine-grained sand for light castings. In the ceramics industry quartz sand is employed as an additive to make faience, porcelain, and other ceramic masses leaner; it is also used in the manufacture of Dinas brick, soluble glass, silicon carbide, abrasive materials, grinding and polishing tools, and sandpaper, in sandblasting equipment, etc. In the metallurgical industry quartz sand is employed as a constituent of metal-smelting charges and for packing furnace hearths and walls; in the chemical and petroleum industries it is used as a catalyst carrier and in the manufacture of filters, while in mining it is employed for wet-packing workings. This material is also used in the manufacture of water-supply filters.

References: Trebovaniya promyshlennosti k kachestvu mineral'nogo syr'ya [Industrial Specifications for Mineral Raw Materials], No. 29 - Ben', I.I., Stekol'noye syr'ye [Glass Raw Materials], Moscow-Leningrad, 1947; Ibid., 2nd Edition, No. 2 - Ramzes, B.Ya., Zubarev, N.N., Pesok kvartsevyy [Quartz Sand], Moscow, 1959; Birch, F., Scherer, D., Speiser, G., Spravochnik dlya geologov po fizicheskim konstantam [Handbook of Physical Constants for Geologists], translated from English, Moscow, 1949; Tatarinov, P.M., Malyavkin, S.F., and Geysler, A.N., Kurs

nerudnykh mestorozhdeniy [Course in Non-Ore-Bearing Deposits], Pt. 2, Leningrad-Moscow, 1935; Cotter, P.G., Mallory, J.B., Sand and gravel, in book: Minerals Yearbook, 1960, Vol. 1, Washington, 1961.

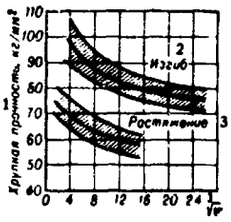
V.V. Nasedkin

SANIV – see Fiber of acrylonitrile-vinylchloride and acrylonitrile-vinylidene chloride copolymers.

SAP – see Sintered aluminum powder.

SARAN – see Polyvinylidene chloride fiber.

SCALE EFFECT is the phenomenon of strength reduction with increase of the dimensions of the specimen or part. Scale effect manifest itself with repeated loadins (see Fatigue, Static Endurance), in conditions of static loading – in brittle (or semi-brittle) fracture, and in the occurrence of creep. The effect of specimen dimensions on the magnitude of the bradking strength (figure), the proportional and yield limits, the plasticity (Table 1) for various metallic and nonmetallic materials has been shown experimentally. The resistance to viscous fracture is practically independent of the specimen size (Table 2).




Variation of breaking strength of phosphorus steel with specimen size (V). 1) Brittle strength, kg/mm$^2$; 2) bending; 3) tension.

Real material contains various surface and internal defects and has microscopic, and frequently also marcroscopic nonuniformities of properties. The macroscopic nonuniformity may be due to technological peculiarities of production (nonuniform hardenability, nonuniform degree of deformation of the entire section in pressure working, work hardening of the surface ayler during mechanical working, etc.). In accordance with the statistical theory of strength, the scale effect in brittle fracture is explained by the fact that with increase of the body size there is an increase of the probability of the presence in the body of

II-53M1

TABLE 1

Effect of Specimen Size on Mechanical Properties of Steel in Tension

| 1 Сталь и вид термич. обработки | 2 Диаметр образца (мм) | $\sigma_{pts}$ 3 | $\sigma_{0.2}$ | $\sigma_b$ | $S_k$ | $\psi$ |
|---|---|---|---|---|---|---|
| | | (кг/мм²) 4 | | | | (%) |
| 5 30ХГСА — закалка с отпуск при 600° (выдержка 2 час., охлаждение на воздухе) | 5 | 78,7 | 81,2 | 93,3 | 164 | 62 |
| | 20 | 65,8 | 75,4 | 91,5 | 151 | 58 |
| 6 30ХГСНА — изотермич. закалка в селитре при 320° | 5 | 42,3 | 84,0 | 122 | 252 | 52,3 |
| | 10 | 35,9 | 78,0 | 121 | 207 | 49,7 |
| | 20 | 34,0 | 73,6 | 119 | 195 | 45,8 |
| | 40 | 32,8 | 71,8 | 119 | 186 | 40,4 |
| 7 18ХНВА — закалка к отпуск при 550° (выдержка 2 час., охлаждение на воздухе) | 5 | 69,6 | 103 | 114 | 195 | 64,6 |
| | 10 | 68,5 | 104 | 115 | 200 | 61,7 |
| | 20 | 62,4 | 97,5 | 113 | 182 | 59,5 |
| | 40 | 53,1 | 95,0 | 111 | 177 | 49,1 |
| 8 40ХНМА — закалка и отпуск при 550° (выдержка 2 час., охлаждение в масле) | 5 | 78,2 | 88,1 | 103 | 171 | 55,7 |
| | 10 | 71,3 | 85,2 | 103 | 171 | 52,6 |
| | 40 | 68,7 | 82,0 | 100 | 152 | 49,2 |

1) Steel and form of heat treatment, 2)specimen diameter (mm); 3) $\sigma_{pts}$; 4) (kg/mm$^2$); 5) 30KhGSA – solution treatment at 600° (soad for two hours, air cool); 6) 30KHGSNA – isothermal solution treatment in potassium nitrate at 320°; 7) 18KhNVA – solution treatment and temper at 550° (soad for two hours, air cool); 8) 40KhNMA – solution treatment and temper at 550° (soad for two hours, oil cool).

TABLE 2

Effect of Specimen Size on Resistance to Viscous Fracture in Torsion (average values of $f_k$ from frequency curves are presented)

| 1 Материал | 2 Режим термич. обработки | 3 Диаметр образца (мм) | 4 Сопротивление срезу $t_k$ (кг/мм²) | 5 Макс. сдвиг при разрушении $g_{max}$ (%) |
|---|---|---|---|---|
| 6 Железо Армко | 7 Отжиг при 800° в течение 2 час. | 5 | 36,2 | 352 |
| | | 10 | 35,0 | 333 |
| | | 20 | 35,4 | 320 |
| | | 40 | 35,0 | 299 |
| 8 Сталь 30ХГСНА | 9 Закалка с 890° в масле, отпуск при 200° | 10 | 125 | — |
| | | 20 | 124 | — |

1) Material; 2) heat treatment condition; 3) specimen diameter (mm); 4) shear strength $t_k$ (kg/mm$^2$); 5) maximal shear at failure $g_{max}$ (%); 6) armco iron; 7) anneal at 800° for two hours; 8) 30KhGSNA steel; 9) oil quench from 890°, temper at 200°.

a more dangerous defect, which determines the brittle strength of the material.

There is also the energetic treatment of scale effect in brittle fracture, in accordance with which the effect of body size on the brittle strength is associated with the increase of the rate of propagation of a brittle crack in larg specimens in connection with the large reserve of elastic energy stored up in this case by the system (specimen) subjected to the action of forces.

In relation to the proportional and yield strengths, the scale effect has primarily a statistical nature and is due to the differing resistance to plastic deformations of quite small volumes of the metal.

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S.I. Kishkina-Ratner

SCALE-RESISTANT CAST IRON – is a cast iron with a high-scale resistance, i.e., a hardy resistance to oxidation and a constancy of volume (low change in dimensions) at high temperatures. The scale-resistant cast irons are subdivided into the white, high-chromium, and the gray cast irons (Tables 1-3).

TABLE 1

Chemical Composition and Mechanical Properties of High-Chromium Scale-Resistant White Cast Irons (GOST 2176-57)

| Марка 1 | 2 Содержание элементов (%) | | | | | | 3 Механич. свойства | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C | Cr | Si | Mn | P | S | $\sigma_b$ | 4 $\sigma_{изг}$ | 7 Стрела прогиба $f_{600}$ (мм), не менее | 8 HB (кг/мм²) |
| | | | | | 5 не более | | 6 (кг/мм²), не менее | | | |
| 9 Х28Л | 0,5–1,0 | 26–30 | 0,5–1,3 | 0,5–0,8 | 0,1 | 0,08 | 35 | 55 | 6 | 220–270 |
| Х34Л | 1,5–2,2 | 32–36 | 1,3–1,7 | 0,5–0,8 | 0,1 | 0,1 | 40 | 60 | 5 | 250–320 |

1) Grade; 2) percentage of the elements; 3) mechanical properties; 4) izg; 5) not more than; 6) (kg/mm$^2$), not less than; 7) deflection $f_{600}$ (mm), not less than; 8) (kg/mm$^2$); 9) Kh..L.

TABLE 2

Chemical Composition of Scale-Resistant Gray Cast Irons (GOST 7769-55)

| Чугун 1 | Марка 2 | 3 Содержание элементов (%) | | | | | | 5 Др. легирующие элементы |
|---|---|---|---|---|---|---|---|---|
| | | C | Si | Mn | P | S | Cr | |
| | | | | | 4 не более | | | |
| 6 Хромистый | ЖЧХ-0,9 11 | 2,8–3,4 | 1,5–2,5 | 1,0 | 0,3 | 0,12 | 0,7–1,1 | — |
| То же 7 | ЖЧХ-1,5 | 2,8–3,4 | 1,7–2,7 | 1,0 | 0,3 | 0,12 | 1,2–1,9 | — |
| | ЖЧХ-2,5 | 3,0–3,5 | 2,8–3,8 | 1,0 | 0,3 | 0,12 | 2,0–2,7 | — |
| 8 Кремнистый (силал) | ЖЧС-5,5 12 | 2,2–3,0 | 5,0–6,0 | 1,0 | 0,3 | 0,12 | 0,5–0,9 | — |
| То же, с шаровидным графитом 9 | ЖЧСШ-5,5-0,1 | 2,4–3,0 | 5,0–6,0 | 0,7 | 0,3 | 0,2 | 0,2 | ⩾0,08 Mg |
| Никелемедехромистый (нирезист) 10 | ЖЧНДХ 13-2 14 | 2,5–3,0 | 1,5–4,0 | 0,5–1,2 | 0,3 | 0,08 | 1,5–2,3 | 14–17 Ni, 6,0–8,5 Cu |

1) Cast iron; 2) grade; 3) percentage of the elements; 4) not more than; 5) other alloying elements; 6) chromium; 7) the same; 8) silicon (Silal); 9) the same with spheroidal graphite; 10) nickel-copper-chromium alloy (Ni-Resist); 11) ZhChKh-; 12) ZhChS-; 13) ZhChSSh-; 14) ZhChNDKh-.

TABLE 3

Mechanical Properties of Scale-Resistant Gray Cast Irons (GOST 7769-55)

| Марка 1 | $\sigma_b$ (кг/мм²), не менее 3 | $\sigma_{изг}$ 2 | Стрела прогиба f (мм), не менее 4 | HB (кг/мм²) 5 |
|---|---|---|---|---|
| 6 ЖЧХ-0,9 | 18 | 36 | 2,5 | 207–285 |
| ЖЧХ-1,5 | 15 | 32 | 2,5 | 207–285 |
| ЖЧХ-2,5 | Не определяется 10 | 32 | 2,0 | 228–363 |
| 7 ЖЧС-5,5 | 10 | 24 | 2,0 | 140–255 |
| ЖЧСШ-5,5-0,1 | 22 | Не определяется 10 | | 228–321 |
| 8 ЖЧНДХ15-7-2 | 18 | То же 11 | | 120–197 |
| 9 | | | | |

1) Grade; 2) izg; 3) ($kg/mm^2$), not less than; 4) deflection f (mm), not less than; 5) $kg/mm^2$; 6) ZhChKh-; 7) ZhChS-; 8) ZhChSSh-; 9) ZhChNDKh-; 10) not determined; 11) the same.

The scale-resistance and the constancy of volume of the white high-chromium irons varies depending on the crhomium content: the iron containing 12% Cr serves satisfactorily up to 840-850°; at 15-17% Cr, the stability reaches up to 950°; at 25% Cr (Kh28L) up to 980°, and at 33% Cr (Kh34L) up to 1050°.

The physical properties of high-chromium scale-resistant white irons are: $\alpha$ at 20° (1/°C) = $9.4\text{-}10.0 \cdot 10^{-6}$; $\lambda$ (cal/cm·sec°C) = 0.05-0.055; $\gamma(g/cm^3)$ = 7.4; linear shrinkage (%) = 1.5-1.8.

Alloying of the high-chromium scale-resistant white iron with nitrogen (0.2%) and titanium (0.2%) gives a finer grain size and increases the mechanical properties of the castings; alloying with molybdenum (3.5%) increases the wear resistance. An increased carbon content increases the hardness but results in a deterioration of the workability.

High-chromium scale-resistant cast iron may be softened by tempering at 780-800° and a subsequent furnace cooling up to 600°, and, further, in air. Castings of high-chromium scale-resistant cast iron are used for furnace fittings, hardening boxes and other parts working at

temperatures of up to 1000°. These cast iron grades are also used as corrosion resistant materials (see Corrosion resistant cast iron).

Gray scale-resistant cast iron is subdivided into pearlite-cementitic (chrome), ferritic (Silals), austenitic (Ni-Resists) iron, and Ni-crosilals. Depending on the melting technology, one distinguishes between Silals and Ni-Resists with lamellar graphite and with spheroidal graphite (Tables 4, 5).

TABLE 4

Comparison of the Scale-Resistance of Scale-Resistant Cast Iron Grades with Lamellar Graphite

| Чугун 1 | Глубина проникновения окислов (мм в год) 2 | |
|---|---|---|
| | атмосфера — воздух при 760° 3 | слегка восстановит. атмосфера печи при 815—925° 4 |
| 5 Серый нелегированный | >20,32 | >25,40 |
| Серый с 1,3% Ni и 0,5% Cr | >20,32 | >25,40 |
| 7 Нирезист (марка ЖЧНДХ15-7-2) | 4,57 | >25,40 |
| То же, 20% Ni 5% Cr | 1,78 | 5,59 |
| 8 То же, 30% Ni 3% Cr | 2,03 | 6,86 |
| То же, 30% Ni 5% Cr, 5% Si | 0,051 | 0,127 |
| 9 Нержавеющая сталь, 12% Ni, 25% Cr | 0,1 | 0,127 |

1) Cast iron; 2) depth of the penetration of oxides (mm per year); 3) in air at 760°; 4) in a weakly reducing furnace atmosphere at 815-925°; 5) gray, non-alloyed; 6) gray with 1.3% Ni and 0.5% Cr; 7) Ni-Resist (grade ZhChNDKh15-7-2); 8) the same; 9) stainless steel.

TABLE 5

Comparison of the Scale Resistance of Scale-Resistant Cast Iron Grades with Spheroidal Graphite

| Чугун 1 | Глубина проникновения окислов (мм в год) 2 | |
|---|---|---|
| | Атмосфера — воздух при 3 | |
| | 700° | 870-920° |
| 4 Ферритный, 2,5% Si . . | 1,06 | 12,50 |
| То же, 5,5% Si 5 . . | 0,10 | 1,29 |
| 6 Нирезист, 20% Ni, 2% Cr | 1,06 | 4,50 |
| То же, 22% Ni . . . . | 1,73 | -- |
| То же, 30% Ni, 5% Cr | 0,10 | -- |
| 7 Нирезист с пластинчатым графитом . . . . | 2,50 | 7,62 |
| Сталь нержавеющая . . 8 | 0 | 0 |

1) Cast iron; 2) depth of the penetration of oxides (mm per year); 3) in air at; 4) ferritic; 5) the same; 6) Ni-Resist; 7) Ni-Resist with lamellar graphite; 8) stainless steel.

Modification by graphitizing additions is used in the melting of the ZhChKh-0.9, ZhChKh-1.5; ZhChKh-2.5, and ZhChSSh-5.5-0.1 scale-resisting cast iron grades. The latter cast iron is also modified by magnesium or magnesium containing alloys.

The machining of the ZhChKh-2.5 cast iron is difficult due to the high chromium content. The ZhChSSh-5.5-0.1 cast iron is characterized by an increased tendency to crack in the cold; this tendency rises with an increased silicon content. Castings of silicon-containing scale-resistant iron (Silals) must be taken from the mold at temperatures higher than 800°, kept in an oven at 800-850° for 4-5 hours and then cooled together with the oven in order to remove internal stresses.

Castings of other scale-resistant iron grades are submitted to a heat treatment in order to remove internal stresses (see Heat treatment of cast iron).

The cast iron grade ZhChKh-0.9 is used for parts working in air or furnace gases of up to 600°; ZhChKh-1.5 is used for parts working in air, furnace gases or generator gases up to 650°; ZhChKh-2.5 is used

for parts working in air or furnace gases of up to 600°; ZhChKh-1.5 is used for parts working in air, furnace gases or generator gases up to 650°; ZhChKh-2.5 is used for parts working under these conditions up to 700° (fire grate bars, cooling frames of Martin furnaces, comb-shaped pipe-holders in boilers, tines and scrapers in pyrite ovens, etc.).

Castings of the silicon-containing iron (Silal) ZhChS-5.5 with lamellar graphite are used for working in air, in furnace gases or generator gases of up to 850°. An additional alloying of the ZhChS-5.5 with 4% Al increases the scale-resistance and the constancy of volume in temperatures of up to 900-950°. The silicon-containing alloy ZhChSSh-5.5-0.1 with spheroidal graphite possesses a similarly increased scale resistance. The silicon-containing iron grades are also used for fire-box fittings and cementation-furnace fittings recurperator pipes, etc.

Aluminum-alloy iron is characterized by a high scale-resistance. This cast iron, known by the name "Chugal'" is used for a great number of parts which work in temperatures of up to 1100°. Pyroferal iron (28-30% Al) is recommended for parts working in temperatures of up to 1200° in strongly oxidizing media; it maintains a high scale resistance in flue gas of different composition. The Ni-Resists (Ni, Ni + Cr, Ni + Cr + Cu) and the Nicrosilals (Ni-Cr-Si) belong to the austenitic cast iron grades.

The (austenitic) Ni-Resist grade ZhChNDKhL-7-2 is used for parts working in temperatures of up to 600° in the combustion products of light-duty engines. It is characterized by a good wear resistance under these conditions. Moreover, it is corrosion-resistant in solutions heated up to 400°. Ni-Resists of various composition are used efficiently as a scale-resistant and corrosion-resistant material for the manufacture of parts in various industrial branches. Ni-Resists with spher-

ical graphite prove the best scale-resistance.

Nicrosilal with lamellar graphite has the following composition: 1.8-2% C; 5% Si; 0.5-1.0% Mn; 16-20% Ni, and 1.5-2% Cr. Its mechanical properties are as follows: $\sigma_b$ = 21-27 kg/mm$^2$; $\delta_1$ = up to 3%. Nicrosilal is used under small loads at temperatures of up to 1100°. Its scale-resistance at 850° is lower than that of the Silals, and therefore it may only replace them when a sufficient ductility of the material is an indispensable requirement. The formation of martensite in the Nicrosilal structure, causing a change in the dimensions and a brittleness of the castings, is avoidable by reducing the silicon content to 4.5% and increasing the nickel content up to 22%.

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A.A. Simkin

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[Transliterated Symbols]

3472 Х.Л = Kh..L = khromistyy legirovannyy = chrome-alloy

3472 ЖЧХ = ZhChKh = zharostoykiy chugun chromistyy = scale-resistant chrome-alloy cast iron

3472 ЖЧС = ZhChS = zharostoykiy chugun silal' = scale-resistant cast iron Silal

3472 ЖЧСШ = ZhChSSh = zharostoykiy chugun s sharovidnym grafitom = scale resistant cast iron with spheroidal graphite

SCALE-RESISTANT NICKEL ALLOYS - see Heat Resistance of Alloys.

SCATTERING OF MECHANICAL CHARACTERISTICS – the variation in the properties of a material in moving from one specimen to another within a single series of identical specimens fabricated from material in a uniform state. This scattering results from fluctuations in the chemical composition of the material, deviations in the technological regimes used for the semifinished products, nonuniformity of material structure (liquation effects, different orientations and properties in the grains themselves, differences in the grain boundaries, presence of inclusions, distortions of the crystal lattice, etc.), and variations in specimen fabrication and testing conditions (variations in heat-treatment regimes, changes in the radius of curvature of the tool cutting edge during working, variations in the accuracy with which the specimens are positioned in the holding device of the test machine, etc.).

TABLE 1

Mechanical Properties of V95 Aluminum Alloy

| Значения свойств | $\sigma_{0,2}$ (кг/мм²) | $\sigma_в$ (кг/мм²) | $\psi_k$ (кг/мм²) | $\psi$ (%) | $\delta$ (%) |
|---|---|---|---|---|---|
| Минимальные . . | 57,2 | 62,8 | 72,5 | 13,5 | 8 |
| Максимальные . . | 60 | 64,5 | 78,5 | 20,8 | 13,3 |
| Средние . . . . . | 58,4 | 63,5 | 75 | 18,5 | 10,1 |

1) Value of characteristic; 2) kg/mm$^2$; 3) minimum; 4) maximum; 5) mean.

Scattering of mechanical characteristics is observed in both single-stage and prolonged static and dynamic tests. Table 1 shows the minimum, maximum, and mean values of the principal mechanical charac-

TABLE 2

Durability of Individual Specimens of V95 Aluminum Alloy

| Номер образца 1 | $\sigma_{макс}$ = 21 кг/мм² 2 | $\sigma_{макс}$ = 30 кг/мм² | Номер образца 1 | $\sigma_{макс}$ = 21 кг/мм² 2 | $\sigma_{макс}$ = 30 кг/мм² |
|---|---|---|---|---|---|
| | N (млн.) 3 | N (тыс.) 4 | | N (млн.) 3 | N (тыс.) 4 |
| 1 | 0,604 | 53 | 12 | 1,762 | 116 |
| 2 | 0,713 | 65 | 13 | 2,430 | 122 |
| 3 | 0,788 | 76 | 14 | 3,020 | 129 |
| 4 | 0,797 | 80 | 15 | 3,834 | 140 |
| 5 | 0,799 | 87 | 16 | 5,009 | 157 |
| 6 | 1,065 | 90 | 17 | 5,990 | 159 |
| 7 | 1,208 | 90 | 18 | 7,832 | 188 |
| 8 | 1,253 | 102 | 19 | 9,713 | 207 |
| 9 | 1,308 | 107 | 20 | 17,620 | 223 |
| 10 | 1,590 | 107 | 21 | 32,701 | 238 |
| 11 | 1,708 | 109 | 22 | 34,684 | 279 |

1) Specimen number; 2) kg/mm$^2$; 3) millions; 4) thousands.

teristics of V95 aluminum alloy, obtained by static tensile testing of a batch of 20 identical specimens 5 mm in diameter.

Especially high scattering (of durability) is noted on prolonged static and fatigue testing. Table 2 shows 44 specimens of V95 aluminum alloy 6.74 mm in diameter arranged in order of increasing durability; these specimens were subjected to cantilever bending at maximum cyclic stresses of 21 and 30 kg/mm$^2$.

The results cited demonstrate that the strength and plasticity of specimens subjected to static elongation and the durability of fatigue-tested specimens may have different (random) values. The function which defines the probability that a random quantity X (a characteristic of a material) will have a value less than the arbitrary real number $\underline{x}$ is the so-called random-distribution function of X,

$$F(x) = P(X < x).$$

The first derivative of the distribution function is called the probability density, p(x):

$$p(x) = dF(x)/dx.$$

The normal distribution (Gasussian distribution) has come into wide practical use. This distribution function has the form

$$F(x)=\frac{1}{\sqrt{2\pi}\cdot\sigma}\int_{-\infty}^{x}e^{-\frac{(x-a)^2}{2\sigma^2}}dx.$$

The probability density is defined by the equation

$$p(x)=\frac{1}{\sqrt{2\pi}\cdot\sigma}e^{-\frac{(x-a)^2}{2\sigma^2}}\ (-\infty<x<\infty),$$

where the constants $\alpha$ and $\sigma_2$ are the distribution parameters. Figure 1 shows the probability density for a normal distribution at different parameter ratios. The cumulative frequency is the experimental estimator for the distribution function, while the relative frequency serves this purpose for the probability density.

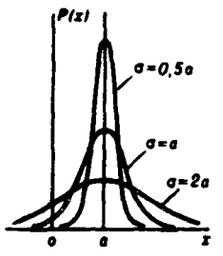
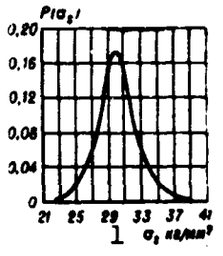



Fig. 1. Probability density for a normal distribution with different parameter ratios.




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Fig. 2. Probability density of the yield strength $\sigma_s$ for ST3 steel. 1) kg/mm$^2$.

TABLE 3

Scattering of the Logarithm of Durability for V95 Aluminum Alloy

| $\sigma_{max}$ (кг/мм²) | n | $\bar{x}=\lg\bar{N}$ | $\bar{s}^2$ | $\bar{s}$ | v |
|---|---|---|---|---|---|
| 30 | 22 | 5,0835 | 0,0370 | 0,192 | 0,038 |
| 24 | 21 | 5,6643 | 0,0287 | 0,170 | 0,030 |
| 21 | 22 | 6,4301 | 0,2870 | 0,535 | 0,084 |

1) kg/mm$^2$.

The normal distribution is usually used in theoretical calculations of resistance to small plastic deformations and of the strength of a material. Fig. 2 shows the distribution curve of the yield strength $\sigma_s$ of type St3 steel. During prolonged static testing the normal distribution follows the logarithm of time to fracture, while during fatigue testing it follows the quantity $x = \lg (N - N_0)$, where N is the number of cycles to fracture and $N_0$ is the threshold of susceptibility in cycles, i.e., the greatest number of cyles for which the probability of fracture at $N \leq N_0 = 0$. Other distributions are also used for statistical processing of the results of fatigue tests.

Arithmetic characteristics can be employed in evaluating the scattering of a random function, the most important of these being: 1) a – the mathematical expectation (mean value); 2) $\sigma^2$ – the dispersion; 3) $\sigma$ – the mean square deviation; 4) v – the variation factor. The mean value and dispersion are the parameters of the normal distribution. These calculated characteristics are referred to as theoretical or general characteristics. The experimental estimators of the general characteristics have the same designations and are labeled $\bar{x}$, $\overline{s^2}$, $\bar{s}$, and $\underline{v}$. They are calculated from the following formuli:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}; \quad \overline{s^2} = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1};$$
$$\bar{s} = \sqrt{\overline{s^2}}; \; v = \bar{s} / \bar{x},$$

were $x_i$ are the assumed values of the characteristic in question on testing and $\underline{n}$ is the number of specimens of the same series tested.

Table 3 shows the statistical characteristics of the scattering of the logarithm of durability (lg N) of specimens of V95 aluminum alloy during fatigue testing (see Table 2).

In fatigue testing the scattering of durability increases as the stress decreases. Scattering depends to a considerable extent on the

size and shape of the specimens; it is higher in specimens with a constricted working area than in those with working areas of uniform resistance. Scattering decreases as cross-sectional area increases. If we compare equal nominal stresses or equal mean durabilities scattering decreases as the stress-concentration level rises. This relationship is explained by the fact that the maximum stress in the concentration zone increases with the stress concentration and scattering decreases as stress rises. If the comparison is made at equal maximum stresses in the concentration zone no relationship is detected between the scattering of durability and the stress-concentration level. It cannot, however, be assumed that the scattering characteristics determined from the results of a single experiment will agree with the corresponding general characteristics.

The mean value, dispersion, and other empirical estimators are themselves random quantities and may have different values when the experiment is repeated. The general characteristics are properly evaluated from experimental results with the aid of so-called confidence intervals, which are defined in terms of a predetermined percentage confidence probability p and the number of test specimens n. The term "confidence interval" means that if an experiment with a given series of specimens is repeated and the confidence interval is found each time these intervals will cover the value of the general characteristic in approximately p per cent of all cases. The confidence intervals for a and $\sigma^2$ are determined from the formuli:

$$\bar{x} - \frac{\bar{s}}{\sqrt{n}} t_{q,n-1} < a < \bar{x} + \frac{\bar{s}}{\sqrt{n}} t_{q,n-1};$$

$$\frac{(n-1)\bar{s}^2}{\chi_2^2} < \sigma^2 < \frac{(n-1)\bar{s}^2}{\chi_1^2},$$

where n is the number of test specimens and $t_{q,n-1}$, $\chi_1^2$, and $\chi_2^2$ are constants which depend on the predetermined confidence probability and

the number of test specimens.

Example. The results of static tensile testing of a series of 20 specimens of V95 alloy were used to determine the mean true tensile strength $s_k$ and the dispersion of this characteristic; $\bar{x} = \bar{s}_k = 72.5$ kg/mm$^2$ and $s^2 = 1.38$ kg$^2$/mm$^4$. It is necessary to determine the 90% confidence intervals for the mean value and dispersion. Tables VIII and XVIII in Reference [2] show that, for $n = 20$ and $p = 90\%$, $t_{q,n-1} = 1.73$, $\chi_1^2 = 10.1$, and $\chi_2^2 = 30.1$.

Hence $72.5 - \frac{1.17}{4.47} \cdot 1.73 < a < 72.5 + \frac{1.17}{4.47} \cdot 1.73$, i.e., 72.0 kg/mm$^2$ $< a <$ 73.0 kg/mm$^2$ and $\frac{19 \cdot 1.38}{30.1} < \sigma^2 < \frac{19 \cdot 1.38}{10.1}$, i.e., 0.87 kg$^2$/mm$^4$ $< \sigma^2 <$ 2.60 kg$^2$/mm$^4$.

Comparisons of materials and calculations of the strength of machine components must take into account the scattering of mechanical properties. In some cases comparing materials without giving due consideration to scattering may lead to erroneous conclusions. For example, the mean durability of V95 alloy during fatigue testing is higher than that of D16 alloy at the same stress level, but, as a result of the large scattering of durability in V95, the durability of D16 determined at a low fracture probability is higher than that of V95.

References: Serensen, S.V. et al., Issledovaniye rasseyaniya kharakteristik vynoslivosti konstruktsionnykh alyuminiyevykh splavov v svyazi s tekhnologiyey ikh proizvodstva [Investigation of the Scattering of Durabil,ty of Structural Aluminum Alloys in Relation to Their Production Technology], Moscow, 1958, Trudy MATI [Transactions of the Moscow Aviation Technological Institute], No. 35; Dunin-Barkovskiy, I.V. and Smirnov, N.V., Teoriya veroyatnostey i matematicheskaya statistika v tekhnike (Obshchaya chast') [Theory of Probability and Mathematical Statistics in Technology (General Portion)], Moscow, 1955; Bolotin, V.V., Statisticheskiye metody v stroitel'noy mekhanike

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[Statistical Methods in Structural Mechanics], Moscow, 1961.

M.N. Stepnov

SCHEELITE – is a mineral with the chemical formula $CaWO_4$ (calcium tungstate). The specific gravity is 5.8-6.2; the cleavability along {111} is medium; the Mohs hardness is 4.5-5; the mineral is usually of a gray, yellow, brown and even of a red color. The crystal system is tetragonal; the dimensions of the unit cell are: a = 5.246 A, c = 11.349 A. Dipiramydal, sometimes tabular crystals based on {001} are also to be found. A bright light-blue luminescence occurs in ultraviolet, cathode and x-rays. Scheelite is found usually as a hydrothermal mineral in quartz veins, more rarely in pegmatites. The greatest scheelite deposits are found in skarns. Garnets and pyroxenes are the usual accessory minerals found in these deposits. Scheelite is often found in wolframite-bearing, gold-bearing, etc., veins. Scheelite is mined for the preparation of tungsten and its compounds. Minable deposits of scheelite are known in the USSR, the US and in other countries. Artificial scheelite crystals may be obtained by Vernenil's method from a smelt or from solvents, the latter being melted alkali chlorides. Scheelite crystals may be used for the detection of $\alpha$ rays and of slow neutrons. It was found recently that scheelite crystals may be used in lasers.

References: Betekhtin, A.G. Kurs mineralogii [Course of Mineralogy], 3rd Edition, Moscow, 1961.

V.P. Butuzov

SCRATCH TEST – determination of the hardness of a material by scratching its surface with a pointed tool (usually a cone with an apical angle of 90°) made of diamond or a hard alloy and measuring the width of the scratch. The scratch hardness is assumed to be the reciprocal of the scratch width at a given constant load. The scratch hardness characterizes the fracture resistance of the material, but not its resistance to plastic deformation (as the impression hardness determined by the Brinnell, Rockwell, or Vickers method does). This test is related to Shear resistance and this explains the fact that the results obtained do not depend to any great extent on preliminary cold-working. The scratch test is similar to simple cutting; according to Ya.N. Mazlov, this test involves measurement of the "cutting, or scratching, force" required to produce a certain scratch width at a constant pressure. In the qualitative scratch test a subsequent microscopic study is made of the crack width in the various structural constituents of the material. The scratch test enters into N.N. Davidenkov's so-called "two-cone method," which permits a rough evaluation of the mechanical characteristics of the test material from the scratch or impression left on its surface by a cone, without preparation of specimens (specimenless test method). (See Technological testing).

Ya.B. Fridman

SEALING FABRICS – see Asbestos fabrics.

SEALING LUBRICANTS – lubricants used for hermetic sealing of various joints. Hydrocarbon and certain soap lubricants are used for this purpose. The gasoline-resistant lubricant (GOST 7171-63) obtained by thickening oxidized castor oil with the zinc salt of castor oil has come into wide use; this material is of low solubility in petroleum products and is employed primarily for sealing the joints of fuel lines, gasoline pumps, the stopcocks of the fuel and oil systems of aircraft, etc. It is difficult to use at low temperatures; in certain cases it is diluted with alcohol (up to 25%) during the winter. Its low melting point (approximately 55°) also restricts the use of this lubricant at elevated temperatures. MGS lubricant (TU MNP 351-53), which is obtained by thickening transformer oil with barium stearate, has better characteristics; it is soluble in petroleum products and is used only for sealing packing glands, threaded joints, stopcocks, and the air, alcohol, glycerine, and water systems of aircraft. The vacuum lubricant (GOST 9645-61) obtained by thickening purified vasoline oil with natural gum rubber (15%) and ceresin (20%) is employed for sealing movable joints, stopcocks, and other components of vacuum installations; this lubricant has a melting point of 50-60°, is very viscous, and has a low vapor tension. We may also include among these lubricants the greases used to seal slits and holes in order to keep dust and moisture out of machinery and instruments. One sealing agent of this type is ZZK-3 grease (TU 376-57), which is a mixture of aluminum soap, ceresin, and petrolatum (20%) with cylinder oil. The separable joints of vacuum equipment are smeared with a mixture (GOST 9646-61) consist-

ing of vacuum grease (11%), ceresin (9%), vasoline oil (20%), and cosmetic kaolin (60%). This soft, plastic mass is easily applied to the joints to be sealed when cold, in contrast to hard, brittle greases of the vacuum picein type (MG UKhP 255-59), which are applied in the molten state.

V.V. Sinitsyn

SEALING PROPERTIES OF RUBBER – an integrated group of rubber properties which ensure sealing of packing subassemblies. Rubber, being a highly elastic material, is indispensable in many designs where use is made of various sealing gaskets, packing glands, V-ring packings and other elements of packing subassemblies. Depending on the intended service, rubber gaskets are divided into vacuum and hydraulic. The first seal joints of instruments and machines in which a high vacuum is maintained, while the second prevent the seeping through of various fluid media, which are subjected to high pressures, through the packing subassembly. The sealing properties of vacuum gaskets are determined primarily by the fact that rubber is impermeable to gases, and those of hydraulic gaskets are determined by their resistance and self-sealing capacity. The resistance of gaskets depends on their rigidity and on the friction forces at the surfaces of contact between the rubber and the metal. To increase the gasket resistance, the deformation of the latter, which is produced by the hydrostatic pressure, is limited by the walls of the groove or of the recess in the metal. At the instant when the gasket is tightly pressed to the groove walls, the hydrostatic pressure, acting on the gasket is transmitted in the rubber gaskets evenly in all directions. As a result of this, as the hydrostatic pressure of the fluid being sealed is increased, the contact stress at the contact between the rubber and the metal is increased also, for which reason the packing capacity of the gasket is also increased (the self-sealing phenomenon).

In V-ring type packing components the self-sealing is realized in

a different manner, since the "whiskers" of the V-ring packing are pressed to the metal surface directly by the hydrostatic pressure. At low temperatures the packing subassemblies frequently lose their air-tightness due to the transformation of the rubber into a solid, glass-like state.

References: Bartenev, G.M. and Peregudova, L.Ye. in the book: Tr. NII rezinovoy promyshlennosti [Trans. of the Scientific Research Institute of the Rubber Industry], collection 2, pages 56-74, Moscow, 1955; by the same author, Ibid., collection 4, pages 71-78, Moscow, 1957; Lepetov, V.A. and Novikov, V.I., Ibid, pages 79-88, by the same authors, Ibid., pages 105-124; Bartenev, G.M. and Kolyadina, N.G., "KiR," No. 10, pages 29-34, 1960; No. 9, pages 27-30, 1961; No. 5, pages 29-33, 1962; Dobrushkin, D.B., Ekel', Ye.S. and Orlov, Z.D., Ibid., No. 9, pages 19-24, 1963.

G.M. Bartenev.

SECANT MODULUS — the characteristic of the strengthening in the elasto-plastic region. It is sometimes termed the modulus of plasticity. It is defined by the tangent of the slopw of the straight line drawn through the coordinate origin and the considered point on the curve $|\sigma = \sigma(\varepsilon)|$ (see figure in article Tangent Modulus). It is designated by the symbol $E_S$, has dimensions of a stress; decreases with increase of the degree of plastic deformation.

S.I. Kishkina-Ratner

SECONDARY BRASS is brass which contains 53-81% Cu, one or more alloying elements and impurities. The secondary brasses are obtained by resmelting waste and scrap (unsuitable products made from the copper alloys). The secondary brass is produced in 12 grades in accordance with GOST 1020-60 (see Table). The secondary brasses are poured in the form of ingots which are used for the preparation of the casting brasses (GOST 1019-47). The ingots are marked on the side with colored stripes depending on the chemical composition.

Chemical Composition and Marking of Secondary Brasses (GOST 1020-60)

| Сплав 1 | Содержание элементов (%) 2 | | | | | Маркировка чушек 3 |
|---|---|---|---|---|---|---|
| | Cu | Al, Fe, Si, Ni | Mn | Pb и Sn | Zn | |
| 4 ЛА | 63—68 | 2—3 Al | — | — | Остальное | Две белые полосы |
| 5 ЛАЖМц | 63—68 | 2,0—4,0 Fe<br>3—7 Al | 1,5—2,5 | — | » | Две синие полосы |
| 6 ЛАЖ | 56—61 | 0,75—1,5 Fe<br>0,75—1,5 Al | 0,1—0,6 | 0,2—0,7 Sn | » | Одна зеленая полоса<br>Одна красная полоса |
| 7 ЛК | 76—81 | 2,5—4,5 Si | — | — | » | Две красные полосы |
| 8 ЛКС | 76—81 | 2,5—4,5 Si | — | 2—4 Pb | » | Одна красная полоса<br>Одна синяя полоса |
| 9 ЛМцС | 55—60 | — | 1,5—2,5 | 1,5—2,5 Pb | » | Одна зеленая полоса<br>Одна синяя полоса |
| 10 ЛМцОС | 55—60 | — | 1,5—2,5 | 0,5—2,5 Pb<br>1,5—2,5 Sn | » | Две черные полосы |
| 11 ЛМцЖ1 | 53—58 | 0,5—1,5 Fe | 3—4 | — | » | Две зеленые полосы |
| 12 ЛМцЖ2 | 50—55 | 0,5—1,5 Fe | 4—5 | — | » | Одна черная полоса<br>Одна белая полоса |
| 13 ЛС | 56—61 | — | — | 0,8—1,9 Pb | » | Одна красная полоса<br>Одна белая полоса |
| 14 ЛОС | 60—80 | — | — | 1,0—3,0 Pb<br>0,5—2,0 Sn | » | Три красные полосы |
| 15 ЛНМцЖА | 58—62 | 0,5—1,1 Fe<br>0,5—1,5 Ni<br>0,5—1,0 Al | 1,5—2,5 | — | » | Три белые полосы |

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1) Alloy; 2) content of elements (%); 3) marking of ingots; 4) LA; 5) LAZhMts; 6) LAZh; 7) LK; 8) LKS; 9) LMtsS; 10) LMtsOS; 11) LMtsZh1; 12) LMtsZh2; 13) LS; 14) LOS; 15) LNMtsZhA; 16) remainder; 17) two white stripes; 18) two blue stripes; 19) one green stripe; 20) one red stripe; 21) two red stripes; 22) one red stripe; 23) one blue stripe; 24) two black stripes; 25) two green stripes; 26) one black stripe; 27) one white stripe; 28) three red stripes; 29) three white stripes.

The secondary brasses contain more impurities than the cast brass-

es prepared from the primary metals. The effect of the impurities on the properties of the secondary brasses is the same as in the ordinary brasses. We should particularly note the effect of sulfur on these brasses when it is present in the form of one or more sulfides. The sulfur gets into the secondary brass primarily from the fuel oil used in the smelting furnaces. Small quantities of copper sulfide have practically no effect on the properties while the iron and antimony sulfides are harmful. Sulfur in the amount of more than 0.1% significantly reduces the fluidity of the secondary brasses, while less than 0.05% does not reduce the properties. The harmful effect of sulfur is considerably reduced with the introduction of 0.08-0.15% Mg.

References: "Foundry", 1956, v. 84, No. 6, p. 122-25. Spravochnik po mashinostroitel'nym materialam [Handbook on Machine Construction Materials], Vol. 2, M., 1959.

Ye.S. Shpichinetskiy

SECONDARY BRONZE – a tin bronze produced in ingots and used as the charge material for producing tin casting bronzes. Secondary bronze is obtained by reprocessing of scrap, chips, and other waste from various types of bronzes containing little tin. The composition of secondary bronzes has been standardized by GOST 614-50 (Table). Their impurity contents correspond to the compositions of tin casting bronzes (GOST 613-50). Tin bronzes produced from secondary bronzes, especially such types as BrOTsS 6-6-3, BrOTsS 5-5-5, and BrOTsS 4-4-17, are inexpensive materials and have antifriction properties quite suitable for use in critical bearings carrying moderate loads.

O.Ye. Kestner

SECONDARY MAGNESIUM ALLOYS are magnesium-base alloys obtained by reprocessing of scrap and discards which are formed in the production and processing of castings and wrought mill products. The secondary magnesium alloys are used in the charge for the production of the industrial magnesium alloys. The secondary magnesium alloys have not been standardized.

A.A. Lebedev

SELENITE – see Gypsum.

**SELF-HARDENING ALUMINUM CASTING ALLOYS** – alloys capable of hardening from the cast state during postcasting cooling (self-hardening) and of additional hardening as a result of subsequent natural aging. This ability makes it possible to eliminate heat treatment from the technological cycle, thus substantially reducing the production cost of cast components and the possibility of development of residual stresses and resultant deformation of the castings. The self-hardening aluminum casting alloys are AL11, an AL-Zn-Si-Mg alloy, and VAL4, an Al-Zn-Mg alloy with additions of Ti and Mn.

TABLE 1

Certain Casting Characteristics of AL11 and VAL4 Alloys

| Сплав 1 | Жидкотекучесть (мм) 2 | Линейная усадка (%) 3 | Интервал кристаллизации (°С) 4 |
|---|---|---|---|
| АЛ11 5 | 600 | 1.0 | — |
| ВАЛ4 6 | 250 | 1.2 | 31 |

1) Alloy; 2) flowability (mm); 3) linear shrinkage (%); 4) crystallization range (°C); 5) AL11; 6) VAL4.

AL11 alloy (zinc silumin) contains a large quantity of Al-Si eutectic, which ensures good casting characteristics and satisfactory

TABLE 2

Typical Mechanical Properties of AL11 and VAL4 Alloys (Individually Cast Samples)

| Сплав 1 | Состояние материала 2 | 3 $\sigma_в$ (кг/мм²) | $\sigma_{0.2}$ (кг/мм²) | $\delta_5$ (%) | НВ (кг/мм²) | $\sigma_{-1}$* (кг/мм²) | $\sigma_{-1}$ (кг/мм²) | $\varepsilon$ | $\sigma_{-1}/\sigma_в$ (кг/мм²) |
|---|---|---|---|---|---|---|---|---|---|
| АЛ11 4 | Литое в песчаную форму, после естественного старения . . . . | 25 | 20 | 3 | 70 | 7200 | 2700 | 0.33 | 0.5 |
| ВАЛ4 5 | Литое в песчаную форму, после естественного старения . . . . | 24 | 17 | 5 | 80 | 6900 | 2600 | 0.33 | 0.5 |

*Cantilever bending of rotating sample; $N = 5 \cdot 10^8$ cycles.

1) Alloy; 2) state of material; 3) kg/mm²; 4) AL11; 5) VAL4; 6) cast in sand form after natural aging.

TABLE 3

Physical Properties of AL11 and VAL4 Alloys

| Сплав[1] | [2] $\gamma$ (g/cm³) | $\alpha \cdot 10$ (1/°C) 20—100° | 20—200° | 20—500° | [3] $\lambda$ (cal/cm·sec·°C) | [4] $c$ при 100° (cal/g·°C) |
|---|---|---|---|---|---|---|
| AL11 5. | 2.4 | — | 24.4 | 26.6 | — | 0.21 |
| BAL4 6. | 2.74 | 23.2 | 24.5 | 25.2 | 0.28 | " |

1) Alloy; 2) g/cm$^3$; 3) cal/cm·sec·°C; 4) $c$ at 100° (cal/g·°C); 5) AL11; 6) VAL4.

hermeticity. The zinc-enriched solid solution explains the rather high mechanical properties of this alloy. It is also good for gas and argon-arc welding and is highly cuttable. Its principal drawback is the fact that it has a lower corrosion resistance than other aluminum alloys, which requires special corrosion-protection measures (see Corrosion of aluminum alloys). AL11 is intended for production of geometrically complex castings which will bear moderate loads. Components can be fabricated from it by any of the common casting methods (see Casting of aluminum shapes).

VAL4 alloy contains 4% zinc, 1.75% magnesium, 0.35% manganese, and 0.15% titanium. It has satisfactory casting properties and a satisfactory corrosion resistance. It displays excellent cuttability, is satisfactory for gas and argon-arc welding, and has low hermeticity. After natural aging for 8–10 days the mechanical properties of the cast alloy are better than those of many heat-treated aluminum casting alloys. An increase of 15–25% over the strength of the naturally aged alloy can be obtained by quenching and artificial aging. The heat-treatment regime involves prequenching heating at 580° for 4–6 hr, cooling in water (80–100°), and aging at 120° for 8–10 hr. VAL4 alloy is intended for casting in sand molds obtained by the lost-metal method and in chill molds.

References: Novyye liteynyye splavy. Tsinkovistyye siluminy [New Casting Alloys. Zinc Silumin], Moscow, 1947; Kolobnev, I.F., Krymov, V.V., Polyanskiy, A.P., Spravochnik liteyshchika. Fasonnoye lit'ye iz alyuminiyevykh i magniyevykh splavov [Handbook of Foundry Work. Casting of Aluminum- and Magnesium-Alloy Shapes], Moscow, 1957; Liteynyye alyuminiyevyye splavy [Aluminum Casting Alloys], Collection of articles edited by I.N. Fridlyander and M.B. Al'tman, Moscow, 1961.

M.B. Al'tman and T.K. Ponar'ina

SELF-HARDENING ALUMINUM SHAPING ALLOYS – alloys which harden when cooled in air. In particular, this characteristic ensures high-strength welds without special hardening of the welded structure. One self-hard-

TABLE 1

Mechanical Properties of V92 Alloy

| Вид полуфабриката 1 | Вид термич. обработки 2 | Механич. свойства (не менее) 3 | | |
|---|---|---|---|---|
| | | $\sigma_b$ (кг/мм²) 4 | $\sigma_{0,2}$ (кг/мм²) 5 | при $l=11,3\sqrt{F}$ (%) |
| Листы холоднокатаные и горячекатаные 6 | Закаленные и естественно состаренные в течение 30 суток 7 | 40–40 | 24–22 | 15–15 |
| | Закаленные и искусственно состаренные 8 | 43–43 | 32–30 | 10–10 |
| Плиты горячекатаные толщиной до 20 мм и от 20 до 50 мм 9 | Закаленные и естественно состаренные в течение 30 суток | 43–39 | 28–27 | 12–9 |
| | Закаленные и искусственно состаренные | 48–43 | 38–35 | 8–8 |
| Полосы, профили, панели с толщиной полки более 5 мм 10 | Закаленные и естественно состаренные в течение 30 суток | 46–42 | 32–28 | 10–11 |
| | Закаленные и искусственно состаренные | 47–44 | 36–30 | 10–10 |
| Прутки всех размеров 11 | Закаленные и естественно состаренные в течение 30 суток | 46 | 32 | 13 |
| | Закаленные и искусственно состаренные | 47 | 36 | 10 |
| Трубы всех размеров 12 | Закаленные и естественно состаренные в течение 30 суток | 42 | 28 | 12 |
| | Закаленные и искусственно состаренные | 44 | 30 | 10 |
| Поковки и штамповки 13 | Закаленные и естественно состаренные в течение 30 суток | 40 | 27 | 5 |
| | Закаленные и искусственно состаренные | 43 | 30 | 7 |

1) Type of semifinished product; 2) type of heat treatment; 3) mechanical properties (no less than); 4) kg/mm$^2$); 5) at; 6) cold-rolled and hot-rolled sheets; 7) hardened and aged naturally for 30 days; 8) hardened and aged artificially; 9) hot-rolled plates less than 20 mm and 20-50 mm thick; 10) strips, shapes, and panels with a border thickness of more than 5 mm; 11) bars of all sizes; 12) tubes of all sizes; 13) forgings and stampings.

ening aluminum shaping alloy is V92, which can be toughened by both natural and artificial aging. Natural aging proceeds slowly, still being incomplete after 30 days. Aging in this manner for 90 days raises the

TABLE 2

Mechanical Properties of V92 Alloy at Different Temperatures*

| Темп-ра испытания (°С) 1 | 2 $\sigma_b$ (кг/мм²) | $\sigma_{0,2}$ (кг/мм²) | δ (%) |
|---|---|---|---|
| −196 | 51 | 31 | 17 |
| 20 | 44 | 27 | 20 |
| 100 | 37 | 23 | 26 |
| 200 | 28 | 21 | 24 |
| 250 | 18 | 13 | 34 |

*Sheets 2 mm thick.

1) Test temperature (°C); 2) kg/mm$^2$.

TABLE 3

Mechanical Properties of V92 Alloy at Elevated Temperatures (Extruded Material)

| Свойства 1 | Темп-ра испытания °С 2 | | | |
|---|---|---|---|---|
| | 20 | 100 | 150 | 200 |
| $E$ (кг/мм²) . 3 . | 7000 | 6500 | 6100 | 5950 |
| $\sigma_b$ (кг/мм²) . . . | 48 | 41 | 33 | 28 |
| $\sigma_{0,2}$ (кг/мм²) 4 . | 37 | 30 | 27 | 24 |
| $\lambda$ при $l=11,3\sqrt{F}$ (%) . . . . . | 7 | 10 | 16 | 14 |
| $\psi$ (%) . . . . . | 11 | 14 | 45 | 50 |

1) Properties; 2) test temperature, °C; 3) kg/mm$^2$; 4) at.

ultimate and yield strengths by 1-3 kg/mm$^2$.

Table 2 shows the mechanical properties of sheets of V92 alloy at low, room, and elevated temperatures, while Table 3 shows those of extruded material. Both types of semifinished product were tested after hardening and natural aging (30 days), being held at the test temperature for 30 min.

At 200° the creep strength of shapes fabricated from V92 alloy is 7 kg/mm$^2$ (for a residual deformation of 0.2%) and their ultimate strength is 14 kg/mm$^2$; both figures are for a test time of 5 hr.

Alloys of this type acquire their maximum mechanical properties after hardening and artificial aging at 100° for 96 hr. Cold-rolled sheets have a higher corrosion resistance when naturally aged or artificially aged at 60° for 24 hr and then at 200° for 1-3 hr; articles fabricated from V92 alloy by hot-deformation processes (hot-rolled sheets more than 3 mm thick, shapes, bars, forgings, and stampings) have a very high corrosion resistance after natural aging or artificial aging under the aforementioned regime. Complete annealing of V92 alloy is carried out at a temperature of 350-400° for 1-2 hr; it is furnace-cooled to

200° and then air-cooled. It is recommended that V92sv wire be used as the rod material in welding V92 alloy.

TABLE 4

Impact Strength of V92 Alloy at Various Temperatures*

| Темп-ра испытания (°С) 1 | −196 | 20 | 100 | 200 | 300 | 350 |
|---|---|---|---|---|---|---|
| $a_н$ кг.м/см² 2 . . . | 2.0 | 2.1 | 2.4 | 2.7 | 3.1 | 3.5 |

*Sheets 6 mm thick.

1) Test temperature (°C); 2) kg-m/cm².

TABLE 5

Physical Properties of V92 Alloy*

| Темп-ра (°С) 1 | 25 | 100 | 200 | 300 | 400 |
|---|---|---|---|---|---|
| λ (кал/см·сек·°С) 2 | 0.32 | 0.33 | 0.34 | 0.35 | 0.36 |
| c (кал/г·°С) . . . 3 | — | 0.22 | 0.24 | 0.25 | 0.26 |

*$\gamma$ = 2.72 g/cm³.

1) Temperature (°C); 2) cal/cm·sec·°C; 3) (cal/g·°C).

TABLE 6

Coefficient of Linear Expansion of V92 Alloy*

| Темп-ра (°С) 1 | 20—100 | 20—200 | 20 | 0 | 20—400 | 100—200 | 200—300 | 300—400 |
|---|---|---|---|---|---|---|---|---|
| α·10⁶ (1/°С) | 26.4 | 27.3 | 27.7 | | 29.3 | 28.3 | 28.6 | 34.1 |

*At 20° $\rho$ = 0.0589 ohm·mm²/m.

1) Temperature (°C).

The properties of a welded joint fabricated by automatic argon-arc welding are as follows: $\sigma_b$ = 37-40 kg/mm²; bending angle – 80-90° (material thickness – 2 mm). The seam is naturally aged for 30 days (without hardening). It is recommended that the weld zone be made somewhat thicker by regulated pickling of the base material.

I.N. Fridlyander

SEMICONDUCTIVE (electrically conductive) GLASS – inorganic glass having the electrical characteristics of a semiconductor. The electron conductivity of inorganic glass can be raised by materially increasing its deep or superficial electrical conductivity. We can distinguish two types of semiconductive glass: 1) glasses which contain elements or oxides with pronounced semiconductive characteristics and consequently have an elevated deep electrical resistance; 2) glasses having semiconductive surface coatings and characterized by a high superficial electrical conductivity, (see Glass with an electrically conductive surface). There are two groups of semiconductive glass with an elevated deep electrical resistance, chalkogenide and oxide glasses.

TABLE 1

| Халькогенид 1 | 2 Температура (°C) | |
|---|---|---|
| | плавления в кристаллич. состоянии 3 | начала размягчения в стеклообразном состоянии 4 |
| $As_2S_3$ | 300 | 212 |
| $As_2Se_3$ | 300 | 187 |
| $As_2Se_3 \cdot As_2Te_3$ | — | 151 |
| $As_2Te_3$ | 367 | 140 |

1) Chalkogenides; 2) temperature (°C); 3) melting point in crystalline state; 4) softening initiation temperature in vitreous state.

TABLE 2

| Системы 1 | 2 Пределы значений электропроводности ($ом^{-1} \cdot см^{-1}$) | 3 Границы максимумов спектральной фоточувствительности (μ) |
|---|---|---|
| $As_2Se_3 - As_2Te_3$ | $10^{-14}$—$10^{-6}$ | 0.6—1.25 |
| $As_2Se_3 - Tl_2Se$ | $10^{-14}$—$10^{-7}$ | 0.6—1.1 |
| $As_2Se_3 - Sb_2Se_3$ | $10^{-10}$—$10^{-10}$ | 0.6—0.8 |
| $Tl_2Se \cdot As_2Se_3 - Tl_2Se \cdot As_2Te_3$ | $10^{-7}$—$10^{-6}$ | 1.0—1.2 |
| $Tl_2Se \cdot As_2Se_3 - Tl_2Se \cdot Sb_2Se_3$ | $10^{-6}$ | 0.95—1.15 |

1) System; 2) maximum and minimum electrical conductivity ($ohm^{-1} \cdot cm^{-1}$); 3) limits of spectral-photosensitivity maxima (μ).

Chalkogenide glasses – oxygen-free vitreous ligatures of the sulfides, selenides, and tellurides (i.e., Chalkogenides) of arsenic, antimony, phosphorous, bismuth, and thalium. They are produced with widely varying combinations of these components and differ in their chemical, physical, electrical, and optical characteristics. The best vitrifying agents are $As_2S_3$ and $As_2Se_3$, especially in combination with one another and with chalkogenides of thalium, antimony, and bismuth. There are many chalkogenide glasses. These materials are obtained by slowly raising the temperature of the raw materials to 900°, usually in hermetically sealed, evacuated vessels. They are low-melting, beginning to soften at lower temperatures than the corresponding crystalline chalkogenides (Table 1).

Chalkogenide glasses have a considerably higher crystallization capacity than oxide glasses. $As_2S_3$ and $As_2Se_3$ have the least tendency toward crystallization. Their electrical characteristics mark chalkogenide glasses as typical electron semiconductors with a hole conductivity mechanism. Their electrical conductivity ranges from $10^{-14}$ to $10^{-1}$ $ohm^{-1} \cdot cm^{-1}$ (depending on their composition) and is higher than that of many crystalline semiconductors (the conductivity of crystalline selenium is $10^{-5}$ $ohm^{-1} \cdot cm^{-1}$). The conductivity of chalkogenides may increase by a factor of $10^{10}$ during the transition from the vitreous to the crystalline state. Table 2 presents data on electrical conductivity and the spectral distribution of the internal photoeffect for certain vitreous chalkogenide systems.

Chalkogenide glasses are generally colored, most frequently ranging from yellow to dark brown; they are transparent in the infrared region of the spectrum (with a maximum transmissivity of 60-80%) and have very simple absorption spectra. Thus, for example, only 2 absorption bands, corresponding to 12.5 and 15.8 μ, are observed at wave-

TABLE 3

| Состав стекол (молекулярные проценты) 1 | | | | | | 2 | 3 |
|---|---|---|---|---|---|---|---|
| $V_2O_5$ | $P_2O_5$ | PbO | BaO | $WO_3$ | $MoO_3$ | | |
| 90 | 10 | — | — | — | — | 4.8 | — |
| 87.54 | 12.46 | — | — | — | — | 4.42 | 78 |
| 65 | 26 | 9 | — | — | — | 6.80 | 81 |
| 53 | 12 | 35 | — | — | — | 6.50 | 107 |
| 70 | 22.5 | — | — | 7.5 | — | 6.17 | 75 |
| 55 | 34 | — | — | 11 | — | 7.14 | 70 |
| 65 | 26 | — | 9 | — | — | 5.14 | 85 |
| 65 | 9 | — | 26 | — | — | 6.88 | 102 |
| 70 | 22.5 | — | — | — | 7.5 | 6.05 | 80 |

1) Composition of glass (molecular percent); 2) electrical resistance log ρ at 20°; 3) coefficient of linear expansion $\alpha \cdot 10^7$ (1/°C) over the range 20-200°.

TABLE 4

| Тип $RO_2$ 1 | Состав стекол (катионные проценты) 2 | | | 3 Электросопротивление log ρ при 20° | 4 Температурный коэфф. электросопротивления (% на 1°C) |
|---|---|---|---|---|---|
| | $RO_2$ | $VO_{2,5}$ | $PO_{2,5}$ | | |
| $LiO_{0,5}$ | 20 | 60 | 20 | 7.2 | 5.82 |
| $KO_{0,5}$ | 10 | 70 | 20 | 5.6 | 5.61 |
| CuO | 20 | 60 | 20 | 5.36 | 5.91 |
| $AgO_{0,5}$ | 20 | 60 | 20 | 6.68 | 6.08 |
| BeO | 10 | 70 | 20 | 5.61 | 5.6 |
| MgO | 10 | 70 | 20 | 5.8 | 5.46 |
| CaO | 20 | 60 | 20 | 7.5 | 6.44 |
| BaO | 20 | 60 | 20 | 7.63 | 6.25 |
| ZnO | 20 | 60 | 20 | 6.88 | 5.59 |
| CdO | 10 | 70 | 20 | 6.0 | 5.56 |
| $TlO_2$ | 10 | 70 | 20 | 5.97 | 5.63 |
| PbO | 20 | 60 | 20 | 6.4 | 6.83 |
| $AsO_{1,5}$ | 20 | 60 | 20 | 6.0 | 6.87 |
| $SbO_{1,5}$ | 20 | 60 | 20 | 5.4—7.4 | — |
| $BiO_{1,5}$ | 10 | 70 | 20 | 6.16 | 5.74 |
| $FeO_{1,5}$ | 20 | 60 | 20 | 7.66 | 6.76 |
| CoO | 10 | 70 | 20 | 6.63 | 6.03 |
| NiO | 10 | 70 | 20 | 6.3 | 5.92 |

1) Type of $RO_2$; 2) composition of glass (cation percent); 3) electrical resistance log ρ at 20°; 4) thermal coefficient of electrical resistance (% per °C).

lengths of from 1 to 18 μ for $As_2Se_3$. $As_2S_3$ exhibits pronounced absorption bands at 4.2 and 6.5 μ and a weaker band at 11 μ. The general character of the optical absorption of the majority of chalkogenide glasses is determined by that of $As_2S_3$ and $As_2Se_3$; certain of these glasses are suitable for the manufacture of high-quality filters with pass-band limits of 0.6 and 2-3 μ. The drawbacks of chalkogenide glasses include their low chemical stability and their tendency toward crystallization.

Vanadium oxide glasses are obtained by fusion of vanadium and phosphorous oxides at 600-110° in pure form or in the presence of BaO, PbO, $Fe_2O_3$, $WO_3$, $MoO_3$, or the oxides of certain alkali-earth and alkali metals.

The physicochemical and electrical characteristics of vanadium oxide glasses vary within rather wide limits, depending on their composition, principally the ratio of $V_2O_5$ to $P_2O_5$; these glasses have pronounced semiconductive characteristics, are distinguished by high electrical conductivity (of the order of $10^{-4}$-$10^{-5}$ $ohm^{-1} \cdot cm^{-1}$ at room temperature), and have an electronic conductivity mechanism. The electrical resistance of different glasses based on $V_2O_5$ and $P_2O_5$ may vary considerably, ranging from $10^{-4}$ to $10^{12}$ ohm·cm.

Table 3 shows the electrical resistance and thermal expansion of vanadium oxide glasses. These materials are usually dark brown or black in color, completely opaque in the visible portion of the spectrum, and capable of passing infrared rays with wavelengths of approximately 4 μ. Table 4 shows the electrical and semiconductive characteristics of these glasses.

One important shortcoming of vanadium oxide glasses is their very low chemical stability, which can be enhanced by replacing the $V_2O_5$ with $P_2O_5$, BaO, PbO, and other oxides.

Semiconductive glasses have material advantages over crystalline semiconductors; they are readily molded, are easily soldered to various metals,have a high transparency in the infrared region of the spectrum, and have a substantially lower "noise" level than polycrystalline semiconductors (this is especially true of vanadium glasses); impurities have virtually no effect on their electrical conductivity and thermal coefficient of conductivity.

The diversity and unusual character of the properties of semicon-

ductive glasses open up broad prospects for their utilization in various semiconductor instruments and devices, particularly as thermal resistors (thermistors) and as light filters and photoresistors, conjoining selective light absorption with increased electrical conductivity.

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S.I. Sil'vestrovich

SEMICONDUCTIVE LACQUER-IMPREGNATED GLASS CLOTH – glass cloth impregnated with a special lacquer containing finely dispersed graphite or some other filler that gives the material semiconductive characteristics; it is used as a semiconductive covering for the windings of high-voltage generators, serving to equilibrate the electric field and protect the insulation from the corona. It is also employed to maintain a constant wall temperature in storage tanks for certain types of fuel. Semiconductive lacquer-impregnated glass cloth based on polyorganosiloxane lacquer is produced in the USSR under the trademark LSK-5 and is supplied in fabric form (from 700 to 1000 mm wide and 0.12-0.20 mm thick) in rolls. This material is characterized by stable electrical properties at elevated temperatures. It has a working temperature of 160-180° and a specific surface resistance of $10^3$-$10^5$ ohms at 20°; the latter index remains virtually unchanged after heating at 180° for 18 hr and subsequent testing at 120°. Under ordinary conditions (20°) semiconductive lacquer-impregnated glass cloth can withstand 200 double bends under a test load of 2.5 kg, while after heat treatment at 200° for 24 hr it can withstand no less than 50 such bends.

References: see the article entitled Lacquered cloth for electrical insulation.

M.B. Fromberg

SEMICONDUCTORS – substances intermediate between conductors and dielectrics (insulators); their electrical conductivity is highly dependent on the temperature, the quantity and nature of the impurities which they contain, and exposure to electrical fields, light, and other external factors. The differences among conductors, semiconductors, and insulators are explained by the zone theory: in pure semiconductors and electronic insulators there is a forbidden energy zone (which is $\lesssim 5$ ev for semiconductors and $\gtrsim 5$ ev for insulators) between the valence zone and the conductive zone. No such region is present in conductors (where the zones may even overlap). The minimum forbidden-zone width and other characteristics of the zone structure govern the electrical conductivity, photoconductivity, parameter temperature functions, and other properties of semiconductors.

Semiconductors include elements such as boron, carbon (diamond), silicon, germanium, tin (gray), selenium, and tellurium, chemical compounds such as silicon carbide and compounds of the $A^{III}B^{V}$ type (indium-antimony, indium-arsenic, gallium-antimony, aluminum-antimony, and other two- or three-component compounds containing at least one element from groups IV-VII of the Mendeleyevian system), and organic substances (polyacenes, azoaromatic compounds, phthalocyanins, certain free radicals, hybrid compounds, etc.).

The electrical conductivity $\sigma$ of a semiconductor, which results from the transfer of electric charges by electrons and holes (an arbitrary concept introduced to explain the processes occurring in these materials; holes are sites vacated by electrons and are assigned the

TABLE 1

General Physical Characteristics of Semiconductors (at 0°C)

| 1 Хим. элемент | 2 Уд. вес | 3 Коэфф. линейного расширения ×10⁻⁶ град⁻¹ | 4 Темп-ра (°C): 5 плавления | 6 кипения | 7 Теплота плавления (кал/г) | 8 Теплоемкость $c_p$ (кал/г·°C) | 9 Коэфф. теплопроводности (кал/см·сек·°C) | 10 Температура испарения (при давлении $10^{-2}$ мм рт. ст.) (°C) | 11 Скорость испарения ×10⁻⁴ (г/см²·сек) |
|---|---|---|---|---|---|---|---|---|---|
| 12 Бор | 2.34 | 8 | 2300 2500 | 2550 | 265 | 0.305 | | 1365 | 4.75 |
| 13 Углерод (алмаз) | 3.51 | 0.81 | 3540 | 4000 | 119.7 | 0.1128 | 0.33 | 2681 | 0.37 |
| 14 Кремний | 2.33 | 6.95 | 1412 | 2600 | 431.2 | 0.181[1] | 0.20 [24] | 1342 | 0.77 |
| [24] | (при 25°) | (при 20—100°) | | | | (при 20—100°) | (при 25°) | | |
| 15 Германий | 5.32 | 6.1 | 936—958 | 2700 | 114.2 | 0.074 [25] | 0.14 [24] | 1251 | 1.27 |
| [24] | (при 25°) | (при 0—300°) | | | | (при 0—100°C) | (при 25°) | | |
| 16 Олово | 7.3 | 21 | 231.9 | 2275 | 14.4 | 0.053 | 0.158 | 1189 | 1.65 |
| 17 Селен | 4.8 | 37 | 220[2] | 688 | 15.4 [26] (по др. данным, 18.4) | 0.084 [24] (при 23—62°) | 0.026 (по др. данн. 27 имеет 0.0005— для металлического селена) | 234 | |
| 18 Теллур | 6.24 | 16 | 452 | 1390 | 7.4 | 0.049 | 0.0144 | 678 | |
| 19 Сурьма | 6.69 | 9.2 | 630 | 1640 | 39 | 0.049 | 0.044 | 678 | 2.95 |
| 20 Фосфор | 1.82 | 125 | 44.1 | 280 | 5.2 | 0.190 [24] (при 0°) | — | — | |
| 21 Мышьяк | 5.72 | 5.6 | 818[3] (при давлении 35 36 атм) | >600 | 22.0 | 0.082 [24] (при 0—100°) | — | 280 | — |
| 22 Сера | 2.07 | 74 | 112.8 | 444.6 | 9.4 | 0.180 | 0.18 | — | — |
| 23 Иод | 4.93 | 93 | 113.5 | 185 | 12 | 0.054 (при 25°) [24] | — | — | |

*According to other data, 0.210 at 18-900°.
**Monoclinic selenium melts at 144°C.
***Sublimates on heating to temperatures above 600°C.

1) Chemical element; 2) specific gravity; 3) coefficient of linear expansion $\times 10^{-6}$ degrees$^{-1}$; 4) temperature (°C); 5) melting; 6) vaporization; 7) heat of fusion (cal/g); 8) heat capacity $c_p$ (cal/g·°C); 9) coefficient of thermal conductivity (cal/cm·sec·°C); 10) vaporization temperature (at a vapor tension of $10^{-2}$ mm Hg) (°C); 11) vaporization rate $\times 10^{-4}$ (g/cm·sec); 12) boron; 13) carbon (diamond); 14) silicon; 15) germanium; 16) tin; 17) selenium; 18) tellurium; 19) antimony; 20) phosphorus; 21) arsenic; 22) sulphur; 23) iodine; 24) at; 25) at a pressure of 36 atm; 26) according to other data, 18.4; 27) according to other data, 0.0005 for metallic selenium.

characteristics of positive charges), and its inverse quantity, the specific resistance $\rho$, which are governed by the concentrations of electrons $n$ and holes $p$, as well as by their mobilities $\mu_n$ and $\mu_p$, are related by the equation: $\sigma = \frac{1}{\rho} = q(n\mu_n + p\mu_p)$, where $q$ is the charge of the electron. The electrical conductivity of a semiconductor ranges from $10^4$ to $10^{-10}$ $(\text{ohm}\cdot\text{cm})^{-1}$.

The characteristics of semiconductors are materially affected by

temperature. The rise in temperature generally causes an increase in electrical conductivity and vice versa, i.e., semiconductors are characterized by a negative temperature coefficient of electrical resistance. The boundary between semiconductors and insulators is arbitrary and also depends on temperature. Semiconductors become insulators near absolute zero. Under certain conditions semiconductors produce a thermal emf under the influence of heat and light (this effect is considerably less pronounced in metals). Contacts involving semiconductors and semiconductors and metals exhibit a rectification effect (nonlinear characteristics). The hardness, brittleness, and tensile strength of semiconductors are more similar to those of insulators than to those of metals. Semiconductors have too few electrons for them to promote malleability and plasticity, as is the case in many metals. Materials such as germanium, silicon, and tellurium behave like glass when dropped or struck.

Semiconductors are characterized by their type of conductivity (electron n-type or hole p-type), specific resistance, charge-carrier life (diffusion length), superficial electron-hole recombination rate, dislocation density, forbidden-zone width, charge-carrier mobility, etc. Tables 1-3 show certain of the characteristics of elementary semiconductors and compounds, while Table 4 shows those of organic semiconductors and Tables 1 and 5 show those of metals and insulators with certain semiconductive properties (these tables were compiled from various data in the literature and are intended only as a guideline).

Rigid requirements are imposed on the purity of semiconductors; for example, germanium is checked for impurities of 40 elements and silicon for impurities of 27 elements. The impurity content should not exceed $10^{-4}$-$10^{-9}$%, especially for aluminum, boron, tungsten, vanadium,

gallium, iron, cobalt, magnesium, manganese, copper, etc.

TABLE 2

Certain Electrical, Magnetic, and Optical Characteristics of Elementary Semiconductors

| 1 Химич. элемент | 2 Ширина запрещенной зоны (эв) | | 3 Подвижность при 300°K ($см^2$/в·сек) | | 6 Собственное сопротивление при 300°K (ом·см) | 7 Диэлектрич. постоянная | 8 Постоянная решетки (A) | 9 Магнитная восприимчивость $\chi \times 10^{-6}$ (СГСМ/г)* | 10 Работа выхода (по фотоэффекту) (эв) | 11 Показатель преломления при $\lambda = 1$ мк и 300° K | 12 Энергия ионизации светом (эв) | 13 Энергия ионизации решетки (эв) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0°K | 300°K | 4 Электронов | 5 Дырок | | | | | | | | |
| 14 Бор | – | 1,39 | – | 10 | – | 6,2 | 8,73 | – | 5,4–4,6 | 3,2 | 0,96–1,27 | 0,88–1,28 |
| 15 Углерод (алмаз) | – | 5,2 | 1850 | 1200 | – | 5,7 | 3,56 | –2,1 | – | – | 5,3 | 5,2 |
| 16 Кремний | 1,17 | 1,09 | 1900 | 425 | $3 \cdot 10^5$ | 12 | 5,43 | –0,3 | 4,37 4,87 | 3,5** | 1,15 | 1,12 |
| 17 Германий | 0,75 | 0,68 | 3600 | 1700 | 47 | 16 | 9,66 | –0,8 | 4,8 | 4 | 0,73 | 0,72 |
| 18 α-олово*** | – | 0,08 | 2000 | 110 | $2 \cdot 10^{-4}$ | 50 | 6,46 | +0,025 | 4,51 | – | – | – |
| 19 Селен: 20 гексагональный | – | 1,79 | – | 1 | – | 6,3 | 4,36 | –1,7 | 4,89 | 2 | 1,5–1,9 | 1,7 |
| 21 аморфный | – | 2,2 | – | – | – | – | – | – | – | 2,45 | – | – |
| 22 Теллур | – | 0,38 | 1100 1500 | 500**** 1000 | 0,1–0,4 | 23 | 2,86***** 3,45 | –3,1 | 4,04 4,25–4,42 | 2,5–3,0***** | – | – |

*At 291°K the magnetic permeability $\chi = \mu - 1$, where $\mu$ is the magnetic permeability.

**At $\lambda > 3$ μ.

***Stable at $t° < 13°C$.

****There are data indicating the existence of two conductive zones separated by a distance of ≈1.6 ev and of two types of holes.

*****Te crystals are composed of helical atoms; the first number indicates the distance along the chain and the second figure the distance between atoms in adjacent chains.

******In the visible region, while at $\lambda > 7$ μ ≃ 5.

1) Chemical element; 2) width of forbidden zone (ev); 3) lability at 300°K (see $m^2$/v·sec); 4) electrons; 5) holes; 6) true resistance at 300°K (ohm·cm); 7) dielectric constant; 8) lattice constant (A); 9) magnetic permeability $\chi \cdot 10^{-6}$ (SGSM/g); 10) work function (from photoeffect); 11) refractive index at $\lambda = 1$ μ U 300°K; 12) photoionization energy (ev); 13) thermal ionization energy (ev); 14) boron; 15) carbon (diamond); 16) silicon; 17) germanium; 18) α-10; 19) selenium; 20) hexagonal; 21) amorphous; 22) tellurium.

A semiconductive material with the requisite properties is usually a monocrystal obtained by Chokhral'skiy's method (extraction from the liquid phase with a monocrystalline semiconductive primer) and zone melting (passing the ingot through the narrow field set up by an electromagnetic coil, which induces a current of sufficient power to heat

TABLE 3

Certain Characteristics of Semiconductive Compounds

| 1 Соединение | 2 Постоянная решетки (Å) | 3 Темп-ра плавления (°C) | 4 Диэлектрич. постоянная | 5 Ширина запрещ. зоны (ев) | | 6 Подвижность ($см^2$/в·сек) | |
|---|---|---|---|---|---|---|---|
| | | | | 0°K | 300°K | 7 электронов | 8 дырок |
| SiC[1]* | 4.3598 | 2700**) | 10.0 | – | 3.1 | 32 | 10—20 |
| [2] | 3.0806 | То же | То же | – | 1.9 | 100—150 | То же |
| ZnSb | 6.47877 | 523 | 15.9 | 0.24 | 0.162 | 27000 | 1000 |
| ZnAs | 6.0584 | 938 | 11.7 | 0.43 | 0.33 | 27000 | 280 |
| ZnP | 5.86875 | 1080 | 10.8 | 1.41 | 1.27 | 5000 | 80 |
| GaSb | 6.0954 | 702 | 14.0 | 0.8 | 0.68 | 4000 | 2000 |
| GaAs | 5.6534 | 1240 | 11.1 | 1.53 | 1.38 | 8000 | 240 |
| GaP | 5.4505 | 1500 | 8.4 | 1.60 | 2.25 | – | 86 |
| AlSb | 6.1355 | 1060 | 10.1 | 1.60 | 1.49 | 400 | 230 |

*β – cubic modification, α – hexagonal modification; at a content of 70.045% Si and 29.955% C this compound has a specific gravity of 3.2, a coefficient of thermal conductivity (which depends on its electrical conductivity) of 0.02-0.08 cal/cm·sec·°C, a heat capacity of 0.15-0.18 cal/g·°C at 20°, and a thermal coefficient of linear expansion of $(4-7)\cdot10^{-6}$ 1/°C.

**The α-SiC monocrystals used in instruments are obtained by crystallization from the gaseous phase at 2100-2600°.

1) Compound; 2) lattice constant (A); 3) melting point (°C); 4) dielectric constant; 5) width of forbidden zone (ev); 6) lability ($cm^2$/v·sec); 7) electrons; 8) holes.

the semiconductor to its melting temperature). Both methods, which are based on diffusion of impurities and their segregation between the liquid and solid phases during melting and solidification, are also used to purify semiconductors. Another factor in the production of semiconductors with the requisite characteristics is controlled addition of alloying elements to the pure monocrystal. The experiments govern the type of conductivity and the quantitative characteristics of the final material. For example, elements of group V or III are added to Ge and Si. The former (donors) yield an electron semiconductor, while the latter (acceptors) yield a hole semiconductor. (For more detail on the production technology of semiconductors see the references.).

The electrical properties of semiconductors make it possible to

produce devices used for generating and amplifying electrical signals (transitors) and for detecting and rectifying alternating current (diodes). The optical characteristics of semiconductors are utilized in the manufacture of photovaristors, photodiodes, and phototransistors. These materials are used as the active medium in generators (amplifiers) of electromagnetic waves in the optical region, or semiconductor lasers, which have a higher efficiency than other lasers (e.g., ruby lasers; see Laser materials). The thermoelectric properties of semiconductors have been utilized as the basis for the development and production of thermoresistors, thermoelements, batteries, thermoelectric generators and coolers, and thermostabilizers. Prospects are quite bright for the manufacture of nonmechanical sources of electrical energy (solar batteries). The creation of areas with uniformly oriented magnetic moments (high magnetic permeability) in certain semiconductors has furnished the basis for the development of ferromagnetic semiconductors (oxides of transition metals and certain compounds of these metals with sulfur, tellurium, and selenium), which have made it possible to produce small-size antennas, cores for permanent magnets, transformers, and induction coils, and other components. Broad prospects have been opened up by research on organic semiconductors, many of which (more than 50) permit production of substances conjoining diverse electrical and mechanical characteristics (elasticity, smoothly varying activation energy, thermo stability at 500° or more, etc.). Semiconductor devices are widely employed in research and production, mensuration technology, computers, equipment for all types of communication (radio, television, telegraphy, etc.) and transportation, the automation of monitoring and control processes in industry and agriculture, scientific research (especially in outer space), medical equipment, and other electronic devices and instruments, many of which can be based only on semiconductors or must

use semiconductor devices, such as microelements, micromodules, microcircuits, solid-state circuits, etc. Certain semiconductors are also used for other purposes; for example, selenium is used for staining and decolorizing glass, while silicon carbide is employed in the manufacture of heating elements for high-temperature furnaces and as a refractory material, an abrasive, etc.

TABLE 4

Electrical Conductivity and Photoconductivity of Certain Organic Semiconductors*

| Вещество[2] 1 | Вид 2 | $\sigma$ (ом·см)$^{-1}$ 3 | $E$ (эв) 4 | $E_\phi$ (эв) 5 |
|---|---|---|---|---|
| **Полиацены** 6 | | | | |
| Коронен 7 | Порошок | 5 | 1,15 | – |
| Тетрацен 8 | Пленка | $10^{-1}$ | 0,85 | 3,6[6]) |
| Хризен 9 | То же | $10^{-3}$ | 1,10 | 3,2[6]) |
| Антрацен 10 | » | $10^{-3}$ | 0,97 | 3,0 |
| Пирен 11 | » | $3\cdot10^{-6}$ | 1,01 | 3,2[6]) |
| Овален 12 | » | – | – | 1,2 |
| То же 13 | Порошок | $3\cdot10^{-8}$ | 0,57 | – |
| Пиранрен 14 | Пленка | – | – | 0,85 |
| То же 15 | Порошок | $10^{-7}$ | 0,54 | – |
| м-нафтодиантрон | То же | $10^{-7}$ | 0,60 | – |
| **Полиацены с хиноидными структурами** 16 | | | | |
| Виолантрон 17 | Порошок | $10^{-3}$ | 0,39 | – |
| То же | Пленка | – | – | 0,84 |
| Антантрон 18 | Порошок | $10^{-4}$ | 0,85 | – |
| Пирантрон 19 | То же | $3\cdot10^{-7}$ | 0,54 | – |
| То же | Пленка | – | – | 1,1[6]) |
| **Азоароматические соединения** 20 | | | | |
| 5,6-*N*-пиридино-1,9-бензантрон 21 | Порошок | $10^{-5}$ | 1,60 | – |
| 1,9,4,10-антрадипиримидин 22 | Порошок | $10^{-5}$ | 1,61 | – |
| Индантрон черный 23 | То же | $3\cdot10^{-7}$ | 1,28 | – |
| Цианантрон 24 | » | $10^{-5}$ | 0,10 | – |
| Индантрон 25 | » | $10^{-10}$ | 0,32 | – |
| Индантрон | Пленка | – | – | 0,80 |

| 1 Вещество | 2 Вид | $\sigma_0$ (ом·см)$^{-1}$ 3 | $E$ (эв) 4 | $E_\phi$ (эв) 5 |
|---|---|---|---|---|
| **Фталоцианины** 26 27 | | | | |
| Свободные от металла 28 | Порошок | $10^{-4}$ | 0,75 | – |
| То же | Пленка | – | – | 1,50 |
| **Свободные радикалы** 29 28 | | | | |
| α, α-дифенил | | – | 0,74 | – |
| β-пикрилгидразил 30 | | – | 0,13 | – |
| **Смешанные соединения** 31 | | | | |
| Перилен – бромный комплекс 32 | Порошок | 1 | 0,07 | – |
| Плазма альбумин (сухая) 33 | То же | $10^{-2}$ | 1,1 | – |
| Фибриноген 34 | Пленка | $10^{-8}$ | 1,4 | – |
| Глобин 35 | То же | – | 0,9 | 1,6 |
| **Монокристаллич. органич. полупроводники**[5]) 36 | | | | |
| Нафталин 37 | Кристалл | – | 3[4]),85 | 3,85 |
| Дифенил 38 | То же | – | 3,5 | 3,9 |
| Антрацен 39 | » 40 | – | 3,1 | 3,0 |

Notes: 1) Only some of the substances known are given as examples for each group of organic semiconductors. 2) The electrical conductivity $\sigma$ of substances in the first six groups depends on the temperature T and is calculated from the formula $\sigma = \sigma_0 \exp(-E/\kappa T)$, where $\sigma_0$ is the dark conductivity, E is the conductivity activation energy, $\kappa$ is Boltzmann's constant, and $E_\phi$ is the threshold at which photoconductivity is first observed. 3) Measured in a monocrystal. 4) In a monocrystal 0.83, 1.35, and 0.75. 5) For monocrystals $\sigma = \sigma_0 \exp(-\Delta E/2\kappa T)$, where $\Delta E$ is the width of the forbidden zone. 6) Here and henceforth the absorption threshold in ev.

1) Substance; 2) form; 3) $\sigma$ (ohm·cm)$^{-1}$; 4) E (ev); 5) $E_\phi$ (ev); 6) polyacenes; 7) coronene; 8) tetracene; 9) chrysene; 10) anthracine; 11) pyrene; 12) ovalene; 13) the same; 14) pyranthrene; 15) m-napththoanthrone; 16) polyacenes with quinoid structures; 17) violanthrone; 18) anthanthrone; 19) pyranthrone; 20) azoaromatic compounds; 21) 5,6-pyridino-1,9-benzanthrone; 22) 1,9,4,10-anthradipyrimidine; 23) indanthrone black; 24) cyananthrone; 25) indanthrone; 26) phthalocyanins; 27) metal-free; 28) free radicals; 29) α, α-diphenyl; 30) β-picrylhydrazyl; 31) hybrid compounds; 32) perylene-bromine complex; 33) plasma albumin;

34) fibrinogen; 35) globin; 36) monocrystalline organic semiconductors; 37) naphthalene; 38) diphenyl; 39) anthracene; 40) crystal.

TABLE 5

Certain Electrical, Magnetic, and Optical Characteristics of Metals and Insulators Exhibiting Semiconductive Properties (Rectification, Photoconductivity, etc.)

| 1 Вещество | 2 Ширина запрещ. зоны 300° К (эв) | 3 Работа выхода по фотоэффекту (эв) | 4 Энергия ионизации светом (эв) | 5 Энергия ионизации теплом (эв) | 6 Магнитная восприимчивость $\times 10^{-6}$ |
|---|---|---|---|---|---|
| 7 Металлы | | | | | |
| 8 β-сурьма | 0,11 | 4,05 | – | – | −8,7 |
| 9 Мышьяк серый | 1,2 | 5,17 | 1,2 | 1,2 | −3,1 |
| 10 Изоляторы | | | | | |
| 11 Фосфор желтый | 2,1 | – | 1,4 | 1,5 | – |
| 12 α-сера | 2,6 | – | 2,4 | 2,6 | −0,49 |
| 13 Йод | 1,25 | – | 1,3 | 1,24 | – |

1) Substance; 2) width of forbidden zone at 300°K (ev); 3) work function, from photoeffect (ev); 4) photoionization energy (ev); 5) thermal ionization energy (ev); 6) magnetic permeability $\times 10^{-5}$; 7) metals; 8) β-antimony; 9) gray arsenic; 10) insulators; 11) yellow phosphorus; 12) α-sulfur; 13) iodine.

Use of semiconductor devices, units, or equipment leads to a considerable decrease in size (by a factor of up to 20), weight (by a factor of up to 50), and power consumption (by a factor of up to 70), to a decrease in heat evolution, to an increase in strength, to a lower inertia, and to an increase in service life and reliability in comparison with electronic instruments in which these materials are not employed.

Semiconductors are playing a rather important role in the achievement of complete electrification of the Soviet Union, the complex mechanization and automation of industry, and the general development of the chemical industry and of all types of transportation and communications. It would also be impossible to do without semiconductors in de-

signing computers and control equipment for planning, evaluating, and regulating the national economy. Semiconductors are also widely used in many of the technical devices of everyday life (cinema, television, magnetophones, etc.).

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V.I. Baranov

SEMISTAINLESS HEAT-RESISTANT STEEL – a 5-10% chrome steel characterized by high corrosion resistance in petroleum-refining products and elevated strength at high temperatures.

As a rule, the carbon content of the steel does not exceed 0.15%. Of the alloying elements, the most commonly used is molybdenum, which is introduced in order to eliminate hot shortness and to increase the high-temperature strength. The chemical composition of semistainless

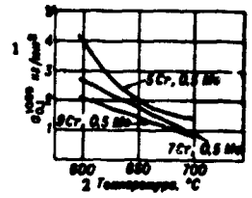



Fig. 1. Variation in creep limit of semistainless heat-resistant steel as a function of temperature. 1) kg/mm$^2$; 2) temperature, °C.

TABLE 1

Chemical Composition of Semistainless Heat-Resistant Steels

| 1 Сталь по ГОСТ 5632–61 | 2 Содержание элементов (%) | | | | |
|---|---|---|---|---|---|
| | C | Si | Mn | Cr | другие элементы 3 |
| 4 X5 | ≤0.15 | ≤0.5 | ≤0.5 | 4.5–6 | — |
| 5 X5M (EKh5M) | ≤0.15 | ≤0.5 | ≤0.6 | 4.5–6 | 0.45–0.6 Mo |
| 6 X5BΦ | ≤0.15 | 0.3–0.6 | ≤0.5 | 4–6 | 0.6–0.7 Mo<br>0.4–0.6 V |
| 7 X6C (ESKh6) | ≤0.15 | 1.5–2 | ≤0.7 | 5–6.5 | 0.6 Ni |
| 8 X6CM (ESKh6M) | ≤0.15 | 1.5–2 | ≤0.7 | 5–6.5 | 0.45–0.6 Mo |
| 9 X8BΦ | 0.08–0.15 | ≤0.6 | ≤0.5 | 7–8.5 | 0.3–0.54 V<br>0.6–1.0 W |
| 10 X7CM | ≤0.15 | 1.5–2 | ≤0.7 | 6.5–8 | 0.45–0.6 Mo |

1) Steel governed by GOST 5632-61; 2) element content (%); 3) other elements; 4) Kh5; 5) Kh5M (EKh5M); 6) Kh5VF; 7) Kh6S (ESKh6); 8) Kh6SM (ESKh6M); 9) Kh8VF; 10) Kh7SM.

heat-resistant steel and its region of application are shown in Table 1, while Table 2 gives the mechanical characteristics. The change in creep limit and ultimate stress of semistainless heat-resistant steel

is shown as a function of temperature in Figs. 1 and 2. For a 5% chrome-molybdenum steel, it is general to employ heat treatment; annealing at 840-860° or normalization at 950°, followed by tempering at various temperatures, and cooling in air. A 5% chrome steel is cinder resistant

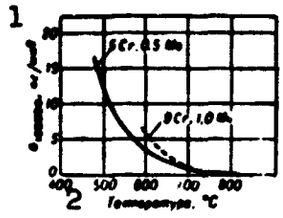



Fig. 2. Variation in ultimate-stress limit of semistainless heat-resistant steel as a function of temperature. 1) kg/mm$^2$; 2) temperature, °C.

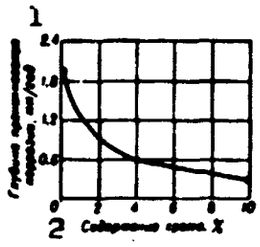



Fig. 3. Effect of chromium content on rate of corrosion of semistainless heat-resistant steel in hot petroleum-distillation products. 1) depth of corrosion penetration, mm/year; 2) chrome content, %.

to 600°, and with a 10% chrome content to 700-750°. Silicon is occasionally introduced into the steel in order to increase oxidation resistance at higher temperatures; this increases the steel resistance to corrosion in combustion products of a high-sulfur fuel. In order to increase the high-temperature strength and the hydrogen-corrosion resistance, vanadium is added.

The ability of semistainless heat-resistant steel to self-harden in air introduces several special characteristics into the technology of products manufactured. After each hot-working operation under pressure or each welding operation, the parts must be cooled very slowly or else annealed at 860°. In certain cases, heating to a temperature

of 760° is sufficient for annealing. An elevated chrome content results in a certain increase in oxidation resistance of the semistainless heat-resistant steel, and sharply raises corrosion resistance in hot petroleum-refining products (Fig. 3). An increase in chrome content to 7% with a molybdenum content of from 0.5 to 1% increases the ultimate stress of the steel.

The semistainless heat-resistant steels also include chrome-silicon steel type 4Kh9S2, 4Kh10S2M (silchrome), which has increased cinder resistance in conjunction with increased high-temperature strength; this steel is employed in the manufacture of furnace equipment and valves for internal-combustion engines (see Valve steel). Steel Kh5 is employed for components of furnace equipment operating at temperatures up to 500°; Kh5M and Kh6SM steels are used for components of petroleum-distillation apparatus (boiler support, cracking-plant slide valves and piping); type Kh6S is used for components of boiler plants operating under increased loads at a temperature of 750°; types Kh8VF and Kh7SM are used for piping, cracking-plant plates, and pump parts.

TABLE 2

Mechanical Properties and Heat Treatment Conditions

| 1 | 2 | 3 | 4 | 5 Механич. свойства (не менее) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Сталь по ГОСТ | Заводская марка | Полуфабрикат | Термич. обработка | $\sigma_в$ (кг/мм²) | $\sigma_т$ (кг/мм²) | $\sigma_{-1}$ (кг/мм²) | δ (%) | ψ (%) | $a_н$ (кгм/см²) 7 |
| 8 1Х5М | 9 ЭИ811М | 10 Пруток | 11 Отжиг при 860±20° | — | 65 | — | 20 | — | — |
| | | Лист | Нормализация при 950—980° и отжиг при 840° | 160 | 60 | 18 | 25 | 55 | 10 |
| 12 1Х5В2Ф | — | 13 Пруток | Отжиг при 840±10° | 170 | 60 | 17 | 22 | 40 | 12 |
| 17 1Х6С | 18 ЭИ811 | — | 19 Отжиг при 840° | 160 | 52 | 28 | 30 | 60 | — |
| 20 1Х6СМ | 21 ЭИ811М | — | 19 Отжиг при 840° | 160 | 55 | 21 | 30 | 55 | — |
| 22 1Х7СМ | — | — | 23 Нормализация при 950° и отжиг при 800—850° | 170 | 62 | 60 | 20 | 60 | — |
| 24 1Х9 | 25 ЭИ811 | — | 19 Отжиг при 860±10°, охлаждение на воздухе | 170 | 60 | 17 | 24 | 50 | 10 |

1) GOST designation of steel; 2) factory designation; 3) semifinished product; 4) heat treatment; 5) mechanical properties (not below); 6) kg/mm$^2$; 7) kg-m/cm$^2$; 8) kH5N; 9) EKh5M; 10) rod; 11) annealing at 860 ± ± 20°; 12) sheet; 13) normalization at 950-980° and annealing at 840°;

14) Kh5VF; 15) rod; 16) annealing at 840 + 10°; 17) Kh6S; 18) ESKh6; 19) annealing at 840°; 20) Kh6SM; 21) ESKh6M; 22) Kh7SM; 23) normalization at 950° and tempering at 800-820°; 24) Kh5; 25) annealing at 860 + + 10°, cooling in air.

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F.F. Khimushin

SEMITOMBAC – copper-zinc alloys containing from 79 to 86% Cu. These alloys include types L85 (85% Cu and 15% Zn) and L80 (80% Cu and 20% Zn) shaping brasses (GOST 1019-47). Depending on their composition and state, the ultimate strength of semitombacs ranges from 27 to 65 kg/ /$mm^2$, while their relative elongation varies from 3 to 60%. Tubes, sheets, strips, and wire are produced from these alloys. As a result of their high mechanical characteristics and corrosion resistance, semitombacs are used for sylphons, flexible hoses, condensor tubes, and wire grids. For the characteristics of these alloys see Shaping brass.

Ye.S. Shpichinetskiy

SENDAST – see High-Permeability soft magnetic alloy.

SEPARATION STRENGTH – a characteristic of the strength of adhesion (see Adhesion) between two flexible materials, such as a strip of a polymer material or glass cloth impregnated with a resin. It is measured from the work of separation per $cm^2$ of glued surface or from the force applied per unit specimen width, which increases with the separation rate. The type of failure also varies with the separation rate. At low separation rates failure has a cohesive character, while at higher rates the cohesion strength of the adhesion increases more rapidly than that of the joint and faigure becomes mixed and then adhesive.

G.M. Bartenev

SEPIOLITE – an argillaceous mineral, hydrated magnesium silicate ($2MgO \cdot 3SiO_2 \cdot nH_2O$), which forms compact ocherous masses. It is white or gray in color, with a brownish or greenish tinge. A fibrous structure can be detected under an electron microscope; the individual fibers, which extend along the c axis, are several hundred A thick and 4–5 μ long. Sepiolite has a specific gravity of 2.06–2.26, a Moos hardness of 2–2.5, and an index of refraction of 1.506–1.520 (increasing with humidity). When dry this mineral eagerly absorbs water. When heated to more than 700° it decomposes to form enstatite, while when heated to above 1075° it also forms β-cristoballite; its melting point lies above 1500°. Sepiolite has a quite substantial specific surface area. According to electron-microscopic measurements, the figure for the external surface of sepiolite particles is 127.6 $m^2/g$. This material has a high resistance to the coagulating action of electrolytes; it is readily decomposed by acids, liberating free silicon.

The high porosity and specific surface, finely acicular crystal habit, and lattice-structure characteristics of sepiolite permit its wide use in the petroleum industry for preparing special drilling solutions resistant to electrolytes, as well as for purifying mineral lubricating oils. In the latter case it yields better results than standard adsorbants. Addition of small quantities of sepiolite to standard refining clays increases the filtration rate and improves the degree of purification of mineral oils. This material is not used in the purification of vegetable oils. Addition of sepiolite to the silicate binder of molding sand raises the strength of the damp mold, increases

its high-temperature gas permeability, and considerably reduces its ultimate strength, which makes it possible to obtain castings of higher quality. Enamels prepared from sepiolite are whiter, stronger, and more acid-resistant than those based on bentonite clays. Sepiolite is used as a drying agent for gases and air in a number of production processes and can be employed as a molecular sieve for recovery of volatile solvents in the chemical industry.

References: Betekhtin, A.G., Mineralogiya [Mineralogy], Moscow, 1950; Chambers, G.P.S., Promyshlemoye ispol'zovaniye glinistogo minerale sepiolita [Industrial Utilization of the Argillaceous Mineral Sepiolite], in collection: Voprosy mineralogii glin [Problems of the Mineralogy of Clays], translated from English, Moscow, 1962, pages 269-291; Preyzinger, A., Rentgenovskoye issledovaniye struktury sepiolita [X-Ray Investigation of the Structure of Sepilote], ibid., pages 178-186; Brindley, G.B., Dannyye po difraktsii rentgenovskikh luchey i electronov dlya sepiolita [Data on the Diffraction of X-Rays and Electrons in Sepiolite], ibid., pages 187-195; Kul'bitskiy, D., Vysokotemperaturnyye fazy sepiolita, attapul'gita i saponita [High-Temperature Phases of Sepiolite, Attapulgite, and Saponite], ibid., pages 196-211; Grim, R.E., Mineralogiya glin [Mineralogy of Clays], translated from English, Moscow, 1956; Grim, R.E., Applied Clay Mineralogy, New York (et al.), 1962; Robertson, R.H.S., Sepiolite: a Versatile Raw Material, Chem. Ind., 1957, 16, No. 46, pages 1492-1495.

V.I. Fin'ko

**SERPENTINE** (Serpentinite) is a hydrothermally modificated massive rock containing 36-40% MgO, about 40% $SiO_2$, 5-13% $Fe_2O_3$ and not more than 1-2% $Al_2O_3$ and CaO. Serpentine has a green color with differently colored spots and stripes – yellowish-green, yellow, dirty dark-green, reddish-brown, and brown; the spottiness or ornamentation, especially clearly visible on polished surfaces, make serpentine similar to snake-skin. Serpentinitic (or chrysotilic) serpentine, a dark-green variously tinted rock with a low hardness, is a variety of serpentine. The precious serpentinite (ophite or serpophite) an opal-like variety of the serpentinite with beautiful green tints, is rarely found in the form of veins. The specific gravity is 2.5-2.7; the bending strength is 420 kg/$/cm^2$ (at atmospheric pressure). The dielectricity constant of the serpentine is: $\varepsilon_{20°} \simeq$ 12.0-14.0; $\varepsilon_{700} \simeq 20.0 \cdot 10^5$. The thermal conduction of serpentine is 0.0003; the magnetic susceptibility is 550-2500; the Mohs hardness is 2.5-3.5; the crushing strength is 630-1230 $kg/cm^2$. Serpentine is workable on a lathe and can be easily polished. It decomposes totally in Hcl and $H_2SO_4$ separating out silica, and also in water which contains $CO_2$; it is resistant to alkalis and to high temperatures. Serpentine has a high industrial significance because the deposits of chrysotile-asbestos, amphibole-asbestos, chromite, magnetite, talcum and soapstone, magnesite, nickel and platinum are genetically connected with it. Serpentine is utilized for the production of high-grade forsterite refractory bricks for the furnaces of cement and dolomite calcination; as a noncompacting mineral fertilizer (silicophosphate," "serpentine-phosphate") for sugar beet crops; as a facing material and

stone for ornaments – for the decoration of chimneys, tables, and columns; as a cementing crumb (in fine-grained form) in the building trade; as a filler substituting talcum in the production of low-grade paper. The possible utilizations of serpentine are: as a chemical raw material for the production of metallic magnesium, magnesium oxide, magnesium carbonate, sulfate, and chloride; for the production of active silica (silica gel), a bleaching material of high adsorptive capacity; of water glass, of hydraulic silicate admixtures to cement, as a rubber-filler (powdered silica gel), and for the production of silicones; as a raw material for the production of bituminous roofing paper (Ruberoid), pigments, insulation slabs, asbestos-yarn and -fabric; for the production of thermophosphate and heat insulating material; of raw ceramics (refractory bricks), electric equipment, boilers, vessels, heatproof products; as a material for the neutralization of the waste sulfuric acid in petroleum refining.

References: Betekhtin A.G., Mineralogiya [Mineralogy], Moscow, 1950; Fizicheskiye svoystva gornykh porod pri vysokikh davleniyakh [Physical Properties of Rocks at High Pressures], Moscow, 1962. Tr. In-ta fiz. Zemli AN SSSR [Transactions of the Institute of Physics of the Earth of the Academy of Sciences USSR], No. 23 (190).

V.I. Magidovich

SEMIHARD BRONZE – pressure-worked bronze deformed to a moderate degree (10-30%) and consequently having increased hardness and strength. Metal in this condition retains sufficient plasticity and is readily stamped or bent. Such cold-working of quenched dispersion-hardened bronzes (e.g., beryllium) corresponds to the most effective tempering, producing the highest strength, hardness, and elasticity. Membranes, silfons, Burdon tubes, flanges, cable, and other fasteners which must have high strength are fabricated from semihard bronzes.

O.Ye. Kestner

SEMISTEEL – is a cast iron founded from a charge containing besides pig iron and waste cast iron, also scrap steel. The quantity of the scrap steel in the charge varies within wide limits and depends on the demanded properties of the casting, its chemical composition, wall-thickness and the founding technology. Scrap steel present in the metal charge reduces the carbon content of the cast iron, increases the dispersity of the metal base and improves the density and the mechanical properties of the castings. The dimensions of the lamellar graphite, precipitated in the gray iron, are diminished when scrap steel is present in the charge.

Semisteel is used for lamellar-graphite gray iron castings which must have an improved, or, sometimes, a mean strength; for castings of modified, white and chilled cast iron, and also for some special cast iron grades.

The addition of steel to the metal charge does not impart any special properties to the castings.

A.A. Simkin

SETTING RATE – the time required for reactive plastics to pass from a molten, flowing state to a solid, nonflowing state. The setting rate of press-powders is the pressing time required to produce products of satisfactory appearance; according to GOST 5689-60, it is the minimum holding time required to produce a standard conical tumbler with a smooth surface and no bulges, grooves, cracks, or other defects. The setting rate of resins is determined on a hot metal plate at temperatures specified by GOST or TU. The resin is applied to the plate and stirred with a glass rod, which is periodically lifted to a height of 10-20 mm, thus forming a fine filament. The setting rate of liquid resins is the time in seconds between application of the resin to the plate and breakage of the filament; the setting time of solid resins is the interval between melting of the resin and breakage of the filament. Setting time can also be determined by other methods (with plastometers, by boiling in water, from the bromine number, from the quantity of extractable substances, etc.). The setting time of press-materials is often expressed as the pressing time in minutes per mm of product thickness.

References: Svornik standartov i tekhnicheskikh usloviy na plastmassy [Handbook of Standards and Technical Specifications for Plastics], Moscow-Leningrad, 1950.

SHABBINESS OF ALUMINUM ALLOYS – a surface defect of aluminum and aluminum-alloy sheet, taking the form of local loss of luster occuring when sheets rub against one another.

Shabbiness of aluminum-alloy sheets develops during shipment as a result of shifting of sheets within bundles, which are generally packed in crates. This defect may also be produced when insufficiently rigid crates bend.

**SHAPES OF VARYING CROSS SECTION FABRICATED FROM ALUMINUM ALLOYS** – shapes whose cross section varies smoothly or in stages along their length. Shapes whose cross sections change in stages are sometimes referred to as shapes with periodic cross section or shapes with end-pieces. Pressing, being the most highly efficient method, is the technique most widely employed in the manufacture of shapes of varying and

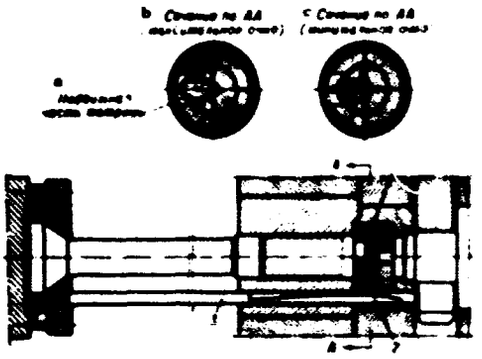


Fig. 1. Pressing of an angle piece of varying cross section: 1) Stationary portion of matrix; 2) movable portion of matrix; 3) copying straightedge. a) Movable portion of matrix; b) section through AA (maximum point); c) minimum point.



Fig. 2. Shape of varying cross section.

periodic cross section, although such shapes can also be produced by machining or by stamping in powerful vertical presses. Movable matrices are used for pressing shapes of varying cross section in horizontal hydraulic presses. As the metal flows through the aperture in the matrix, the size of this aperature is varied (together with the metal-flow rate) with the aid of a copying device, which makes it possible to ob-

tain a uniform variation in cross section over the length of the shape (Fig. 1). Shapes of periodic cross section are pressed by stepwise displacement of the matrix. The segment of the shape with the least cross sectional area is pressed first and, by shifting the matrix, the remainder of the shape, with a larger area, is then pressed. If the shape has several consecutive changes in cross section the matrix is shifted



Fig. 3. Shape of periodic cross section. 1) Basic cross section; 2) end-piece.



Fig. 4. Shape of periodic cross section with transition zone: 1) Basic cross section; 2) transition zone; 3) end-piece.

| 1 Расположение образцов | 2 Сплав Д16 | | | 4 Сплав В95 | | |
|---|---|---|---|---|---|---|
| | $\sigma_в$ | $\sigma_{0,2}$ | $\delta$ | $\sigma_в$ | $\sigma_{0,2}$ | $\delta$ |
| | 3 (кг/мм²) | | (%) | (кг/мм²) | | (%) |
| 5 Основное сечение | 44–50 | 35–38 | 9–10 | 60–62 | 55–58 | 7–8 |
| 6 Переходная зона | 43–44 | 30–32 | 10–11 | 57–58 | 50–52 | 6–7 |
| 7 Заготовка в продольном направлении | 43–45 | 30–31 | 9–10 | 60–62 | 55–56 | 6–7 |
| 8 Заготовка в поперечном направлении | 41–44 | 29–31 | 4–5 | 56–57 | – | 4–5 |

1) Location of specimens; 2) D16 alloy; 3) kg/mm$^2$; 4) V95 alloy; 5) basic cross section; 6) transition zone; 7) end-piece in longitudinal direction; 8) end-piece in transverse direction.

several times. The transverse cross section of a shape of varying cross section can be varied linearly or in accordance with any other predetermined law, depending on the contour of the copying edge. The maximum permissible deviation should be no more than 4 mm per running meter and no more than 12 mm over the entire length of the shape; a deviation of this magnitude corresponds to the maximum that can be handled with existing tensio-straightening methods. The mechanical characteristics of shapes of varying cross section are identical to those of shapes of constant cross section. Shapes of periodic cross section are produced in lengths of from 0.8 to 18 m (Fig. 2); they consist of the basic

cross section and end-pieces (Fig. 3). A transition zone is sometimes provided to facilitate deformation of the metal (Fig. 4). End-pieces range in length from 200 to 800 mm and are intended for the manufacture of fittings – areas by which the shape can be fastened to other structural elements. The basic cross sections of such shapes can vary widely in configuration, while the majority of end-pieces are more or less rectangular. In connection with the nonuniformity of metal flow during the transition from one cross section to another it is necessary to limit the thicknesses of shape elements. The minimum thickness of elements lying near the center of gravity of an end-piece should be no less than 2-3 mm, since the nonuniformity of metal flow during the initial end-piece pressing period results in crinkling at the transition point. In order to obtain the requisite mechanical properties the permissible degrees of shape-element deformation must be correctly selected. In pressing end-pieces from ingots the minimum permissible elongation ratio is 3-4.

The best ratio between the area of the end-piece and that of the basic cross section is 5. The table shows the mechanical characteristics of the basic cross section, transition zone, and end-pieces for shapes fabricated from D16 and V95 alloys.

The increased ultimate and yield strengths of the basic cross section are due to the fact that it is hardened during tension-straightening, while theend-pieces are not hardened. When pressing shapes of periodic cross section from V95 alloy it is recommended that the ingots be subjected to high-temperature homogenization (at 475° for 24 hr) if the end-pieces must have high mechanical characteristics in the transverse direction.

References: Matveyev, B.I., Zhuravlev, F.V., Tekhnologiya pressovaniya profiley peremennogo i periodicheskogo secheniy iz legkikh splav-

ov [Techniques for Pressing Shapes of Varying and Periodic Cross Section from Light Alloys], Moscow, 1959.

B. I. Matveyev

SHAPING BRONZE -- a bronze intended for pressure working (forging, pressing, and hot or cold rolling). Shaping bronzes are used in the manufacture of semifinished products such as forgings, shapes, round, square, rectangular, and hexagonal sections, tubes, strips, bands, sheets, and wire. Tin bronzes containing up to 8% Sn or alloyed with zinc (up to 4%), phosphorus (up to 0.4%), and lead (up to 4%) are pressure-worked. When the Sn content is more than 8% and substantial quantities of Zn and P are present a brittle eutectoid appears in the structure of the alloy, making pressure working difficult. The presence of undesolved lead makes shaping bronzes hot-short, so that the content of this element is limited to 2-3%. Bars, tubes, strips, bands, sheets, wire, and screening are fabricated from these bronzes. Only bars are manufactured from BrOF7-0.2 bronze, which is the strongest and most difficult to pressure-work (TsMTU 669-41); bars, strips, and bands are produced from BrOF6.5-0.15 GOST 1761-50); BrOF6.5-0.4, which is the most durable, is used in the manufacture of screen wire (GOST 5017-49) and bands (TsMTU 3352-53); hot-pressed bars and thin-walled tubes for Burdon manometer springs (GOST 2622-44) are produced from BrOF4-0.25; bars (GOST 6511-60), wire (GOST 5221-50), strips, and bands (GOST 1761-50) are fabricated from BrOTsS4-3; BrOTsS4-4-2.5 is used in the manufacture of strips and bands (TsMTU 3444-53 and 512-41). Of the tin-free bronzes, aluminum bronzes of all types readily undergo pressure working; these include aluminum-iron, aluminum-manganese, aluminum-iron-nickel, etc., bronzes. Alloys containing 11% Al are used in practice, since a higher aluminum content causes the alloy to become brittle. Shaping

bronzes containing 9-12% Al have good hot workability; the presence of a β-phase in bronze at this aluminum content ensures high plasticity at elevated temperatures. Binary alloys containing 4-8% Al exhibit especially good pressure-workability when hot or cold; bronzes of this composition (BrA5 and BrA7) are produced as strips and bands from 0.10 to 1.2 mm thick. Pressure working is hampered when the alloy contains several % iron, manganese, and nickel. BrAMts9-2 bronze is produced in strips 1.0-02.5 mm thick, bands 0.4-1.0 mm thick, and bars 5 mm in diameter. BrAZh9-4 bronze is used in the manufacture of bars, while BrAZh-Mts10-3-1.5 and BrAZhN10-4-4 are produced in bars and tubes; the latter have a minimum wall thickness of 5 ± 0.5 mm, a minimum diameter of 50 mm, a maximum diameter of 220 mm, and a maximum thickness of 50 ± 4 mm. The silicon-manganese bronze BrKMts3-1, which is produced in bars, strips, bands, and wire 0.1 mm in diameter, and the beryllium bronzes BrB2.5, BrB2, etc., also have good pressure-workability. One special feature of Beryllium bronzes is their ability to undergo dispersion hardening during annealing; being highly plastic in the quanched state, they acquire high elasticity, strength, and hardness when annealed. Beryllium-bronze strips are produced with a minimum thickness of $0.05^{-0.01}$ mm. For the mechanical properties of semifinished products of shaping bronzes see the articles entitled: High-hot-strength shaping bronze, Durable shaping bronze, Structural shaping bronze, Tool shaping bronze, Spring shaping bronze, Bronze bars, Bronze wire, and Bronze tubes.

According to the condition of the material, semifinished products can be classified as soft (annealed or quenched for dispersion-hardening alloys), semihard (cold-worked to 30-40%), hard (cold-worked to 50-80%) and ultrahard (deformed by more than 80%).

References: Smiryagin, A.P., Promyshlennyye tsvetnyye metally i splavy [Commercial Nonferrous Metals and Alloys], 2nd Edition, Moscow, 1956.

O.Ye. Kestner

SHEAR – fracture of a material under the action of tangential stresses in any loading mode (extension, torsion, compression, bending, etc.). The onset of shear is always preceded by plastic deformation, without which fracture due to tangential stresses is called spallation. The term "shear" is used to designate the fracture of bolts, rivets, nails, etc., by forced displacement perpendicular to the axis of the sheared component. In this case we can distinguish single shear (one shear plane) and double shear (two shear planes). However, in materials with a low Rupture resistance fracture under such loading may occur by rupture along planes inclined to the rod axis. Pure shear generally cannot be obtained, since warping, a certain amount of bending, etc., participate. Torsional fracture of hollow cylindrical rods of plastic materials (along planes perpendicular to the rod axis) most closely approximates the conditions of pure shear.

Ya.B. Fridman

SHEARING MODULUS — see Modulus of Elasticity.

SHEARING TEST – is the determination of the resistance of materials to transverse shear; it consists in the destructive testing of specimens or parts (bolts, rivets, dowels, etc.) in devices of the "fork-lug" joint type (double shear) or of the overlapping joint type (single shear). The shearing test is carried out on universal testing machines. The assembly may work with compression or stretching (Fig. ). The shearing strength $\tau_{sr}$ is determined according to the formula $\tau_{cp}=\frac{P_{макс}}{2F}$ in the case of double shear, and by the formula $\tau_{cp}=\frac{P_{макс}}{F}$ in one of single shear, where $P_{maks}$ is the maximum shearing load, F is the cross section area of the specimen. The magnitude of $\tau_{sr}$ is conditional because the shearing stress is accompanied by bending and crumpling whose part depends on the conditions of the experiment (diameter of the specimen, thickness of the shearing blades, ightness of the fit of the specimen in the hole of the blade and of the blade in the assembly, and the degree of blunting of the edges of the working hole). The double shearing test is more preferable because it diminishes the bending effect. The shearing strength depends on the test speed. Optimum shearing test conditions are established by experience: loading speed not higher than 10-20 mm/min, the thickness of the shearing blade approximately equal to the diamter of the specimen. The true shearing strength $t_k$ of metals is determined by the formula $t_k=\frac{P_{макс}}{F_{ср}}$, where $P_{maks}$ is the load in the moment the specimen is sheared, and $F_{sr}$ is the virtual area of the shear determined on the fracture in which usually the crumpling crescent and the shearing region are clearly discernible.

The shearing strength of sheet, laminated and fibrous nonmetallic

materials is determined in a direction perpendicular to the surface (crosscut) of the sheet or fiber, in the plane of the sheet (shear, shift), and between the layers or fibers (cleaving). The tests are carried out according to GOST 6336-52, and GOST 8698-58.

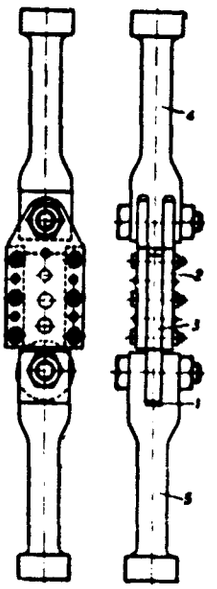


Fig. Device for the double shear test: 1) Blade; 2) jaw; 3) packing; 4) and 5) rods.

References: ratner S.I., Kadobnova N.V., and Petrov Ye.A., Osobennosti metodiki ispytaniya na srez [Peculiarities of the Shearing Test Methods], "zavodskaya laboratoriya," 1954, No. 3, page 332.

N.V. Kadobnova

SHEAR STRAIN – see Shear.

SHEAR STRENGTH – the maximum tangential stress at the instant of fracture by shear. This quantity is determined experimentally by tensile, compression, torsion, and double-shear tests. The shear strength, $t_k$, is often determined by torsion of a solid or hollow cylindrical specimen, in which case $t_k = \frac{1}{2\pi d^3}(3M_k + \theta\frac{dM}{d\theta})$, where $M_k$ is the torsional moment at fracture, d is the diameter of the specimen, and $\theta$ is the greatest torsional angle (at fracture). On extension $t_k = S_k/2$, where $S_k$ is the Fracture strength (the final ordinate on the diagram of true tensile stresses). The term shear strength is also used to refer to an arbitrary stress characterizing the strength of bolts, rivets, and other elements under double or single shear (see Shear testing). This arbitrary shear strength is designated by the symbol $\tau_{sr}$.

References: Ratner, S.I., Prochnost' i plastichnost' metallov [Strength and Plasticity of Metals], Moscow, 1949; Fridman, Ya.B., Mekhanicheskiye svoystva metallov [Mechanical Properties of Metals], 2nd Edition, Moscow, 1952.

N.V. Kadobnova

**SHEATHING FABRIC** – is used for making special sheaths, for sheathing and protection of various objects standing in the open (automotive vehicles, aircraft, etc.), from atmospheric and other effects. Sheathing fabrics must be strong, water repellent, resistant to the effect of microorganisms and sun light, dense, in order to ensure the protection of objects from dust and moisture. Cotton and flax fabrics (for tents and waterproof capes) and sailcloths with the weight of 1 $m^2$ from 300 to 600 g are primarily used as sheathing fabrics. To impart water-repellent properties to sheathing fabrics as well as to impart resistance to the action of microorganisms and sun light, they are subjected to combined impregnation by anti-rot and water-repellent compounds; the dried or well squeezed out fabric is treated by a paraffin-stearin emulsion, then impregnated by an aluminum salt solution, washed and dried. As a result of this treatment the fabric acquires water-repellent properties. Sheathing fabrics which were subjected to combined impregnation also acquire an increased abrasion resistance. Sheathing fabrics which are only treated by the water-repellent solution wear out and lose water repelling properties substantially faster than fabrics with combined impregnation. Sheathing fabrics impregnated by the combined method have high water-repellent properties, are resistant to the effect of microorganisms and have a high wear resistance. The table on page  shows the indicators of sheathing fabrics which are used for making covers for various purposes.

III-76t1

## Indicators of Fabrics Used for Covers for Various Purposes

| Ткани 1 | Номер артикула или образца 2 | Ширина (см) 3 | Номер пряжи 4 | | Вес 1 м² (г) 5 | Число нитей на 10 см 6 | | Минимальное разрывное усилие полоски ткани шириной 50 мм (кг) 7 | | Вид переплетения 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | основа 9 | уток 10 | | основа | уток | основа | уток | |
| | | | 11 Хлопчатобумажные ткани | | | | | | | |
| 12 Плащ-палатка | 610 | 66 | 34/2 | 20 | 301 | 278 | 224 | 90 | 80 | Полотняное 13 |
| Парусина бревенчатовая 14 | 11301 | 75 | 28/3 | 28/3 | 480 | 248 | 116 | 144 | 75 | То же |
| 15 То же | 11302 | 75 | 40/5 | 40/5 | 550 | 269 | 118 | 170 | 110 | » |
| 16 Чехольные хлопчатобумажные ткани, разработанные ПНИХБИ | | | | | | | | | | |
| | 5294 | 75 | 65/2 | 24 | 246 | 392 | 238 | 77 | 83 | Полуворсистое 17 |
| | 5292 | » | 65/2 | 34 | 253 | 375 | 358 | 82 | 83 | Рогожка |
| | 5295 | » | 65/2 | 34 | 254 | 380 | 382 | 83 | 89 | То же 18 |
| | 5280 | » | 65/2 | 65/2 | 266 | 368 | 413 | 78 | 101 | » |
| | 5275 | » | 65/2 | 65/2 | 236 | 354 | 340 | 78 | 77 | Саржа 2/2 19 |
| | | | 20 Льняные ткани | | | | | | | |
| 21 Парусина | 1110 | 75 | 8 я/м | 6 о/с | 515 | 256 | 98 | 165 | 105 | Полотняное |
| То же | 1111 | 75 | 7,5 я/м | 5 о/с | 580 | 228 | 102 | 190 | 170 | То же |
| | | | 22 | 23 | | | | | | |

1) Fabrics; 2) type or standard number; 3) width (cm); 4) yarn number; 5) weight of 1 $m^2$ (g); 6) thread count per 10 cm; 7) minimum rupture strength of a 50 mm wide strip (kg); 8) weave type; 9) warp; 10) weft; 11) cotton fabrics; 12) waterproof cape; 13) plain; 14) canvas sailcloth; 15) same as above; 16) cotton sheathing fabrics elaborated by the PNIKhBI; 17) semidouble thread; 18) coarse canvass; 19) 2/2 serge; 20) flax fabrics; 21) sailcloth; 22) 1/m; 23) o/s.

References: Simigin, P.A., Zusman, M.N. and Raykhlin, F.I., Zashchitnyye propitki tekstil'nykh materialov [Protective Impregnation of Textile Materials], Moscow, 1957; "Text. Res. J.," Vol. 22, No. 11, 1952; "Text. World," Vol. 94, No. 3, 1944.

P.A. Simigin, M.N. Fomina

SHIPBUILDING STEEL – steel used for welded ship hulls. A number of specific requirements are imposed on these steels to ensure that they are sufficiently plastic and have no tendency toward brittle fracture. Evaluation of the plasticity of shipbuilding steels from their $\delta$ and $\psi$ is inadequate. For this purpose bending tests are made on specimens with a thickness equal to the sheet thickness and a width of 5 times this thickness. For low-alloy steels it is customary to regard the results of bending tests on broad specimens as satisfactory if, with a mandrel having a diameter equal to twice the sheet thickness, they can be bent through an angle of 120° without formation of tears or cracks and then rebent through 180° without complete failure.

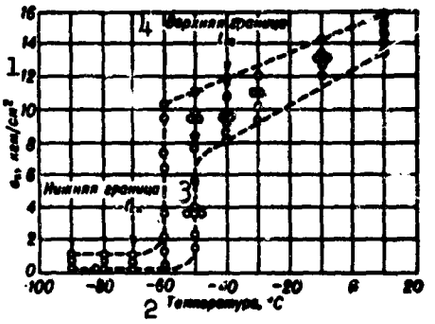



Fig. 1. Impact strength of SKhL-4 steel as a function of temperature. 1) kg-m/cm$^2$; 2) temperature, °C; 3) lower limit of $t_{kn}$; 4) upper limit of $t_{kn}$.

Brittle fracture of hull-type shipbuilding steel may occur during cold straightening of the sheets, during cold-bending operations, or under the influence of external stresses during welding. In order to avoid brittle fracture during cold straightening and bending it is sufficient that broad specimens of sheet shipbuilding steel withstand

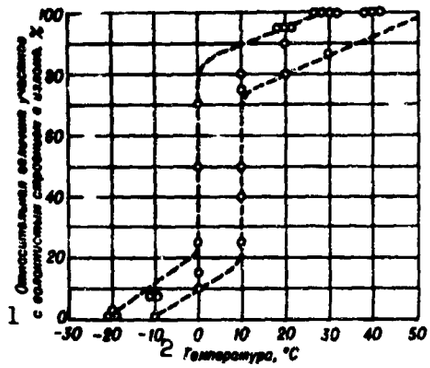



Fig. 2. Relative size of areas with a fibrous structure in fractures in specimens of SKhL-4 steel as a function of temperature. 1) Relative size of areas with fibrous structure in fracture, %; 2) temperature, °C.

bending tests. The tendency of shipbuilding steels to undergo brittle fracture when subjected to external stresses during welding is evaluated with the aid of other special impact-bending tests on Menage specimens at a temperature of −40° and tests for type of fracture; only ordinary-quality carbon steel is not subjected to such testing. It has been established that shipbuilding steels are not subject to brittle fracture during assembly when the critical transition interval from the viscous to the brittle state during impact testing of Menage specimens at reduced temperatures lies below −40° (Fig. 1). The minimum impact strength exhibited by the type of steel in question while still in the viscous state is taken as the norm for tests at −40°. Viscous fracture is of the matte fibrous type, while brittle fracture is of the lustrous crystalline type. Tests for type of fracture are conducted on specimens cut from sheets with a gas torch and then notched. The specimens are fractured by static press-loading at room temperature. Figure 2 shows the typical relationship between the relative fibrosity of fractures in specimens of heat-treated SKhL-4 steel and temperature. It can be seen from examination of Fig. 2 that different requirements must be imposed for evaluation of the quality of shipbuilding steels exhibiting

different types of fracture as a function of tendency toward brittle fracture. The highest-quality steel should be required to display completely fibrous fracture or fracture with a fibrous area of no less than 60-70%. For shipbuilding steels whose brittle-transition range lies at room temperature when large specimens are tested fractures need contain only small fibrous areas. It is important, however, that the fibrous areas occur in the fracture both along the lateral margins, where fracture accompanied by formation of fibrous areas (or shear) occurs in steel under low stresses, and in the central region, where fracture takes place on through stressing. The area of the fibrous regions should constitute 20-30% of the total fracture area. Shipbuilding steels are produced in the hot-rolled or heat-treated state, depending on their composition and the sheet thickness; shapes are hot-rolled.

TABLE 1

Chemical Composition of Shipbuilding Steels

| Сталь 1 | 2 Содержание элементов (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | C | Si | Mn | S | P | Cr | Ni | Cu |
| | | | | 3 не более | | | | |
| Ст. 3 4 | 0.14—0.22 | 0.12—0,35 | 0. 5—0,60 | 0.05 | 0.05 | <0.3 | <0.5 | <0.4 |
| Ст. 4 5 | 0.18—0.25 | 0.12—0,35 | 0,4—0,7 | 0.05 | 0.06 | <0.3 | <0.3 | <0.4 |
| 09Г2 6 | <0.12 | 0,2—0,4 | 1.45—1,75 | 0.04 | 0.04 | <0.3 | <0.3 | <0.3 |
| МК-35 7 | <0.12 | 0,6—1,1 | 1,3—1.65 | 0.04 | 0.04 | <0.3 | <0.3 | 0,15—0,30 |
| МК-40 8 | <0.12 | 0,6—1,1 | 1,3—1.65 | 0.04 | 0.04 | <0,3 | <0,3 | 0,15—0,30 |
| СХЛ-4 9 | <0.12 | 0,6—1,1 | 0.5—0,8 | 0,04 | 0.04 | 0.6—0.9 | 0.5—0.8 | 0.4—0.65 |
| 10 СХЛ-45 | <0.12 | 0.7—1.0 | 0.5—0.9 | 0.035 | 0.035 | 0.4—0.7 | 1.3—1.6 | 0.3—0.6 |
| 09Г2С 11 | <0,12 | 0.5—0,8 | 1,3—1,7 | 0.035 | 0.035 | <0.3 | <0.3 | <0.3 |

1) Steel; 2) content of elements (%); 3) no more than; 4) St.3; 5) St.4; 6) 09G2; 7) MK-35; 8) MK-40; 9) SKhL-4; 10) SKhL-45; 11) 09G2S.

Table 1 shows the chemical composition of high-quality weldable carbon and low-alloy shipbuilding steels. In addition to killed carbon steel with a silicon content of from 0.12 to 0.35%, GOST 5521-50 provides for prcduction of silicon-free rimmed steel; however, it is im-

TABLE 2

Mechanical Characteristics of Carbon Shipbuilding Steels

| Сталь 1 | Вид проката 2 | $\sigma_в$ (кг/мм²), не менее 3 | $\frac{\sigma_т}{\sigma_в}$ % | $\delta_{10}$ (%), не менее | $\delta_5$ (%), не менее |
|---|---|---|---|---|---|
| Ст. 3С 5 | Толстый лист 9 | 38–40<br>41–43<br>44–47 | 22 | 23<br>22<br>21 | 27<br>26<br>25 |
| | Тонкий лист 10 | 38–47 | — | 16 при толщине 2–2,5 мм<br>17 при толщине 3–3,5 мм,<br>18 при толщине 3,75 мм | |
| | Фасонный прокат 11 | 38–40<br>41–43<br>44–47 | 22 | 23<br>23<br>21 | 27<br>26<br>25 |
| Ст. 4С 6 | Толстый лист | 42–44<br>45–48<br>49–52 | 24 | 21<br>20<br>19 | 25<br>24<br>23 |
| | Тонкий лист | 42–52 | — | 14 при толщине 2–2,5 мм,<br>15 при толщине 3–3,5 мм,<br>16 при толщине 3,75 мм | |
| | Фасонный прокат | 42–44<br>45–48<br>49–52 | 24 | 21<br>20<br>19 | 25<br>24<br>23 |
| Ст. 4Л 7 | Толстый лист | 42–50 | 25 | 20 | 24 |
| Ст. 4Ф 8 | Тонкий лист | 41–47 | 24 | 20 | 24 |

1) Steel; 2) type of rolled product; 3) ($kg/mm^2$), no less than; 4) (%), no less than; 5) St.3S; 6) St.4S; 7) St.4L; 8) St.4F; 9) thick sheets; 10) thin sheets; 11) shapes; 12) at thickness of.

possible to recommend rimmed steel for welded hulls, since it exhibits an increased tendency toward brittle fracture.

Table 2 shows the mechanical characteristics of carbon shipbuilding steels in the as-delivered state, according to GOST 5521-50 (steel with the index S is intended for unflanged sheets, steel with the index F for flanged sheets, and steel with the index L for sheets for hull areas exposed to ice) Carbon steel is generally produced in the hot-rolled states. Sheet steel up to 12 mm thick inclusive and shaped steel is at present used for critical welded structures. Low-alloy shipbuild-

ing steels are employed when thicker sheets are required. Carbon shipbuilding steels are produced in sheets and shapes; in addition to tensile testing, the usual narrow specimens are subjected to cold bending by 180° over a mandrel with a diameter equal to half the thickness of the sheet or shape wall for St.3 steel and twice the sheet thickness for St.4 steel.

Table 3 shows the mechanical characteristics of low-alloy shipbuilding steels and the requirements imposed on type of fracture.

Electrodes of type UONI-13/45 are used for manual welding of carbon steel and 09G2 manganese steel, electrodes of type UONI-13/45A are used for welding MK-35, MK-40, and SKhL-4 steels, and electrodes of type UONI-13/55 are used for welding SKhL-45. Automatic welding of shipbuilding steels is carried out with type Sv08A low-carbon wire under OSTs-45 flux. Shipbuilding steels can also be welded at low temperatures, except when in sheets more than 20 mm thick, which should not be welded at temperatures below −25°. Weldable shipbuilding steels have a low carbon content and a rather considerable content of various alloying additives, so that the austenitic transition observed on cooling has characteristic peculiarities. very sluggish formation of perlite and very intensive decomposition of austenite to form ferrite over a broad range of subcritical temperatures. This transformation involves formation of ordinary ferrite along the boundaries of the austenitic grains at higher temperatures. At lower temperatures an intermediate transformation involving precipitation of carbon-saturated acicular ferrite within the grains and formation of a carbide phase takes place. In practice it is very difficult to completely suppress this intermediate transformation by increasing the cooling rate when quenching hull sheets and heat-treated shipbuilding steels always contain a considerable amount of ferrite. If the ferrite is formed at rather high tempera-

tures the austenite becomes carbon-enriched, which causes a sharp drop in its martensitic-transformation point. As a result, after cooling in air from high temperatures shipbuilding steels often have a structure consisting of ferrite and high-carbon martensite rather than of ferrite and perlite. On quenching ferrite precipitation occurs at lower temperatures, the austenite becomes considerably less carbon-enriched, and the transformation of austenite to martensite occurs at higher temperatures. The usual carbide segregation and coagulation processes take place during subsequent high tempering and the steel acquires a sorbitic structure with a certain amount of structurally free ferrite. Since the austenitic transformation always occurs at temperatures below the recrystallization threshold when shipbuilding steels are properly quenched in water, phase cold hardening has a material influence on the characteristics of these steels. The refinement of crystal structure resulting from phase cold hardening causes a simultaneous increase in impact strength and rupture resistance, the latter being quite substantial. For this reason the effect of quenching on low-carbon alloy steel is wholly useful, greatly reducing its tendency toward brittle fracture. Actual grain size has a particular influence on the tendency of low-alloy shipbuilding steels toward brittle fracture. The smaller the grains, the less is the tendency of the steel to exhibit brittle fracture. The best combination of properties in low-alloy shipbuilding steels is achieved by quenching in water and subsequent high tempering, provided that quenching is conducted from the minimum heating temperature required to ensure complete transition to the austenitic state and that the actual grain size is the minimum achievable for the steel in question.

Cold or hot bending is employed in the manufacture of components with complex shapes from [illegible]ilding steels. Cold deformation causes the increase in strength normal for all steels, this being accompanied

TABLE 3

Mechanical Characteristics of Low-Alloy Shipbuilding Steel

| Сталь | Вид проката | Состояние поставки | $\sigma_b$ | $\sigma_{0.2}$ | $\delta_{10}$ | $\psi$ | $a_н$ | Площадь излома, имеющего волокнистое строение (%) |
|---|---|---|---|---|---|---|---|---|
| | | | (кг/мм²) | | (%) | | (кгм/см²) | |
| 1 | 2 | 3 | 4 | | | | 5 | 6 |
| 09Г2 | Листы толщиной: 13 | 17 | | | | | | |
| 7 | 4–15 мм | Горячекатаные | 45 | 30 | 18 | — | 3 | 85 |
| 8 | 16–20 мм | То же 18 | 45 | 30 | 18 | 45 | 3 | 85 |
| | 21–30 мм | Закалка и отпуск | 45 | 30 | 18 | 45 | 5 | 75 |
| | Фасонный прокат 14 | Горячекатаный | 45 | 30 | 18 | — | — | — |
| 09Г2С | Листы толщиной 32–56 мм | 19 — | 46 | 30 | 18 | 50 | 5 | 50 |
| МК-35 | Листы толщиной: | | | | | | | |
| | 4–9 мм 15 | Горячекатаные | 50–70 | 35 | 16 | — | — | — |
| 9 | 10–14 мм | То же | 50–66 | 35 | 18 | — | 4 | 60 |
| | 16 мм | » | 50–66 | 35 | 18 | 50 | 4 | 60 |
| | 18–32 мм | Закалка + отпуск | 50–64 | 35 | 16 | 50 | 5 | 60 |
| | Фасонный прокат | Горячекатаный | 50 | 35 | 18 | — | 3 | — |
| МК-40 | Листы толщиной: | | | | | | | |
| | 4–9 мм | Горячекатаные | 54–75 | 40 | 16 | — | — | — |
| 10 | 10–14 мм | Закалка + отпуск | 54–70 | 40 | 18 | 50 | 5 | 60 |
| | 16–32 мм | Закалка + отпуск | 54–66 | 40 | 16 | 50 | 5 | 60 |
| СХЛ-4 | Листы толщиной: | | | | | | | |
| | 4–5 мм | Горячекатаные | 54–75 | 40 | 16 | — | 4 | 30 |
| 11 | 6–8 мм | То же | 54–70 | 40 | 16 | — | 4 | 30 |
| | 9–15 мм | » | 54–66 | 40 | 16 | — | 4 | 30 |
| СХЛ-45 | Листы толщиной 4–15 мм | » | 58–68 | 45 | 16 | — | 3,5 | — |
| | Фасонный прокат 16 | » | 58–68 | 45 | 16 | — | 5 (при 20°) 20 | — |
| 12 | | | | | | | | |

1) Steel; 2) type of rolled article; 3) as-delivered condition; 4) ($kg/mm^2$); 5) ($kg\text{-}m/cm^2$); 6) fracture area with fibrous structure (%); 7) 09G2; 8) 09G2S; 9) MK-35; 10) MK-40; 11) SKhL-4; 12) SKhL-45; 13) sheets with thickness of; 14) rolled shapes; 15) sheets 32–56 mm thick; 16) sheets 4–15 mm thick; 17) hot-rolled; 18) the same; 19) quenching and tempering; 20) at.

by approximation of the values of $\sigma_b$ and $\sigma_{0.2}$ and a decrease in $\delta$; there is also a marked increase in the tendency of the steel toward brittle fracture under the influence of cold working and, to a still greater degree, on subsequent aging. Fine-grained steel is embrittled to a lesser extent than coarse-grained steel. Mechanical aging is most intensive at a heating temperature of 400°, heating at higher temperatures reducing the tendency of the steel toward brittle fracture. High tempering (at temperatures of the order of 650°) restores the initial characteristics of cold-worked structural steels.

In contrast to forging, the metal undergoes only slight deformation during hot bending. The change in characteristics during this operation is consequently governed principally by the temperature regime. There is a material difference between these operations only if plastic de-

formation is completed at temperatures below 600°. In this case it is necessary to take cold working into account. Like normalization, hot bending of the simple carbon-manganese steel 09G2 increases rather than reduces its characteristics. Heating an alloy steel to high temperatures causes a substantial change in its tendency toward brittle fracture and in virtually all its mechanical characteristics. The decrease in $\sigma_{0.2}$ is the most substantial and important, serving as the basis for calculating the strength of hull structures. The general rule that strength is altered as the heating temperature is raised does not hold for low-carbon steel. The varying behavior of steels on heating is to a considerable extent governed by the individual characteristics of the melts.

Hot bending materially increases the tendency of low-alloy steel toward brittle fracture. Hot bending can consequently be employed only in special cases, where it is impossible to fabricate the desired component by cold bending or to conjoin hot bending with subsequent quenching and high tempering. The corrosion characteristics of low-alloy shipbuilding steels differ little from those of carbon steel.

A.A. Kroshkin

SHOCK-ABSORPTION RUBBER ... rubber used in the manufacture of shock absorbers for protecting machinery, instruments, and buildings against

Physical and Mechanical Characteristics of Principal Shock-Absorption Rubbers

| Амортизаторы 1 | Предел прочности при разрыве (кг/см²) 2 | Относительное удлинение (%) 3 | Твердость по ТМ-2 4 | Температура хрупкости (°С) 5 | Маслостойкость 6 |
|---|---|---|---|---|---|
| Сборные 7 | 60 | 600 | 45–50 | −55 | Немаслостойка 20 |
| Сварные 8 | | | | | |
| Пластинчатые 9 | 160 | 500–600 | 55–60 | −55 | То же 21 |
| АКСС (до нагрузки 15 кг) 10 | 50 | 500 | 50–60 | −45 | " |
| 11 АКСС (до нагрузки 160 кг) | 100 | 450 | 60–65 | −40 | Маслостойка 22 |
| АКСС (до нагрузки 400 кг) 12 | 110 | 400 | 50–60 | −40 | То же |
| 13 АН | 60 | 600 | 35–50 | −55 | Немаслостойка |
| АП 14 | 100 | 450 | 60–55 | −40 | Маслостойка |
| 15 АР (до нагрузок 250-500, 1000 кг) | 150 | 550 | 35–45 | −50 | Немаслостойка |
| 16 АР (до нагрузок 600-1200, 2000 кг) | 160 | 490 | 65–60 | −45 | То же |
| 17 Цилиндрические | 160 | 600–800 | 55–60 | −55 | " |
| Резино-пневматические АП 18 | 150 | 550 | 35–45 | −50 | " |
| 19 Резино-пружинные АД | 50 | 200 | 60–65 | −70 | " |

1) Shock absorber; 2) ultimate tensile strength (kg/cm²); 3) relative elongation (%); 4) hardness in TM-2 apparatus; 5) embrittlement temperature (°C); 6) oil resistance; 7) sectional; 8) welded; 9) plate; 10) AKSS (loads of up to 15 kg); 11) AKSS (loads of up to 160 kg); 12) AKSS (loads of up to 400 kg); 13) AN; 14) AP; 15) AR (loads of up to 250-500, 1000 kg); 16) AR (loads of up to 600-1200, 2000 kg); 17) cylindrical; 18) rubber-pneumatic AP; 19) rubber-spring AD; 20) not oil-resistant; 21) the same; 22) oil-resistant.

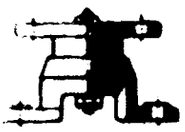


Fig. 1. Sectional rubber shock absorber.



Fig. 2. Flat shock absorber for instruments.

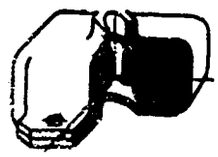


Fig. 3. AKSS shock absorber.



Fig. 4. AM shock absorber.

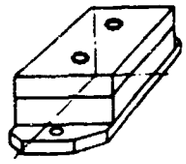


Fig. 5. Two-plate AP shock absorber.

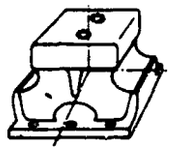


Fig. 6. AR arch shock absorber.



Fig. 7. Cylindrical shock absorber.



Fig. 8. Sleeve shock absorber.

shaking, vibration, and shocks. The following types of shock absorbers are manufactured from shock-absorption rubber: 1) sectional shock absorbers, which are units of machinery (instruments) and consists of rubber and metallic elements fabricated separately and assembled into

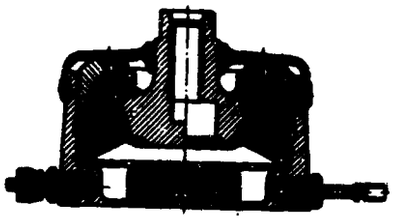


Fig. 9. Rubber-pneumatic shock absorber.

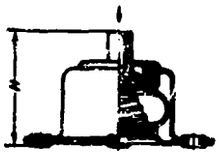


Fig. 10. Rubber-spring shock absorber.

a shock-absorbing device (Fig. 1); 2) welded shock absorbers, which are rubber-components in which the rubber is fastened to the metal during vulcanization. The first two types of shock absorbers absorb the kinetic energy of shocks, vibration, and shaking by deformation of the rubber, while damping is effected as a result of the hysteresis characteristics of the rubber. The most common and promising of the welded shock absorbers are plate instrument absorbers (Fig. 2), type AKSS absorbers (Fig. 3), type AM absorbers (Fig. 4), two-plate AP absorbers (Fig. 5), AR arch absorbers (Fig. 6), cylindrical absorbers (Fig. 7), and sleeve absorbers (Fig. 8, 9) rubber-pneumatic shock absorbers, in which the kinetic energy is absorbed by deformation of the rubber and by heating and compression of the air contained in the absorber, while damping results from the hysteresis characteristics of the rubber (Fig. 9); 4) rubber-spring shock absorbers, in which the kinetic energy is absorbed by a deformable spring, while damping is provided for by air in a rubber bulb and, to some extent (especially at low temperatures), by the hysteresis characteristics of the rubber of the bulb (Fig. 10).

The Table shows the physical and mechanical characteristics of the rubbers used in the manufacture of shock absorbers.

References: Iorish, Yu.I., Zashchita samoletnogo oborudovaniya ot vibratsii [Protection of Aircraft Equipment Against Vibration], Moscow, 1949; Gorelik, B.M., Applied Vibration Calculations for Rubber-Metal Shock Absorbers, Tr. N.-i. in-ta resin. prom-sti [Transactions of the Scientific Research Institute of the Rubber Industry], 1955, Collection 2; Gorelik, B.M., Certain Characteristics of Rubber as a Structural Material, Ibid.; Grigor'yev, Ye.T., Raschet i konstruirovaniye rezinovykh amortizatorov [Calculation and Design of Rubber Shock Absorbers], Moscow, 1960.

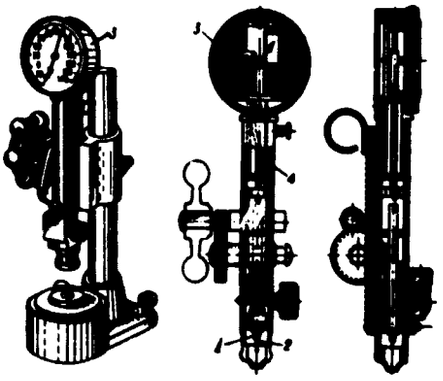
B.M. Gorelik

SHORE HARDNESS – physicomechanical characteristic of a material, which determines its ability to resist local plastic deformation produced by a freely falling hammer dropped from a constant height and equipped by a diamond or hard alloy tip. The Shore hardness (or hardness number) HS is determined by the height of the hammer's rebound and is expressed in arbitrary dimensionless units, which are read off directly on the scale of the Shore scleroscope. The Shore hardness scale is graduated in a manner such that HS = 100 corresponds to the hardness of high-carbon steel quenched to martensite. The Shore hardness is used very infrequently due to the substantial scattering in the test results. This method is replaced by the more accurate and reliable material hardness tests (Brinell, Rockwell, Vickers). Approximate empirical relationships are known which relate the Shore hardness of carbon steels to the ultimate strength $\sigma_b$ and the Brinell hardness HB: HB = 7HS; $\sigma_b$ = = 2.5 HS.

References: Avdeyev, B.A., Ispytatel'nyye mashiny i pribory [Testting Machines and Instruments], Moscow, 1957.

I.V. Kudryatsev and D.M. Shur

SHORE'S SCLEROSCOPE – is a device to determine the hardness of metallic materials by the elastic rebound method, based on the dependence of the height of rebound of a freely falling elastic hammer on the hardness of the tested specimen or object (Fig.). The hammer with a diamond or hard-alloy tip, formed as a ball or a truncated cone, falls from a constant height on the surface of the specimen within a pipe and sets in action the rebound-height meter whose scale is graduated in units of Shore hardness ($S_H$). The pipe of the scleroscope is fixed on a support with a vertical rod holding the device, or it is pressed by hand vertically to the surface of the object. The adjustment of the device is carried out by means of the usual hardness standards (by Rockwell, for example).



Shore's scleroscope. 1) Block; 2) tip; 3) height-meter; 4) pipe.

References: Avdeyev, B.A., Ispytaltel"nyye mashiny i pribory [Testing Machines and Devices], Moscow, 1957.

I.V. Kudryavtsev and D.M. Shur

SHORTNESS – is the destruction after a small plastic deformation. Shortness is a collective term concerning the tensile strength, the low resistance to the growth of cracks, the sensitivity to notches, and the margin of elastic energy. A high resistance to shortness must be provided for the reliability of welded ships, tanks, bridges, cores of nuclear reactors, rockets, etc.

Ya.B. Fridman

SHORT-TIME RESISTANCE (ultimate strength) – the highest conventionally specified stress which is withstood by a specimen in a tensile test. It is denoted $\sigma_b$ or $\sigma_{pch}$. It is calculated from the formula $\sigma_b = p_b/F_0$, where $p_b$ is the highest load (in kg) preceding the breaking of the specimen, and $F_0$ is the initial cross sectional area of the specimen in $mm^2$ or $cm^2$.

S.I. Kishkina-Ratner

SHRINKAGE – reduction in the linear dimensions or volume of a body as a result of loss of moisture, hardening, crystallization and other physical or physicochemical processes. The shrinkage of concretes, ceramic and building materials is determined by the loss of moisture due to drying. The reduction in the product's dimensions in this case is directly proportional to the quantity of moisture which evaporats. Nonuniform shrinkage results in warpage and even cracking of products. Shrinkage of metals is observed upon transition from the molten into the solid state and on crystallization of the metal. Shrinkage of fabrics results in reducing the dimensions of fabrics and textile articles in the production, storage, washing, etc. The shrinkage of fabrics is produced by relaxation of hyperelastic tensile deformations, to which the fabric was subjected in the production process. Heating of polymeric materials results in heat or thermal shrinkage, and in irreversible reduction in dimensions and volume and reversible changes in dimensions and volume with heating or cooling which depends on the thermal expansion coefficient (see Coefficient of Linear Thermal Expansion).

Molded products made from olding compounds and molding materials change dimensions upon cooling which is the so-called molding shrinkage.

The molding shrinkage is determined (GOST 5689-60) by comparing the dimensions of the molding part of the mold and a standard molded disk 100 ± 1 mm in diameter and is calculated from the formula

$$x=\frac{(d-d_1)\cdot 100}{d_1}.$$

where $\underline{d}$ and $d_1$, respectively, are the diameters of the molding part of the mold and the molded disk at a temperature of 20 $\pm$ 5°. The disk's dimensions are determined with an accuracy of 0.02 mm not earlier than 16 and not later than 24 hours after molding.

S.A. Reytlinger, M.S. Krol'.

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[Transliterated Symbols]

3567 ГОСТ = GOST = Gosudarstvenny obshchesoyuznyy standard = All-Union State Standard

SHRINKAGE – the decrease in specimen height during compression. It is characterized by the relative shortening, $\varepsilon_{sch} = (h_0 - h)/h_0$, where $h_0$ is the initial height of the specimen and $\underline{h}$ is its height after compression or at a given point in the test; it is generally the final shrinkage that is determined. Shrinkage tests (GOST 8817-58) determine the ability of materials intended for fastening components to withstand a given degree of shrinkage. In metalworking shrinkage is a forging operation, entailing an increase in transverse dimensions as a result of a decrease in height (this operation is carried out with drop-hammers and presses).

N.V. Kadobnova

SIEVE FABRICS – are used for screening bulk materials (pigments, graphite, cement, dry glue, etc.). A finish consisting of gelatine, liquid petrolatum, olein and acetic acids, soap and Formalin is applied to sieve fabrics. The following sieve fabrics are made: silk (GOST 4403-56) from twisted raw silk using the openwork and mixed (openwork with card) weaves which form fixed free spaces (holes) between the warp and weft threads; capron (STU 35-253-63) with a card weave; from monofiber; threads which form the holes (cells) are fastened by polymethylmetracrylate amulsion finishing. 36 types of capron sieve fabrics are produced (7-21, 23-27, 29, 32, 35-38, 43, 46, 49, 52, 55, 58, 61, 64, 67, 70, 73 and 76). Sieve fabrics are differentiated by the weight (depending on the warp and weft thread thickness); light- and heavy-duty; by the number (depending on the number of holes per unit length); the light duty fabrics have Nos. 7-76, while the heavy duty fabrics have Nos. 71-380. The number of light duty sieve fabrics is determined by the number of holes per linear cm of the warp and weft, the number of heavy duty fabrics is determined by the number of holes per 10 linear cm of the warp and weft. The width of silk sieve fabrics of all numbers (with the exception of No. 380) with the hems is 97 ± 1.5, for No. 380 it is 112 ± 1.5 cm, the width of each hem is 0.7-1 cm; the width (cm) of capron sieve fabrics is 97 ± 3 (No. 7-18), 96 ± 2 (19-35) and 95 ± ± 2 (Nos. 38-76). The indicators of capron sieve fabrics: weight of 1 $m^2$ is 27-140 g, strength of a 50 × 200 mm of the warp and weft is 20-90 kg, elongation 20-30%.

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Indicators of Silk Sieve Fabrics

| Метрический номер (швейцарский) 1 | Число нитей на 10 см 2 | | Минимальный вес 1 м² (г) 3 | Минимальное разрывное усилие ткани шириной 50 мм (кг) 4 | | Удлинение при разрыве (%) 5 | | Минимальная стойкость на истирание (число оборотов прибора) 6 | Размер отверстий (мк) 7 |
|---|---|---|---|---|---|---|---|---|---|
| | основа | уток | | основа | уток | основа 8 | уток 9 | | |
| 7 (0000) | 150 | 70 | 45 | 26 | 25 | 19 | 17 | 150 | 1250 |
| 9 (000) | 180 | 90 | 45 | 26 | 25 | 19 | 17 | 150 | 900 |
| 11 (00) | 220 | 110 | 43 | 24 | 23 | 19 | 17 | 175 | 710 |
| 15 (0) | 300 | 150 | 46 | 25 | 24 | 19 | 17 | 175 | 500 |
| 19 (1) | 380 | 190 | 43 | 24 | 23 | 19 | 17 | 200 | 400 |
| 21 (2) | 420 | 210 | 47 | 26 | 25 | 19 | 17 | 200 | 360 |
| 23 (3) | 460 | 230 | 42 | 24 | 23 | 19 | 17 | 250 | 315 |
| 25 (4) | 500 | 250 | 46 | 25 | 24 | 19 | 17 | 250 | 280 |
| 27 (5) | 540 | 270 | 48 | 27 | 26 | 19 | 17 | 300 | 250 |
| 29 (6) | 580 | 290 | 43 | 24 | 23 | 18 | 17 | 300 | 220 |
| 32 (7) | 650 | 320 | 47 | 26 | 25 | 18 | 17 | 300 | 200 |
| 35 (8) | 175 | 350 | 48 | 25 | 25 | 18 | 17 | 300 | 180 |
| 38 (9) | 190 | 380 | 39 | 22 | 21 | 18 | 17 | 175 | 160 |
| 43 (10) | 215 | 430 | 39 | 21 | 20 | 17 | 15 | 175 | 140 |
| 48 (11) | 230 | 460 | 38 | 21 | 20 | 18 | 15 | 175 | 125 |
| 49 (12) | 245 | 490 | 40 | 21 | 20 | 17 | 15 | 175 | 125 |
| 52 (13) | 260 | 520 | 43 | 21 | 20 | 17 | 15 | 150 | 110 |
| 55 (14) | 275 | 550 | 32 | 19 | 17 | 17 | 14 | 125 | 110 |
| 58 (15) | 290 | 580 | 32 | 17 | 16 | 16 | 12 | 100 | 110 |
| 61 (16) | 305 | 610 | 33 | 17 | 16 | 16 | 12 | 100 | 100 |
| 64 (17) | 320 | 640 | 34 | 17 | 16 | 16 | 12 | 100 | 90 |
| 67 (18) | 335 | 670 | 31 | 16 | 15 | 16 | 12 | 100 | 90 |
| 70 (20) | 350 | 700 | 32 | 16 | 15 | 16 | 12 | 100 | 80 |
| 73 (21) | 365 | 730 | 33 | 16 | 15 | 16 | 12 | 100 | 80 |
| 76 (22) | 380 | 760 | 35 | 16 | 15 | 16 | 12 | 100 | 71 |
| 71 (18) | 142 | 71 | 54 | 32 | 32 | 20 | 20 | 450 | 1150 |
| 80 (22) | 160 | 80 | 50 | 32 | 31 | 20 | 200 | 450 | 1000 |
| 90 (25) | 180 | 90 | 55 | 34 | 33 | 20 | 20 | 450 | 900 |
| 100 (28) | 200 | 100 | 51 | 32 | 31 | 20 | 18 | 450 | 800 |
| 110 (30) | 220 | 110 | 50 | 34 | 31 | 20 | 18 | 500 | 710 |
| 120 (32) | 240 | 120 | 53 | 33 | 32 | 21 | 18 | 500 | 630 |
| 130 (34) | 260 | 130 | 50 | 32 | 31 | 21 | 18 | 500 | 560 |
| 140 (36) | 280 | 140 | 52 | 33 | 32 | 21 | 18 | 500 | 530 |
| 150 (40) | 300 | 150 | 54 | 34 | 33 | 21 | 18 | 500 | 500 |
| 160 (42) | 320 | 160 | 48 | 31 | 30 | 21 | 18 | 450 | 450 |
| 170 (46) | 340 | 170 | 50 | 32 | 31 | 21 | 18 | 450 | 400 |
| 180 (48) | 360 | 180 | 52 | 33 | 32 | 21 | 18 | 450 | 360 |
| 190 (50) | 380 | 190 | 47 | 31 | 30 | 21 | 18 | 450 | 360 |
| 200 (54) | 400 | 200 | 48 | 31 | 30 | 21 | 18 | 450 | 315 |
| 210 (56) | 420 | 200 | 49 | 31 | 30 | 22 | 18 | 450 | 280 |
| 230 (60) | 460 | 230 | 49 | 30 | 29 | 22 | 18 | 450 | 280 |
| 240 (64) | 480 | 240 | 50 | 31 | 30 | 22 | 18 | 450 | 250 |
| 250 (66) | 500 | 250 | 51 | 30 | 22 | 18 | 18 | 450 | 250 |
| 280 (70) | 520 | 260 | 53 | 32 | 31 | 22 | 18 | 450 | 250 |
| 280 (72) | 560 | 280 | 48 | 31 | 30 | 22 | 18 | 450 | 220 |
| 380 | 190 | 380 | 39 | 22 | 21 | 18 | 17 | 175 | — |

1) Metric number (Swiss); 2) thread count per 10 cm; 3) minimum weight of 1 $m^2$ (kg); 4) minimum rupture strength of a 50 mm wide fabric strip (kg); 5) elongation at break (%); 6) minimum abrasion resistance (revolutions of the device); 7) hole dimensions (microns); 8) warp; 9) weft.

I. Yu. Sheydeman

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[Transliterated Symbols]

3570 ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standard = All-Union State Standard

3570 СТУ = STU = Soyuznyye tekhnicheskiye usloviya = Soviet Union technical specifications

SIGMA-PHASES – metallic compounds with an equiatomic composition (50 atom-% of each component). These phases were first detected in iron-chromium systems, taking the form of FeCr; they were later found in other binary systems (Fe-V, Co-V, Co-Cr, Ni-V, etc.) and in a number of ternary systems. The sigma-phase crystal lattice is of a very complex tetragonal type with a large number of atoms in the elementary cell (a lattice of the β-uranium type). Such phases are characterized by very high hardness and brittleness, a high electrical resistance, and a low Curie point; they are nonferromagnetic at room temperature. Prolonged heating at temperatures above 550-600°, where sigma-phases are formed in steels of definite composition, greatly reduces the impact strength of the alloy. Sigma-phases also cause a decrease in the creep resistance of steel on prolonged loading; such phases are consequently particularly undesirable in high-hot-strength steels intended for long-term operation.

M.L. Bernshteyn

SILEX – see Silicon.

SILICATE TRIPLEX – laminated material consisting of cemented plates of silicate glass; it is used for glazing of automobile vehicles, aircraft, helicopters, ships, railroad rolling stock, testing stands, etc. Silicate triplex glass plates serve as transparent screens which protect the cementing layer from direct external effects, while the cementing layer binds together fragments should the glass become damaged, improving the protective properties and safety in using the silicate triplex. The strength of the cementing layer and of its bound with the glass plate surfaces changes depending on the temperature regime. The temperature range in which the cementing layer changes from the glass-like brittle state (at low temperatures) to the fluid state and degradation (at elevated temperatures), is substantially smaller than the range over which the strength characteristics of the glass remain unchanged. The thermal coefficient of expansion of materials which are used for the cementing layer is substantially higher than that for silicate glass. Silicate triplex is a heterogenic structure with internal stresses which vary depending on the temperature. Silicate triplex not intended for load-receiving purposes is made from two sheet glass plates of identical dimensions having an ultimate strength of up to 300 $kg/cm^2$. The plates are cemented by a polyvinylbutyral film (butafoil) with a thickness of 0.5-1 mm, the total thickness of silicate triplex is 5-6 mm. Plates of the same thickness, which are not subjected to hardening heat treatment, i.e., to quench hardening, can be used for making components of intricate configuration and large overall dimensions (curved shields of automotive vehicles). This silicate triplex is

intended for use at temperatures from -60° to +60°, the optimum range is from -15° to +40°. Silicate triplex intended for load-receiving purposes and subjected to various loads (aircraft cabin glazing, etc.) differs from silicate triplex not used for load-receiving purposes. One of its plates (most frequently that facing the insides of the glazed object) is made thicker and is designed for maximum loads. The maximum stresses which arise in both plates of the triplex should not exceed the allowable stresses. The second plate is usually made from glass 4-5 mm thick. Load-receiving silicate triplexes are made from hardened glass plates which have the following ultimate strength in tension and flexure: for 4-5 mm thick plates up to 700-800 $kg/cm^2$; for 6-20 mm thick plates up to 1000-1200 $kg/cm^2$, the cementing layer is not less than 2-3 mm. The use of transparent polymers with a high thermal stability (nonplasticized polyvinylbutyrol film, organosilicon compounds, etc.) extend the upper limit of the working temperatures. Silicate triplex operating at highly variable temperatures has a hardened heat-resistant glass with an expansion coefficient of $45 \cdot 10^{-7}$ and less.

A characterization of the properties of the basic materials of construction used in the manufacture of silicate triplex glass of the ordinary type is given in: GOST 7132-61. Polished sheet glass; GOST 9438-60. Cementing polyvinylbutyrol film; TU Len SNKh 33062-60. The framing material brands are B-79 and B-66-8.

The gluing together and framing of silicate triplex glass involves the following basic operations: assembly of the stack (stacking), cold and hot gluing under vacuum, liquid or gas pressing in autoclaves. Maximum evacuation of air from the triplex stack, relaxation of internal stresses in the cementing material and adhesion of materials along the surfaces being glued together are ensured in the gluing and framing process. The parameters of the operational regimes: temperature, pres-

sure, time are established by the production process depending on the type and materials of the product.

Norms for silicate triplex are set up on the basis of optical characteristics: refraction of the ray and translucence, which depends on the dimensions, shape and materials of the given glazing component. Bent triplex glass (preferably in the form of elements of surfaces of revolution) are more difficult to produce and have large optical aberrations. Hence use is made of various versions of triplex framing, which ensure a bound between the triplex and the frame and uniform distribution of loads along the edge. Plastic materials and metallic fittings (frames) are used for framing. The gaps are filled with compensating gaskets. It is recommended that calibrated tools (screw drivers, wrenches) be used for installation, that temperature gaps be provided and care be taken to produce no concentrated stresses. Scratches and other surface defects are stress raisers in glass plates and norms for them are set up by technical specifications for the glazing components. To prevent loss of transparency (fogging up and icing) use is made of electrical heating which, as a rule, is automatically adjusted if the specific power going for heating exceeds 0.1-0.15 $w/cm^2$. For heating uniformity the electrically heated field is made rectangular with the bus bars located on two parallel sides. Depending on the type of adjustment apparatus, semiconductor devices (thermistors) or wire resistances (platinum and nickel), put into direct heat contact with the glass surface being heated, are used as sensors for the glass heating temperature.

V.I. Aleksandrov

III-89t3

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[Transliterated Symbols]

3575 ГОСТ = GOST = Gosudarstvennyy obshchesoyuznyy standart = All-Union State Standard

3575 ТУ Лен СНХ = TU Len SNKh = Tekhnicheskiye usloviya Leningradskogo Sovnarkhoza = Technical Specifications of the Leningrad Sovnarkhoz

SILICIDES – compounds of silicon and metals formed at high temperatures. We can differentiate monosilicides, containing one silicon atom, and disilicides, containing silicon atoms. Both types are referred to as silicides in this article. Being metallic compounds of silicon and transition metals, silicides are similar to borides, carbides, and nitrides in a number of their physical and mechanical properties (Table 1), but are distinguished by low strength and hardness and substantially lower melting point; as a rule, the melting points of silicides are lower than those of the corresponding metals. The structure of these compounds, in contrast to that of fluorides, carbides, and nitrides, is produced by replacement of the metal atoms by silicon atoms. Many silicides are characterized by a laminar structure with rather sharply delimited layers of metal and silicon atoms, which facilitates slip and reduces creep resistance at elevated temperatures. The majority of silicides exhibit a high electrical conductivity of the metallic type, with the exception of those of chromium, iron, manganese, Rhenium, barium, lanthanum and certain other elements, which are semiconductors. These compounds have rather high thermoelectric characteristics and a relatively high thermal conductivity. Their mechanical properties have not been sufficiently well studied, except for those of molybdenum silicide, which is widely used in technology.

It has been established that the $\sigma_{-b}$ ($kg/mm^2$) of molybdenum disilicide ($MoSi_2$) bares the following relationship to temperature: 113 at 20°, 40.5 at 1000°, 35.0 at 1200°, 34.0 at 1400°, and 4.5 at 1.500°; at 980, 1040, and 1100° the $\sigma_b$ of $MoSi_2$ is 21.0, 9.4, and 5.9 $kg/mm^2$

TABLE 1

Characteristics of the Silicides of High-Melting Metals

| Свойства 1 | Силицид титана $TiSi_2$ 2 | Силицид циркония $ZrSi_2$ 3 | Силицид гафния $HfSi_2$ 4 | Силицид ванадия $VSi_2$ 5 | Силицид ниобия $NbSi_2$ 6 | Силицид тантала $TaSi_2$ 7 | Силицид хрома $CrSi_2$ 8 | Силицид молибдена $MoSi_2$ 9 | Силицид вольфрама $WSi_2$ 10 | Силицид рения $ReSi_2$ 11 | Силицид урана $USi_2$ 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 Молекулярный вес | 104,08 | 147,40 | 234,78 | 107,11 | 149,09 | 237,11 | 108,19 | 152,16 | 240,10 | 242,69 | 266,14 |
| 14 Содержание кремния: ат. % | 66,67 | 66,67 | 66,67 | 66,67 | 66,67 | 66,67 | 66,67 | 66,67 | 66,67 | 66,67 | 66,67 |
| 15 вес. % | 53,98 | 38,11 | 21,91 | 52,44 | 37,68 | 21,09 | 51,91 | 36,78 | 23,32 | 23,17 | 15,74 |
| 16 Уд. вес (г/см³) | 4,13 | 4,86 | 8,01 | 4,66 | 5,66 | 9,1 | 4,96 | 6,24 | 9,72 | 11,21 | 8,9 |
| 17 | | | | | | | | | | | 8,9 |
| 18 $t_{пл}$ (°C) | 1540 | 1700 | 1750 | 1660 | 2160 | 2200 | 1,500 | 2030 | 2165 | 1? | 1720 |
| 19 Теплота образования при 298°K (ккал/моль) | 42,9 | 38 | | 75 | 80 | 26,2 | 28,6 | 26 | 24,6 | 24,6 | |
| 20 с при 20° (кал/моль·°C) | 12,87 | | | | | | 12,65 | 13,2? | | | |
| λ (кал/см·сек·°C) | 0,111 | 0,0171 | | 0,183 | 0,197 | 0,0521 | 0,0251 | 0,05 | 0,115 | | |
| ρ (мком·см) | 16,9 | 75,8 | | 66,5 | 58,6 | 66,1 | 914 | 21,6 | 11,2 | 5,11 | |
| Термич. коэфф. электросопротивления ($10^3 \cdot град^{-1}$) | 1,3 | 1,3 | | | | 1,12 | | 6,24 | 4,98 | | |
| | (20–2000) | (20–120) | | | | (20–120) | | (20–120) | (20–120) | | |
| α·10⁶ (1/°C) при 20–1200° | 8,8 | 8,6 | | 11,2 | 11,7 | 8,8 | ~10,0 | 7,9 | 4,9 | | |
| Термоэлс (мкв/град) | +5,2 | +14,7 | | +10,5 | +14,4 | +15,0 | +15,0 | 5,6 | 4,5 | 15,1 | |
| 25 Работа выхода (эв) | | | | | 3,6 | 4,9 | 4,5? | 4,58 | | | |
| E (кг/мм²) | 26500 | 26800 | | | | | | 51000 | | | |
| 27 $\sigma_{изг}$ | 21,0 | | | | | | | 44,6 | | | |
| $\sigma_{-1}$ | 11,8 | | | | | | | 11,2 | 4,2 | | |
| $R_1^{20}$ | 81 | | | | | | | 75 | | | |
| H | 880 | 1060 | 930 | 960 | 1050 | 1400 | 1110 | 1200 | 1400 | 1,1 | |

1) Characteristic; 2) titanium silicide; 3) zirconium silicide; 4) hafnium silicide; 5) vanadium silicide; 6) niobium silicide; 7) tantalum silicide; 8) chromium silicide; 9) molybdenum silicide; 10) tungsten silicide; 11) rhenium silicide; 12) uranium silicide; 13) molecular weight; 14) silicon content; 15) atom-%; 16) % by weight; 17) specific gravity ($g/cm^3$); 18) $t_{pl}$ (°C); 19) heat of formation at 298°K (kcal/mole); 20) c at 20° (cal/mole·°C); 21) λ(cal/cm·sec·°C); 22) ρ (μohm·cm); 23) thermal coefficient of electrical resitance ($10^3 \cdot ^1/_{град}$); 24) $\alpha \cdot 10^6$ (1/°C) at 20–1200°; 25) thermal emf (μv/degree); 26) work function (ev); 27) E($kg/mm^2$).

respectively. $MoSi_2$ has an inadequate creep resistance, pronounced creep being observed at temperatures above 1000°; $\alpha_n$ is less than 1.1 $kg\text{-}m/cm^2$. A sharp increase in plasticity and a decrease in strength are noted at 1450–1500°.

Silicides exhibit high resistance to acids, mixtures of acids, and alkalies (Tables 2 and 3). Certain silicides are highly resistant to molten metal; thus, $MoSi_2$ does not react with molten lead, tin, or sodium at temperatures of up to 1000°. Zinc heated to 800° may dissolve 1% Si, which precipitates on cooling; molten Ag and Hg have virtually no effect on $MoSi_2$. Molten aluminum reacts intensively with $MoSi_2$, forming molybdenum aluminide. Molten iron, copper, chromium, and platinum react with $MoSi_2$ to form binary and ternary silicide phases.

TABLE 2

Solubility of Silicides in Certain Acids*

| Кислота 1 | γ(г/см³) или концентрация 2 | Время обработки (час) 3 | $TiSi_2$ | $ZrSi_2$ | $VSi_2$ | $NbSi_2$ | $CrSi_2$ | $MoSi_2$ | $WSi_2$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | 4 нерастворимый остаток (%) | | | | | | |
| HCl | 1,19 | 1 | 5 Нр | Нр | Нр | Нр | — | — | — |
| | | 2 | 99,7 | — | — | — | 44,5 | 59,4 | 99,2 |
| | 1:1 | 1 | Нр | Нр | Нр | Нр | — | 99,6 | Нр |
| $H_2SO_4$ | 1,84 | 2 | 99,6 | — | — | — | — | — | — |
| | | 3 | — | Нр | Нр | Нр | — | 99,2 | — |
| | | 4 | — | — | — | — | — | — | Нр |
| | 1:1 | 2 | 99,6 | — | — | — | — | 99,8 | — |
| | | 3 | — | Нр | Нр | Нр | — | — | — |
| | | 4 | — | — | — | — | — | — | Нр |
| | 1:10 | 2 | 99,8 | — | — | — | — | — | — |
| | | 3 | — | Нр | Нр | Нр | — | — | — |
| | | 4 | — | — | — | — | — | — | Нр |
| $H_3PO_4$ | 1,21 | 2 | 99,7 | 99,9 | 99,5 | — | — | 96,7 | — |
| HF | 1,15 | 1 | — | — | — | Брс | — | Рч | — |
| | | 2,5 | Брс | Нр | Брс 6 | — | — | 7 — | 8 Рч |
| | | 3 | — | — | — | — | — | — | — |
| $KHSO_4$ | — | 1 | Нр | — | — | — | — | Нр | Рч |
| | | 2 | — | Нр | — | — | — | — | — |

*Nr – does not dissolve, Rp – dissolves completely, Rch – dissolves partially, Brs – majority of compound dissolves, forming a salt which precipitates.

1) Acid; 2) $\gamma(g/cm^3)$ or concentration; 3) exposure time (hr); 4) undissolved residue (%); 5) Nr; 6) Brs; 7) Rch; 8) Rp.

TABLE 3

Solubility of Silicides in Alkaline Media

| Щелочи 1 | $TiSi_2$ | $ZrSi_2$ | $VSi_2$ | $NbSi_2$ | $TaSi_2$ | $CrSi_2$ | $MoSi_2$ | $WSi_2$ |
|---|---|---|---|---|---|---|---|---|
| NaOH (1%-ный раствор) 2 | 4 Не растворяется | | | | | | | |
| NaOH концентрированная 3 | 5 Растворяется в течение 30 мин. | | | | | | | |
| $Na_2CO_3$ + S | Не растворяется в течение 1 часа 6 | | | | | | Не растворяется в течение 1 часа | |
| $Na_2O_2$ | 7 Растворяется в течение 15 мин. | | | | | | | |

1) Alkali; 2) 1% solution; 3) concentrated; 4) does not dissolve; 5) dissolves within 30 min; 6) does not dissolve within 1 hr; 7) dissolves within 15 min.

TABLE 4

Production Regimes for Certain Silicides

| 1 Силицид | Непосредств. соединение порошков металлов с кремнием 2 | | Кремнетермич. восстановление 5 | |
|---|---|---|---|---|
| | темп-ра (°С) 3 | выдержка (мин.) 4 | темп-ра (°С) | выдержка (мин.) |
| $TiSi_2$ | 1000 | 120 | 1350 | 60 |
| $ZrSi_2$ | 1100 | 120 | — | — |
| $VSi_2$ | 1200 | 30 | 1550 | 30 |
| $NbSi_2$ | 1000 | 30 | 1400 | 30 |
| $TaSi_2$ | 1100 | 60 | 1600 | 60 |
| $CrSi_2$ | 1000 | 30 | — | — |
| $MoSi_2$ | 1000 | 30 | — | — |
| $WSi_2$ | 1000 | 30 | — | — |

1) Silicide; 2) direct combination of powdered metals with silicon; 3) temperature (°C); 4) holding time (min); 5) silicothermo reduction.

Silicides are produced by direct synthesis from the elements involved or by reduction of metal oxides with silicon in accordance with the reaction MeO + Si → MeSi + SiO. The former method is simpler and is more frequently employed industrially. Table 4 shows the production regimes for certain silicides.

Articles are fabricated from silicides by separate pressing and subsequent sintering or by hot pressing, which combines the aforementioned process. Blanks pressed from powers are dried to a final moisture content of 4-6% at room temperature or in vacuum dryers before sintering. Silicide products are also manufactured by hot pressing at 1400-1750° under a pressure of 200-250 kg/cm$^2$. They can be finished by the ultrasonic, anodomechanical, or electric-discharge method or with abrasives.

Silicides are employed in many branches of technology. $V_3Si$ is used as a superconductor and $ReSi_2$ as a semiconductor in technical physics and automation. Many silicides are used as high-hot-strength materials, particularly $NoSi_2$, which is employed for the casings of high-temperature thermocouple electrodes (for measurements in air at

temperatures of up to 1700°) and for the heating elements of high-temperature resistance furnaces intended for operation in oxidizing media at temperatures of up to 1650-1700°. $MoSi_2$ and $ReSi_2$ are also used for protective coatings on metals, preventing oxidation at temperatures of up to 1600-1700°.

References: Samonsov, G.B., Silitsidy i ikh ispol'zovaniye v tekhnike [Silicides and Their Technical Utilization], Kiev, 1959; Samsonov, G.V., Portnoy, K.I., Splavy na osnove tugoplavkikh soyedineniy [Alloys Based on High-Melting Compounds], Moscow, 1961; Kotel'nikov, R.B., in collection: Tekhnologiya tsvetnykh metallov [Technology of Nonferrous Metals], Moscow, 1958, page 339; Samsonov, G.V., Koval'chenko, M.S., Verkhoglyadova, T.S., Zhurnal neorganicheskoy khimi [Journal of Inorganic Chemistry], 1959, Vol. 4, No. 12, page 2759.

K.I. Portnoy

SILICON BRASS is a brass in which the primary alloying component is silicon. Silicon brass has higher corrosion resistance in atmospheric conditions and in sea water than the simple brasses. Silicon brass works well by pressure in hot and cold conditions. Additions of silicon improve the mechanical and casting properties of the brasses, reduce the electrical conductance.

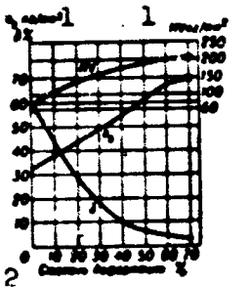


Fig. 1. Variation of mechanical properties of the LK80-3 brass as a function of the degree of deformation. 1) kg/mm$^2$; 2) degree of deformation (%).

Silicon significantly narrows the region of the α-phase. The silicon brasses, just as the other brasses, retain high plasticity to very low temperatures. Industry produces in accordance with GOST 1019-47 the grade LK80-3 wrought silicon brass and the grades LK80-3L and LKS80-3-3 cast silicon brasses. The Table presents the chemical composition and the mechanical properties of the standard silicon brasses. The physical properties of the LK80-3 brass are: $\gamma$ = 8.6 g/cm$^3$; $\alpha = 17.0 \cdot 10^{-6}$ (20°) 1/°C; c = 0.1 (20°) cal/cm-sec-°C; $\rho$ = 0.2 (20°) ohm-mm$^2$/m; E = 9800 kg/mm$^2$. The melting

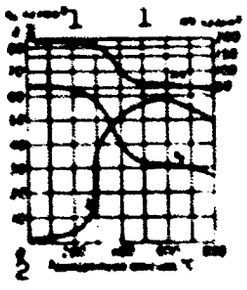


Fig. 2. Variation of mechanical properties of the LK80-3 brass with annealing temperature. 1) kg/mm$^2$; 2) annealing temp. °C.

is 900°; hot working is performed in the 750-850° range; the anneal temperature is 500-600°. The LK80-3 brass is used for forgings and stampings. The LK80-3L is used for fabrication of cast frames, gears and details for sea-going vessels, and the LKS80-3-3 is used for cast bearings and bushings.

References: Mal'tsev M.V., Barsukova T.A., Borin F.A., Metallografiya tsvetnykh metallov i splavov [Metallography of Nonferrous Metals and Alloys], M., 1960; Smiryagin A.P., Promyshlennyye tsvetnyye metally i splavy [Industrial Nonferrous Metals and Alloys], 2nd ed., M., 1956.

Ye.S. Shpichinetskiy

Chemical Composition and Mechanical Properties of Silicon Brasses

| Марка латуни по ГОСТ 1019—47 1 | 2 Содержание элементов (%) | | | | 3 Механич. свойства | | | Состояние материала 5 |
|---|---|---|---|---|---|---|---|---|
| | Cu | Si | Pb | Zn | 4 $\sigma_b$ (кг/мм²) | δ (%) | НВ (кг/мм²) | |
| ЛК80-3 12 | 79—81 | 2.5—4.0 | — | Остальное 6 | 30—40<br>60—70 | 45—60<br>5—10 | 90—100<br>160—180 | Мягкий 8<br>Твердый (наклеп 50%) 9 |
| ЛК80-3Л 13 | 79—81 | 2.5—4.5 | — | То же | 30—50 | 15—40 | 90—110 | Литой 10 |
| ЛКС80-3-3 14 | 79—81 | 2.5—4.5 | 2—4 | 7 » | 30—50 | 10—20 | 90—110 | То же 11 |

1) GOST 1019-47 brass type; 2) contents of elements (%); 3) mechanical properties; 4) kg/mm$^2$; 5) state of material; 6) LK80-3; 7) rest; 8) soft; 9) hard (50% workhardened); 10) LK80-3L; 11) same; 12) cast; 13) LKS80-3-3.

SILICON BRONZE is a bronze in which the primary alloying component is silicon, present in the alloy in the amount of 3.4%, sometimes to 5%. The maximal solubility of silicon in copper is 6.7% at a temperature of 726°; with reduction of the temperature the solubility falls and at 350° amounts to 3.9%. The mechanical properties of copper containing up to 3% Si are improved, the strength and plasticity are increased, but with increase further of the silicon content the elongation falls (Table).

Mechanical Properties of Cast Silicon Bronzes

| Содержание Si (%) a | b $\sigma_b$ (кг/мм²) | $\delta$ (%) | HB (кг/мм²) b |
|---|---|---|---|
| 1 | 20 | 43 | 54 |
| 2 | 26 | 56 | 63 |
| 3 | 30 | 66 | 73 |
| 4 | 37 | 53 | 88 |
| 5 | 41 | 25 | 112 |
| 6 | 39 | 4 | 162 |

a) Si content (%); b) ($kg/mm^2$).

Widest use is made of the type BrKMts3-1 silicon bronze which contains 1-1.5% Mn and 2.75-3.5% Si. In certain cases use is made of the silicon nickel bronze BrKN1-3 (2.4-3.4% Ni; 0.6-1.1% Si; 0.1-0.4% Mn), which is a dispersion hardening alloy. It is used in the production of forgings and rods. Hardening of the BrKN1-3 bronze is accomplished from 850-875°, tempering at 450-475°, pressure working in the 800-960° interval. The BrKMts3-1 bronze, produced in the form of strip, bar, rod and wire, has a structure consisting of a uniform solid solution and is easily pressure worked. In the work hardened condition it is used for

springs and elastic details, and also for the replacement for the tin-phosphor and tin-zinc bronzes for details of various purposes. The BrKN1-3 bronze is used for the fabrication of wear-resistant details operating at elevated temperatures (see Wrought Bronze).

References: Smiryagin A.P., Promyshlennyye tsvetnyye metally i splavy [Industrial Nonferrous Metals and Alloys], 2nd ed., M., 1956; Shpagin A.I., Antifriktsionnyye splavy [Antifriction Alloys], M., 1956; Turkin V.D., Rumyantsev M.V., Struktura i svoystva tsvetnykh metallov i splavov [Structure and Properties of Nonferrous Metals and Alloys], M., 1947.

O.Ye. Kestner

SILICONE PLASTICS are hard infusible plastics obtained by mixing thermoreactive silicone resins with fibrous (asbestos, glass fiber) and powder-like (ground quartz, talc) inorganic fillers and other additives. Silicone plastic products are fabricated by hot pressing and pressure casting.

KMK-218 is a fibrous plastic based on methyl poly siloxane resin, asbestos and ground quartz. It is used for the fabrication of arc-resistant electrotechnical products - arc-damping chambers for contractors of large electric locomotives, labyrinth spark-damping chambers, etc. It is intended for extinguishing arcs with potential to 3300 v, current of 4000 a and a temperature of 300-350°. KMK-218-1 is a fibrous plastic based on methyl poly siloxane resin, asbestos and ground quartz. It is used for the fabrication of electrotechnical products operating for long periods at elevated (300-350°) temperatures. K-71 is a fibrous plastic based on methyl poly siloxane resin, asbestos, ground quartz and catalytic additives. It is used for the fabrication of electrotechnical products operating at a temperature of 300-350° under conditions of tropical humidity. K-41-5 is a fibrous plastic based on methyl phenyl poly siloxane resin, asbestos, ground quartz and catalytic additives. It is intended for the fabrication of electrotechnical products for operation at temperatures of 300-350° and has high mechanical properties. KPZh-9 is a molding composition based on methyl polysiloxane resin, long-fiber asbestos, ground quartz and modifying additives. It is used for fabrication of electrotechnical products operating at temperatures of 350-400°. It permits short-term heating to 500°. MFK-20 is a molding

composition based on melamine and methyl polysiloxane resin KM-9 and a mineral filler. It is used for the fabrication of thermal- and arc-resistant products for electrotechnical purposes operating under conditions of tropical humidity at a temperature of 200-250°. KMS-9 is a molding composition based on methyl poly-siloxane resin, glass fiber filler and ground quartz. It is used for the fabrication of products for electrotechnical use at a temperature of 300-350°. It has high dielectric properties. KF-9 is a molding composition based on methyl polysiloxane resin, modified by polytetrafluorethylene. It is used for the fabrication of products for high frequency and radioelectronic equipment operating at 250-300°. It permits the fabrication of thin-walled products of complex configuration. Molding compound 176 is a composition based on methyl polysiloxane resin and organic and mineral fillers. It is used for the fabrication of products for radiotechnical use operating at elevated temperatures.

The basic conditions for processing and the physical properties of the silicone plastics are given in the table.

Properties of Silicone Plastics

| Характеристики 1 | Единица измерения 2 | Пластмассы 3 — лаковый 4 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | КМК-218 | КМК-218 лаковый | К-71 | К-41-5 | КОК 9 | МФК 20 | КМС 9 | КФ 9 | № 178 |
| 5 Формуемость: прессуемость 6 | — | Удовлетворит. 50 | Хорошая | Удовлетворит. | Хорошая | Хорошая | Хорошая | Удовлетворит. | Хорошая | Хорошая |
| текучесть по Рашигу 7 | мм | >90 49 | >90 | >90 | 140 | >100 | >80 | >90 | >120 | >90 |
| 8 Прессование: темп-ра 9 | °C 40 | 150±5 | 150±5 | 165±5 | 110—180 | 150—150 | 150—170 | 150±5 | 140—150 | 150±5 |
| 10 давление 11 | кг/см² | 300 | 200—300 | 450 | 400 | 300—500 | 300—500 | 300—500 | 200—300 | 200—300 |
| выдержка | мин/мм 41 | 1,5 | 1,5 | 1,5 | 1,5 | 1,5 | 1,0 | 1,5 | 1,5—2,0 | 1,5—2,0 |
| 12 термообработка 160° 13 | час | 5,0 | 5,0 | 20(200) | 20(200) | 5,0 | 6,0 | 5,0 | 5,0 | 5,0 |
| Степень сжатия | 42 % | 3—5 | 3—5 | 3—5 | 3—5 | 3—5 | — | 5—8 | 2—3 | 2—3 |
| 14 Усадка после формования | | 0,5—1,0 | 0,5—1,0 | 0,5—1,0 | 0,5—1,0 | 0,5—1,0 | 0,5—1,0 | 0,2—0,5 | 0,2—0,5 | 0,2—0,5 |
| Уд. вес 16 | | 1,8—2,0 | 1,8—2,0 | 1,8—2,0 | 1,9—2,0 | 1,8—2,0 | 1,8—2,0 | 1,6—1,9 | 1,6—1,7 | 1,8—2,0 |
| Предел прочности: | | | | | | | | | | |
| 17 при растяжении | кг/см² | — | — | 150—180 | 150—180 | 150—180 | — | 150—180 | — | — |
| при сжатии 18 19 | кг/см² | 1100—1400 | 1100—1400 | — | — | 1100—1400 | — | 1100—1500 | 200—300 | — |
| при изгибе | кг/см² | 300—500 | 350—500 | 250—300 | 500—900 | 400—700 | 400—500 | 400—900 | 250—350 | 150 |
| 20 Ударная вязкость 21 | кг·см/см 43 | 4,5—7 | 8—10 | 4,5—6 | 18—25 | 15—30 | — | 17—60 | 15—20 | 2,5 |
| Твердость (по Бринелю) | кг/мм² | 25—28 | 20 | 20 | 20 | 25—30 | — | 25—30 | 8—10 | — |
| Теплостойкость (по Мартенсу) 22 23 | 44 °C | 270 | 270 | 200 | 300 | >250 | 190 | >250 | 250 | 250 |
| Водопоглощаемость | % | 0,35 | 0,3 | — | 0,25 | 0,25 | — | 0,3 | 0,06 | — |
| 24 Уд. объемное сопротивление | ом·см 45 | $10^{14}$—$10^{15}$ | $10^{14}$—$10^{15}$ | $10^{14}$—$10^{15}$ | $10^{14}$—$10^{15}$ | $10^{14}$—$10^{15}$ | $10^{14}$ | $10^{13}$—$10^{14}$ | $10^{13}$—$10^{14}$ | — |
| Уд. поверхностное сопротивление 25 | ом 46 | $10^{13}$—$10^{14}$ | $10^{13}$—$10^{14}$ | $10^{13}$—$10^{14}$ | $10^{13}$—$10^{14}$ | $10^{13}$—$10^{14}$ | $10^{13}$ | $10^{12}$—$10^{13}$ | $10^{13}$—$10^{14}$ | — |
| 26 Тангенс угла диэлектрич. потерь при частоте $10^6$ гц | — 47 | 0,2—0,3 | 0,2—0,3 | — | — | 0,2—0,3 | — | 0,01—0,005 | 0,002—0,004 | 0,07 |
| 27 Пробивное напряжение | кв/мм | 5—6 | 5—7 | 2—5 | 2—5 | 5—7 | 4,5—5,0 | 4—8 | 15—16 | — |
| 28 Диэлектрич. проницаемость при частоте $10^6$ гц | — | 5—7 | 5—7 | 5—7 | 5—7 | 5—7 | — | 4—6 | 2,5—3 | 5,5 |
| Дугостойкость: 29 | | | | | | | | | | |
| при 10 мм | сек 48 | >180 | >180 | >180 | >180 | — | >120 | >180 | — | — |
| 30 при 30 мм | " | >180 | >180 | >180 | >180 | — | — | >180 | — | — |
| при 60 мм | " | >180 | — | — | — | — | — | — | — | — |
| 31 Рабочая темп-ра при длительности 1000 час | C | 350 | 350 | — | — | 350—400 | 200 | 350 | 250 | — |
| Горючесть 32 | — | Не горит 51 | | | — | | Горит | — | | — |
| 33 Действие: солнечного света 34 | — | Устойчивы | | | | | | | | |
| слабых кислот | — | Устойчивы | | | | | | | | |
| 35 сильных кислот 36 | — | Мало изменяются 58 | | | | Устойчивы | — | Мало изменяются | Устойчивы | |
| сильных щелочей 37 | — | Изменяются значительно 59 | | | | — | — | — | — | — |
| 38 органич. растворителей | — | Устойчивы 57 | Устойчивы, кроме ацетона и его производных, сложных эфиров | Устойчивы 57 | | — | — | Устойчивы, кроме ацетона и его производных, полных эфиров | | — |
| Обрабатываемость 39 | — | Удовлетворительная 49 | | | | Хорошая | | Плохая 54 | Хорошая | |

1) Characteristics; 2) measurement unit; 3) lacquer; 4) plastics; 5) formability; 6) extrudability; 7) Raschig yield; 8) extruding; 9) temperature; 10) pressure; 11) duration; 12) heat treat at 160°; 13) percent compression; 14) shrinkage after forming; 15) specific weight; 16) ultimate strength; 17) tension; 18) compression; 19) bending; 20) impact strength; 21) Brinnel hardness; 22) heat resistance (Martens); 23) water absorption; 24) specific volumetric resistance; 25) specific surface resistance; 26) tangent of dielectric loss angle at a frequency of $10^6$ Hz; 27) breakdown voltage; 28) dielectric constant at $10^6$ Hz; 29) arc resistance; 30) at; 31) operating temperature for 100 hours exposure; 32) flammability; 33) resistance to; 34) sunlight; 35) weak acids; 36) strong acids; 37) strong alkalis; 38) organic solvents; 39) machining quality; 40) kg/cm$^2$; 41) min/mm; 42) hours; 43) kg-cm/cm$^2$; 44) kg/mm$^2$; 45) ohm-cm; 46) ohms; 47) kg/mm; 48) seconds; 49) satisfactory; 50) good; 51) does not burn; 52) combustible; 53) resistant; 54) changes little; 55) changes considerably; 56) resistant, except to acetone and its derivatives, complex esters; 57) poor.

SILICONIZED GRAPHITE – a composition material consisting of graphite, silicon carbide, and a small amount of silicon. This material is obtained by treating electrode graphite with silicon vapor at high temperatures (1700-2000°). Its chemical composition is 40-60% graphite, 40-50% silicon carbide, and 0.5-0.3% silicon. The characteristics of siliconized graphite vary within wide limits, depending on the type of initial graphite, its density, and the siliconizing regime.

Characteristics of Siliconized Graphite

| Свойства 1 | Единица измерения 2 | Показатели 3 |
|---|---|---|
| Плотность . . 4 . | 10 г/см³ | 2,2—2,3 |
| $\sigma_{изг}$ . . . . . | кг/мм² | 7,0—8,0 |
| $\sigma_{-b}$ . . . . . | » | 17,0—20,0 |
| 5 Предел усталостной прочности на базе $10^7$ циклов . . . . . | » | 3,0—4,0<br>6—8 |
| 6 Длительная прочность за 100 час. при 1200° (по сопротивлению изгибу) . . . . | » | 6,0—7,0 |
| 7 $a_н$ при 20° . . . | 12 кгм/см² | 0,20—0,25 |
| 8 $\alpha \cdot 10^6$ в интервале 20—800° . . . . | 13 1/°C | 4,0—5,0 |
| 9 $\lambda$ в интервале 20—1000° . . . . . | кал/см·сек·°C | 0,024 |

1) Characteristic; 2) unit of measurement; 3) value; 4) density; 5) ultimate fatigue strength based on $10^7$ cycles; 6) long-term strength over 100 hr at 1200° (bending resistance); 7) $\alpha_n$ at 20°; 8) $\alpha \cdot 10^6$ over the range 20-80°; 9) $\lambda$ over the range 20-1000°; 10) g/cm$^3$; 11) kg/mm$^2$; 12) kg-m/cm$^2$; 13) cal/cm·sec.°C.

Siliconized graphite is used principally for manufacturing various aircraft components which must function at high temperatures and under errosive conditions.

D.K. Ablov

SILICONORGANIC ADHESIVE -- is a compound based on diverse monomer and polymer siliconorganic compounds. It is characterized by a high heat resistance. It is used for the bonding of heat resistant nonmetallic materials and of metals. Joints bonded with VK-2 and VK-6 adhesive remain stable at temperatures higher than 425°. The heat resistant and frostproof cement-adhesive Ts-7-165-32 is used for the fixing of wire-type strain gauges and makes it possible to measure the elastic dynamic deformations of rotating and resting pieces at temperatures of 800° and above. The adhesives VKT-2 and VKT-3 are mixtures of a modified siliconorganic resin with the copolymer of butyl methacrylate and acrylic acid in organic solvents with addition of tri-ethanolamine; they are used for the bonding of glass-fiber insulators on metals. VKT-3 differ from VKT-2 by the content of a filler which provides a rapid curing of the adhesive; the working life of the adhesive is only 45-60 minutes in this case. The adhesive cures at room temperature without pressure. The maximum strength of the joint is obtained after 3 days drying in air. The VKT-2 and VKT-3 adhesives are efficient up to 400°; their joints are shakeproof; action of water, oil and kerosene does not reduce the strength.

The heat resistant adhesives KT-15, KT-9, and KP-9 are used for the bonding of polysiloxane rubbers on metals. The KT-15 adhesive joins vulcanized siliconorganic rubbers with metals. The adhesive joints are resistant to water, gasoline and fuel. The KT-9 adhesive is a 25% solution of a rubber compound and siliconorganic resin in benzene. Two layers of adhesive are applied during the bonding process. The first layer

is dried at 100° for 30 minutes, the second at room temperature for 60 min. The vulcanization is carried out by placing the bonded part in the cold press, increasing the pressure and gradually raising the temperature to 150°. The cooling is carried out without at first reducing the pressure. A heat treatment of the rubber-metal products at 200° for 240 hours does not affect the properties of the adhesive joints. The KP-9 adhesive is used for the bonding of vulcanized polysiloxane rubbers on metals. It is applied on the metal in one layer only, the drying is carried out at 120° for 1 hours, with subsequent cooling for 15-20 min. The bonding pressure is 2 $kg/cm^2$; the temperature is 200°, and the holding time under pressure is 2 hours. The adhesive joints provide sufficient strength up to 200°.

D.A. Kardashev

SILICOORGANIC PLASTIC FOAM – a light material produced from silicoorganic resins (polysiloxanes) and having a cellular structure. It is manufactured by heating a mixture consisting of a resin, a gas-forming agent (porophore), a catalyst, and a filler; at 100-160° the resin melts and the gas thus liberated causes the viscous mass to foam. In order to obtain complete setting the foam is heated at 200-250° for 6-48 hr. The linear shrinkage after these operations is 2-3%. Foams can also be produced from hydrogen-containing silicoorganic compounds. Hydrogen is liberated when ≡ SiH groups react with amino- or hydroxyl-containing substances, causing the polymer system formed to foam.

Silicoorganic foams are thermostable and resist oxidation by atmospheric oxygen at 200-250°; when certain fillers are present they can briefly withstand oxidation at 300-450°. Vigorous thermal oxidation of silicoorganic foams accompanied by splitting-off of organic radicals occurs at temperatures above 350°, while at 750-800° the organic products liberated ignite. Addition of epoxy, phenol-formaldehyde, and polyurethane resins to silicoorganic resins improves the strength indices of foams produced from them, but reduces their resistance to thermal oxidation and increases their dielectric losses and thermal conductivity. Solidified foams of this type do not corrode metals; they swell in nonpolar and weakly polar organic solvents.

Silicoorganic foams are not suitable for direct production of foam in structures, since their high shrinkage, low elasticity, and high coefficient of linear expansion create severe stresses in the foam filler during cooling and it may crack or separate from the surrounding sur-

faces. Such foams can be produced directly only in products intended for a single use. The foam sets while the structure is in operation and the polymerization shrinkage is compensated for by thermal expansion.

Elastic foams, which are suitable for direct production in structures, can be obtained from silicoorganic resins containing areas with a linear structure. However, the strength of such materials is low and prolonged operation in air at 250-300° leads to structuring of the polymer, shrinkage, development of internal stresses, and cracking. The table shows the characteristics of silicoorganic foams.

Characteristics of Silicoorganic Plastic Foams

| 1 Показатели | К-60 | 2 ПК-33 | 3 ПК-5Т |
|---|---|---|---|
| 4 (Объемный вес (г/см³) | 0.25 | 0.33 | 0.15 |
| 5 Предел прочности при сжатии при 25° (кг/см²): | | | |
| 7 после прогрева 5 час. при 400° 6 | 2.0 | 3.5 | 1.5 |
| 8 Влагопоглощение при 95% относительной влажности воздуха 168 час. (%) 9 | — | 0.1—0.3 | 0.1—0.3 |
| Линейная усадка (%): | | | |
| после прогрева 48 час при 250° 10 | 1.50 | 0.8 | 1.20 |
| после прогрева 5 час. при 400° | — | 1.2 | 1.50 |
| Теплопроводность (ккал/м·час·град) 11 | 0.04 | — | — |
| 12 Диэлектрич. проницаемость при $10^{10}$ гц | 1.25 | 1.6 | 1.4 |
| 13 Тангенс угла диэлектрич. потерь при $10^{10}$ гц | 0.0025 | 0.007 | 0.0011 |
| 14 Ударная вязкость (кг·см/см²) | 0.12 | — | — |
| 15 Коэффициент линейного расширения (20—100°) | $12 \cdot 10^{-6}$ | — | — |
| 16 Огнестойкость | 17 Не горючи | | |

1) Characteristic; 2) PK-33; 3) PK-5T; 4) bulk weight ($g/cm^3$); 5) ultimate compressive strength at 25° ($kg/cm^2$); 6) after heating at 250° for 200 hr; 7) after heating at 400° for 5 hr; 8) water absorption after 168 hr at 95% relative humidity (%); 9) linear shrinkage (%); 10) after heating at 250° for 48 hr; 11) thermal conductivity (kcal/m·hr·degree); 12) dielectric permeability at $10^{10}$ cps; 13) tangent of dielectric-loss angle at $10^{10}$ cps; 14) impact strength ($kg \cdot cm/cm^2$); 15) coefficient of linear expansion (20-100°); 16) combustion resistance; 17) incombustible.

Silicoorganic foams can be glued to various materials; they are fastened to metals with glues that set without heating. Before gluing an underlayer of VS-10T, VK-32-200, or some other glue is applied to the metal. Silicoorganic foams are used as heat-resistant fillers and heat-insulating materials for operation at temperatures of 200-450°.

References: Penoplastmassy [Plastic Foam], collection of articles, edited by A.A. Moiseyev et al., Moscow, 1960; Khimiya i prakticheskoye primeneniye kremneorganicheskikh soyedineniy [Chemistry and Applications of Silicoorganic Compounds], in book: Vtoraya Vsesoyuznaya konferentsiya po khimii i prakticheskomu primeneniyu kremneorganicheskikh soyedineniy [Second All-Union Conference on the Chemistry and Practical Applications of Silicoorganic Compounds], No. 4, Leningrad, 1958.

M.Ya. Borodin

SILLIMANITE – a mineral of the silicate class ($Al_2SiO_5$). It is identical to kyanite and andalusite in chemical composition and application. Sillimanite is encountered primarily in acicular crystals. It is synthesized from aluminous materials at 180-450° in the presence of boron salts or sulphuric acid. This metal may be gray, light brown, light green, or blue in color. It is virtually unaffected by acids. Sillimanite has a specific gravity of 3.23-3.25, a Moos hardness of 7, a compression resistance of 450-600 $kg/cm^2$, and a slip resistance of $2.1 \cdot 10^3$ $kg/cm^2$ at an omnidirectional pressure of 10,000 $kg/cm^2$ and $11.8 \cdot 10^3$ $kg/cm^2$ at a pressure of 50,000 $kg/cm^2$. Its specific heat capacity is 0.743 at 0° and 1.22 at 1200°; it decomposes at 1545-1700°. Mullitization increases the volume of sillimanite by 4%. Deformation of sillimanite material begins at a load of 2 $kg/cm^2$ at 1650-1700°; the $t_{pl}$ of this mineral is 1790°. Sillimanite products have a compressive strength of 600-800 $kg/cm^2$, a Richter wear resistance of 0.2 mm at 1000 m and 0.6 mm at 3000 m, a heat resistance of 50-73 heating-cooling cycles (over a range of 850 + 5°), and a coefficient of thermal expansion of 0.37-0.42. Such products have a high resistance to thermal shock and to acids and alkalies, as well as high dielectric characteristics.

Minerals of the sillimanite group occur naturally in rocks in conjunction with quarts and other silicates, from which they are separated by floatation and other concentration methods; sillimanite is more difficult to float than kyanite.

Sillimanite is used in the manufacture of silumin and heat-resist-

ant, chemically stable refractory materials with a high alumina content, in metallurgy, in the production of glass, and in the cement and ceramics industries (for pyrometric tubes, spark plugs, laboratory vessels, and other ceramic products which must have high mechanical strength and dielectric characteristics).

References: Betekhtin, A.G., Kurs mineralogii [Course in Mineralogy], 3rd Edition, Moscow, 1961; Belyankin, D.S., Ivanov, B.V., and Lapin, V.V., Petrografiya tekhnicheskogo Kamnya [Petrography of Technical Rocks], Moscow, 1952; Budnikov, P.P. et al., Tekhnologiya keramiki i ogneuporov [Technology of Ceramics and Refractory Materials], 3rd Edition, Moscow, 1963; Milovidov, S.M., Tekhnologiya kianitovogo syr'ya i yego promyshlennoye ispol'zovaniye [Technology and Commercial Utilization of Kyanite Raw Materials], in collection: Bol'shiye Keyvy. Problems kol'skikh kianitov [The Bol'shiye Keyvy Mountains. Problem of Kol'skiy Kyanites], Leningrad-Moscow, 1940; Minerals Yearbook, 1958, Vol. 1, Wash., 1959.

P.P. Smolin

SIIMANAL – see Hard magnetic shaping alloy.

SILON – see Perlon.

SILOXANE RUBBER – is the product of the polycondensation of alkyl dichlorosilanes. It is used for the production of diverse elastic packings working at temperatures from –60° to 200-300°. At normal temperatures, siloxane rubber is considerably inferior to other types of synthetic rubbers with regard to its technological and physicomechanical properties: the tensile strength of gums from siloxane rubbers is 30-45 $kg/cm^2$, the relative elongation is 200-300% (compared with up to 300 $kg/cm^2$ and 800% for the other types of synthetic rubbers). The properties of siloxane rubber do not change after aging at 200° for 500 hrs (gums from natural and other synthetic rubbers become degradated within 3-15 hrs at the same conditions). The resistance to abrasion and to tear of gums on the basis of siloxane rubber are considerably inferior in comparison with hydrocarbon rubbers; but they are characterized by a high resistance to the action of oxygen, ozone, sunlight, and aggressive media. Siloxane rubber is colorless, ordorless, almost nonvolatile, and nontoxic. The electric insulation properties of siloxane rubbers are extremely high and remain also in the case of a high moisture content. The properties of siloxane rubber, especially its ability to maintain the elasticity at low temperatures, the oilproofness, the heat resistance and the other characteristics depend to a high degree on the type and the structure of the organic radical of the rubber molecule. Modifications of siloxane rubber are known, in which a part of the methyl radicals is substituted by vinyl, ethyl, or phenyl radicals and by functional groups of fluorine and cyan derivatives. Siloxane rubber which contains ethyl radicals (instead of methyl radicals) is charac-

terized by an increased frostproofness (-80°, the frostproofness of the common siloxane rubber is -55°). Introduction of fluorine and cyanpropyl groups increase the oilproofness of the siloxane rubber. A low quantity of vinyl groups secures a more rapid and complete vulcanization; in this case, rubbers are obtained with valuable technical properties (lacking in degradation when aged in the absence of air at 250°, and a low accumulation of the residual deformation). Another type of modification of siloxane rubber is obtained by the introduction of boron, phosphorus, etc., atoms into the principal chain; the former increase the thermal stability of siloxane rubbers up to 350-400°, the latter - the adhesivity of the rubber and of its vulcanization products. The field of the application of siloxane rubber is determined by their specifical properties, at first, by the exclusive thermal stability, the good frostproofness and the high dielectric characteristics; these rubbers are rubbers for special purposes, they are used mainly in those fields of industry where other rubber types can not compete with them.

F.A. Galil-ogly

**SILUMIN** – a binary alloy of aluminum and silicon. Several types are produced, varying in impurity content. The Table shows the chemical compositions and applications of silumins, according to GOST 1521-50.

Chemical Compositions and Applications of Silumins

| Марка 1 | 2 Химич. состав | | 3 Примеси, не более | | | | | 5 Примерное назначение |
|---|---|---|---|---|---|---|---|---|
| | Si | Al | Fe | Ca | Ti | Mn | сумма Cu+Zn 4 | |
| 6 СИЛ-0 | 10–13 | Остальное 9 | 0,35 | 0,10 | 0,10 | 0,10 | 0,15 | 10 Приготовление сплавов спец. назначения и сплава АЛ4 при отливке деталей в песок. |
| 7 СИЛ-1 | 10–13 | Остальное | 0,50 | 0,10 | 0,15 | 0,5 | 0,15 | 11 Приготовление литейных сплавов для деталей, отливаемых в песок и в кокиль. |
| 8 СИЛ-2 | 10–13 | Остальное | 0,70 | 0,20 | 0,20 | 0,5 | 0,20 | 12 Приготовление сплавов, обрабатываемых давлением. 13 Приготовление литейных сплавов, предназначенных для литья под давлением. |

1) Type; 2) chemical composition; 3) impurities, no more than; 4) total; 5) typical application; 6) SIL-0; 7) SIL-1; 8) SIL-2; 9) remainder; 10) preparation of special-purpose alloys and AL4 alloy for sand-casting components; 11) preparation of casting alloys for components cast in sand and chill molds; 12) preparation of alloys to be pressure-worked; 13) preparation of casting alloys intended for pressure casting.

Silumin is produced in smooth and necked pigs weighing from 6 to 14 kg. The term silumin is also applied to alloys based on Al-Si, e.g., AL4, AL9, AL11, etc. (see Aluminum casting alloys).

Electrothermal silumen is an aluminum-silicon (12.5% Si) alloy produced by filtration from aluminum-silicon (up to 70% Al, 28% Si, and 1-5% Fe) obtained by electrothermal reduction of alumina ($Al_2O_3$) and silica ($SiO_2$) with carbon. Alloys manufactured with electrothermal silumin have the same characteristics as aluminum alloys produced with the corresponding type of silumin containing the same quantity of impurities and obtained by alloying aluminum with silicon.

Modified silumins are aluminum alloys based on Al-Si and containing more than 6% Si; they are subjected to special treatment in order to obtain a fine (modified) crystal structure (see Modification of alloys). Sodium is used for modifying hypoeutectic and eutectic silumins. Red phosphorus is general employed to refine the structure of eutectic silumins with a high silicon content (more than 13%). A total of 0.05-0.08% sodium is added to the molten metal from a mixture of sodium and potassium halides, the so-called modifying flux. Modification is sometimes carried out with metallic sodium. The role of sodium evidently reduces to formation of a film of binary sodium silicide (NaSi or of the ternary compound $NaAlSi_4$, which isolates the silicon crystallites and hampers their growth during crystallization. Phosphorus is usually added to the molten metal in the form of copper phosphide or mixed with KCl and $K_2TiF_6$. Modified silumins are widely employed industrially for casting complex shapes. Among the drawbacks of sodium modification we must include conta ination of the metal with nonmetallic inclusions. It is extremely difficult to cope with this defect, since modification is carried out immediately before the metal is cast and after it is refined, in order to avoid burning the sodium and reducing its modifying effect. In order to prevent contamination of the metal during modification it is recommended that a universal flux with a simultaneous refining and modifying action be used or that the metal be vacuum-treated after modification (see Refining of aluminum alloys).

References: Bochvar, A.A., Metallovedeniye [Phys. Metallurgy], 5th Edition, Moscow, 1956; Al'tman, M.B. et al., Plavka i lit'ye splavov tsvetnykh metallov [Smelting and Casting of Nonferrous Alloys], Moscow, 1963; Belyayev, A.I., Metallurgiya legkikh metallov [Metallurgy of Light Metals], 4th Edition, Moscow, 1954; Kolobnev, I.F., Krymov, V.V., Polyanskiy, A.P., Spravochnik liteyshchika, Fasonnoye lit'ye iz

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alyuminiyevykh i magniyevykh splavov [Foundry Worker's Handbook. Casting of Aluminum- and Magnesium-Alloy Shapes], Moscow, 1957.

M.B. Al'tman

SILVER, Ag – a chemical element in group I of the Mendeleyevian periodic table, with an atomic number of 47 and an atomic weight of 107.870; it has two stable isotopes, $Ag^{107}$ (51.35%) and $Ag^{109}$ (48.65%), and the radioactive isotopes $Ag^{100}$ and $Ag^{111}$. The silver content of the earth's crust amounts to $1 \cdot 10^{-5}$% by weight, this element being found both in the native state and in compounds (AgS, AgCl, etc.). Silver is a metal with a density of 10.5 g/cm$^3$, a $t^\circ_{pl}$ of 960.5°, and a $t^\circ_{kip}$ of 2212°. Because of its fine luster and nonoxidizability silver is used in the jewelry trade and in the manufacture of mirrors. It forms light-sensitive compounds that are widely employed in photography and cinematography. Silver produces numerous alloys with other metals and these are used in electronics, dentistry, and other branches of technology (see Precious metals).

O.Ye. Zvyagintsev

SIMILARITY OF STRESS CYCLES – the condition in which the ratio of the maximum stresses during alternate repeated loading equals the ratio of the mean stresses and the ratio of their amplitudes.

G.T. Ivanov

SINGLE SHEAR – fracture of a material under tangential stresses in one plane parallel to the action direction of the external forces. Components such as rivets or bolts joining two overlapped tension-loaded plates are subject to single shear.

N.V. Kadobnova

SINTERED ALUMINUM ALLOYS (SAS) – aluminum materials obtained from alloyed aluminum powders or from mixtures of powdered aluminum and powdered alloying elements by briquetting, sintering, and deformation. The powders used in manufacturing SAS can be produced by dispersing molten aluminum alloys or by mixing powdered alloying elements with oxidized aluminum powder or scale. The method used to produce the powder has a considerable influence on the properties of certain materials. One scheme for the manufacture of semifinished products from SAS includes the following operations: preparation of the powders, sintering of the briquettes, and hot pressing (extrusion) into the desired semifinished products or blanks for pressure working. SAS are manufactured in cases where production of materials with special physical characteristics (low $\alpha$ and $\lambda$) requires addition of a quantity of alloying elements which makes it difficult or impossible to cast the alloys in the usual manner.

TABLE 1

Mechanical and Physical Characteristics of SAS-1

| Темп-ра испыт-ния (°С)[1] | $\sigma_в$ [2] | $\delta$ (%) | $\alpha \cdot 10^6$ (1 °С) | $\sigma_{в\ 100}$ |
|---|---|---|---|---|
| 20 | 32–32 | 1.0 | 14.5–15.5 | – |
| 100 | 20.5 | 1.0 | 15.0–16.0 | – |
| 200 | 14.0 | 1.0 | 15.0–16.0 | 11.0 |
| 300 | 14.5 | 1.5 | 16.0–17.0 | 6.0 |

1) Test temperature (°C); 2) kg/mm$^2$.

SAS with special physical characteristics include SAS-1, which has the lowest $\alpha$ of any aluminum alloy. The chemical composition of SAS-1 is 25–30% Si, 5–7% Ni, and the remainder Al. The powder used for

TABLE 2

Mechanical Characteristics of Pressed Bars of SAS-D16 and SAS-V96 (with $Al_2O_3$ contents of up to 5%)

| Материал 1 | 2 Темп-ра испытания (°С) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20 | | 100 | | 200 | | 300 | |
| | $\sigma_b$ (кг/мм²) 3 | δ (%) | $\sigma_b$ (кг/мм²) | δ (%) | $\sigma_b$ (кг/мм²) | δ (%) | $\sigma_b$ (кг/мм²) | δ (%) |
| САС-Д16 . . . 4. | 57 | 17 | 53 | 15 | 25 | 11 | 12 | 10 |
| САС-В96 . . . 5. | 72 | 5,4 | 64 | 6 | 34 | 9 | 19 | 16 |

1) Material; 2) test temperature (°C); 3) kg/mm$^2$; 4) SAS-D16; 5) SAS-V96.

this material is obtained by dispersion of the alloy; it has a particle size of no more than 100 μ. The strength of the sintered alloy at room temperature amounts to 22-32 kg/mm$^2$ and is reduced when a mixture of powders is used as the initial material. Its coefficient of linear expansion does not depend on the method by which the powder is produced. Table 1 shows themechanical and physical characteristics of SAS-1.

This material has a specific gravity of 2.75, E = 8000 kg/mm$^2$ (at 20°), λ = 0.21 (25°) cal/cm·sec·°C, and ρ = 0.105 (20°) ohm·mm$^2$/m. SAS-1 can be satisfactorily deformed only by hot pressing (extrusion) at temperatures of up to 550°. It is produced in bars, from which the desired components are fabricated by cutting. SAS-1 has satisfactory cuttability and good hermeticity and is not strengthened by heat treatment. The corrosion resistance of SAS-1 is low. SAS-1 can be satisfactorily butt-welded, in which case the strength of the weld at room temperature amounts to 90% of that of the base material. It is recommended that SAS-1 be used for components of instruments which must function in couples with steel over the temperature range 20-200°, where a combination of a small α and a low γ is required. SAS based on standard aluminum alloys are of considerable interest, retaining the high char-

acteristics inherent in these alloys at room temperature and acquiring properties similar to those of sintered aluminum powder at elevated temperatures. Moreover, in this case it is possible to obtain semifinished products without the metallurgical defects associated with casting, pressure working, etc. The powders employed for SAS manufactured from standard aluminum alloys are produced by dispersion of the molten alloy. The grain size of the powder should not exceed 60-100 μ. Semifinished products of SAS may contain 3-6% $Al_2O_3$. Table 2 shows the mechanical characteristics of pressed bars of SAS-D16 and SAS-V96.

All the other physical and mechanical characteristics of SAS-D16 and SAS-V96 correspond to those of semifinished products fabricated from ingots of D16 and V96 alloys. These materials are heat treated in accordance with the regimes for D16 and V96. It must be noted that the microstructure of SAS is virtually independent of the heating temperature. The same semifinished products can be fabricated from SAS-D16 and SAS-V96 as from the ordinary alloys D16 and V96.

References: Teploprochnyy material iz spechennoy alyuminiyevoy pudry (SAP) [A Heat-Resistant Material of Sintered Aluminum Powder], collection of articles edited by I.N. Fridlyander and B.I. Matveyev, Moscow, 1961; Alyuminiyevyye splavy [Aluminum Alloys], collection of articles, No. 2, Moscow, 1963.

B.I. Matveyev

SINTERED ALUMINUM POWDER (SAP) – an alloy of aluminum and its oxides obtained by sintering and deformation of dispersed aluminum powder. SAP is considerably stronger at 300–550° than aged aluminum alloys and can function at these temperatures for 10,000 hours or more while retaining stable characteristics and structure. This is due to the presence of uniformly distributed finely-dispersed high-melting aluminum oxide in the aluminum base (as a second phase); at high temperatures these oxides do not enter into mutual diffusion with the base. Semifinished products of SAP have a corrosion resistance as high as that of pure aluminum. They are recommended for brief operation at ambient temperatures of up to 1000° and for prolonged operation at 300–550°. Aluminum poweder of type APS is used in the manufacture of semifinished products of SAP (Table 1).

TABLE 1

Characteristics of Type APS Powder

| Марка порошка 1 | 2 Состав порошка (%) | | | | | Насыпной вес (г/см³), не менее 5 |
|---|---|---|---|---|---|---|
| | $Al_2O_3$ | Fe | Жиры 3 | $H_2O$ | 4 Al | |
| | | не более | | | | |
| 6 АПС-1 | 6,0–9,0 | 0,2 | 0,25 | 0,1 | Остальное | 1 |
| 7 АПС-2 | 9,1–13,0 | 0,2 | 0,25 | 0,1 | » | 1 |
| 8 АПС-3 | 13,1–18,0 | 0,2 | 0,25 | 0,1 | 10 » | 1 |
| 9 АПС-4 | 18,1–22,0 | 0,2 | 0,25 | 0,1 | » | 1 |

1) Type of powder; 2) composition of powder (%); 3) fats; 4) no more than; 5) bulk weight (g/cm3), no less than; 6) APS-1; 7) APS-2; 8) APS-3; 9) APS-4; 10) remainder.

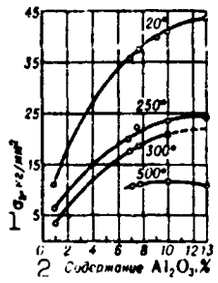
The powder is prepared from a pulverizate obtained by dispersion of molten aluminum, which is then ground to scale (flakes) 0.5–1 μ thick and 10–30 μ in length and width in ball mills with a regulated oxygen content. In order to increase its bulk weight the scale is nod-

TABLE 2

Mechanical Characteristics of Certain Semifinished Products of SAP

| Марка САП 1 | Содержание $Al_2O_3$ (%) 2 | 3 Свойства | 4 Температура испытания (°С) 20 | 350 | 500 | 5 Свариваемость |
|---|---|---|---|---|---|---|
| САП-1 прессованный 6 | 6,0–9,0 | $\sigma_b$ (кг/мм²)<br>$\sigma_{0,2}$ (кг/мм²)<br>$\delta$ (%) | 30–12<br>21–24<br>5–8 | 14–16<br>14–15<br>4–6 | 7–8<br>5–6<br>2–3 | Не сваривается плавлением 12 |
| САП-1 катаный 7 | 6,0–9,0 | $\sigma_b$ (кг/мм²)<br>$\sigma_{0,2}$ (кг/мм²)<br>$\delta$ (%) | 27–28<br>20–23<br>8–10 | 12–14<br>10–11<br>6–7 | 4,6–4,5<br>3,0–3,5<br>3–4 | Сваривается плавлением 13 |
| САП-2 прессованный 8 | 9,1–13,0 | $\sigma_b$ (кг/мм²)<br>$\sigma_{0,2}$ (кг/мм²)<br>$\delta$ (%) | 34–35<br>26–28<br>4–6 | 15–16<br>14–15<br>3–4 | 10–11<br>7,0–7,5<br>1,5–2,5 | Не сваривается плавлением |
| САП-3 прессованный 9 | 13,1–18,0 | $\sigma_b$ (кг/мм²)<br>$\sigma_{0,2}$ (кг/мм²)<br>$\delta$ (%) | 40–42<br>30–32<br>3,5–4,5 | 19–20<br>15–16<br>1,5–2 | 12–12,5<br>9–9,5<br>1,5–1,8 | Не сваривается плавлением |
| САП-4 прессованный 10 | 18,1–22,0 | $\sigma_b$ (кг/мм²)<br>$\sigma_{0,2}$ (кг/мм²)<br>$\delta$ (%) | 44–46<br>36–38<br>1,5–2,0 | 21–23<br>18–19<br>1,0–1,2 | 13,0–13,5<br>10–11<br>1,0–1,2 | Не сваривается плавлением |

1) Type of SAP; 2) $Al_2O_3$ content (%); 3) characteristics; 4) test temperature (°C); 5) weldability; 6) pressed SAP-1; 7) rolled SAP-1; 8) pressed SAP-2; 9) pressed SAP-3; 10) pressed SAP-4; 11) kg/cm$^2$; 12) cannot be fusion welded; 13) can be fusion welded.




1) $\sigma_b$, kg/mm$^2$; 2) $Al_2O_3$ content, %.

ulized (conglomerated) into an aluminum powder with a grain size of 50-100 μ. The production technology for semifinished products of SAP consists in briquetting the powder, sintering, and deformation in accordance with regimes similar to those employed for deforming ordinary aluminum alloys. Sheets, bars, tubes, shapes, rivet wire, foil up to 0.03 mm thick, and complex stampings are produced from SAP-1 and SAP-2. Pressed semifinished products and stampings are manufactured from SAP-3 and SAP-4; such products have a maximum weight of 500-700 kg. Table

2 shows the mechanical characteristics of pressed and rolled semifinished products.

The short-term strength of SAP decreases by a factor of 3-3.5 as the test temperature is raised from 20° to 500°, while that of aged aluminum alloys decreases by a factor of 20-25. In contrast to aluminum alloys, the δ of SAP decreases as the temperature rises. It must be noted that the strength of SAP increases with the $Al_2O_3$ content of the powder. When the $Al_2O_3$ content is increased from 1% to 13% the strength of the SAP increases from 7-8 to 44 kg/mm$^2$ (Fig.), while its elongation decreases from 35% to 5%. The greatest increase in strength is observed in SAP containing up to 7% $Al_2O_3$. Strength varies slowly as the $Al_2O_3$ content is further increased. SAP with an elevated $Al_2O_3$ content has roughly the same characteristics as structural aluminum alloys. SAP is materially stronger at 300-500° than the most hot-strong aluminum alloys. The strengthening effect of $Al_2O_3$ decreases somewhat as the temperature rises, but increases slightly at 500° and an $Al_2O_3$ content of 7-13%. As a result of their structural stability, SAP products retain their characteristics on prolonged annealing. Table 3 shows the influence of heating time at an annealing temperature of 500° on the mechanical characteristics of SAP-1. The properties of semifinished products of SAP are virtually independent of heating time at temperatures of up to 500°.

TABLE 3

Influence of Annealing Time on the Strength of SAP-1

| Темп-ра отжига (°C) 1 | Длительность отжига (часы) 2 | $\sigma_b$ (кг/мм$^2$), при 20° 3 |
|---|---|---|
| Без отжига | — | 34—35 |
| 500 | 50 | 34—35 |
| | 100 | 33—34 |
| 4 | 10 000 | 32—33 |

1) Annealing temperature (°C); 2) annealing time (hr); 3) $\sigma_b$ (kg/cm$^2$) at 2°; 4) without annealing.

TABLE 4

Long-Term Strength of SAP-1 and SAP-2 over 100 hr

| Темп-ра испытания (°С) 1 | 2 $\sigma_{100}$ (кг/мм²) | |
|---|---|---|
| | САП-1 3 | САП-2 4 |
| 250 | 10 | 12 |
| 350 | 8,5 | 9 |
| 500 | 5,0 | 5,5 |

1) Test temperature (°C); 2) $\sigma_{100}$(kg/mm$^2$); 3) SAP-1; 4) SAP-2.

TABLE 5

Basic Physical Characteristics of SAP-1 and SAP-2

| Свойства 1 | САП-1 2 | САП-2 3 | Чистый Al 4 |
|---|---|---|---|
| 5 Уд. вес (г/см³) | 2,73 | 2,75 | 2,7 |
| 6 $\alpha \cdot 10^6$ (1/°С) при 20—100° | 23,0 | 19,5 | 24 |
| 100—200° | 23,0 | 20,2 | 25 |
| 200—300° | 23,9 | 29,0 | 26 |
| 300—400° | 25,3 | 21,7 | 27 |
| 400—500° | 26,3 | 22,7 | — |
| 7 $\lambda$ (кал/см·сек·°С) при 20—500° | 0,4—0,36 | 0,34—0,33 | 0,46 |

1) Characteristic; 2) SAP-1; 3) SAP-2; 4) pure Al; 5) specific gravity (g/cm$^3$); 6) $\alpha \cdot 10^6$(1/°C) at 20-100°; 7) $\lambda$(cal/cm·sec·°C) at 20-500°.

TABLE 6

Corrosion Resistance of SAP

| Содержание (%) 1 | | 2 $\sigma_b$ (кг/мм²) | | δ (%) | |
|---|---|---|---|---|---|
| $Al_2O_3$ | Fe | 3 до коррозии | 4 после коррозии | до коррозии | после коррозии |
| 1,0 | 0,05 | 11,6 | 12,2 | 34 | 32 |
| 10,5 | 0,08 | 37,5 | 39,0 | 6,6 | 6,8 |
| 11,5 | 0,08 | 37,8 | 38,5 | 6,0 | 6,1 |

1) Content (%); 2) $\sigma_b$(kg/mm$^2$); 3) before corrosion; 4) after corrosion.

SAP-1 and SAP-2 have almost the same long-term strength, which exceeds that of any aluminum shaping alloy (Table 4). Table 5 shows the basic physical characteristics of SAP-1 and SAP-2 in comparison with those of pure aluminum.

SAP has a high corrosion resistance. Testing of SAP specimens in a solution of 3% NaCl and 0.1% $H_2O$ (Table 6) for 6 months caused only slight pitting but no decrease in mechanical characteristics. No tra-

ces of corrosion can be detected when the iron content of the powder is less than 0.2%.

The slight increase in strength after corrosion testing characteristic of this material is due to additional oxidation during corrosion. Semifinished products of SAP can be anodized when necessary. SAP can be satisfactorily welded by the butt, contact, and fusion methods. Fusion welds in sheets of SAP-1 1.5 mm thick have a strength of 33 $kg/mm^2$ at room temperature and 5-6 $kg/mm^2$ at 500°. SAP-1 can be satisfactorily deformed when heated to 450-570° (by forging, stamping, pressing, and rolling). Cold sheaths 2.0 mm thick can be satisfactorily rolled to thicknesses of 0.3-0.05 mm. SAP-2, SAP-3, and SAP-4 are satisfactorily deformed during hot pressing, but are somewhat less satisfactory for rolling; stamping requires utilization of a stressed state which ensures minimal tensile stresses (efusion, stamping in closed dyes, etc.). SAP-1 sheets are deep drawn at 300-450°; the maximum per-pass drawing factor is 1.3-1.8. The minimum bending radius for sheaths is eight times their thickness at room temperature, three times their thickness at 350°, and 1.5 times their thickness at 45°. SAP is readily cut. It is not strengthened by heat treatment.

References: Teploprochnyy material iz spechennoy alyuminyevoy pudry (SAP) [A Heat-Resistant Material of Sintered Aluminum Powder (SAP)], collection of articles edited by I.N. Fridlyander and B.I. Matveyev, Moscow, 1961; Alyuminiyevyye splavy [Aluminum Alloys], No. 2, Sintered Alloys, edited by I.N. Fridlyander, Moscow, 1963.

B.I. Matveyev

SINTERED CHROMIUM – compact chromium obtained by powder metallurgy. Finely powdered chromium usually serves as the initial product for production of compact chromium. Satisfactory results can be obtained by using electrolytically refined chromium, monocrystals of chromium iodide, or a mixture of refined chromium and chromium iodide as the initial raw material. Chromium obtained by other methods (unrefined electrolytic chromium, aluminothermal chromium, etc.) either cannot be pressed at 20° or form weak briquettes even at high pressures (up to 3 $t/cm^2$). At elevated temperatures the pressure required decreases and the density of the pressed briquettes increases. There are methods for pressing chromium preliminarily heated to 800–1000° under impact loads. The pressed briquettes are subjected to sintering and deformation. After such thermomechanical processing the density of pressed chromium approximates that of cast metals. Sintering of the pressed blanks is generally carried out at 1500–1550°. The heating time depends on the temperature, the cross-sectional area of the blank, etc. (For a blank with d = 50 mm the sintering time at 1500° is approximately 5 hr). Chromium is usually sintered under an overpressure created with an inert gas or hydrogen (astatic or circulating atmosphere) that has been preliminarily dried and purified. When air is admitted or the gas is not sufficiently well purified the chromium becomes contaminated, which causes the characteristics of the sintered metal to deteriorate.

The density and other properties of sintered chromium are most effectively enhanced by hot deformation of the metal. Such deformation can be successfully effected by flow under nonuniform omnidirectional

compression at 1450-1550°. The metal is heated in a hydrogen or an inert gas and deformation is carried out in air. The specific pressure for a single-pass reduction in area of 80% should be approximately 80 kg/mm$^2$. Dross molding of components from powders makes it possible to produce articles too complex or too large for ordinary pressing. Suspensions of metallic chromium powder in liquids with chemical reagents added to prevent nonuniform settling of the particles is employed for dross casting. The dross is characterized by the metal-liquid ratio, the viscosity, and the quantity $P_n$.

The mechanical characteristics of sintered chromium, especially its plasticity, are lower than those of remelted metal. On the other hand, the technological and economic advantages of powder-metallurgical methods make it expedient to employ them in the production of certain chromium and chromium-alloy components. Alloys of the Cr + 30% Co + + 6% W type manufactured by powder-metallurgical methods have properties similar to those of alloys produced by metallurgical methods, although they have a lower $\gamma$ and $\sigma_{0.2}$. Several alloys based on chromium and aluminum oxide or magnesium oxide (e.g., chromium + 10% aluminum oxide) have been developed. After sintering and deformation such an alloy has the following mechanical characteristics at various temperatures: at 20° $\sigma_b$ = 38 kg/mm$^2$ and fracture is brittle; at 650° $\sigma_b$ = 38 kg/mm$^2$, $\sigma_{0.2}$ = 36 kg/mm$^2$, and $\delta$ = 0.5%; at 815° these quantities equal 33 kg/mm$^2$, 29 kg/mm$^2$, and 3.5% respectively, while at 980° they equal 19 kg/mm$^2$, 18 kg/mm$^2$, and 14% respectively. At 815° and above the alloy is plastic and exhibits rather high strength, although its impact strength is low. This type of alloy can be used for components requiring a metal with high strength, corrosion resistance in oxidizing atmospheres, and low specific gravity, but not one with high plasticity and impact strength. For example, these alloys can function reliabl

under static conditions and compressive loads. Components for blanks are hot pressed from alloys of the Cr + (10-15%) Ni type and then sintered. The latter operation is carried out at 1200-1300° in a circulating atmosphere of dry, purified hydrogen (the shrinkage of the alloy during sintering reaches 17-20°). The alloys can be deformed by flow under nonuniform omnidirectional compression at 1000-1350°. Despite the high deformation temperature the alloys are intensively cold worked, which increases their brittleness. Use of a lubricant facilitates deformation and enhances tool durability. The alloys are heat treated after deformation. The distinctive feature of such alloys is their high hardness (HB = 650 $kg/mm^2$).

Certain chemical compounds of chromium have valuable properties. For example, chromium carbide is only slightly less hard than the carbides of other transition metals (H $\simeq$ 2500 $kg/mm^2$), is less high-melting (its $t^\circ_{pl}$ is approximately 1895°), has a comparatively low $\gamma$ (6.68 $g/cm^3$), and is more corrosion resistant than any other carbide in oxidizing atmospheres and certain aggressive fluids. Cermet alloys based on chromium carbide have a number of valuable characteristics: high hardness at normal and elevated temperatures, good corrosion resistance, and high abrasion resistance.

A production technology has been developed for the manufacture of articles from chromium-carbide alloys; these include nozzles for sand blasting equipment, knife edges with working temperatures of up to 1400°, pressform insertion pieces for calibrating ferrographite bushings, and linings for large tube-drawing dies. These alloys are also employed in the production of components or pumps and other machinery which must operate in aggressive fluids. In many cases use of cermet alloys based on chromium carbide rather than high-melting metals and their compounds is technically justified and economically expedient.

III-81s3

Chromium-carbide materials have been developed for building up on fast-wearing machine components, punching dies, etc. Electrodes with coatings of chromium carbide and graphite have also been developed. Chromium carbide is added (in quantities of approximately 10%) to tungsten carbide, titanium carbide, and mixtures of these compounds in the manufacture of solid alloys by cermet methods. A higher chromium carbide content embrittles such alloys. Chromium carbide increases the corrosion resistance of cermet alloys.

I.O. Panasyuk

SINTERED MAGNESIUM ALLOY – a material obtained from powdered magnesium and magnesium alloys by powder metallurgy. Production of semifinished products of magnesium and its alloys by this method makes it possible to obtain a fine-grained structure and to add magnesium-insoluble metals and nonmetallic materials which cannot be introduced into the alloy by ordinary fusion. It is possible to produce magnesium powders for subsequent pressing of semifinished products and various components by milling, by dispersion of the molten metal with the aid of inert gases, or by centrifugal atomization of the molten metal. Articles pressed from coarse-grained powder (with a particle size of up to 0.1 mm) has a compressive yield strength 30–40% higher than that of articles pressed from the cast metal. This high compressive yield strength is maintained in components with a large cross-sectional area. Sintered magnesium alloy can be strengthened by mixing a powdered alloy which is a solid solution of some component in magnesium with a powdered metal that reacts chemically with the dissolved component. The resultant chemical compound of these two components precipitates from the solid solution and may have a strengthening effect analogous to dispersion hardening. A hardenable material of this type can be obtained from a mixture of two powdered alloys, e.g., one a solid solution of aluminum in magnesium and the other a solid solution of zirconium in magnesium. Heat treatment of this metal produces the high-melting compound $AlZr_3$, which precipitates from the solid solution and strengthens the alloy. An alloy which displays no tendency toward corrosion cracking and has higher mechanical characteristics than the

initial alloys can be obtained by pressing a mixture of powdered MA2 and MA1 alloys. At room temperature the mechanical characteristics of bars of powdered magnesium with a grain size of up to 0.1 mm are identical to those of bars pressed from cast alloy, while at 300° the characteristics of the former are higher by a factor of 2.

References: Mod. Metals, 1957, Vol. 13, No. 2, page 86; J. Metals, 1950, Vol. 188, No. 2, page 297; Eisenkolb, Fr., Poroshkovaya metallurgiya [Powder Metallurgy], translated from German, Moscow, 1959.

A.A. Kazakov

SINTERED MOLYBDENUM – a high-melting material manufactured by powder metallurgy. In order to obtain compact (nonporous) metal the sintered blanks are pressure worked (by foring, drawing, or rolling) in both the hot and cold states. Sintered molybdenum is distinguished by a fine crystalline structure and the majority of its characteristics are equal to those of metal obtained by smelting in vacuum arc furnaces. Powder metallurgy is simpler, cheaper, and more efficient than smelting, but sintered molybdenum contains a larger amount of impurities, particularly oxygen, and is more difficult to weld than smelted molybdenum.

Characteristics of Sintered Molybdenum

| Свойства 1 | 2 Показатели | |
|---|---|---|
| | 3 спеченный молибден | спеченный молибден деформированный 4 (70–90%) |
| Плотность (г/см³) 5 | 9.8–10 | 10.2–10.3 |
| Пористость (остаточная (%) 6 | 2.5–3.0 | 0.3–0.5 |
| *HB* (кг/мм²) 7 | 100–123 | 150–180 |
| $\sigma_b$ (кг/мм²) | 24–30 | 48–60 |
| $\sigma_{изг}$ (кг/мм²) | 60–65 | 100–120 |
| δ (%) | 0.5–1.0 | 1.5–3.0 |
| $a_д$ (кгм/см²) 8 | 1–1.12 | 1.5–1.8 |
| λ при 20–500° (кал/см·сек·°С) 9 | 0.32–0.38 | 0.38–0.3 |
| $\alpha \cdot 10^6$ при 20–500° (1/°С) 10 | 5.3–6.0 | 5.8–6.12 |
| $\sigma_{изг_{100}}$ (кг/мм²) | 2–2.5 | 3–3.5 |

1) Characteristic; 2) value; 3) sintered molybdenum; 4) sintered deformed molybdenum (70-90%); 5) density (g/cm³); 6) residual porosity (%); 7) kg/mm²; 8) $a_n$ (kg-m/cm²); 9) λ at 20-500° (cal/cm·sec·°C); 10) $\alpha \cdot 10^6$ at 20-500°C (1/°C).

Sintered molybdenum, even that not subjected to additional pressure working, has a high resistance to gas-flow erosion and can consequently be used for nozzle linings briefly exposed to working tempera-

tures of up to 2300-2400°. Sintered molybdenum is employed in various alloys as well as in its pure form. It is most widely used as a constituent of contacts for welding equipment and various electronic instruments (see Cermet contacts).

References: Meyerson, G.A., Zelikman, A.N., Metallurgiya redkikh metallov [Metallurgy of the Rare Metals], Moscow, 1955; Molibden [Molybdenum], Handbook, edited by A.K. Nathanson, translated from English, Moscow, 1959.

V.S. Rakovskiy

SINTERED NIOBIUM – compact niobium obtained by powder metallurgy. In order to produce this material powdered niobium or a mixture of powdered niobium with 20-30% by weight niobium hydride (a product of the reprocessing of waste metal) is pressed with a binder (gasoline) under a pressure of from 1 to 10 $t/cm^2$ (depending on the coarseness and quality of the powder) into moldings with typical sizes of 20 × × (20-30) × (600-700) $mm^3$. These moldings are then sintered at 2250-2300° for 6 hr in indirect vacuum furnaces or, more frequently, by direct heating (with welding equipment), passing an electric current through the molding. A very complex process involving formation of compact metal from the powder, which is accompanied by grain growth and simultaneous vacuum refining of the metal, takes place during sintering; for example, when a powder with a grain size <5 μ obtained by reduction of potassium fluoroniobate with sodium and containing 98.9-99.2% (by weight) Nb, approximately 0.5% $O_2$, 0.1% $N_2$, 0.15% C, and is sintered in a vacuum of $1 \cdot 10^{-2}$-$5 \cdot 10^{-4}$ mm Hg, plastic metal containing 99.4-99.7% Nb and impurities of 0.02-0.06% Ti, Fe, Si, $O_2$, and $N_2$, ~0.01% C, and $<1 \cdot 10^{-4}$% Pb is obtained. The linear shrinkage during sintering is 15-20%. High-purity sintered molybdenum is obtained by sintering moldings of niobium reduced by the carbothermal method at 2300° (see Carbothermal niobium, High-purity niobium. Sintered niobium is used in the production of alloys by smelting and in the founding of blanks of varying d for pressed tubes or is cold forged with a redution in thickness of 50% and vacuum annealed (second sintering) at 2150-2200° for 1-3 hr in order to compact the metal and weld up the

compressed micropores. This raises the density of the metal from 7.8-8.0 to 8.53 g/cm$^3$. The hardness HB of the moldings after sintering, forging, and second sintering is 60-70, 100-130, and 60-80 kg/mm$^2$ respectively. After second sintering sintered-niobium plates and bars of the aforementioned quality have the following mechanical characteristics: $\sigma_{pts}$ - 25-30 kg/mm$^2$, $\sigma_{0.2}$ - 30-34 kg/mm$^2$, $\sigma_b$ - 39-43 kg/mm$^2$, and $\delta$ - 10-18%. They are identical to cast metal of the same quality (see Cast niobium). Plates 8 mm thick are rolled without annealing into strips and foil up to 20 mm thick and with one annealing into products 12 μ or less thick. Sintered-niobium moldings (16-24) x 16 x (400-500) mm$^3$ in size are produced in the USSR in accordance with RE TU 71-58 and contain $\geq$99.4% (by weight) Nb + Ta (Ta $\leq$ 1.5%) and no more than 0.1% Fe, 0.1% Ti, and 0.09% Si.

O.P. Kolchin

SINTERED TANTALUM – compact tantalum obtained by powder metallurgy. In order to produce this material powdered tantalum or a mixture of powdered tantalum with 20–50% by weight powdered tantalum hydride (a product of the reprocessing of waste metal, see Tantalum) is pressed into moldings with a binder (gasoline or solutions of paraffin in gasoline, glycerine in alcohol, etc.) under a pressure of 1.5–2.5 t/cm$^2$ for fine-grained powders or 5–10 t/cm$^2$ for coarse-grained powders. The maximum molding size is 32 x 64 x 760 mm$^3$, the usual size is 20 x 20 x 600 mm$^3$, and the molding weight is 2.5–10 kg or more. These moldings are preliminarily sintered at 1450–1500° and then at temperatures of up to 2600° in direct-heating vacuum furnaces (welding equipment) by passing an electric current through the molding (this operation can also be carried out without preliminary sintering). The sintering time for a molding 20 x 20 mm$^2$ in cross-section is 9–10 hr under a vacuum of $1 \cdot 10^{-2}$–$1 \cdot 10^{-4}$ mm Hg. A very complex physicochemical process, involving formation of compact metal from the powder, which is accompanied by grain growth, shrinkage of the molding, and simultaneous vacuum refining of the metal, takes place during sintering. This method is the principal production process for tantalum. For example, a coarse electrolytic powder containing 97.2% (by weight) Ta, 0.6% Nb, 0.94% $O_2$, 0.40% C, 0.23% Si, 0.20% Fe, 0.06% Ni, and 0.16% Ti is used to produce plastic metal containing 99.80–99.85% (by weight) Ta + Nb, $\leq$ 0.03% C, and virtually no impurities of Si, Fe, Ni, or Ti. The resultant moldings have a density of 14–15 g/cm$^3$. They are cold-forged into bars or plates with a reduction in cross-sectional area of no less than 15–25%

and then heated in a vacuum at a temperature somewhat below the basic sintering temperature in order to sinter the micropores brought to the surface during forging. Forging involving deformation by 25% and vacuum annealing are sometimes repeated. This produces compact blanks (bars and plates), which are converted to wire and sheets respectively by the usual cold-pressure-working methods (see Tantalum wire). Sintered tantalum is also suitable for recasting into ingots and for smelting of alloys (see High-purity tantalum, Tantalum alloys).

References: Samsonov,G.V., Konstantinov, V.I., Tantal i niobiy [Tantalum and Niobium]. Moscow, 1959; Miller, G.L., Tantalum and Niobium, London, 1959.

O.P. Kolchin

**SINTERED TITANIUM ALLOY** – a material obtained by pressing powdered titanium calcium hydride and powdered titanium alloys in steel pressforms under a pressure of 1.5-3.0 $t/cm^2$ or by the hydrostatic method under a pressure of 800 atm (0.8 $t/cm^2$) and sintering the resultant product at 1350-1450° under a vacuum of $10^{-2}$-$10^{-3}$ mm Hg for 1-5 hr (depending on the composition of the alloy and the size of the article to be sintered). The surface of sintered titanium alloy is silvery and smooth and contains no cracks, bubbles, or other defects; this material has a density equal to 97-99% of that of compact deformed metal. Its residual porosity (1-3%) is distributed uniformly throughout its entire volume. The pore size ranges from 1 to 5 μ. The table shows the characteristics of sintered titanium and certain sintered titanium alloys. The macrostructure of sintered titanium is shown in the figure.



Sintered titanium and sintered titanium alloy have roughly the same impurity contents: 0.08-0.2% $O_2$, 0.04-0.06% C, 0.03-0.06% $N_2$, 0.04-0.08% Si, 0.05% Ca, and $\leq$ 0.01% $H_2$. Sintered titanium and its alloys readily undergo all types of machining and have a high corrosion resistance in air at any humidity, in salt water, in hot or cold diluted and concen-

trated solutions of alkalies and alkali and alkali-earth chlorides, and in organic and dilute mineral acids. There are data indicating that these materials are satisfactorily resistant to not overly hot acidic solutions of Cu, Fe, Cr, and Ni sulfates. Small machine and instrument components can be fabricated from sintered titanium and sintered titanium alloys by pressing in steel pressforms, as can finished products or articles brought to final size (after sintering) by machining. It is also possible to produce articles of complex shape or large size by machining unsintered briquettes obtained by hydrostatic pressing at 800-1000 atm.

Characteristics of Sintered and Deformed Titanium Alloys and Titanium

| Сплав 1 | 2 В спеченном состоянии* | | | | | | 6 В деформированном состоянии | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 γ (г/см³) | 4 HB (кг/мм²) | 4 σв (кг/мм²) | δ (%) | ψ (%) | 5 aн (кгм/см²) | γ (г/см³) | HB (кг/мм²) | σв (кг/мм²) | δ (%) | ψ (%) | aн (кгм/см²) |
| Титан 7 | 4,45 | 217 | 68 | 20 | 24 | 2,5 | 4,52 | 220 | 70 | 25 | 50 | 5,51 |
| Титан + 2% Cr 8 | 4,50 | 241 | 77,5 | 12,6 | 20,9 | — | 4,57 | 248 | 92,5 | 18 | 45 | — |
| Титан + 6% Al 9 | 4,33 | 278 | 85 | 14 | 18 | 2 | 4,36 | 285 | 98 | 15 | 44 | 4,7 |

*The relative density of all sintered specimens is 96-99%.

1) Alloy; 2) sintered; 3) γ (g/cm$^3$); 4) kg/mm$^2$; 5) $\alpha_n$ (kg-m/cm$^2$); 6) deformed; 7) titanium; 8) titanium + 2% Cr; 9) titanium + 6% Al.

Porous strips and sheets of sintered titanium with a porosity of 20-50% can be obtained by direct rolling of the powders and subsequent sintering at 1000-1050°; they can be used as filtering elements for liquids and gases. Compact strips with characteristics similar to those of strips produced by the usual method can be obtained by further pressure working of porous strips. Sintered-titanium and sintered-titanium-alloy blanks are pressure worked (forged, rolled, or pressed) to produce sheets, tubing, bars, and wire. Deformation improves the characteristics of the sintered metal.

Powdered titanium is obtained in the form of a dispersed powder with a grain size of 1-5 μ by reduction of titanium dioxide ($TiO_2$) with calcium hydride ($CaH_2$) at 1150° in accordance with the reaction:

$$TiO_2 + 2CaH_2 \longrightarrow Ti + 2CaO + H_2.$$

Powdered titanium alloys are obtained by mixing alloying additives in oxide form (e.g., $Al_2O_3$, $V_2O_5$, $MoO_3$, etc.) with the titanium dioxide and calcium hydride before reduction.

The final powdered titanium (or alloy) contains impurities of 0.08-0.2% $O_2$, 0.04-0.06% $N_2$, 0.04-0.06% C, 0.03-0.06% Si, 0.02-0.05% Ca, 0.01-0.05% $H_2$, and up to 0.3% Fe and Ni (total). Powdered titanium is used as a getter (gas absorbent) in the radio industry and in the manufacture of sintered titanium and titanium-alloy products.

References: Timoshenko, N.N. et al., metallokeramicheskiye splavy na titanovoy osnove [Cermet Alloys Based on Titanium], TsM [Nonferrous Metals], 1960, No. 3; Borok, B.A. et al., Pressovaniye i prokatka trub iz metallokeramicheskogo titana [Extrusion and rolling of Cermet Titanium Tubing], ibid., No. 9; Borok, B.A. et al., Polucheniye titanovoy lenty putem prokatki poroshkov [Production of Titanium Strips by Rolling of Powders], ibid., No. 11; Meyerson, G.A., Kolchin, O.P., Sb. nauch. tr. Mosk. in-ta tsvetn. met. i zolota [Collection of Scientific Works of the Moscow Institute of Nonferrous Metals and Gold], 1955, No. 25.

B.A. Borok

**SINTERED TUNGSTEN** – tungsten obtained by powder metallurgy. Pressing is carried out either in steel press forms (for small articles and moldings) or in rubber molds by the hydrostatic method (for large articles). The pressing pressure is 2-3 t/cm$^2$. Heat treatment consists

Physical and Mechanical Characteristics of Sintered Tungsten

| Свойство 1 | Показатель 2 |
|---|---|
| $\gamma$ (г/см$^3$) 3 | 17,5—18 |
| HB (кг/мм$^2$) 4 | 140—150 |
| $\sigma_b$ (кг/мм$^2$) 5 | 80—90 |
| $\delta$ (%) | 5—6 |
| E (кг/мм$^2$) 6 | 30 000—35 000 |
| $a_д$ (кгм/см$^2$) 7 | 2—2,5 |
| $t°_{пл}$ (°C) | 3370 |
| $\lambda$ (10—500°) (кгл/см·сек·°C) 8 | 0,3—0,38 |
| $\alpha \cdot 10^6$ (200—500°) (1/°C) | 4,5—4,8 |
| $\rho$ (мком·см) 9 | 4,8—5 |

1) Characteristic; 2) value; 3) $\gamma$(g/cm$^3$); 4) HB(kg/mm$^2$); 5) $\sigma_b$(kg/mm$^2$); 6) E(kg/mm$^2$); 7) $\alpha_n$(kg-m/cm$^2$); 8) $\lambda$(10-500°)(cal/cm·sec·°C); 9) $\rho$(μ ohm·cm).

in preliminary sintering, which is usually carried out in a hydrogen atmosphere at 1200-1300° or small blanks (e.g., moldings), and final treatment by passing an electric current through the component and heating it to a temperature that is generally 90-95% of its melting temperature; the latter operation is conducted in special welding equipment, in a vacuum or hydrogen. Large articles and blanks are usually sintered in induction or resistance furnaces in a vacuum or hydrogen atmosphere at 200° without preliminary sintering. Moldings or other blanks of sintered tungsten are reworked into wire, sheets (by forging), and drawn and rolled products. The initial operations in pressure working are carried out with the component heated, while the

final operations are generally conducted at room temperature. Sintered tungsten not subjected to pressure working is used for contacts in various instruments, powder-engine nozzles for operation at 3000° or more, ionizers, and other articles.

References: Smitells, K.J., Vol'fram [Tungsten], translated from English, Moscow, 1958; Meyerson, G.A., Zelikman, A.N., Metallurgiya redikh metallov [Metallurgy of the Rare Metals], Moscow, 1955; Rakovskiy, V.S., Sakl;nskiy, V.V., Poroshkovaya metallurgiya v mashinostroyenii [Powder Metallurgy in Machine Building], 2nd Edition, Moscow, 1963.

V.S. Rakovskiy

SITALLS – vitrious crystalline materials obtained by crystallization of glasses. They can be divided into two groups, slag sitalls (Sh) and technical sitalls (TS). Slags obtained in ferrous and nonferrous metallurgy, coal ash, and other industrial wastes are used as the raw material for slag sitalls. Technical sitalls are produced from glasses used with natural and synthetic raw materials. This process utilizes glasses with compositions such that a single mineral or a solid solution of several minerals is formed on crystallization. In order to create the requisite conditions for heterogeneous crystallization these glasses include crystallization catalysts. Sitalls have an unusual combination of physical and chemical properties: low specific gravity (they are lighter than aluminum), high mechanical strength (especially on compression), hardness, hot strength, heat resistance, chemical stability, and radiotransparency, and other distinctive characteristics. Sitalls are widely used in industry and construction, serving both as an inexpensive substitute for ferrous and nonferrous metals, wood, porcelain, ceramics, and concrete and as a new material having better properties than those previously used. Data on slag-sitall and foam-slag-sitall products are presented below.

Sheet slag sitall (LSh) is used in the construction of public, residential, and industrial buildings for interior and exterior wall sheating, flooring, staircases, window sills, balcony and porch railings, coverings for balcony tiles and residential entrys, etc. LSh is employed in the chemical, foodstuffs, and other industries as a chemically stable and wear-resistant material (where cast stone, alloy

steel, or nonferrous metals are now used). It is produced in black, white, and other colors, in sheets up to 300 x 600 mm in size and from 3 to 25 mm thick. LSh can be polished on one or both sides, be left untreated, or have a hammered surface. The edges of the sheets can be polished or rough-cut and left unpolished.

Corrugated slag sitall (VSh) (slate type) – a black or gray roofing and siding material for industrial and residential construction, principally for the grooves and walls of industrial shops utilizing hot production processes or aggressive media. Sheets of VSh are up to 3 x 6 m in size and the thickness of sheets equivalent in bending strength to slate or corrugated iron does not exceed 3 mm; sheets may be as thick as 10 mm. The spacing of the corrugations is the same as for slate. The nailing holes can be made during manufacture or assembly. The edges of VSh are roughly the same as those of slate.

TABLE 1

Properties of Sitalls and Slag and Foam-Slag Sitalls

| | Ситалл 1 | Листовой шлакоситалл 2 | Волнистый шлакоситалл 3 | Пеношлакоситалл 4 | Шлакоситалловые панели 5 | Шлакоситалловые трубы 6 |
|---|---|---|---|---|---|---|
| 7 Объемный вес (г/см³) | 2,5–2,7 | 2,5–2,65 | 2,5–2,65 | 0,3–0,7 | 1,0–6,0 | – |
| 8 Прочность (кг/см²): | | | | | | |
| 9 на изгиб | 900–3500 | 900–1300 | 900–1300 | – | 900–1300 | 900–1300 |
| 10 на сжатие | 5000–15000 | 5000–6500 | 5000–6500 | 60–140 (при объемном весе 0,6–0,8) | 5000 | 5000–6500 |
| 11 Прочность на истирание (кг/см²) | 0,016–0,03 | 0,016–0,03 | – | – | – | – |
| 12 Коэффициент термич. расширения (α·10⁻⁷, 1/°C) | 0–200 | 65–75 | – | – | – | – |
| 13 Темп-ра размягчения (°C) | 900–1700 | 950 | 900–950 | 950 | – | – |
| 14 Термостойкость (°C) | 200–1100 | 250 | 250 | – | – | 240 |
| 15 Теплопроводность (ккал/м·час·°C) | – | 1,0–1,2 | 1,0–1,2 | 0,07–0,15 (при объемном весе 0,3–0,6) | 0,9 при толщине панели 160–170 мм | 1,0–1,2 |
| 16 Теплоемкость (ккал/кг·°C) | 0,17–0,2 | 0,17–0,2 | 0,17–0,2 | 0,18 | – | 0,2 |
| 17 Влагопоглощение (%) | 0 | 0 | 0 | 5–7 | – | – |
| 18 Химич. стойкость к серной кислоте (%) | | | 99,8 | | | |
| 19 Диэлектрич. постоянная при частоте 10¹⁰ гц | 4,5–8,0 | 6,2–7,0 | – | – | – | – |
| 20 Тангенс угла диэлектрич. потерь при частоте 10¹⁰ гц | 0,001–0,02 | 0,004–0,007 | – | – | – | – |
| 21 Рабочая темп-ра (°C) | | | до 750 | | | |

1) Sitall; 2) sheet slag sitall; 3) corrugated slag sitall; 4) foam-slag sitall; 5) slag-sitall panels; 6) slag-sitall pipes; 7) bulk weight (g/cm3); 8) strength (kg/cm2); 9) on bending; 10) on compression;

11) wear resistance ($kg/cm^2$); 12) coefficient of thermal expansion ($\alpha \cdot 10^{-7} \cdot 1/°C$); 13) softening temperature (°C); 14) heat resistance (°C); 15) thermal conductivity (kcal/m·hr·°C); 16) heat capacity (kcal/kg·°C); 17) moisture absorption (%); 18) chemical stability in sulfuric acid (%); 19) dielectric constant at $10^{10}$ cps; 20) tangent of angle of dielectric loss at $10^{10}$ cps; 21) working temperature (°C); 22) at a bulk weight of 0.4-0.6; 23) at a bulk weight of 0.3-0.6; 24) at a panel thickness of 160-170 mm; 25) up to.

Froth-slag sitall (P) – a new heat-insulating and structural material resembling glass foam in appearance but with a crystalline structure. It can have a uniform foam structure throughout its entire volumn or a foam structure with an underlayer of solid sitall. It is produced in blocks and panels consisting only of foam sitall and sitall – foam-sitall blocks and panels ranging from 300 x 300 x 50-100 mm to 3000 x 6000 x 50-100 mm in size. The faces of blocks are treated on both sides, while sitall – foam-sitall panels are treated on only one side (the porous side).

Slag-sitall panels (ShP), or compacted P, can be used as nonsupporting hung panels for the exterior walls of large-panel public, residential, and noncommercial buildings and as panels for roofing residential buildings. One or both sides of ShP are polished or hammered (having been left untreated after rolling and crystallization) and coated with black or colored ceramic paints. ShP are produced in sizes of 3 x 6, 3 x 9, and 3 x 12 m and have polished faces; they are interchangeable. The panels weigh up to 200 kg each.

Slag-sitall pipes (ShP) can be used for forced or unforced delivery of hot and cold liquids and suspensions (ordinary, agressive, or abrasive), as well as for loose materials. ShT are produced with flared ends, like cast-iron and ceramic pipes, and with thin walls and smooth ends. Flared ShT are joined by the methods used for flared cast-iron and ceramic pipes, while those with smooth ends are joined by the meth-

ods used for glass tubing. Flared ShT are manufactured in the same sizes as cast-iron and ceramic pipes, ranging from 1 to 6 m in length and from 50 to 500 mm in diameter; pipes with smooth ends have walls from 3 to 6 mm thick, while flared pipes have walls from 10 to 30 mm thick.

Basins, sinks, bathtubs, half-baths, wash tubs, pans, and other products can be fabricated from sitall; these are black or white or are coated with ceramic paints of various colors. The design and dimensions of such products are essentially the same as those of articles fabricated from steel or cast iron, but they are no thicker than products fabricated from faience. Sitall sanitary-engineering products have the products of the initial materials. Table 1 shows the characteristics of sitalls, slag sitalls, and foam-slag sitalls.

TABLE 2

Characteristics of Slag-Sitall Insulators

| Параметры 1 | Единица измерения 2 | Фарфоровые изоляторы И-118 Славянского з-да 3 | Ситалловые изоляторы И-11 з-да Автостекло 4 |
|---|---|---|---|
| 5 Сухоразрядное напряжение | 12 кв | 83.8 | 91—102 |
| 6 Микроразрядное напряжение | » | 52 | 58—66 |
| 7 Разрушающая нагрузка на растяжение | кг | 5400—8000 | 5000—9500 |
| 8 Диэлектрич. постоянная материала при частоте 50 гц | 13 — | 14 6.5—7.0 | 6.5—7.5 |
| 9 Разрушающая нагрузка на сжатие | кг | Не испытывались | 21 000—40 000 |
| 10 Тангенс угла диэлектрич. потерь материала при частоте 50 гц | — | 0.058 | 0.028 |
| 11 Вес изолятора | кг | 5.26 | 2.83 |

1) Parameter; 2) unit of measurement; 3) I-118 porcelain insulators produced by the Slavyanskiy Plant; 4) I-11 sitall insulators produced by the Avtosteklo Plant; 5) dry-discharge voltage; 6) microdischarge voltage; 7) tensile strength; 8) dielectric constant at 50 cps; 9) compressive strength; 10) tangent of angle of dielectric loss at 50 cps; 11) weight of insulator; 12) kv; 13) kg; 14) not tested.

Technical sitalls and slag sitalls in white and black can be used as substitutes for porcelain in the manufacture of all types of insula-

tors. These materials have a higher mechanical strength and heat resistance than porcelain. Sitall insulators can consequently be smaller and lighter than porcelain insulators. Despite a reduction in weight by a factor of almost 2, slag-sitall insulators of type I-118-1 are completely acceptable substitutes for porcelain insulators. Table 2 shows the characteristics of slag-sitall insulators.

I.I. Kitaygorodskiy

SLAG INCLUSIONS IN ALUMINUM ALLOYS – see Nonmetallic inclusions in aluminum alloys.

**SLEEVE BRAIDING FILAMENTS** – are spun articles made from cotton, chemical and glass fibers which are used to give sleeves for industrial usage strength and body. Filaments for braiding sleeves must have high strength with low thickness, good bend resistance, elasticity and low elongation at operating loading. Sleeve braiding is performed basically at an angle of 54°44' to the longitudinal axis of the sleeve. Depending

Physical and Mechanical Properties of Filaments for Braiding Sleeves

| Структура нитей 1 | Толщина нитей (не более, мм) 2 | Количество кручений на 1 м 3 | | Минимальная разрывная нагрузка при испытании нити длиной 200 мм (кг) 4 | Удлинение при разрыве (не более, %) 5 | Вес 100 м (г) 6 | Нормальная влажность (%) 7 |
|---|---|---|---|---|---|---|---|
| | | 1-е | 2-е | | | | |
| 12/3 | 0.55 | 220 | – | 3.0 | 9.0 | 25±1 | 8 |
| 12/4 | 0.70 | 200 | – | 4.0 | 11.0 | 39±1 | То же |
| 12/5 | 0.75 | 160 | – | 5.2 | 11.0 | 40±1 | " " |
| 12/6 | 0.80 | 150 | – | 6.5 | 11.0 | 50±1 | " " |
| 20/2/3 | 0.50–0.60 | 640–680 | 230–280 | 4.5 | 8.0 | 30±1 | " " |
| 37/17 | 0.80 | 120 | – | 8.5 | 11.0 | 45+2 −1 | " " |
| 37/17 ОП 9 (особопрочная) | 0.77 | 130 | – | 9.5 | 11.5 | 45+2 −1 | " " |
| 37/6/3 10 | 0.67 | 300 | 100 | 7.5 | 7.5 | 33+2 −1 | " " |
| 37/5/3 ГИ-8 | 0.68–0.72 | 360–300 | 170–190 | 8.0 | 8.0 | 40+2 −1 | " " |
| 37/5/3 ГИ-10 | 0.64–0.70 | 345–300 | 165–185 | 8.5 | 8.5 | 40+2 −1 | " " |
| 40/6 10 | 0.45 | 350 | – | 2.2 | 2.2 | 15+2 −1 | " " |

1) Filament structure; 2) filament thickness (no more than, mm); 3) number of twists per meter; 4) minimal breaking load in testing filament 200 mm long (kg); 5) breaking elongation (no more than, %); 6) weight of 100 running meters (g); 7) normal moisture content (%); 8) same; 9) OP (extra strength); 10) GI.

on the sleeve strength requirements, use is made of 1-3 braids fabricated from cotton filaments for sleeve braiding with number of elements N equal to 12, 20, 37, 40, etc. The physical and mechanical properties of the filaments for sleeve braiding are presented in the table.

Yarn No. 37 made from fine-fibered cotton og groups 1-2 is used for the 37/5/3 GI-8 and 37/t/3 GI-10 filaments. After spinning, the GI-

II-66n1

10 and 20/2/3 filaments are subjected to stretching with thermal fixation.

S.Ye. Strusevich

SLIP – a type of deformation characterized by parallel displacement of one portion of a solid relative to another. This is the basic physical mechanism of plastic deformation. Slip is determined principally by the Tangential stresses. Luders-Chernov lines are traces of slip on individual grains (crystallites). The greatest slip value is the so-called maximum slip. The maximum slip is directed along the surfaces of greatest tangential stresses, which lie at an angle of 45° to the surface of greatest Normal stresses. Under tension the planes of maximum slip are inclined at an angle of 45° to the axis of the specimen; when a cylindrical rod is subjected to torsion these planes are perpendicular to the axis of the specimen and parallel to its genetrix. When substantial plastic deformation is present the slip directions may differ from those noted above as a result of rotation of the slip surfaces.

Ya.B. Fridman

SLIP BANDS – see Luders-Chernov lines.

SLIP LINES – see Luders-Chernov lines.

SMITH DIAGRAM – a graph showing the relationship between the mean and limiting stresses of a cycle (Fig. 1). The Smith diagram is constructed with the aid of Fatigue curves obtained by testing 3-4 series of identical specimens, using different mean cyclic stresses for each series (Fig. 2). The mean stresses and amplitudes lie at points A-D, which correspond to the total durability (the base); these are used to calculate the maximum and minimum) stresses, which are the ordinates of analogous points in the Smith diagram (see Fig. 1). Each base corresponds to its own Smith diagram. The ordinates of the points on the

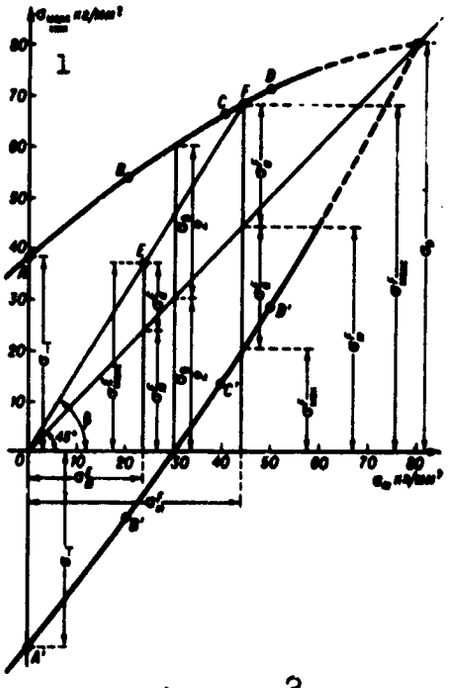


Fig. 1. 1) kg/mm$^2$.

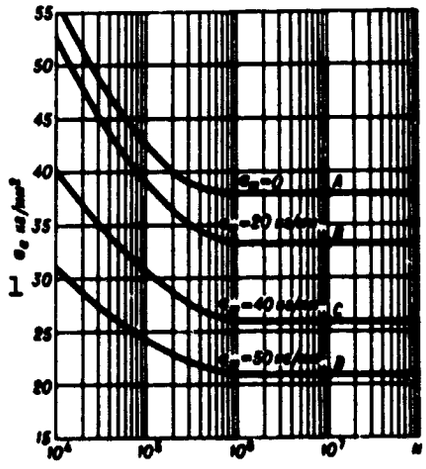


Fig. 2. 1) kg/mm$^2$.

curve AD represent the ultimate strength:

$$\sigma'_{max} = \sigma'_m + \sigma'_a = \sigma_{-1} + \sigma'_m (1 - \psi_\sigma).$$

where

$$\psi_\sigma = \frac{\sigma_{-1} - \sigma_a^F}{\sigma_m^F} = \frac{2\sigma_{-1} - \sigma_0}{\sigma_0}$$

and is the coefficient of the sensitivity of the material or component to the asymmetry of the cycle. The ordinates of the points n the curve A'D' represent the minimum cyclic stresses:

$$\sigma_{min} = \sigma_m - \sigma_a = (1 + \psi_\sigma)\sigma_m - \sigma_{-1}.$$

The ordinates of the points E, which lie between AD and A'D' on the diagram, represent the safe maximum cyclic stresses:

$$\sigma_{max}^E = \sigma_m^E + \sigma_a^E.$$

When the cycles are similar the ratio of the ultimate strength to the maximum safe cyclic strength $\sigma_{max}^E$ is the coefficient of reserve strength, $n_z = \sigma_{maks}^F / \sigma_{maks}^E$; all the foregoing is valid for moderate negative stresses and for tangential stresses.

G.T. Ivanov

SMYVKA – a mixture of organic solvents for removing old lacquer and paint from painted surfaces. Ordinary smyvka, SD (ob.), is most widely used for removing nitrocellulose, oil, and glyphtalic coatings. SD (ob.) consists of 47% acetone, 19% ethylacetate, 7% turpentine, 6% ethyl alcohol, 8% toluol or xylol, 10.8% napthalene, and 2.2% paraffin. Special smyvka, SD (spets.), is used for removing paints based on reversible film-forming agents (perchlorovinyl, nitrocellulose, polyacrylic, etc. materials); this solution consists of 30% acetone, 30% ethylacetate, 10% ethyl alcohol, and 30% toluol or xylol. SD (spets.) with 1.5% phosphoric acid (with a specific gravity of 1.7), 3% ethylcellulose, and 0.5% paraffin added per liter of smyvka has a good washing action with respect to many types of coatings. Its principal drawback is the fact that corrosion may occur when copper, aluminum, or magnesium alloys are exposed to it for prolonged periods. It must consequently be thoroughly removed after the coating has been washed off and care must be taken that it does not get into structural assemblages. Coatings of all types are most effectively removed with AFT-1 smyvka, which consists of 19.5% acetone, 28% toluol, 47% formalglycol, 5% nitrocellulose, and 0.5% paraffin. In order to remove a coating the smyvka is successively applied to individual areas rather than to the entire surface at once, applying it sparingly instead of "flooding" the surface. The smyvka causes the coating to swell and become wrinkled; after the paint has swollen sufficiently it is removed.

I.I. Denker

SODALITE – the mineral sodium chloride aluminosilicate ($3Na_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2NaCl$); it has a Moos hardness of 5.5-6 and a specific gravity of 2.13-2.29. It dissolves in HCl to form silica gel. It can be synthesized from a silicon-alumina gel at 150-450° in the presence of an excess of sodium chloride. Synthetic sodalite has sorptive properties and is capable of ion-exchange reactions, like zeolite. Because of its beautiful blue color sodalite, which is similar in composition to lazurite, is used as an artistic and decorative stone.

References: Barrer, R., White, E., Gidrotermal'naya khimiya silikatov [Hydrothermal Chemistry of Silicates], Chapter 2, Sinteticheskiye kristallicheskiye alyumosilikaty natriya [Synthetic Crystalline Sodium Aluminosilicates], in collection: Fizicheskaya khimiya silikatov [Physical Chemistry of Silicates], translated from English and German, Moscow, 1956; Betekhtin, A.G., Kurs mineralogiya [Course in Mineralogy], 3rd Edition, Moscow, 1961; Field, D.S.M., Sodalite and Apatite in Canada, Canad. Mining. J., 1951, Vol. 72, No. 9.

P.P. Smolin

SODIUM DIVINYL RUBBER (SKB) – is the product of the polymerization of divinyl in the presence of metallic sodium. The molecular weight of the sodium divinyl rubber lies within 10,000 and 900,000. The plasticity of the sodium divinyl rubber depends on the value of the average molecular weight, the polymers with a high molecular weight having a lower plasticity. The sodium divinyl rubbers are subdivided into non-core-type and core-type rubbers, depending on the polymerization method. Besides, the produced rubbers are subdivided into grades differing with regard to the plasticity, the physicomechanical properties and the working methods. Special grades of sodium divinyl rubbers are also delivered: polydiene, dielectric, and foodstuff rubbers. The polydiene rubber is a mixture of sodium divinyl rubber with polydienes (low-molecular polymers of piperylene, hexadienes, etc.). The dielectric rubbers differ from the sodium divinyl rubbers for general purposes in the low alkali content (not more than 0.2%). The foodstuff rubbers, in contrast to all other grades of sodium divinyl rubber, are not prepared with the antioxidant Neozone D, but 2% vaseline oil is added. The specific gravity of the nonfilled sodium divinyl rubber is 0.92. Sodium divinyl rubber is soluble in gasoline, benzene, carbon disulfide, and in a number of aliphatic and aromatic hydrocarbons. The sodium divinyl rubber with a plasticity of 0.45 according to Karer has a specific volume resistance of $10^{14}$-$10^{15}$ ohm·cm. It becomes hardned under the action of oxygen, its strength does increase, and the relative elongation does decrease; at the same time, the solubility of the rubber is lowered. Addition of antioxidants to the rubber inhibits the effect of oxygen. In the fabrica-

tion, the antioxidant phenyl-β-naphthylamine (Neozone D) is added in a quantity of 0.5-1% to the rubber. Sodium divinyl rubber is easily workable in mixing and forming equipments; its technological properties surpass those of all other rubbers. Raw sodium divinyl rubber has an insignificant tensile strength: the tensile strength of nonfilled vulcanized rubbers is equal to 18-22 $kg/cm^2$ at a relative elongation of 550-600%. Addition of active fillers (carbon blacks, for example) into compounds of sodium divinyl rubbers increases strongly the physicomechanical characteristics of the vulcanized rubbers. Vulcanized sodium divinyl rubbers with carbon black as a filler have an ultimate tensile strength of 130-155 $kg/cm^2$ and a relative elongation of 500-600%. The resilience at room temperature is equal to 44-50% for vulcanized rubber without carbon black, and equal to 28-32% for such filled with carbon black. The lower limit of elasticity belongs to the more plastic, the upper one to the less plastic rubbers. Sodium divinyl rubber is widely used for the production of all basic types of rubber products.

References: Borodina I.V., Nikitin A.K., Tekhnicheskiye svoystva sovetskikh sinteticheskikh kauchkukov [The Technical Properties of Soviet Synthetic Rubbers], Leningrad-Moscow, 1952; Koshelev F.F., Klimov N.S. Obshchaya tekhnologiya reziny [The General Technology of Rubber], 2nd edition, Moscow, 1958.

M. D. Gordin

SOFT BRASS is brass which can be pressure worked in the annealed condition. Soft brass is highly plastic. The degree of softness of semimanufactures made from the soft brasses is characterized by the magnitude of the tensile strength and the relative elongation, and for strip and sheet is characterized by the Erichsen penetration depth. The present standards indicate the minimal values of the mechanical properties which the various types of soft brass must have as a function of the composition and form of the semimanufactures. In certain foreign standards for the soft brasses, indications are given not only of the minimal, but also the maximal values of the tensile strength.

For mechanical properties of the soft brasses see articles on Wrought Brass, Brass Ribbon, Brass Tubes, Brass Sheet and Strip, Brass Wire, Brass Rods.

Ye.S. Shpichinetskiy

SOFT BRONZE – pressure-worked bronze annealed at high temperatures to remove all internal stresses and restore its structure. Dispersion-hardening shaping bronzes are referred to as "soft" in the quenched state. Subsequent tempering greatly improves their hardness and strength and reduces their elongation. All these bronzes are readily stamped, bent, etc. The hardness of different soft bronzes varies from 40 to 100 $kg/mm^2$, depending on their composition. Erickson testing has shown the plasticity of a soft-bronze band 0.1-0.25 mm thick to be 7-9 mm (at a punch radius of 10 mm). These alloys are used when components are to be subjected to additional deformation during production (bending, stamping, etc.).

O.Ye. Kestner

SOFTENING TFMPERATURE – see Vitrification temperature.

SOFTENING TEMPERATURE (determination by ring and ball method) - the temperature at which amorphous substances (bitumins, etc.) poured into a ring are deformed by 25 mm under the weight of a ball on heating. The determination is made in accordance with GOST 1424-57.

M.S. Krol'

SOFT MAGNETIC MATERIALS - see Alloys with Special Physical Properties.