D. A. Ramey B-83

Properties of Selected Commercial Glasses

CORNING GLASS WORKS
CORNING, NEW YORK

Contents

Foreword

In presenting the data contained in this booklet, Corning Glass Works recognizes the expanding use of its products by engineers and designers. From the almost numberless varieties of glass that have been developed for special applications, we have selected a few of the more important ones for the present purpose. Mechanical, electrical, chemical and other properties are included wherever such data are currently available.

An important difference exists between various glass compositions as to price and availability. This is due to the greater total use of some and the consequent employment of larger melting and forming facilities. Except when special characteristics are necessary for electrical, optical or other reasons, use of the high-production glasses is generally recommended. Examples of such general purpose glasses are:

Glass 0010—PYREX Brand Clear Potash Soda Lead. Principal use is for lamp tubing because of excellent electrical properties.

Glass 0080—CORNING brand Soda Lime. For general service where heat resistance is not of prime importance.

Glass 0120—PYREX Brand Clear Potash Soda Lead. Available as tubing or multiform. Excellent electrical properties.

Glass 6720—CORNING brand White Opal.

Glass 7740—PYREX brand Clear Resistant Borosilicate. For industrial or domestic service where resistance to heat, corrosion and abrasion are important.

Glass 7900—VYCOR brand Clear High Silica. For service at temperatures over 250°C. and up to 800°C. or where ultra-severe thermal shocks will be encountered.

With its long experience in countless problems of glass utilization, Corning Glass Works is prepared to render invaluable service and advice to its customers. We sincerely hope that you will look to Corning for the solution to all of your problems involving glass use and glass composition.

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Introduction

Glass is a noncrystalline material that has no regular internal structure. It is rigid at ordinary temperatures and soft or almost fluid at high temperatures. It has no definite freezing point, but becomes solid because its viscosity increases progressively to values which, for all practical purposes, are infinitely great.

Although silica sand (SiO_2) is a principal ingredient of most glasses, melting economy and flexibility of properties require the addition of other melting agents and modifiers. Thus, depending on the choice of these additional constituents, glasses can be classified into several groups with characteristic properties.

Soda lime glasses (or lime glasses) used for lamp envelopes, bottles, and window glass are melted from silica that has been fluxed with lime (CaO), and soda (Na_2O) plus small quantities of other oxides. A typical lime glass composition is approximately as follows:

Silica—SiO_2	72%
Soda—Na_2O	15%
Lime—CaO	9%
Magnesia—MgO	3%
Alumina—Al_2O_3	1%

Lime glasses are low in cost, easily hot-worked and are usually specified for service where high heat resistance and chemical stability are not required.

Lead glasses are used for electric light bulb stems, neon sign tubing, crystal tableware and certain optical components. A typical composition is given below:

Silica—SiO_2	68%
Lead Oxide—PbO	15%
Soda—Na_2O	10%
Potash—K_2O	6%
Lime—CaO	1%

Lead glasses are useful because of their good hot workability, high electrical resistivity and high refractive indices. Dense lead glasses serve as shields to cut off X-rays and gamma radiations.

Borosilicate glasses are used for baking and cooking dishes, chemical laboratory glassware, boiler gauge glasses, glass pipe, etc. Their compositions are usually similar to the following:

Silica—SiO_2	80%
Boric Oxide—B_2O_3	14%
Soda—Na_2O	4%
Alumina—Al_2O_3	2%

Reasonable manufacturing cost coupled with high chemical stability, low coefficients of thermal expansion, high heat shock resistance and excellent electrical resistivity make borosilicate glasses the best choice for most industrial applications.

Glasses composed almost entirely of silica are made by chemically removing the flux from a borosilicate glass after it has been melted and formed to the desired shape. Since removal of the flux leaves voids in the glass it is necessary to consolidate each piece by an additional firing operation. Considerably more expensive than the other three types of glass, its principal applications are at high temperatures since it does not begin to soften until it reaches 1000°C. and can be regularly used at temperatures as high as 800°C. The low thermal expansion coefficient of such high silica glass enables it to easily withstand the most severe thermal shocks. Its chemical composition is:

Silica	96% at least
Boric Oxide	3% at most
Other oxides	1% at most

COLORED GLASSES

Lime, lead and borosilicate glasses can all be colored by the addition of metallic oxides that become suspended or dissolved in the parent glass without substantially changing its chemical composition or physical properties.

Glasses are so different from metals that some discussion of their physical properties is necessary before the engineer can properly appreciate the data given in Table 2 (pages 8 and 9). For example, shear strength means much when associated with metals but it has little or no significance in glasses. Similarly, hardness of glasses must be measured and reported in terms that rarely apply to ductile materials. These notes discuss the specific properties of glass that require explanation before they can be correctly evaluated from tabulated data.

Mechanical Properties

STRENGTH

Glass, like other ceramics, is a brittle material. Thus, it does not plastically deform before failure and it fractures only from tensile stresses, never from shear or compression. The stress-strain curve for glasses is a straight line up to the breaking point.

The intrinsic strength of all glasses is extremely high, possibly as much as 3,000,000 p.s.i. Glass fibers have supported tensile stresses of over 1,000,000 p.s.i. The useful or everyday strength of glass is but a small fraction of the above figures because of stress concentrations due to surface imperfections. A rod of glass with perfect surfaces may be as strong as steel, but normal handling introduces surface imperfections that limit its ultimate strength to about 10,000 p.s.i. Another consequence of surface faults is the introduction of a time factor, so that glass is stronger under momentary loading than under prolonged stresses.

When an adequate safety factor is provided, the prolonged working stress for annealed glass is taken as 1,000 p.s.i. and for tempered, or thermally strengthened glass as 2,000 to 4,000 p.s.i., depending on the piece in question. It should be noted that the composition of glass has no practical effect on its strength although most borosilicate glasses resist scratching and therefore usually give better mechanical service. The above figures can be used for all commercial glasses.

ELASTICITY

For all ordinary purposes it can be assumed that glass is perfectly elastic up to the point of fracture. The Young's Modulus of elasticity varies from 6 to 13,000,000 p.s.i. but most commercial glasses have values between 9 and 10,000,000 p.s.i. Values are listed in Table 2.

Poisson's ratio can be taken as 0.20, since it is seldom less than 0.18 or more than 0.22.

HARDNESS

The hardness of glass cannot be measured by the Brinell or Rockwell machines but is usually evaluated by scratch tests or impact abrasion tests.

On the Mohs scale of scratch hardness glasses lie between apatite, (5) and quartz, (7). Some common materials that are hard enough to scratch glass include agate, sand, carborundum, hard steel and emery. Glasses are harder than mica, mild steel, copper, aluminum and marble.

Impact abrasion resistance of glasses is evaluated by measuring their resistance to sandblasting under standard conditions. Values recorded are relative only, showing resistance as compared to soda lime plate glass which is arbitrarily given a value of unity. Data for various glasses are listed in Table 2.

Thermal Stresses

STEADY STATE THERMAL STRESSES

Stresses due to steady state thermal gradients can be either innocuous or dangerous, depending entirely on the degree of constraint imposed by some parts of the item upon others or by the external mounting. Thus under minimum constraint and maximum uniformity of gradient through the thickness, very large temperature differences can be tolerated. Under complete constraint, the tensile stress on the cool side depends only on the temperature difference and on the glass properties (expansion, elastic and thermal) and can be calculated. The formula is:

$$S = \frac{\alpha E \Delta T}{2 (1 - \mu)}$$

where

S = maximum stress (tension on cooler surface, compression on hotter surface)

α = coefficient of linear thermal expansion

E = Young's Modulus of elasticity

μ = Poisson's ratio, and

ΔT = temperature differential between the two surfaces.

When complete constraint is imposed, it is important to know the temperature difference that approaches the danger point of $S = 1{,}000$ p.s.i.

This is $$\Delta T_{1000} = \frac{2000 (1 - \mu)}{E\alpha}$$

Column 9, Table 2, lists for tubes and constrained plates, the face to face temperature differentials that will cause a tensile stress of 1,000 p.s.i. on the cooler face.

For glass 7740 the listed figure is 48°C. Therefore a furnace sight glass in a fully constraining frame with an inner surface temperature of 148°C. and an outside face temperature of 100°C. will be under a tensile stress of 1,000 p.s.i. at the outside surface.

It must be remembered that temperature differential means temperature difference between the two glass surfaces, exclusive of gradients across the surface itself. In air, particularly, an appreciable difference exists between surface temperature of the glass and of the air moving past it.

TRANSIENT THERMAL STRESSES

When glass is suddenly cooled, such as by removal from a hot oven, tensile stresses are introduced in the surfaces and compensating compressional stresses in the interior. Conversely, sudden heating leads to surface compression and internal tension. In either case the stresses are temporary (transient) and disappear on attainment of temperature uniformity. Since the strength of glass is greater under momentary stress than under prolonged load, thermal shock endurance cannot be directly calculated but is generally determined by empirical testing.

Since glass fails only in tension, and usually at the surface, the temporary stresses from sudden cooling are much more damaging than those resulting from sudden heating, assuming of course, that all surfaces are heated or cooled at the same time.

The transient thermal stresses increase directly with expansion coefficient and in a complex way with glass thickness. They also depend upon the shape of the article and on the method of chilling or heating. Thus, a complicated shape would be more severely stressed than a simple one. Sudden chilling by immersion in cold water is more rigorous than by blowing with cold air.

Column 8 of Table 2 illustrates the most extreme case: direct plunging into cold water. Cooling into less severe media, such as air, permits much higher temperatures than those listed. When special applications lead to problems in which these data are not useful, the technical services of Corning Glass Works should be employed.

Heat Transmission

THERMAL CONDUCTIVITY

At room temperature the thermal conductivity of glasses ranges from .0016 to .0029 cal./cm./sec./°C., with the most common compositions near the upper end of the range. At a mean temperature of 200°C. the values are greater by 20 to 25%.

For glass 7740, used frequently in heat-transfer applications, the thermal constants are listed below:

Thermal conductivity at 25°C. = 0.0023 cal./(sec.) (cm.^{2}) (°C./cm.)
= 6.7 B.T.U./(hr.) (ft.^{2}) (°F./in.)
= 0.025 watts/ (in.^{2}) (°C./in.)

Mean specific heat (25°–175°C.) = 0.20 cal./(gm.) (°C.) or B.T.U./ (lb.) (°F.)

Thermal diffusivity .... = 0.0056 cm.^{2}/sec.

Emissivity coefficient, radiant energy .... = 0.94

GLASS IN HEAT EXCHANGERS

Although the thermal conductivity of glass is only a small fraction of that of metals, the overall heat transfer is frequently determined largely by film coefficients of heat transfer at the surfaces. This is particularly true where the heat is carried away only by natural air convection. Consequently, where film resistance is high, the thermal efficiency of a heat exchanger equipped with glass tubes may approach that of a similar unit equipped with metal tubes. In addition, the glass surfaces remain free of oxide, and generally of other adhering material, so that its effectiveness does not deteriorate.

In specific cases, the conditions may be analyzed and the overall heat transfer calculated in accordance with accepted methods, such as are given by W. H. McAdams, ("Heat Transmission," McGraw-Hill Book Co., Inc.). Table 1 gives data for several commonly encountered conditions in heat exchangers equipped with jacketed tubes and special .030″ wall tubes made of glass 7740. Sizes listed refer to inside diameter. Wall thickness is .030″ for ¾″, .060″ for 1″, 1½″ and 2″ tubes, .090″ for 3″ tubes, and .125″ for 4″ tubes.

TRANSMISSION OF RADIANT HEAT

Many glasses effectively transmit heat radiation from incandescent Tungsten filaments and similar sources. Transmission of heat energy increases with source temperature so that most of the energy from high temperature sources is transmitted through the glass by radiation rather than by conduction. Data for glasses 7740 and 7900 are shown in Figure 1.

TABLE 1—Typical Overall Heat Transfer Coefficients for Various Size Jacketed Tubes of Glass 7740

Process	*Fluid Inside Glass 7740 Tube*	*Mass Velocity G Inside lb./(hr.) (sq. ft.)*	*Average Inside Temp. ° F.*	*Fluid Outside Tube (In Jacket)*	*Mass Velocity G Outside lb./(hr.) (sq. ft.)*	*Average Outside Temp. ° F.*	*Approx. Overall "U" B.T.U./(hr.) (sq. ft.) (° F.)*				
							¾″*	1″	1½″	2″	3″
Liquid Cooling	Saturated Aqueous Chlorine Soln.	5 x 10^5	150° F.	Water	5 x 10^5	100° F.	150	94	94	94	68
Liquid Heating	5% HCl Soln.	5 x 10^5	150° F.	Steam	.....	250° F.	165	114	114	114	89
Condensing Pure Vapor	Benzene	.....	176° F.	Water	5 x 10^5	100° F.	137	86	86	86	64
Gas Cooling	Dry Diatomic Gas	8 x 10^3	200° F.	Water	5 x 10^5	100° F.	4.9	4.4	4.4	4.4	3.6

*Type tubing (.030″ wall) in shell and tube heat exchangers.

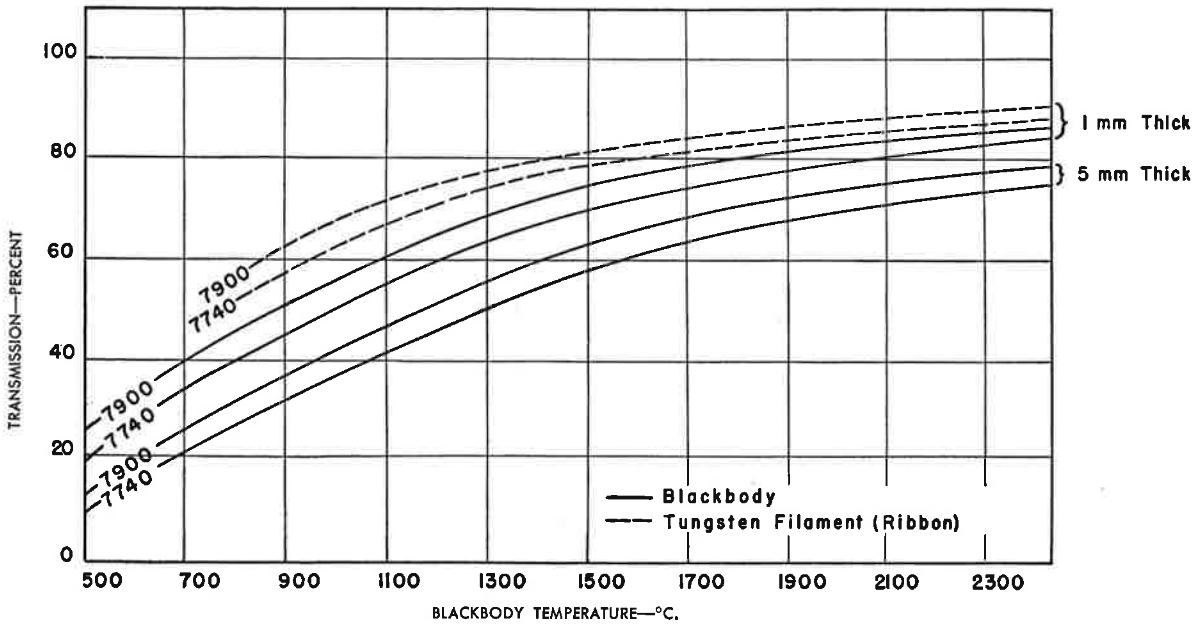

Fig. 1—Transmission of Radiant Energy—Glasses 7740 and 7900

Electrical Properties

Glasses are widely used in the electrical industry for insulators, incandescent lamp and electronic tube components, neon sign tubing, sealing beads, fuse bodies, etc. The desirable properties of electrical glasses include the following:

(a) High dielectric strength

(b) High volume resistivity

(c) High surface resistivity and hard smooth surfaces that do not carbonize or become conducting under the action of arcs.

(d) Low power factor and loss factor.

Table 3, (page 10) compares some of the electrical properties of glasses with those of other frequently used insulating materials. It should be noted that the data given for dielectric strength are intrinsic only and apply where failure of the surrounding medium, (air, oil, vacuum, etc.) can be avoided.

The important properties of electrical glasses are given in Table 2. Some of these properties are discussed in detail below.

DIELECTRIC STRENGTH

The dielectric strength of glass is very high indeed. Thus, in applications, this property is relatively unimportant compared with the problem of design to prevent flashover and, in laboratory testing, to the necessity of employing rather unusual dimensions or conditions to insure true breakdown. One such expedient is the use of thin sections. Another is testing under oil.

Figure 2, (page 10), shows the range of breakdown voltages in various thicknesses of glass 7740. Both of the above mentioned methods were employed in determining these data.

It should be noted that dielectric breakdown voltage decreases with increase in frequency and temperature. At elevated temperatures, breakdown is governed mainly by the resistivity of the glass at those temperatures. Dielectric breakdown voltages for lime glass plates tested under oil are about 75% of those for borosilicate glass 7740.

The subject of dielectric strength is treated in detail in "Electrical Properties of Glass" by Littleton and Morey, John Wiley and Sons, N.Y. (1933), page 149; and an article "Puncture Tests Affected by Strength of Oil," by Littleton and Shaver, Electrical World, 91, 759 (1928). *(Continued on pages 10, 11)*

TAB

1	2	3	4	5	6	7				8		
						UPPER WORKING TEMPERATURES (Mechanical Considerations Only)				Thermal Shock Res. Plates 6″x6″		
						Annealed		Tempered		Annealed		
Glass Code	Type	Color	Principal Use	Forms Usually Available	Thermal Expansion Coeff.—/°C.	Normal Service °C.	Extreme Limit °C.	Normal Service °C.	Extreme Limit °C.	⅛″ Thk. °C.	¼″ Thk. °C.	½″ Th °C.
0010	Potash Soda Lead......	Clear	Lamp Tubing	T	$91x10^{-7}$	110	380	—	—	65	50	3
0041	Potash Soda Lead......	Clear	Thermometers	T	$85x10^{-7}$	110	400	—	—	70	60	4
0080	Soda Lime	Clear	Lamp Bulbs	B M T	$92x10^{-7}$	110	460	220	250	65	50	3
0120	Potash Soda Lead......	Clear	Lamp Tubing	T M	$89x10^{-7}$	110	380	—	—	65	50	3.
0281	Soda Lime	Clear	General Purpose	—	$87x10^{-7}$	110	475	240	270	70	60	4
1720	Aluminosilicate	Clear	Ignition Tube	—	$42x10^{-7}$	200	650	400	450	135	115	7.
1990	Low Loss Iron Sealing...	Clear	Sealing	—	$127x10^{-7}$	100	310	—	—	45	35	2.
2405	Hard Red.............	Red	General	B P U	$43x10^{-7}$	200	480	—	—	135	115	7.
2475	Soft Red.............	Red	Neon Signs	T	$93x10^{-7}$	110	440	—	—	65	50	3.
3320	Hard Sealing..........	Canary	Tungsten Sealing	—	$40x10^{-7}$	200	480	—	—	145	110	8
6720	Opal	White	General	P	$80x10^{-7}$	110	480	220	275	70	60	4
6750	Alabaster	White	Lighting Ware	B P R	$87x10^{-7}$	110	420	220	220	65	50	3.
6810	Opal	White	Lighting Ware	B P R	$69x10^{-7}$	120	470	240	270	85	70	4.
7050	Borosilicate	Clear	Series Sealing	T	$46x10^{-7}$	200	440	235	235	125	100	7
7052	Borosilicate	Clear	Kovar Sealing	B M P T	$46x10^{-7}$	200	420	210	210	125	100	7
7070	Borosilicate	Clear	Low Loss Electrical	B M P T	$32x10^{-7}$	230	430	230	230	180	150	10
7250	Borosilicate	Clear	Baking Ware	P	$36x10^{-7}$	230	460	260	260	160	130	9
7340	Borosilicate	Clear	Gauge Glass	T	$67x10^{-7}$	120	510	240	310	85	70	4
7570	Soldering Glass........	Clear	Sealing	—	$84x10^{-7}$	100	330	—	—	—	—	—
7720	Borosilicate	Clear	Tungsten Sealing	B P T	$36x10^{-7}$	230	460	260	260	160	130	9
7740	Borosilicate	Clear	General	B P S T U	$32.5x10^{-7}$	230	490	260	290	180	150	10
7760	Borosilicate	Clear	Electrical	B P	$34x10^{-7}$	230	450	250	250	160	130	9
7900	96% Silica	Clear	High Temp.	B P T U M	$8x10^{-7}$	800	1090	—	—	1250	1000	75
7910	96% Silica	Clear	u v Transmission	B T U	$8x10^{-7}$	800	1090	—	—	1250	1000	75
7911	96% Silica	Clear	u v Transmission	T	$8x10^{-7}$	800	1090	—	—	1250	1000	75
7940	Fused Silica...........	Clear	Ultrasonic	—	$5.6x10^{-7}$	900	1100	—	—	1250	1000	75
8160	Radiotron Tube	Clear	Electrical	—	$91x10^{-7}$	110	380	—	—	65	50	3
8800	Borosilicate	Clear	Thermometers	—	$60x10^{-7}$	200	510	—	—	100	80	6
8870	High Lead	Clear	Sealing or Electrical	M T U	$91x10^{-7}$	110	380	180	180	65	50	3
8871	Capacitor	Clear	Electrical	—	$103x10^{-7}$	125	360	—	—	55	45	3
9700	....	Clear	u v Transmission	T U	$37x10^{-7}$	220	500	—	—	150	120	8
9741	....	Clear	u v Transmission	B U T	$39x10^{-7}$	200	390	—	—	150	120	8

COLUMN 5

B—Blown Ware
M—Multiform Ware
P—Pressed Ware
R—Rolled Sheet
S—Plate Glass
T—Tubing and Rod
U—Panels

COLUMN 7

These data approximate only. Freedom from excessive thermal shock is assumed. See Column 8.

At extreme limits annealed glass will be very vulnerable to thermal shock. Recommendations in this range are based on mechanical considerations only. Tests should be made before adapting final designs.

COLUMN 6

From 0° to 300°C. in/in/°C. or cm/cm/°C.

COLUMN 8

These data approximate only. See Text Page 5.

Based on plunging sample into cold water after oven heating. Resistance of 100°C. means no breakage if heated to 110°C. and plunged into water at 10°C. Tempered samples have over twice the resistance of annealed glass. Glasses 7900, 7910, 7911 cannot be tempered.

ALL DATA SUBJECT TO NORM

LE 2

9	10				11	12	13	14			15			16
Thermal Stress Resistance °C.	Viscosity Data				Impact Abrasion Resistance	Density (Sp. Gr.)	Modulus of Elasticity lb./sq. in.	Log₁₀ of Volume Resistivity			Dielectric Properties at 1 Mc and 20°C.			Refractive Index Sod. D Line (.5893 Microns)
	Strain Point °C.	Annealing Point °C.	Softening Point °C.	Working Point °C.				25°C.	250°C.	350°C.	Power Factor	Dielectric Const.	Loss Factor	
19	395	430	626	970	—	2.85	9.0×10^6	17.+	8.9	7.0	.16%	6.7	1.%	1.539
19	425	465	648	990	—	2.89	—	—	7.5	5.9	—	—	—	1.545
17	470	510	696	1000	1.2	2.47	9.8×10^6	12.4	6.4	5.1	.9	7.2	6.5	1.512
17	395	435	630	975	—	3.05	8.2×10^6	17.+	10.1	8.0	.12	6.7	.8	1.560
18	490	530	707	1015	—	2.48	—	—	6.5	5.2	—	—	—	—
29	670	715	915	1200	—	2.53	12.7×10^6	—	11.4	9.5	.38	7.2	2.7	1.530
13	330	360	496	755	—	3.47	8.4×10^6	—	10.1	7.7	.04	8.3	.33	—
36	505	540	770	1085	—	2.50	—	—	—	—	—	—	—	1.507
17	460	505	690	1040	—	2.59	—	—	7.8	6.2	—	—	—	1.511
40	495	540	780	1155	—	2.29	—	—	8.6	7.1	.30	4.9	1.5	1.481
19	495	535	775	1015	—	2.58	—	—	—	—	—	—	—	1.507
18	440	475	672	1040	—	2.63	—	—	—	—	—	—	—	1.513
23	490	530	768	1010	—	2.65	—	—	—	—	—	—	—	1.508
34	460	500	703	1025	—	2.25	—	16.	8.8	7.2	.33	4.9	1.6	1.479
34	435	480	708	1115	—	2.28	—	17.	9.2	7.4	.26	5.1	1.3	1.484
70	455	495	—	1100	4.1	2.13	7.3×10^6	17.+	11.2	9.1	.06	4.0	.24	1.469
43	485	530	780	1190	3.2	2.24	—	15.	8.2	6.7	.27	4.7	1.3	1.475
20	535	580	785	1140	—	2.43	11.5×10^6	16.	8.5	6.9	—	—	—	1.506
—	345	365	440	560	—	5.42	8.1×10^6	—	10.6	8.7	.22	15.	3.3	—
45	485	525	755	1110	3.2	2.35	9.5×10^6	16.	8.8	7.2	.27	4.7	1.3	1.487
48	520	565	820	1220	3.1	2.23	9.3×10^6	15.	8.1	6.6	.46	4.6	2.1	1.474
51	480	525	780	1210	—	2.23	9.1×10^6	17.	9.4	7.7	.18	4.5	.79	1.473
200	820	910	1500	—	3.5	2.18	9.6×10^6	17.	9.7	8.1	.05	3.8	.19	1.458
200	820	910	1500	—	3.5	2.18	9.6×10^6	17.+	11.2	9.2	.024	3.8	.091	1.458
200	820	910	1500	—	3.5	2.18	9.7×10^6	17.+	11.7	9.6	.019	3.8	.072	1.458
290	1050–approx.		1500+	—	—	2.20	10.5×10^6	—	—	—	.001	3.8	.038	1.459
18	395	435	627	975	—	2.98	—	—	10.6	8.4	.09	7.0	.63	1.553
27	530	570	755	—	—	2.39	—	—	—	—	—	—	—	1.502
22	390	430	580	805	.6	4.28	7.6×10^6	17.+	11.8	9.7	.08	9.5	.86	1.693
15	350	385	527	770	—	3.84	8.3×10^6	—	11.1	8.8	.05	8.4	.42	—
42	520	565	804	1195	—	2.26	—	15.	8.0	6.5	—	—	—	1.478
40	410	450	705	—	—	2.16	—	17.+	9.4	7.6	—	—	—	1.468

COLUMN 9
Resistance in °C. is the temperature differential between the two surfaces of a tube or a constrained plate that will cause a tensile stress of 1000 p.s.i. on the cooler surface. See Text Page 5.

COLUMN 10
See Page 13. These data subject to normal manufacturing variations.

COLUMN 11
Data show relative resistance to sandblasting.

COLUMN 12
Units are grams/c.c.

COLUMN 14
Data at 25° extrapolated from high temp. readings and are approximate only.

GLASSES 7910 AND 7911
Electrical properties measured on lamp worked specimens.

AL MANUFACTURING VARIATIONS

TABLE 3—Comparison of Electrical Properties of Insulating Materials at Room Temperature

Material	*Intrinsic Dielectric Strength*		*Dielectric*	*Volume Resistivity*
	Thickness (mm)	*(Kv/cm)*	*Constant*	*(ohm–cm)*
1. Cellulose Acetate	.025–.12	2300**	5.5	10^{12}
2. Glass				
Borosilicate No. 7740	.10	4800*	4.8	10^{16}
Soda Lime	.10	4500*	7.0	10^{12}
Soda Lead	.10	3100*	8.2	10^{14}
3. Mica, Muscovite Clear Ruby	.020–.10	3000–8200**	7.3	10^{17}
4. Phenolic Resin	.012–.04	2600–3300**	7.5	10^{11}
5. Porcelain, Electrical	......	380**	4.4–6.8	10^{14}
6. Silica, Fused	......	5000*	3.5	10^{18}
7. Rubber, Hard	.10–.30	2150**	2.8	10^{13}
8. Porcelain, Steatite—Low Loss	......	500**	6.0–6.5	10^{15}

Intrinsic dielectric strength can be realized only under special test conditions and is very much higher than the working dielectric strength attainable in ordinary service. These data are listed for purposes of comparison.

* Values of P. H. Moon and A. S. Norcross. Trans. A.I.E.E. 49, 755, (1930).

** Values of S. Whitehead. World Power, Pg. 72, Sept. 1936.

Table from "Glass, the Miracle Maker," by C. J. Phillips (Pitman Publishing Co., New York, N. Y.).

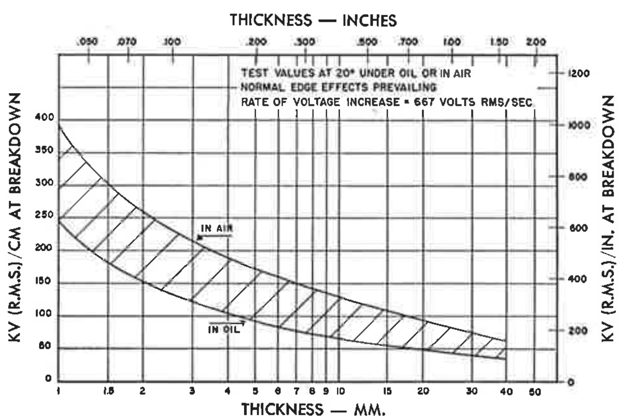

Fig. 2—Range of Values of 60 Cycles RMS Voltages at Dielectric Breakdown for Glass 7740

VOLUME RESISTIVITY

Measurements of volume resistivity are made at temperatures of 250° and 350°C. Data for other temperatures, especially in the lower ranges, are obtained by extrapolation of the straight line relationship between log resistivity and reciprocal of the absolute temperatures. Figure 5 shows log of resistivity plotted against temperatures in degrees C.

SURFACE RESISTIVITY

Surface resistivity depends more upon the surface films than on the composition of the glass itself although the borosilicate glasses are better than lime glasses in this regard. A film of moisture, particularly in the presence of dirt or dissolved gases, seriously lowers the surface resistivity. This effect is substantially reduced by treating the glass surface with water repellent silicones so that the moisture forms into discrete droplets rather than a continuous film. These effects are shown in Figure 3.

POWER FACTOR

Several glasses with exceptionally low power factors have been developed in recent years. These glasses, numbers 7070, 7761, 7900, 7910 and 8870 all have power factors of less than .1% at room temperature and 1 megacycle. Figure 6 shows variation of power factor with glass temperature. It should be noted that there is relatively little increase until temperature exceeds 100°C.

electrical properties—continued

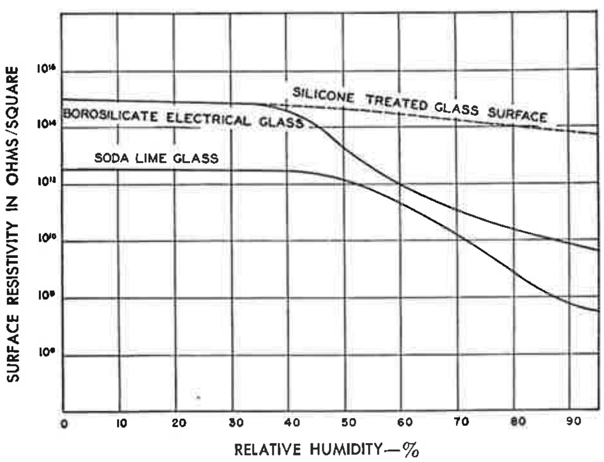

Fig. 3—Surface Resistivity of Glasses vs. Relative Humidity. Values given are Markedly Affected by any Contamination on the Surface of the Sample

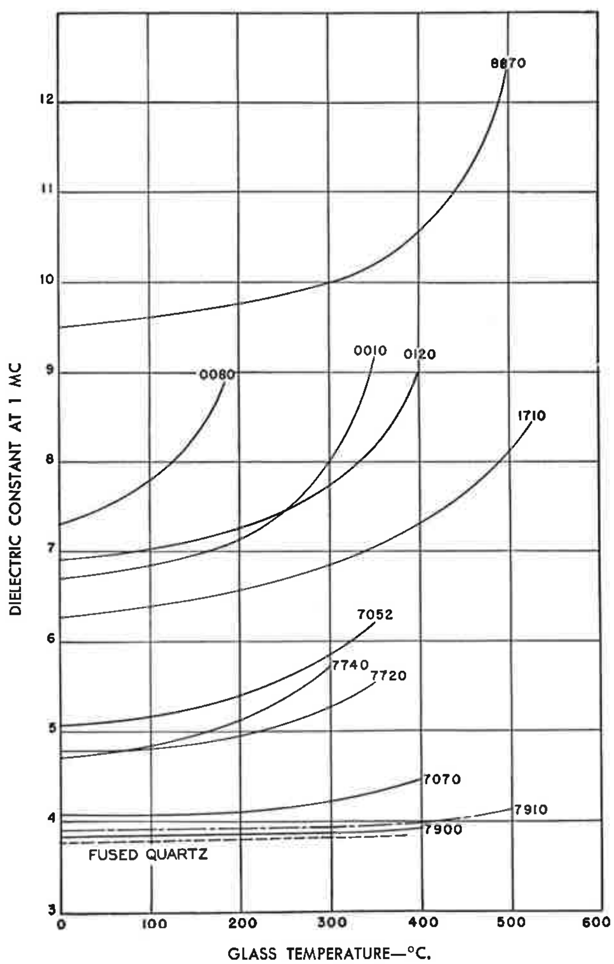

Fig. 4—Variation of Dielectric Constant with Glass Temperature. Curves marked 1710 apply as well for Glass 1720

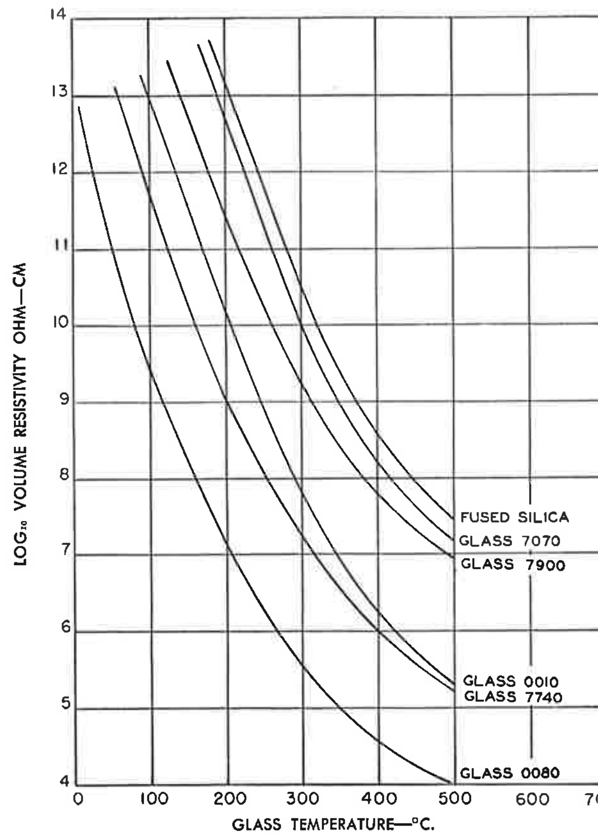

Fig. 5—Volume Resistivity

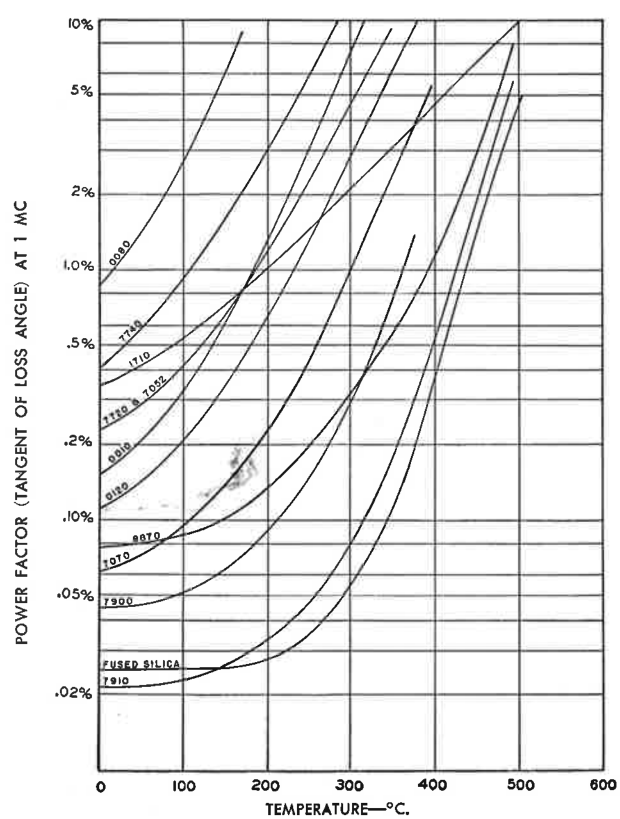

Fig. 6—Power Factor

Corrosion Resistance

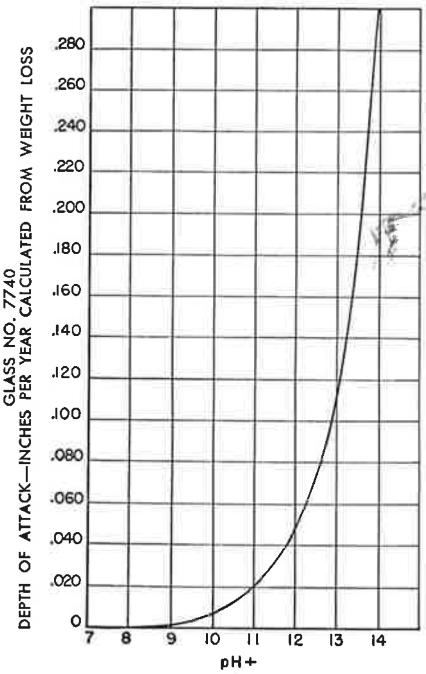

Fig. 7

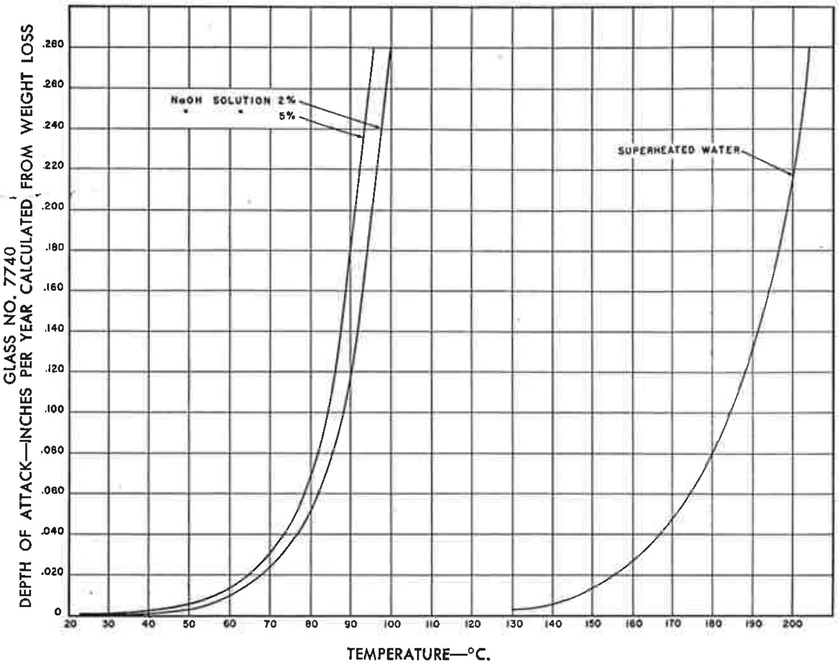

Fig. 8

For practical purposes a discussion of the chemical corrosion of glass can be very simple indeed. Glass is attacked by so few reagents that we can correctly say it is measurably affected only as follows:

(1) Hydrofluoric Acid—serious corrosion

(2) Hot Concentrated Phosphoric Acid—serious corrosion

(3) Alkaline Solutions—see detailed data below

(4) Superheated Water—see details below.

Borosilicate glasses, especially 7740, and high silica glasses like 7900 are more resistant to most forms of chemical attack and, generally speaking, they should be used where this is a problem.

ALKALINE ATTACK

Cold alkaline solutions, dilute or concentrated, attack glasses very slowly but as temperature is increased the rate of corrosion rises rapidly. Figure 7 shows how rate of attack increases with alkalinity and Figure 8 shows variation with temperature and concentration.* Both these figures apply to borosilicate glass 7740 and show relative magnitude rather than exact data since operating conditions greatly affect performance. The following points may be helpful to the reader:

(1) Agitation of liquor in contact with the glass intensifies attack since the products of decomposition are removed more rapidly and more corrosive liquor contacts the glass. Figure 8 represents unstirred tests.

(2) For equal concentrations by weight, the attack of glass 7740 by other reagents compares with that of sodium hydroxide approximately as follows:

(a) Potassium Hydroxide (KOH)—approx. the same
(b) Lithium Hydroxide (LiOH)—about 50% as severe
(c) Sodium Carbonate (Na_2CO_3)—less severe
(d) Ammonium Hydroxide (NH_3OH)—about 5% as severe.

EFFECT OF SUPERHEATED WATER

Glass is the standard material for both high and low pressure boiler gauges and although it is attacked by water at elevated temperatures (over 300°F.) the rate is rarely high enough to prevent satisfactory service life. Attack increases with temperature and alkalinity of the water. It is also accelerated when a boiler gauge is so placed that cold drafts cause excessively high steam condensation above the water line.

Figure 8 shows rate of attack at various temperatures. Here again, since service conditions are so important the data show order of magnitude rather than absolute rate of attack.

* In calculating depth of attack from weight loss we have neglected the fact that in dilute alkaline solutions at low temperatures the attack may be a form of selective leaching. Rate is so small in these ranges that the error resulting from this omission is not important.

Viscosity Data

At ordinary temperatures the viscosity of glass is so high that it can be considered to be infinite. As the temperature is raised, however, the viscosity decreases and the glass gradually assumes the character of a liquid. Four points on the viscosity temperature curve have been arbitrarily chosen to represent the softness of the glass at important points in its change from solid to liquid. These points, or reference temperatures, are listed in Table 2, Column 10.

The following definitions for strain, annealing and softening points are taken from those tentatively adopted by the American Society for Testing Materials; that for Working Point is employed by Corning Glass Works and corresponds to the upper end of the working range as defined by A.S.T.M.

Strain Point. The temperature, at the lower end of the annealing range, at which the internal stress is substantially relieved in 4 hours. The strain point corresponds to a viscosity of $10^{14.50}$ poises when measured by the Tentative Method of Test for Annealing Point and Strain Point of Glass (A.S.T.M. Designation: C. 336).

In general the strain point represents the extreme upper limit of servicability for annealed* glass.

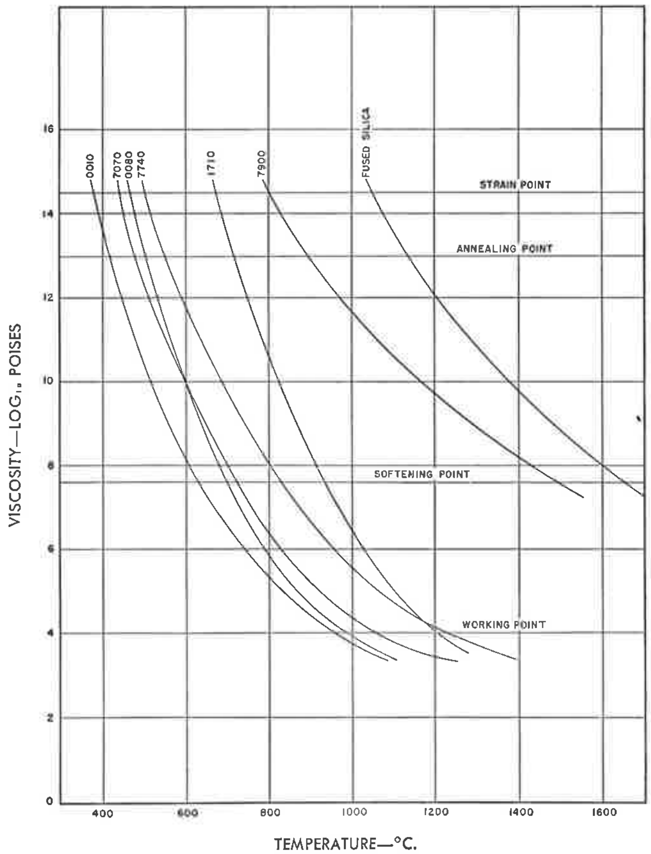

Fig. 9—Viscosity—Temperature Curves

Annealing Point. The temperature, at the upper end of the annealing range, at which the internal stress is substantially relieved in 15 minutes. The annealing point corresponds to a viscosity of $10^{13.00}$ poises when measured by the Tentative Method of Test for Annealing Point and Strain Point of Glass (A.S.T.M. Designation: C. 336).

In an annealing operation the glass is heated somewhat above the annealing point and slowly cooled to somewhat below the strain point. Distortion of the glass becomes a problem about 50°C. above the annealing point.

Softening Point. The temperature at which a uniform fiber, 0.55 to 0.75 mm. in diameter and 23.5 cm. in length, elongates under its own weight at a rate of 1 mm. per min. when the upper 10 cm. of its length is heated in the manner prescribed in the Tentative Method of Test for Softening Point of Glass (A.S.T.M. Designation: C. 338) at a rate of approximately 5° C. per min. For glass of density near 2.5 gm./cm.^{3} this temperature corresponds to a viscosity of $10^{7.6}$ poises.

At the softening point the glass deforms very rapidly and starts to adhere to other bodies.

Working Point. The temperature where the glass is soft enough for hot working by most of the common methods. Viscosity at the working point is 10^4 poises.

Figure 9 shows viscosity curves for some representative glasses.

* Tempered glasses are limited to a considerably lower absolute maximum temperature because they begin to lose their temper in the region below the strain point. See Table 2, Column 7.

Bibliography

A.S.T.M. Standards of Glass and Glass Products
April, 1955, Page 74

"Properties of Glass," G. W. Morey
Reinhold Pub. Corp., 1938

"Glass the Miracle Maker," C. J. Phillips
Pitman Pub. Corp., 1948

"VYCOR brand Industrial Glassware," Corning Glass Works
Bulletin B-91

"Laboratory Glassware," Corning Glass Works
Bulletin LP36

"Glass...Its Increasing Importance in Product Design,"
Corning Glass Works Bulletin IZ-1

"Manufacture and Design of Commercial Glassware,"
Corning Glass Works Bulletin B-84

"Glass Engineering Handbook,"
E. B. Shand

Lightingware

Laboratory glassware

Gauge glasses

Glass pipe

Glass tubing

Signalware

Optical glass

Appliance glassware

Industrial glassware

Electrical glassware

Household glassware

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