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TRANSLATION

NEW NONMETALLIC MATERIALS FOR RADIO EQUIPMENT
MANUAL FOR DESIGNERS

By

Dmitriy Dmitriyevich Churabo

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WRIGHT-PATTERSON AIR FORCE BASE

OHIO

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NEW NONMETALLIC MATERIALS FOR RADIO EQUIPMENT;
MANUAL FOR DESIGNERS

BY: Dmitriy Dmitriyevich Churabo

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CERAMICS

Materials obtained by baking mixtures of different inorganic materials (clay, talc, barium, magnesium oxide, and so forth) under high temperature are called "ceramic materials."

Ceramic materials are characterized by good electric insulation properties (small angle of loss), mechanical simplicity, heat-resistivity and high volume resistivity in the presence of increased temperatures.

High-frequency vacuum-tight ceramic materials

The following belong to the group of the high-frequency vacuum-tight materials which are used in vacuum apparatus:

steatite ceramics of the following types: ordinary steatite. and steatites 11, 52 and 623;

alundum ceramics of the following types: ceramites, 102 and G26.

Composition of ceramic materials, %

Composition (mass) of ceramics	Steatite				Alundum		
	Ordinary Steatite	11	52	623	Ceramite	102	G26
Raw talc	84	--	91.6	47.3	--	4	--
Fired talc	--	70	--	21.2	--	--	--
Alundum	--	--	--	--	--	60	77
Magnesium oxide	--	20	--	3.7	1	--	3
Barium carbonate	10	5	--	11.2	--	8	--
Fired clay	--	--	--	--	69	--	--
Clay	5	5	--	16.6	24.5	25	--
Kaolin	--	--	5.2	--	--	--	--
Barium diborate	--	--	--	--	--	--	15
Boracite	--	--	3.2	--	--	--	--
Potassium carbonate	--	--	--	--	5.5	3	5
Fired alumina	1	--	--	--	--	--	--

Basic Data

Indicators	Steatite ceramics				Alundum ceramics		
	Ordinary Steatite	11	52	623	Ceramite	102	a26
Specific gravity, g/cm^3	2.7	2.7	2.7	3.2	3.2	3.4	3.4
Water absorption, %	0	0	0	0	0	0	0
Average coefficient of linear expansion ($\alpha \cdot 10^7$) in the temperature range:							
20-200°C	66	72	--	64	50	51	56
20-300°C	67	77	--	64	--	54	64
20-400°C	68	79	--	66	--	56	68
20-500°C	70	82	--	67	--	58	74
Heat Conductivity, kgcal/cm.sec.deg.	5	6.9	--	4.5	--	5.6	7.5
Critical point, kg/cm^2:							
stretching	500	--	--	350	500	500	--
compression	5000	--	--	--	700	--	--
bending	1400	--	1700	--	1600-2500	1600	2000
Volume resistivity, ohm·cm., at a temperature of:							
200°C	10^{12}	10^{14}	5.10^{10}	3.10^{11}	--	3.10^{11}	10^{12}
300°C	5.10^{10}	10^{12}	6.10^{9}	2.10^{10}	5.10^{10}	3.10^{9}	3.10^{10}
400°C	4.10^{8}	3.10^{10}	6.10^{7}	4.10^{8}	--	1.10^{8}	1.10^{8}
500°C	5.10^{7}	2.10^{9}	3.10^{6}	3.10^{7}	--	1.10^{7}	2.10^{7}
Dielectric strength at 20°C and 50 hertzs	6	7	5	5	8	6	7

Basic Data (Continued)

Indicators		Steatite ceramics				Alundum ceramics		
		Ordinary Steatite	11	52	623	Ceramite	102	G26
Tangent of the dielectric loss angle. tg $\delta \cdot 10^4$ at:								
Wave length m	Temperature °C							
300	20	7	3	3	9	--	9	3
300	300	16	9	18	34	--	36	8
10	20	40	40	--	40	--	40	10
10	100	--	50	--	--	--	--	--
10	200	--	70	--	--	--	50	--
10	300	--	80	--	--	--	70	--
Firing temperature °C		1350	1380	1290	1320	1380	1340	1370

Forsterite

Forsterite is a high-frequency vacuum-tight dielectric ceramic material; dimagnesium silicate is its base; it is obtained by simultaneous firing of talc and magnesium oxide.

Forsterites of the types 11, F-56, LF-11, T-17, FP-56 and K-2 (cordierite) have very low dielectric losses, varying with frequency and temperature increase. These materials have a greater (relative to steatites) coefficient of expansion. This makes possible almost perfect joints when they are combined with metals, titanium in particular. The firing temperature of forsterite materials reaches 1350-1400° C.

Basic data

Specific gravity	2.8 g/cm^3
Water absorption	0—0.2%
Thermoresistivity	poor
Softening temperature	1350—1400°C
Coefficient of linear expansion	$(90 \div 100) \cdot 10^{-7}$
Critical point:	
rupture	550—800 kg/cm^2
compression	5600—6800 kg/cm^2
bending	1250—1600 kg/cm^2
Mohs hardness	7.5 kg/cm^2
Electric stability	9-10 kv/mm
Dielectric strength at 25° C and 50 hertz	6—6.5
Tangent of the dielectric loss angle at 25° C and 50 hertz	$(3 \div 5) \cdot 10^{-4}$

Steatite

Steatite materials of the types: ordinary, LB(BK-92), 623 (No. 7) are high-frequency vacuum-tight ceramic dielectrics which are obtained by firing objects formed from pure talc or from talc with various additives in air at the temperature 1230-1350° C. As a result of the firing, materials are obtained which have low dielectric losses, but have low thermoresistivity.

Basic data

Specific gravity	2.7 g/cm^3
Water absorption	0—0.01%
Thermoresistivity	poor
Softening temperature	1300—1400°C
Heat conductivity	6.10^{-3} kgcal/cm·sec·deg
Coefficient of linear expansion in the temperature range: 200—100°C	$64 \cdot 10^{-7}$
200—700°C	$(83 \div 90) \cdot 10^{-7}$
Critical point:	
rupture	210—680 kg/cm^2
compression	3500—6400 kg/cm^2
bending	700—1700 kg/cm^2
Mohs hardness	7.5 kg/cm^2
Electric stability	10—35 kv/mm
Dielectric strength at 50 hertz	5—6.5
Tangent of the dielectric loss angle at 50 hertz	$(3 \div 30) \cdot 10^{-4}$

Steatite ceramics of the types B-17, STs-4, S-55, SK-1

Steatite ceramics on a talc base of the types B-17, STs-4, S-55 and SK-1 are used in the production of ceramic control parts which determine the stability of radio apparatus, as well as of certain types of ceramic condensers.

Steatite B-17 has good dielectric and mechanical indicators. It is used for control parts of small size produced by pressing, stamping and heat casting in metal molds.

Basic data

Indicators	Magnitude of indicators			
	B-17	STs-4	S-55	SK-1
Specific gravity, g/cm^3	2.9—3	3	3	3.18
Coefficient of linear expansion in the temperature range 20-100° C	$7—7.5 \cdot 10^{-6}$	--	$6.5—7 \cdot 10^{-6}$	$6.5 \cdot 10^{-6}$
Tensile strength under bending, kg/cm^2	1400—1500	1400—1800	1600—2000	1560
Volume resistivity at 100 ± 5°C, ohm·cm	$6 \cdot 10^{12}$	$10^{12}—10^{-13}$	$1 \cdot 10^{13}$	$1 \cdot 10^{15}$
Electric stability, kv/mm	20	25—29	20	65
Dielectric strength at 10^6 hertz	6—6.5	6.5—7	6—7	7.05
Tangent of the dielectric loss angle at 10^6 hertz:				
at 20 ± 5°C	0.0006—0.0008	0.0003—0.0005	0.0003—0.0006	0.0006
at 80 ± 5°C	0.0008—0.0009	0.0003—0.0005	0.0006—0.0007	--
Firing temperature, °C	1350	1280	1280	1350
Shrinkage coefficients upon firing at water bond:				
contour	1.11—1.12	1.23—1.29	1.24—1.26	--
height	1.12—1.15	1.16—1.19	1.17—1.18	--

Steatite STs-4 is used for high-voltage condensers produced by drawing, pressing, stamping and heat casting.

Steatite S-55 is used for high-frequency control parts and condensers formed by drawing.

Steatite SK-1 is distinguished by higher electric characteristics than the other steatites, especially by electric stability and volume resistivity. These properties, as well as the loss-angle tangent, can be preserved even with increased temperature. Radio parts which work under high stress and increased temperatures, high-voltage, high-frequency insulators, lamp panels, bases for fabricated condensers, et cetera, are made from steatite SK-1.

Production methods are limited to pressing, stamping and heat casting.

Steatite S-61

Steatite S-61 belongs to control ceramics. It is a soft material with a barium glass-phase. It is used for high-frequency insulators and other objects which work under conditions of increased temperature (up to 300° C).

Basic data

Specific gravity	3.08 g/cm^3
Coefficient of linear expansion	$0.67 \cdot 10^{-5}$
Tensile strength under bending	1470 kg/cm^2
Volume resistivity	$1 \cdot 10^{15}$ ohm·cm
Electric stability	64 kv/mm
Dielectric strength at:	
50 hertz	6.9
10^6 hertz	6.6
Temperature coefficient of the dielectric constant	$+80 \cdot 10^{-6}$

Tangent of the dielectric loss angle at 10^6 hertz:

at 20°C	0.0006
at 100°C	0.0008
at 300°C	0.0023
at 50 hertz	0.0009

Firing temperature 1320°C

Steative SKSh

Steatite SKSh is a hard material with a talc base. It is used for high-frequency ceramic control parts.

Basic data

Specific gravity	3.1 g/cm^3
Coefficient of linear expansion	$0.7 \cdot 10^{-5}$
Tensile strength under bending	1470 kg/cm^2
Volume resistivity	$1 \cdot 10^{15}$ ohm·cm
Electric stability	57 kv/mm
Dielectric strength at:	
50 hertz	7.0
10^6 hertz	6.5
Temperature coefficient of the dielectric constant	$+90 \cdot 10^{-6}$

Tangent of the dielectric loss angle at 10^6 hertz:

at 20°C	0.0008
at 100°C	0.0011
at 300°C	0.0029
at 50 hertz	0.0017

Firing temperature 1310°C

Steatite TK-21

Steative TK-21 is a soft material with a calcium glass-phase. It is used for insulators of various designs and dimensions.

Basic data

Specific gravity	2.31 g/cm^3
Coefficient of linear expansion	$0.7 \cdot 10^{-5}$
Tensile strength under bending	1590 kg/cm^2
Volume resistivity	$2 \cdot 10^{14}$ ohm·cm
Electric stability	42.5 kv/mm
Dielectric strength at:	
50 hertz	6.4
10^6 hertz	6.35
Temperature coefficient of the dielectric constant	$+125 \cdot 10^{-6}$
Tangent of the dielectric loss angle at 10^6 hertz	
at 20°C	0.0017
at 100°C	0.0027
at 300°C	0.0087
at 50 hertz	0.0040
Firing temperature	1290°C

Zircon

Zircon is a high-frequency vacuum-tight ceramic dielectric. Zircon, with a zircon content of up to 60%, serves as the basic raw material for zirconic materials. All zirconic materials which possess zero porosity are very hard and abrasive, which gives great difficulties for the preparation and fabrication of the parts after their firing.

Basic data

Specific gravity	3.1 g/cm^3
Porosity (to water absorption)	0—0.2%
Thermoresistivity	satisfactory
Coefficient of linear expansion:	
at 200—100°C	$32 \cdot 10^{-7}$
at 20—700°C	$45 \cdot 10^{-7}$
Critical point:	
rupture	800—1200 kg/cm^2
compression	6400—12000 kg/cm^2
bending	1600—1850 kg/cm^2
Mohs hardness	8
Electric stability	10—20 kv/mm
Dielectric strength at 25° C and 50 hertz	7.2
Tangent of the dielectric loss angle at 25° C and 50 hertz	$(8 \div 9) \cdot 10^{-4}$
Softening temperature	1400—1450°C

Radio control ceramics

Radio control ceramics--radio-porcelain, pyrophyllite ceramics, ultra-porcelain, radio-steatite, aluminum oxide, zirconic porcelain--are used for control parts with great mechanical simplicity. Basic data are given in the table ~~(see page 140)~~.

Ultra-porcelain UF-50

Ultra-porcelain UF-50 belongs to earth clay ceramics. It is used for control parts with high mechanical simplicity and thermoresistivity, and also for high-frequency condensers.

Basic data

Specific gravity	3.2—3.4	g/cm^3
Coefficient of linear expansion at the temperature range from 20 to 100° C	$0.7 \cdot 10^{-5}$	
Tensile strength under bending	2600—3200	kg/cm^2
Volume resistivity	$(1 \div 9) \cdot 10^{13}$	ohm·cm
Electric stability	25—30	kv/mm
Dielectric strength at 0.5-5 mhertz	8—8.5	
Temperature coefficient of the dielectric constant at the temperature range 20-80° C at 0.5-5 mhertz	$+(110 \div 130) \cdot 10^{-6}$	
Tangent of the dielectric loss angle at 1 mhertz:		
at 20°C	0.0003—0.00006	
at 80°C	0.0006—0.0008	
at 200°C	0.0007—0.0009	
at 300°C	0.0009—0.0015	
Firing temperature	1340±20°C	

Ultra-porcelain UF-53

Ultra-porcelain UF-53 belongs to earth clay ceramics. It is used as a vacuum-tight ceramic and also for high-frequency condensers and for control parts with high mechanical simplicity.

Basic data

Specific gravity	3.2—3.4	g/cm^3
Coefficient of linear expansion at the temperature range from 20 to 100° C	$0.5 \cdot 10^{-5}$	

Tonsile strength under bending	2700—3200 kg/cm^2
Volume resistivity	$(3 \div 9) \cdot 10^{-13}$ ohm·cm
Electric stability	25—30 kv/mm
Dielectric strength at 0.5-5 mhertz	8—8.5
Temperature coefficient of the dielectric constant at the temperature range 20-80°C at 0.5-5 mhertz	$+(110 \div 30) \cdot 10^{-6}$
Tangent of the dielectric loss angle at 1 mhertz	
at 20°C	0.0003—0.0005
at 80°C	0.0004—0.0006
at 200°C	0.0009—0.0012
at 300°C	0.0012—0.0013
Firing temperature	1360±20°C

Technical porcelain

Technical porcelain—high temperature, low temperature, control, chemically stable, thermostable, pyrometric, high durability—is used for control parts (of the type of insulators) with high mechanical simplicity.

Basic data

Indicators	Radio porcelain	Pyrophyllite ceramics	Ultra-porcelain	Radio-steatite	Aluminum oxide	Zirconic porcelain
Specific gravity, g/cm^3	2.5—2.6	2.5	2.9	2.5—2.6	3.8	3.68
Tensile strength under stretching, kg/cm^2	100—300	100—180	100—450	450—600	600	900
Same under static bending, kg/cm^2	500—700	500—700	1200—1400	1200—1600	1200—2000	1750
Same under compression, kg/cm^2	4000—5000	4000—5000	6000—8000	6000—8000	8000—10000	6500
Heat conductivity, kgcal/cm·sec·deg	0.015	0.015	0.003	0.02	0.03—0.05	--
Coefficient of linear expansion	$4 \cdot 10^{-6}$	$(5 \div 10) \cdot 10^{-6}$	$4.5 \cdot 10^{-6}$	$7 \cdot 10^{-6}$	$7 \cdot 10^{-6}$	$4.9 \cdot 10^{-6}$
Surface resistivity at 20-25° C and relative humidity 70%, ohm	10^{11}—10^{12}	10^{11}—10^{12}	10^{12}	--	10^{12}	--
Volume resistivity at 20-25°C, ohm·cm	10^{13}—10^{15}	10^{15}—10^{16}	10^{16}	--	10^{18}	--
Electric stability at 20-25°C and 50 hertz, kv/mm	15—20	15—20	15—30	23—25	15	--
Dielectric strength	5.6—6.5	6.5—6.0	6.5—7.0	6.0—6.5	9—10	9.3

Basic data (Continued)

Indicators	Radio porcelain	Pyrophyllite ceramics	Ultra-porcelain	Radio-steatite	Aluminum oxide	Zirconic porcelain
Temperature coefficient of dielectric strength	$(2\div3)\cdot10^{-4}$	$4\cdot10^{-4}$	$(1\div1.2)\cdot10^{-4}$	10—15	$(1.2\div1.5)\cdot10^{-4}$	--
Tangent of the dielectric loss angle at 1-36 mhertz and 20-25°C	0.003—0.006	0.005—0.007	0.0005—0.601	0.003—0.0009	0.0001—0.0005	0.0011
Onset temperature of the dielectric loss angle increase, °C	150—190	100—110	--	--	450	--

Basic data

Type of porcelain	Mobs hardness	Fire Resistivity °C	Specific gravity, g/cm3	Volumetric weight g/cm3	Water absorption %	Dielectric strength
High-voltage	7	1580	2.5	2.40—2.45	0.0	8.5
Low-voltage	6	1580	2.48	2.2	0.0—0.3	5.8
Control	6	1560	2.48	2.25	0.0—0.3	5.7
Chemically stable	7	1660	2.50	2.32	0.0	8.0
Thermostable	6	1600	2.60	2.5	0.0—0.3	9.46
Pyrometric	7	1770	2.60	2.43—2.45	0.0—0.1	12.4
High durability	7	1620	2.60	2.56—2.60	0.0—0.1	9.65

Type of porcelain	Electric stability, kv/mm	Coefficient of linear expansion (20—700°C)·10-6	Thermal stability under change of temperature (fall of temperature from 200 to 17°C)	Critical point of unglazed porcelain, kg/cm^2		
				Under impact bending	Under bending	Under compression
High-voltage	14	3.75	6—8	1.8—2.0	600	4500—5000
Low-voltage	--	3.80	6—8	1.8	620	4000
Control	--	3.80	6—8	1.8	580	3500—3600
Chemically stable	14	3.40	10	1.8	700	5000
Thermostable	12	--	20—30	2.2	650	4000
Pyrometric	8	4.10	6—8	2.5	850	5000—5200
High durability	14	3.90	6—8	2.5	750	6600—7000

Basic data

Properties	Ceramics							
	Tricond T-80	Tricond T-60	Tricond T-30	Tricond T-25	Thermocond TK-M	Tiglin	Thermocond	Titano-barium ceramics
Area of use	High voltage contour and separating condensers		Small size compensating contour and fabricated condensers		Condensers for low-power stable oscillation contours			Condensers replacing low-capacity paper condensers and special condensers
Dielectric loss angle at radio-frequencies t = 20°C	1—2	1—2	2—3	1—2	1—2	2—4	1—2	50—70
t = 100°C	2—4	2—4	3—4	2—3	2—3	4—6	2—3	--
Dielectric strength	75—80	55—80	25—30	25—30	20—25	12—14	15—20	--
Temperature coefficient of the dielectric strength ($X10^{-6}$)	—(730±70)	—(570±70)	—(300±70)	—(130±50)	—(50±30)	—(40+20)	+(30±30)	Variable
Volume resistivity, ohm·cm t = 100°C	10^{12}—10^{13}	10^{12}—10^{13}	$5\cdot10^{12}$—$5\cdot10^{13}$	10^{12}—10^{13}	10^{13}—$5\cdot10^{13}$	10^{13}—$5\cdot10^{13}$	10^{13}—$5\cdot10^{13}$	10^{11}
t = 300°C	10^{9}—10^{10}	10^{9}—$5\cdot10^{9}$	$5\cdot10^{9}$—10^{10}	10^{10}—$5\cdot10^{10}$	10^{10}—$5\cdot10^{10}$	10^{10}—10^{11}	10^{10}—10^{11}	$5\cdot10^{7}$
Electric stability under constant pressure, kv/cm	100	100	100	100	100—150	100—150	100—150	20—40
Coefficient of linear expansion	$7.5\cdot10^{-6}$	$7.5\cdot10^{-6}$	$6.5\cdot10^{-6}$	$6.4\cdot10^{-6}$	$5.8\cdot10^{-6}$	$5.8\cdot10^{-6}$	$5.0\cdot10^{-6}$	--
Specific gravity, g/cm^3	3.9	3.8	3.3	3.9	4.0	3.0	2.9	5.0

Condenser ceramics

Condensers ceramics--tricond T-80, T-60, T-30, T-25, thermocond TK-M, tiglin--are used for small-size high-voltage condensers and other similar ones.

The basic data are given in the table (see page 17).

Vacuum ceramics

Vacuum ceramics--porous aluminum oxide and radio-steatite--are used for parts for electro-vacuum apparatus.

Basic data

Indicators	Magnitude of the indicators	
	Porous aluminum oxide	Porous radio-steatite
Specific gravity, g/cm^3	2.5	2
Coefficient of linear expansion	$5.5 \cdot 10^{-6}$	$8 \cdot 10^{-6}$
Tensile strength under bending, kg/cm^2	600—800	350—550
Resilience, $kg \cdot cm/cm^2$	2—3	1.5—2
Volume resistivity at temperature 100°C, ohm·cm	10^{13}	10^{13}
Dielectric strength	5—6	4—5
Loss angle with radio-frequencies at temperature 20°C, min	0.5—1	0.1—1.5
Temperature coefficient of dielectric strength in the range 200—300°C	$+140 \cdot 10^{-6}$	--

Pyrophyllite

Pyrophyllite is a ceramic dielectric. Before firing it can be subjected to any kind of processing, after firing it can be ground.

Basic data

Specific gravity	2.5 g/cm^3
Water absorption	0.2%
Working temperature limit	1000°C
Coefficient of linear expansion	$5 \cdot 10^{-6}$
Tensile strength	
under bending	600 kg/cm^2
under compression	6000 kg/cm^2
under stretching	100 kg/cm^2
Surface resistivity	$1 \cdot 10^{12}$ ohm
Volume resistivity	$1 \cdot 10^{15}$ ohm·cm
Electric stability at 50 hertz	15 kv/mm
Dielectric strength at 50 hertz	6
Tangent of the dielectric loss angle at 10^6 hertz	$6 \cdot 10^{-3}$

Ceramic masses KM-1 and K-20

Ceramic masses KM-1 and K-20 are corundomullite ceramics, and are characterized by good plasticity and high electric and mechanical simplicity.

Mass KM-1 is used for control parts, high-voltage low-frequency condensers, mass K-20, for large control parts and high-frequency condensers.

Basic data

Indicators	Magnitude of indicators	
	KM-1	K-20
Specific gravity, g/cm^3	3.0	3.2
Coefficient of linear expansion at temperature range from 20 to 100°C	$(0.32\div0.35)\cdot10^{-5}$	$(0.35\div0.4)\cdot10^{-5}$
Tensile strength under bending, kg/cm^2	1800—2200	1500—1800
Volume resistivity at 100°C, ohm·cm	1.10^{13}—$1\cdot10^{14}$	$9\cdot10^{12}$—$1\cdot10^{13}$
Electric stability, kv/mm	30—35	30
Dielectric constant at 0.5-5 mhertz	6.8—7.4	7.2—7.5
Temperature coefficient of the dielectric constant at the temperature range 20—80°C	$+(110\div30)\cdot10^{-6}$	$+(80\div100)\cdot10^{-6}$
Tangent of the dielectric loss angle at 1 mhertz		
at 20±5°C	0.0014—0.0018	0.0004—0.0007
at 80±5°C	0.0020—0.0024	0.0007—0.0010
Firing temperature, °C	1350±20	1380±20

Fifth Section

GLASS

Glass is a transparent, amorphous, thermoplastic substance of inorganic origin. Various oxides (silicates) enter into the composition of inorganic glass. A typical characteristic of glass is its gradual transformation from a solid to a liquid state, and vice versa, i.e., the absence of a sharply defined melting point.

Organic glass is a totally colorless, transparent, thermoplastic material, with a polymethylacrylate base; it is produced in sheets of various thicknesses.

Organic glass ST-1 and ST-2-55

(ST-1 VTU MHP BU 11-57 and ST-2-55 RTU MHPBU-27-56)

Glass ST-1 and ST-2-55 can be worked at higher temperatures (up to +150°C) than the serial organic glass SOT (polymethylphtalate, plasticized by a 6% dibutylphtalate).

Glass dissolves in acetone, and does not swell in oil; only glass ST-2-55 swells in benzine (0.08%).

Basic data

Indicators	Magnitude of indicators	
	ST-1	ST-2-55
Specific gravity, g/cm^3	1.18	1.19
Thermostability, °C	110—120	130—135
Coefficient of linear expansion ($\cdot 10^6$) at:		
20°C	77	69
100°C	115	84
Index of refraction	1.48	1.48
Tensile strength, kg/cm^2		
under static bending	1207	1212
under static stretching	780	923
Specific elongation, %	4	3.3
Stretching rigidity modulus, kg/cm^2	32,100	41,600
Resilience, kg·cm/cm^2	12.5	14.6
Brinell hardness, kg/mm^2	23.7	29.9
Swelling after 7 days in water, %	0.4	0.65

Technological indications

Glass ST-1 is glued with a dichlorethane based glue, and glass ST-2-55 with V31-F9 glue.

Glass can be subjected to any kind of mechanic processing, and also to welding. The welding is done at a temperature of 180—200°C in 20-30 min at a pressure of 10-15 kg/cm^2.

Organic triplex of the types OT-16 and OT-ST-1

(VTU 20-58)

Organic triplex is prepared from organic glass and elastic coating; a special under-layer is used to fuse them firmly. When the under-layer is used, the fusion will bear more than 100 kg/cm^2 at normal temperatures; with an increase in temperature its strength is less, and with a decrease it is greater. The thickness of the coating depends on the thickness of the triplex; thus, for example, the thickness of the coating will be of 2 mm for a triplex thickness of 10 mm.

Parts made of organic triplex are molded at the temperatures: for OT-16 thermostat at 125±2°C for 30 min, for OT-ST-1 at 160±2°C for 20 min. Organic triplex and glass each admit visible rays of the spectrum; organic glass is more transparent to ultra-violet rays. Mechanical processing, gluing and other technological operations are similar to those used for producing parts from organic glass.

A comparison of the mechanical properties of organic triplex with glass at different temperatures is given in the following table.

Materials	Tensile strength under rupture, kg/cm^2, and specific elongation, %						Tensile strength under compression, kg/cm^2	Brinell hardness, kg/mm^2	Tensile strength under bending, kg/cm^2: of a flat sample	Tensile strength under bending, kg/cm^2: of a sample with a cut 1 mm deep	Tensile strength under shearing, kg/cm^2	Rigidity modulus E, kg/cm^2
	Temperature °C											
	-60		+20		+60		+20					
OT-16	750	1.3	625	6.3	254	17	1026	22	990	453	103.5	26,000
OT-ST-1	1060	2.2	675	4	410	4.5	1188	21	970	—	100	25,800
Organic glass	1100	0.5	700	3.5	400	20	1280	22	990	—	—	29,000

Resilience at various temperatures, kg·cm/cm^2

Temperature, °C	-60	-40	-20	0	+20	+40	+60	+80	+100
OT-16	17.4	15	16.3	16.2	16.2	37.1	29.2	24.2	51.5
OT-ST-1	16.9	16.7	15.7	15.1	16.2	18.8	40.5	23.2	36.3

Organic aviation glass ST-1

(RTU-BU-115-55)

Organic glass of the type ST-1 is a nonplasticized polymer of methyl methacrylate, containing a phenyl salicylate additive.

Glass of the type ST-1 is prepared by casting in molds. Two kinds of organic glass A and B are produced, depending on the surface and optical distortion.

Dimensions (mm):	Allowance by thickness:
4x1400x1600	
7x1400x1600	for 4±0.7 mm
8x1400x1600	for 7.8 and 10 mm+1-0.65 mm
10x1400x160	for 18±1 mm
18x1100x1250	

Type A glass may be distinguished from type B by the data shown in the table, for optical properties.

Basic data

Brinell hardness	21 kg/mm^2
Resilience	12 $kg \cdot cm/cm^2$
Tensile strength under stretching	780 kg/cm^2
Specific elongation	3%
Rigidity modulus under stretching	29,000 kg/cm^2
Softening temperature	100°C
Pellucidity	91%
Photoluminescence after exposure to ultraviolet light	2.5%
Silver stability	In the sheets "visible silver" must not appear during storage, transportation and firing before molding.

Thickness of the sheets, mm	Type A		Type B	
	Angular distortion	Displacement of the image	Angular distortion	Displacement of the image
4, 7, 8 & 10	6	2	8	3
18	8	2	9	3

Note: Optical indicators are not regulated for the distance of 35 mm from the edge of the sheet.

Glass S-88-13

(NIO.027.622 MRTP)

Glass S-88-13 is used for electro-vacuum apparatus.

Basic data

Coefficient of linear expansion (in the temperature range 20-100°C)	$89 \cdot 10^{-7}$
Softening temperature	570°C
Thermal stability	125°C
Upper limit of the firing zone	505°C
Lower limit of the firing zone	385°C
Temperature at which the volume resistivity of the glass equals 100 milliohms·cm	240°C
Tangent of the dielectric loss angle at 6 mhertz and 29°C	$50 \cdot 10^{-4}$
Chemical stability	IV hydrolytic class

Glass ZS-11

(NIO.027.621 MRPT)

Glass ZS-11 is used for electro-vacuum apparatus.

Basic data

Coefficient of linear expansion (in the temperature range 20-100°C)	$40 \cdot 10^{-7}$
Softening temperature	620°C
Thermal stability	260°C
Upper limit of the firing zone	520°C
Lower limit of the firing zone	385°C
Temperature at which the volume resistivity of the glass equals 100 milliohms·cm	300°C
Tangent of the dielectric loss angle at 6 mhertz and 20°C	$40 \cdot 10^{-4}$
Chemical stability	IV hydrolytic class

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