GLASS

G.E.C. GLASS WORKS

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INTRODUCTION

Since the last edition of this publication, many changes and advances have taken place, both in the manufacturing methods and in the range of glasses available.

Over a dozen new glasses are referred to in this issue and the important physical properties are summarized in a convenient table for quick reference.

We offer this handy and condensed account of our products for the convenience of our many friends in the Glass Industry hoping that it will be at one and the same time an interesting and useful reference book.

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GLASSES MANUFACTURED AT THE G.E.C. GLASS WORKS

In the following pages, technical data are given for a number of glasses manufactured by the G.E.C. Glass Works. In every case they are special-purpose glasses, carefully specified as to composition and physical properties. Control is exercised during manufacture on those physical properties which are most important for the purpose for which the individual glass is to be employed.

Of the glasses listed, some are manufactured at the Company's Wembley works and others at Lemington-on-Tyne, Northumberland. In general, all pot-melted and special glasses are melted at Lemington, manufacture at Wembley being confined to the automatic production of bulbs and tubing from X.4., X.8., L.1. and M.6.

Glasses described in the following pages are tabulated below.

GLASSES

X.8. SODA GLASS

G.E.C.

The description X.8. was a development of former WEMBLEY glasses X.7. and X.4. necessitated by the period 1939–1945. It combined the properties essential to the automatic production of lamp and valve bulbs on Westlake and Ohio Machines and for the automatic production of tubing by the Danner process. It is a soda-lime-silica glass containing magnesia and boric oxide. A typical chemical composition is given below. This glass is now used for the production of tubing by the Danner process.

Seals may be made between X.8. and chrome iron alloys of 20% to 30% Chromium, e.g. F.V.T. (22% Cr) and Pyrista (26% Cr).

Chemical Composition

A typical composition is:

Silica (SiO_2)	70·5%
Alumina (Al_2O_3)	2·6%
Calcium Oxide (CaO)	5·7%
Magnesium Oxide (MgO)	2·9%
Sodium Oxide (Na_2O)	16·3%
Potassium Oxide (K_2O)	1·2%
Boric Oxide (B_2O_3)	0·5%
Sulphur Trioxide (SO_3)	0·2%

Coefficient of Linear Thermal Expansion

Thermal expansion of X.8. is controlled between the limits $9{\cdot}55 \pm 0{\cdot}15 \times 10^{-6}$ measured between 20°C. and 350°C. A typical thermal expansion curve is shown in Fig. 1.

Softening Temperature

There are two methods for defining softening temperature. The simplest and the one in widest use is to define it as the highest point reached on the thermal expansion curve.

$$\text{Softening Temperature (Mg point)} = 560° \pm 10°\text{C.}$$

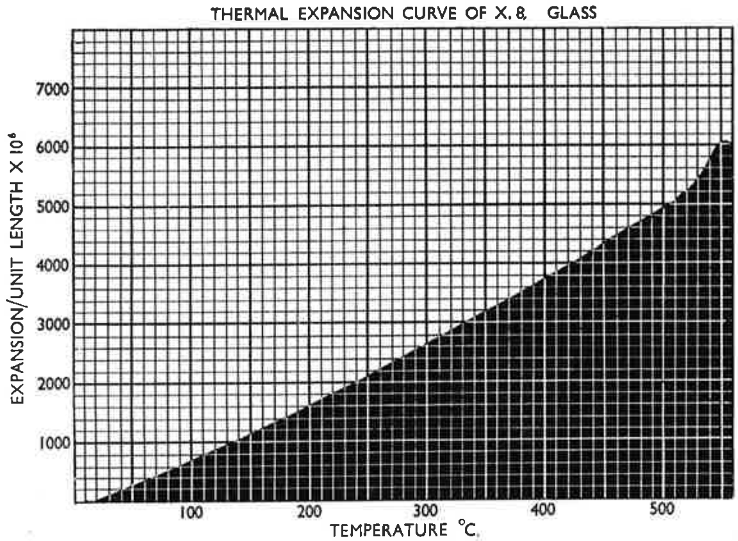
Another method of defining softening temperature depends upon the rate of extension of the fibre under its own weight and corresponds to a viscosity of $10^{7{\cdot}6}$ poises. On this basis,

$$\text{Softening Temperature} = 715° \pm 15°\text{C.}$$

Density

This is not an important property and for all soda glasses in this range will not depart by more than $\pm 0{\cdot}005$ from the value 2·49 at 25°C.

FIG. 1



Refractive Index

The refractive index is again not important in the production of bulbs and tubing, but for reference purposes will be found to be within the range $1{\cdot}514 \pm 0{\cdot}005$ at 20°C.

Electrical Resistivity

For the purpose of comparison with other glasses the following data are quoted:

Log_{10} Electrical Resistivity (Ohm. cm.)

at	20°C.	12+
	100°C.	9·4
	200°C.	7·1
	300°C.	5·5

Dielectric Constant and Loss Angle (tan δ)

Typical values at room temperature (20°C.) for various frequencies are:

Frequency cycles/second	*Dielectric Constant*	*Loss Angle (tan δ)*
10^6	7·1	0·0096
3×10^7	7·0	0·0078

Devitrification Temperature

Wembley soda glasses are very stable on 'lamp' working, but devitrification temperature is used as a control in manufacture and is maintained within the limits of 815° to 840°C.

The devitrification temperature so quoted is that at which by infinitely slow cooling the first traces of devitrification products could appear.

Annealing Range

In the annealing of articles manufactured from tubing the annealing schedule specified in the appendix should be followed. The annealing range of X.8. glass in from 530° to 400°C.

X.4. LIME SODA GLASS

G.E.C.

This composition is now used only for machine blown bulbs and is the same as that employed for the production of glass bulbs made by the ribbon machine. It is a slightly harder glass than that employed for tubing, its thermal expansion being a little lower, but its other characteristics are closely similar. The Westlake and Ohio machines at Wembley and the M.16. machine at Lemington all operate on this composition, the products being lamp bulbs (which are too large for the ribbon machine) and Vacuum flask blanks. A typical chemical composition is given below.

Chemical Composition

A typical composition is:

Silica (SiO_2)	72·5%
Alumina (Al_2O_3)	1·3%
Calcium Oxide (CaO)	6·5%
Magnesium Oxide (MgO)	3·0%
Sodium Oxide (Na_2O)	15·9%
Potassium Oxide (K_2O)	0·3%
Sulphur Trioxide (SO_3)	0·3%

Coefficient of Linear Thermal Expansion

The thermal expansion of X.4. glass is controlled between the limits $9{\cdot}35 \pm 0{\cdot}15 \times 10^{-6}$ measured between 20°C. and 350°C.

Softening Temperature

As measured by the highest point reached on the thermal expansion curve this is 570° ± 10°C.

Density and Refractive Index

The values for these properties are very similar to those of X.8. and X.4/3. glasses.

Density at 25°C. = $2{\cdot}48 \pm 0{\cdot}005$

Refractive Index at 20°C. = $1{\cdot}513 \pm 0{\cdot}005$

L.1. LEAD GLASS

G.E.C.

L.1. is a mixed alkali lead oxide-containing glass of excellent electrical insulation and working properties developed primarily for the manufacture of machine-drawn tubing for making pinches and exhaust tubes in lamp and valve manufacture and neck tubing for cathode ray tube bulbs. It is employed also in the form of mouth-blown bulbs as the envelope of many large transmitting valves and for pressings in the production of pressed screens and covers for cathode ray tubes. In these latter uses a very high standard of glass quality is required with freedom from all flaws such as stones, blisters and cord. This glass seals directly to platinum and 'copper-clad' wire, giving substantially stress-free seals, and may also be sealed to 50/50 nickel-iron alloy.

Chemical Composition

A typical composition is:

Silica (SiO_2)	56·0%
Lead Oxide (PbO)	30·0%
Alumina (Al_2O_3)	1·3%
Potassium Oxide (K_2O)	8·0%
Sodium Oxide (Na_2O)	4·6%

Coefficient of Linear Thermal Expansion

The thermal expansion of L.1. is controlled between the limits $9{\cdot}05 \pm 0{\cdot}15 \times 10^{-6}$ measured between 20°C. and 320°C. Fig. 2 shows a specimen thermal expansion curve.

Softening Temperature

As shown on Page 7 the highest point reached on the thermal expansion curve is 470°C. and in general

Softening Temperature (Mg point) = 470° ± 10°C.

When measured by the rate of extension of a fibre under its own weight, corresponding to a viscosity of $10^{7\cdot6}$ poises,

Softening Temperature = 610° ± 15°C.

Density

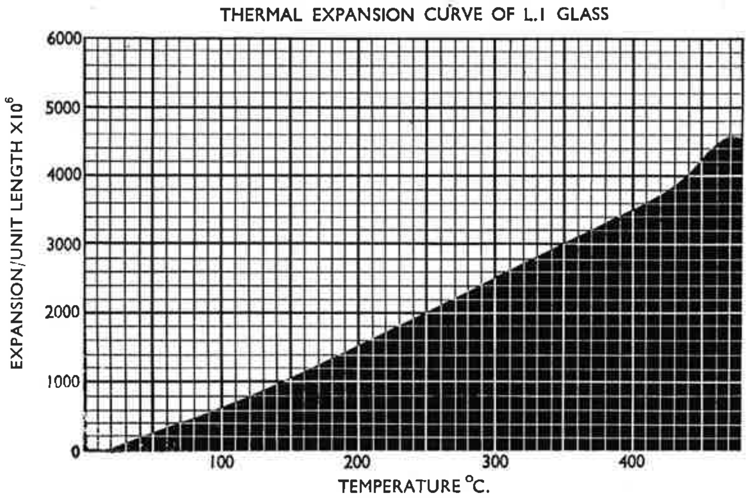
Due to its high lead oxide content L.1. glass is much denser than soda glass and in calculating tonnages from dimensions allowance must be made for this.

Average density of L.1. glass = 3·08 at 25°C.

Refractive Index

This property is closely related to density and is therefore highest for lead glasses. The refractive index of L.1. glass lies within the range 1·565 ± 0·005 at 20°C.

FIG. 2



Electrical Resistivity

At room temperatures and at normal lamp operating temperatures, the electrical resistivity of L.1. glass is approximately one hundred thousand times greater than that of soda glass so that its value as a medium for sealing electrical conductors, as in a lamp or valve pinch is at once apparent. Typical values are given below:

Log$_{10}$ Electrical Resistivity (Ohm. cm.)	
at 20°C.	17+
100°C.	14·9
200°C.	11·3
300°C.	8·9
400°C.	7·2

Dielectric Constant and Loss Angle (tan δ)

Typical values at room temperature (20°C.) for various frequencies are:

Frequency cycles/second	*Dielectric Constant*	*Loss Angle (tan δ)*
10^6	7·0	0·0012
3×10^7	7·0	0·0016

Devitrification Temperature

L.1. is inherently a very stable glass and tests carried out in the devitrification range for more than 100 hours fail to show any signs of crystallization.

Annealing Range

The annealing range of L.1. glass is from 430°C. to 340°C. In annealing articles made from tubing the annealing schedule specified in the appendix should be followed. The lower thermal expansion of L.1. glass compared with soda will normally balance its greater density so that no significant difference occurs in the maximum permissible heating and cooling rates to avoid fracture.

M.6. 'WHITE NEUTRAL' GLASS

M.6. is a chemically neutral glass made solely in the form of machine-drawn tubing. It is largely employed in the manufacture of medical ampoules and fulfils all the requirements of British Standard Specification No. 795 for neutrality. It is intermediate in thermal expansion between the 'soft' glasses, soda and lead (X.8. and L.1.), and the 'hard' glasses (W.1., H.H. and H.26X.), and is in fact sometimes employed in the making of 'graded seals'.

The demand for M.6., formerly a pot-melted glass, is now such that it is made in a continuous melting tank. The first such tank for the manufacture of tubing by the Danner process to be put into operation in this country was in fact for the production of this glass. Further developments in tube drawing have resulted in the installation of new equipment which now makes the production of M.6. the most modern Danner machine process in Europe.

Chemical Composition

A typical composition is:

Silica (SiO_2)	71·6%
Boric Oxide (B_2O_3)	9·9%
Alumina (Al_2O_3)	5·5%
Zinc Oxide (ZnO)	0·4%
Barium Oxide (BaO)	2·8%
Calcium Oxide (CaO)	0·3%
Sodium Oxide (Na_2O)	7·9%
Potassium Oxide (K_2O)	1·4%

Chemical Neutrality

M.6. is carefully controlled to preserve its chemical neutrality and daily checks are carried out to ensure compliance with the specification. The requirements of the test are:

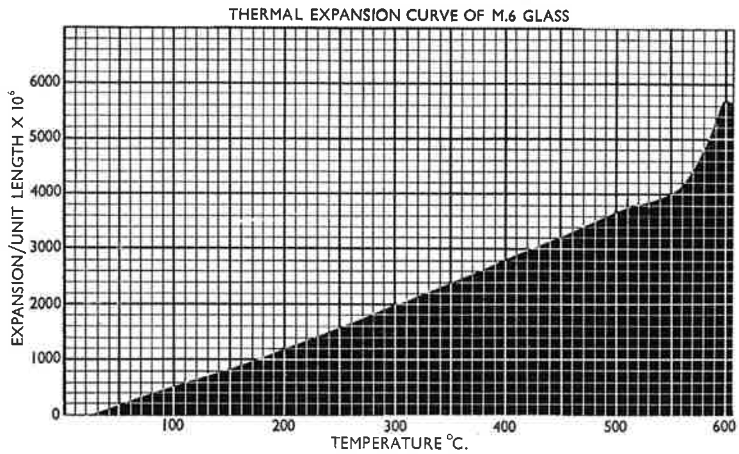
Fill the ampoules to their prescribed capacity with acid solution of methyl red*, seal by means of a blowpipe and heat in steam at a pressure of 15 lb. per square inch for half an hour. Cool and examine the colour of the solution. The Glass passes the test if the colour of the test solution has not changed from pink to the full yellow colour of methyl red.

Users sometimes report ampoules failing to pass the neutrality test, and this usually occurs after storage in unsuitable conditions. Attention is drawn to the extract from the specification quoted.

*Acid solution of methyl red: Mix 20 millilitres of strong solution of methyl red (·04% methyl red in 75% alcohol; pH= 5·2) with 8·3 millilitres of N/50 hydrochloric acid and a sufficient quantity of distilled water to produce 1,000 millilitres.

G.E.C.

FIG. 3



(*Extract from the B.S. No. 795*)

'Ampoules which have once passed the test on whole ampoules may fail to do so after being stored. Whenever possible, the test is carried out not more than fourteen days before the ampoules are to be used. If a batch of ampoules which has passed the test but has been stored does not subsequently pass the test, a sample of them *may* be re-submitted to the test after each ampoule has been washed internally with a 5% v/v aqueous solution of glacial acetic acid, followed by three washings with water. If the sample then passes the test, each ampoule of the batch is similarly washed before being used.'

Coefficient of Linear Thermal Expansion

Control of M.6. composition is effected on the basis of the neutrality test. Although not specifically controlled for other properties this results indirectly in controlling all other properties. The thermal expansion is within the range $5{\cdot}7 \pm 0{\cdot}15 \times 10^{-6}$ measured between 20°C. and 350°C.

Softening Temperature

Measured by the highest point reached on the thermal expansion curve:

Softening Temperature (Mg point) = 600°C. ± 10°C.

Measured by the rate of extension of a fibre under its own weight at a viscosity of $10^{7{\cdot}6}$ poises:

Softening Temperature = 780°C. ± 10°C.

Density at 25°C. the density is $2{\cdot}42 \pm 0{\cdot}005$.

Devitrification Temperature

A control employed in the manufacture of M.6. tubing is the determination of devitrification temperature on account of the higher temperatures at which tube drawing takes place. In lamp working on the bench or in automatic ampoule making machines the glass is very stable and no devitrification should ever be encountered. Variation in devitrification temperature is employed simply as a sensitive control of composition, the control limits being 1160°C. to 1240°C.

Annealing Range

The annealing range of M.6. glass is between 575°C. and 470°C. Articles of white neutral glass are invariably manufactured from tubing and the annealing schedule shown in the appendix should be followed.

W.1. BOROSILICATE GLASS

W.1. is a hard borosilicate glass developed in the first place to make strain-free seals with tungsten metal. Its mechanical and thermal properties are such, however, as to make it a very satisfactory medium for the envelopes of high-wattage lamps which have to withstand high operating temperatures. At the present time all W.1. bulbs are mouth-blown and the tubing is hand-drawn. A variety of pressings are made which have to be resistant to thermal shock. High standards of quality are required in this glass, for many of the products are X-ray bulbs, expensive radio transmitting valves, and projector lamp bulbs. Other uses include aerodrome runway lighting fittings in the form of pressings, which in some applications, apart from their resistance to heat shock, have to possess sufficient mechanical strength to permit aircraft to run over them.

Chemical Composition

A typical composition is :—

Silica (SiO_2)	75·5%
Boric Oxide (B_2O_3)	17·0%
Alumina (Al_2O_3)	2·0%
Sodium Oxide (Na_2O)	4·0%
Potassium Oxide (K_2O). . . .	1·5%

Coefficient of Linear Thermal Expansion

As with all special glasses for sealing to metals the thermal expansion is the important control exercised in manufacture to preserve the ability to give strain-free seals, and in this case also the resistance to thermal shock. The control limits are $3{\cdot}75 \pm 0{\cdot}1 \times 10^{-6}$, measured between 20°C. and 400°C.

Softening Temperature

As shown on the thermal expansion curve, the highest point reached on the curve is 580°C. and the softening temperature (Mg point) determined by this method lies in the range 580° ± 10°C.
By the extension of a fibre under its own weight, at a viscosity of $10^{7\cdot6}$ poises,

Softening Temperature = 760° ± 15°C.

Density and Refractive Index

In common with most glasses containing high proportions of boric oxide, W.1. is appreciably lighter and of lower refractive index than soda glasses.

Density at 25°C. = 2·25 ± 0·005
Refractive Index at 20°C. = 1·478 ± 0·005

Electrical Resistivity

W.1. is not quite so good electrically as L.1. but is a considerably better insulator than ordinary soda glass. At operating temperatures of 400°C.–450°C. however, it approaches L.1. in electrical resistivity with the advantage that it does not soften at these temperatures as would L.1. glass. Values are as follows:

	Log$_{10}$ Electrical Resistivity (Ohm. cm.)
at 20°C.	16·4
100°C.	12·8
200°C.	10·0
300°C.	8·2
400°C.	6·8

Dielectric Constant and Loss Angle (tan δ)

Typical values at room temperature (20°C.) for various frequencies are:

Frequency cycles/second	*Dielectric Constant*	*Loss Angle (tan* δ)
10^6	4·9	0·0028
3×10^7	4·8	0·0028
$9{\cdot}4 \times 10^9$	4·6	0·0061

X.4/3. LIME SODA GLASS

This glass was originally melted in pots but increasing demand has necessitated the use of a continuous tank. It is a straight forward soda glass of lower iron content intended specifically for the production of the outer vacuum jackets of mercury vapour discharge lamps, but has since found a number of uses, i.e. for pressing prismatic illuminating ware on account of its good colour, and for the base glass for sodium resistant tubing on account of its low iron content. X.4/3. has more recently replaced the pot-melted glass B.8., previously used for the mouth-blown production of small bulbs and other bulbs of special shape which are required in quantities insufficient for machine production.

Chemical Composition

A typical chemical composition is:

Silica (SiO_2)	72·0%
Alumina (Al_2O_3)	1·5%
Calcium Oxide (CaO)	5·2%
Magnesium Oxide (MgO)	3·1%
Sodium Oxide (Na_2O)	17·5%
Potassium Oxide (K_2O)	0·2%
Boric Oxide (B_2O_3)	0·5%

Coefficient of Linear Thermal Expansion

This is maintained between $9{\cdot}65 \pm 0{\cdot}15 \times 10^{-6}$ over the range 20°C to 350°C.

Softening Temperature

As measured by the highest point reached on the thermal expansion curve this is 550°C ± 10°C.

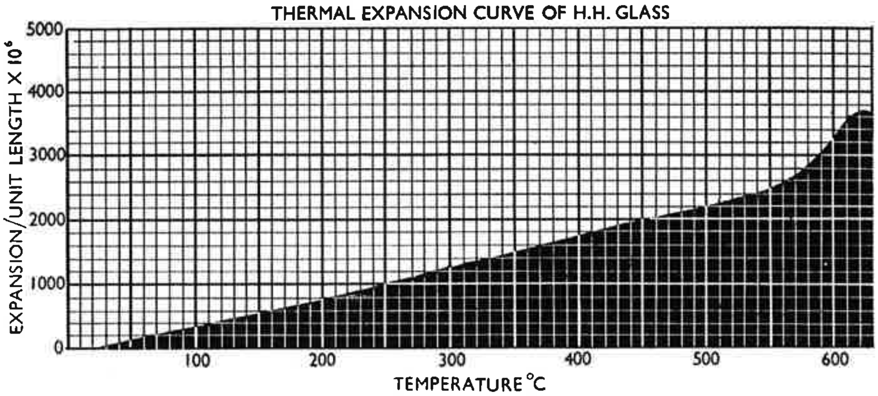


FIG. 4

H.H. GLASS

Chronologically H.H. was the first of the hard glasses made specifically for sealing to molybdenum. In recent years its applications have been largely transferred to W.1. and tungsten seals, but some cases still remain for which H.H. is technically desirable either on account of the molybdenum seals or on account of the slightly greater hardness (25°C. or so) which H.H. has over W.1. It is correctly described as a borosilicate heat-resisting glass and apart from sealing to molybdenum finds its chief applications as lamp envelopes for high temperature service.

Chemical Composition

A typical composition is:

Silica (SiO_2)	72·0%
Alumina (Al_2O_3)	4·0%
Calcium Oxide (CaO)	3·0%
Magnesium Oxide (MgO)	0·5%
Boric Oxide (B_2O_3)	13·0%
Sodium Oxide (Na_2O)	3·5%
Potassium Oxide (K_2O)	4·0%

Coefficient of Linear Thermal Expansion

Being intended for sealing to the metal molybdenum, this property is controlled within the limits $4{\cdot}7 \pm 0{\cdot}15 \times 10^{-6}$ measured between 20°C. and 450°C. It will be noted that this value is slightly higher than the thermal expansion of H.26X. glass ($4{\cdot}6 \pm 0{\cdot}10 \times 10^{-6}$) similarly intended for sealing to molybdenum. This difference arises due to the difference in softening points of the two glasses, namely, 770°C. for H.26X. and 625°C. for H.H.

Softening Temperature

For the highest point reached on the thermal expansion curve:

Softening Temperature (Mg point) = 625° ± 10°C.

Measured by the rate of extension of a fibre under its own weight: at a viscosity of $10^{7 \cdot 6}$ poises.

Softening Temperature = 800° ± 15°C.

Density

As with other borosilicate glasses this is not an important property but will be found to lie within the range 2·33 ± 0·005 at 25°C.

Electrical Resistivity

In electrical resistance H.H. is intermediate between W.1. and H.26X., being slightly superior to W.1. although, practically, there is little significant difference above 200°C.

	Log_{10} Electrical Resistivity (ohm. cm.)
at 20°C.	16·8
100°C.	12·9
200°C.	9·9
300°C.	7·9
400°C.	6·6

Annealing Range

The annealing range is from 590°C. to 500°C., and for articles made from tubing the schedules in the appendix should be followed.

H.26X. GLASS

G.E.C.

The hardest of the borosilicate glasses is H.26X., an alkali-free glass of high softening point made in the form of mouth-blown bulbs and hand-drawn tubing for the manufacture of high-pressure mercury vapour lamps. For this purpose it is essential that the glass seals to molybdenum and should have high electrical and thermal shock resistance. The glass is also used for certain types of projector lamps which run very hot in service, its high softening temperature safeguarding the lamp against collapse of the envelope.

Chemical Composition

The nominal composition of this glass is as follows. It will be noted that the glass contains no alkali, and further the iron oxide content is maintained at a low value so as not to impair the Ultra-violet transmission properties of the glass.

To obtain this low iron content with a glass melted at 1570°C. necessitates the use of the purest batch ingredients, and tank blocks highly resistant to the corrosive action of the glass.

A typical composition is:

Silica (SiO_2)	54·3%
Alumina (Al_2O_3)	21·0%
Boric Oxide (B_2O_3)	8·0%
Calcium Oxide (CaO)	13·5%
Barium Oxide (BaO)	3·1%
Iron Oxide (Fe_2O_3)	0·10% (Max.)

Coefficient of Linear Thermal Expansion

To make a satisfactory seal to molybdenum this property is controlled between the limits $4{\cdot}6 \pm 0{\cdot}1 \times 10^{-6}$ measured between 20°C. and 580°C. A typical expansion curve is shown in Fig. 5.

Softening Temperature

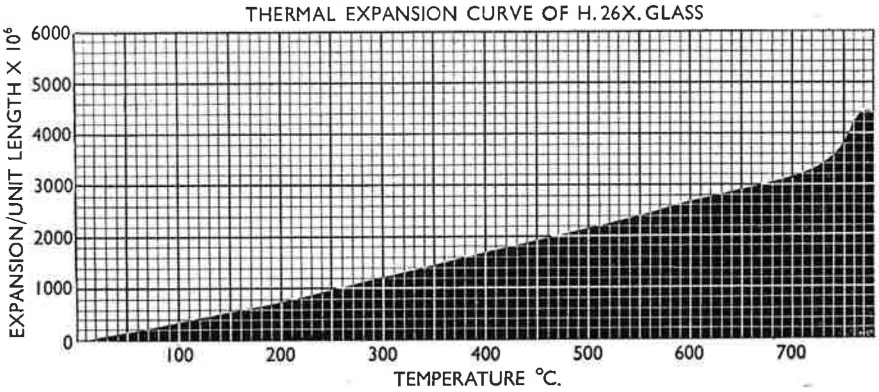
Measured by the highest point reached on the thermal expansion curve:

Softening Temperature (Mg point) = 770° ± 10°C.

Measured by the rate of extension of a fibre under its own weight at a viscosity of $10^{7.6}$ poises,

Softening Temperature = 930° ± 15°C.

FIG. 5



Density

The density is higher than for most borosilicate glasses, being 2·55 ± 0·005 at 25°C.

Refractive Index

Due to the barium oxide content this property has a slightly higher value than for ordinary soda glass, being 1·535 ± 0·005 at 20°C.

Electrical Resistivity

H.26X. has the highest electrical resistivity of all glasses, so high in fact that it is not readily measured below 200°C. Values are as follows:

	Log$_{10}$ Electrical Resistivity (ohm.cm.)
at 100°C.	16·6
200°C.	13·6
300°C.	11·6
400°C.	10·2
500°C.	9·0

Dielectric Constant and Loss Angle (tan δ)

Typical values at room temperature (20°C.) for various frequencies are:

Frequency cycles/second	*Dielectric Constant*	*Loss Angle (tan δ)*
10^6	5·8	0·0008
3×10^7	5·8	0·0016

Annealing Range

The annealing range of H.26X. is from 725°C. to 600°C. On account of the high temperatures involved in annealing this glass, which are in excess of any temperatures reached in available continuous lehrs, articles of H.26X. glass are customarily kiln or box annealed, when the schedule in the appendix should be followed.

Old code Number	Revised Code No.	Composition	Chief uses and matched seals	Manufacture	Coefficient of Thermal expansion per °C × 10⁶ (20°–350°C)	Thermal Shock Resistance †°C
L1	—	Lead	Electrical. 50/50 nickel iron alloy Copper clad 42–43% nickel iron alloy 52% iron 42% nickel 6% chrome alloy 48% iron 47% nickel 5% chrome alloy	B.T.P.S	9·05(2)*	120
L15	—	Lead	Platinum. 50/50 nickel iron alloy	B.T.	8·65	125
X8	—	Soda–lime	General. 26–30% chrome iron alloys	T	9·55	115
X4	—	Soda–lime	Bulbs, Tumblers, Vacuum Flasks	B	9·35	115
X4/3	—	Soda–lime	General. 20–25% chrome iron alloys	B.T.P	9·65	115
M6	—	Alumino-borosilicate	Ampoules and vials	T	5·7	190
HR9	—	Borosilicate	Lighting refractors	P	5·15	210
SBN124	—	Borosilicate	54% iron 29% nickel 17% cobalt alloy	B.T.P.S.E	5·1	210
FCN	—	Borosilicate	54% iron 29% nickel 17% cobalt alloy. Molybdenum	B.T.P.E	4·75	220
SBN475	—	Borosilicate	54% iron 29% nickel 17% cobalt alloy. Molybdenum	B.T.P.E	4·75	220
H26X	—	Aluminosilicate	High temperature lamps. Molybdenum	B.T.P.S.E	4·6(4)*	230
HH	—	Borosilicate	Molybdenum. Graded glass seals	B.T.P	4·7(3)*	225
W1	—	Borosilicate	Tungsten	B.T.P.S	3·75	300
CSG3	—	Alkali silicate	Copper. High expansion austenitic steel	R(T).G.S	14·95	65
NSG2	—	Soda baria	Nickel. Some mild steels	R(T).G.S	12·7	80
ISG20	—	Soda baria	Iron. Mild steels	R(T).G.S	11·7	85
ISG30	—	Soda baria	Iron. Mild steels	R(T).G.S	12·5	80
Q1	—	Vitreous silica	Lamps	T	0·5	—
WQ31	**WQ10**	High silica	Vitreous silica seals to Tungsten	RE	1·0	—
WQ20	—	High silica	Silica graded seals	R	2·0	—
WQ41	**WQ25**	High silica	Silica graded seals to Pyrex	R	2·5	—
WQ42	**WQ30**	High silica	Silica graded seals to Pyrex & W1	R	3·0	—
GS1	**GS52**	Borosilicate	Graded glass seals	R	5·2	205
GS2	**GS59**	Borosilicate	Graded glass seals	R	5·9	180
GS3	**GS66**	Borosilicate	Graded glass seals	R	6·6	160
GS4	**GS72**	Borosilicate	Graded glass seals	R	7·2	150
GS5	**GS78**	Lead	Graded glass seals	R	7·8	135
GS6	**GS84**	Lead	Graded glass seals	R	8·4	125
GSS34	—	Lead borate	Glass solder for L1	G	8·0 (1)*	—
GSS1	—	Lead borate	Glass solder for X8	G	8·9 (1)*	—
GSS38	—	Lead borate	Glass solder for Mica to X 8	G	9·4 (1)*	—

NOTE: The code numbers (Column 2) of the graded seal glasses have been revised so that the number sequence following either WQ or GS is that of the mean thermal expansion coefficient (20°– 350°C) × 10⁷ of the glass.

B–Blownware
T–Tubing and Rod
P–Pressed ware
R–Rod
G–Granular
S–Sintered preforms
E–Enamel suspension

OF SOME G.E.C. GLASSES

Maximum Service Temperature °C	Upper Annealing Temperature $10^{13\cdot0}$ poises °C	Mg. Softening Point $10^{12\cdot2}$ poises °C	Littleton Fibre Softening Point $10^{7\cdot6}$ poises °C	Volume electrical resistivity $\log_{10} \rho$ ohm cm. °C					Dielectric Properties at 20°C						Density gm./cc.	Refractive index (sodium line)
									10^6c/s		3×10^7c/s		$9{\cdot}4 \times 10^9$c/s			
				20	100	200	300	400	K	tan δ	K	tan δ	K	tan δ	25°C	20°C
350	430	470	610	>17	14·9	11·3	8·9	7·2	7·0	0·0012	7·0	0·0016	—	—	3·08	1·565
350	430	470	615	—	—	—	—	—	—	—	—	—	—	—	—	—
450	530	560	715	>12	9·4	7·1	5·5	4·4	7·1	0·0096	9·0	0·0078	—	—	2·49	1·514
450	530	570	725	>12	9·5	7·1	5·6	4·5	—	—	—	—	—	—	2·48	1·513
450	520	550	710	>12	9·2	6·8	5·4	4·3	—	—	—	—	—	—	—	—
—	570	600	780	—	—	—	—	—	—	—	—	—	—	—	2·42	1·497
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·509
440	530	550	740	16·8	12·9	9·9	7·9	—	5·2	0·0024	5·2	0·0026	5·2	0·0080	2·29	1·492
430	520	540	710	>17	13·8	10·7	8·5	7·1	4·9	0·0020	4·9	0·0024	4·8	0·0062	2·25	1·481
420	510	530	725	>17	14·5	11·1	9·0	7·5	—	—	—	—	—	—	2·24	1·479
640	750	770	930	>17	16·6	13·6	11·6	10·2	5·8	0·0008	5·8	0·0016	—	—	2·55	1·535
540	600	625	800	16·8	12·9	9·9	7·9	6·6	—	—	—	—	—	—	2·33	—
500	560	580	760	16·4	12·8	10·0	8·2	6·8	4·9	0·0028	4·8	0·0028	4·6	0·0061	2·25	1·478
300	450	485	570	>14	11·1	8·0	5·9	—	9·5	0·0020	—	—	—	—	2·78	1·616
380	500	520	650	>14	11·1	8·3	6·6	—	9·2	0·0036	—	—	—	—	2·96	1·564
380	500	525	655	>14	11·3	8·5	6·6	—	—	—	—	—	—	—	2·93	1·564
380	500	520	645	>14	11·3	8·5	6·6	—	—	—	—	—	—	—	2·93	1·565
—	—	—	—	—	—	13·4	10·9	9·1	—	—	—	—	—	—	2·20	1·458
—	750	815	1210	>17	13·6	10·5	8·7	7·3	—	—	—	—	—	—	—	—
—	730	775	1190	>17	14·1	11·1	9·2	7·8	—	—	—	—	—	—	—	—
—	690	730	1150	>17	14·1	11·8	9·8	8·4	—	—	—	—	—	—	—	—
—	640	690	1075	>17	14	11·8	9·8	8·4	—	—	—	—	—	—	—	—
540	600	625	800	—	—	—	—	—	—	—	—	—	—	—	—	—
530	600	625	780	—	—	—	—	—	—	—	—	—	—	—	—	—
530	600	625	765	—	—	—	—	—	—	—	—	—	—	—	—	—
530	600	625	765	—	—	—	—	—	—	—	—	—	—	—	—	—
440	530	560	705	—	—	—	—	—	—	—	—	—	—	—	—	—
350	490	515	655	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	370	460	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	370	445	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	365	430	—	—	—	—	—	—	—	—	—	—	—	—	—

*NOTES: * Column 6 αThermal expansion is measured over the temperature range 20°–350°C except where indicated as follows* (1) 20°–220°C
(2) 20°–320°C
(3) 20°–450°C
(4) 20°–580°C

†Column 7 Thermal shock resistance test in accordance with J. Soc. Glass Tech. 1937, ***21***, ***463*** *with water as the shock medium.*

H.R.9. HEAT RESISTING GLASS

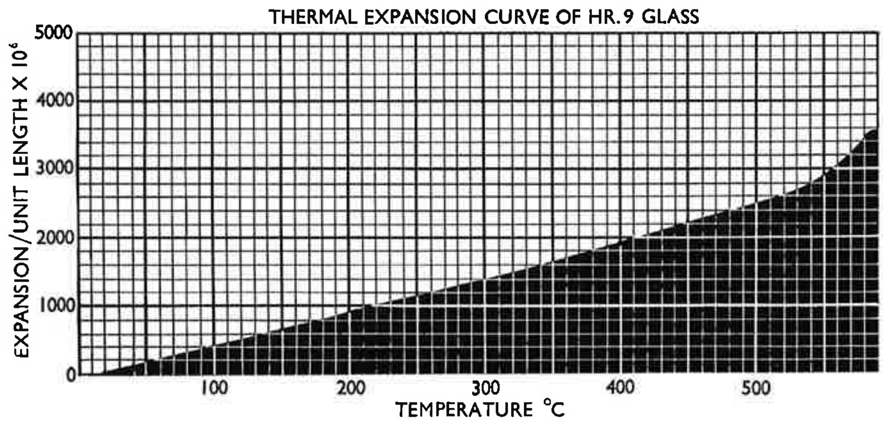
A glass of the heat-resisting type though not of such low thermal expansion as W.1. or H.H. is H.R.9. This is a borosilicate glass not required to seal specifically to any particular metal, but made expressly for the manufacture of pressed street-lighting refractors. The essential requirement, therefore, is that pressings made from it must be able to withstand in service all climatic conditions likely to be encountered.

Chemical Composition

A typical composition is:

Silica (SiO_2)	68·5%
Boric Oxide (B_2O_3)	12·5%
Alumina (Al_2O_3)	2·8%
Lead Oxide (PbO)	6·5%
Barium Oxide (BaO)	1·0%
Calcium Oxide (CaO)	0·9%
Magnesium Oxide (MgO)	0·3%
Sodium Oxide (Na_2O)	7·5%

FIG. 6



Coefficient of Linear Thermal Expansion

To ensure adequate resistance to thermal shock this property is controlled between the limits $5{\cdot}15 \pm 0{\cdot}15 \times 10^{-6}$ measured between 20°C. and 350°C.

Annealing Range

The annealing range is from 570°C. to 450°C. Due to its lower thermal expansion, approximately one-half that of soda glass, once the lower annealing temperature has been reached the glass may be cooled down to room temperature much more rapidly without risk of fracture.

OPAL AND COLOURED GLASS

In addition to the normal range of colourless glasses a wide range of opal and coloured glasses is manufactured for the production of illuminating ware and special applications such as coloured lamps for dark room illumination, signalling and indicator lamps. They may be produced in the form of blown bulbs, hand-drawn tubing and pressings.

Generally, coloured glassware is produced to a specification defining the light-transmitting properties and physical properties such as thermal expansion and softening points are of lesser importance. They are all special glasses in the sense that they are melted when required and it is only possible in this publication to indicate the range of colours manufactured.

Opal Glass

Opal 27

A 'solid' opal in the form of blown ware and pressings is made and known as Opal 27. It is melted in small day tanks or pots and is employed principally for the production of opal lamp bulbs, blown illuminating ware and pressings.

Coloured Glasses

A large range of coloured glasses is manufactured in the Company's Glass Works at Lemington. These cover a wide range of light transmission specifications and the more important colours are known by the following descriptions.

Blue	Daylight Blue and Light Daylight Blue Continental Daylight Blue Dark Blue — known as Admiralty Blue.
Red	Aviation Red Photo Ruby Dark Ruby — known as Admiralty Ruby.
Orange	R.6 Orange for Fireglow effect.
Yellow	Aviation Yellow Cadmium Yellow.
Amber	Photo Amber Light Amber Dark Amber.
Green	Aviation Green Light Green Dark Green.
Black	U.V.5 — transmitting ultra-violet light but almost no visible light

The bulk of the output of coloured glasses is in the form of blown bulbs and hand-pressings. Tubing can be supplied in all these colours.

SODIUM RESISTANT GLASS NA.10.

Na.10. is a sodium resistant glass which is melted in platinum pots to give a glass resistant to sodium metal vapour and free from all impurities. These requirements can only be met by a composition consisting essentially of soda, alumina and boric oxide melted from the purest available material and free from any contamination of the containing vessel. Owing to the very high boric oxide content the melting temperature is comparatively low (1250°C.) and it is possible to melt the glass on a commercial scale in platinum pots each holding about 75lb. of glass.

Na.10. is employed only in the form of an internal flashing on X.4/3. lime soda glass tubing, this composite tubing then being made up into sodium vapour discharge lamps.

A high degree of purity is essential to prevent blackening of the glass under operating conditions due to the action of the sodium metal vapour with which it is in contact.

Chemical Composition

A typical composition is:

Boric Oxide (B_2O_3)	48·0%
Alumina (Al_2O_3)	24·0%
Silica (SiO_2)	8·0%
Calcium Oxide (CaO)	6·0%
Sodium Oxide (Na_2O)	14·0%
Iron Oxide (Fe_2O_3) less than	0·025%

Thermal Expansion and Strain

With such a soft glass, thermal expansion measurements cease to be of value in determining the suitability of the glass for sealing to the base glass X.4/3. The glass is, therefore, normally controlled by measurement of the degree of strain in the inner layer of Na.10. in the composite tube. The inner layer of sodium resistant glass of the annealed tube should preferably be in slight compression and the maximum permissible stresses allowed are controlled within the following limits measured by the retardation of polarized light through a cross-section of the tube:

Maximum permissible stress, from 10 mμ/mm. tension to 130 mμ/mm. compression.

Thickness of the Na.10. layer

For satisfactory performance of the composite tube it is apparent that the sodium resistant layer must be sufficiently thick to give adequate protection from the sodium metal vapour to the base X.4/3. glass, but not so thick as to set up high stresses at the X.4/3./Na.10. boundary. The thickness of the flashed inner layer is therefore controlled between the limits 0·025 to 0·075 mm.

The above tests are carried out immediately after manufacture of every pot of Na.10. glass and, during the actual process of tube drawing, samples are repeatedly taken for measurement.

Electrical Resistivity

High electrical resistance and high resistance to the action of sodium metal vapour cannot be obtained at the same time. The electrical resistivity of Na.10. is low and therefore any electrical conductors requiring to be sealed into the X.4/3./Na.10. tube must first be sheathed with a glass of satisfactory electrical resistance. (See S.S.3. glass).

SHEATHING GLASS S.S.3.

G.E.C.

This glass is of high electrical resistance and is employed solely for sheathing standard copper-clad lead-in wires to prevent electrolysis of the pinch in lamps employing flashed glasses, such as Na.10. The glass must seal to copper-clad wire and to the base glass X.4/3., and its expansion must not exceed that of the base glass.

Chemical Composition

A typical composition is:

Silica (SiO_2)	67·0%
Boric Oxide (B_2O_3)	2·0%
Alumina (Al_2O_3)	0·5%
Barium Oxide (BaO)	15·0%
Calcium Oxide (CaO)	0·5%
Sodium Oxide (Na_2O)	7·0%
Potassium Oxide (K_2O) . . .	8·0%

Coefficient of Linear Thermal Expansion

Over the range 20°C. to 400°C. this property is controlled between the limits $9{\cdot}45 \pm 0{\cdot}10 \times 10^{-6}$.

Electrical Resistivity

Measured at 200°C. the electrical resistivity of S.S.3 glass is not less than 10^{10} ohm.cm., i.e. almost as high as that of L.1 glass.

F.C.N. SEALING GLASS

G.E.C.

F.C.N. is one of the range of special borosilicate glasses made originally for sealing to Fernico, which metal is now seldom used. It seals well to Nilo.K. alloy and it is possible to make seals to molybdenum which are substantially stress-free.

It has certain special applications, not fully covered by S.B.N.124 glass, particularly in devices where its low power loss (K.tan δ) is an advantage.

It has been used in the production of glass to metal terminals, in the production of valve parts and in the manufacture of high wattage tungsten filament bipost lamps but for a number of these applications S.B.N.124 glass is now preferred.

F.C.N. is a pot melted glass which requires finely controlled melting conditions for its successful production and is manufactured in the form of mouth-blown bulbs, hand-drawn tubing and pressings.

Chemical Composition

A typical composition is:

Silica (SiO_2)	65·5%
Boric Oxide (B_2O_3)	23·0%
Alumina (Al_2O_3)	3·5%
Calcium Oxide (CaO)	0·5%
Sodium Oxide (Na_2O)	5·0%
Potassium Oxide (K_2O)	2·5%

Coefficient of Linear Thermal Expansion

This property is controlled within the limits $4{\cdot}75 \pm 0{\cdot}15 \times 10^{-6}$ measured between the range 20°C. and 350°C.

Softening Temperature

Measured by the highest point reached on the thermal expansion curve,

Softening Temperature (Mg point) = 540°C. ± 10°C.

It will be noted that although of much higher boric oxide content than any of the other borosilicate glasses its softening point is much lower and comparable with ordinary soda glass. This is typical of all such glasses containing very high proportions of boric oxide:

Electrical Resistivity

This glass has an electrical resistance only very slightly below that of L.1. Typical values are:

	Log_{10} Electrical Resistivity (ohm. cm.)
at 20°C.	17 +
100°C.	13·8
200°C.	10·7
300°C.	8·5
400°C.	7·1

Dielectric Constant and Loss Angle (tan δ)

Typical values at room temperature (20°C.) for various frequencies are:

Frequency cycles/second	*Dielectric Constant*	*Loss Angle (tan δ)*
10^6	4·9	0·0020
3×10^7	4·9	0·0024
$9{\cdot}4 \times 10^9$	4·8	0·0062

S.B.N.124 KOVAR AND NILO-K SEALING GLASS

The increasing use of glass to metal sealing techniques in the electronics industry has created a demand for a number of special glasses sealing to particular alloys. Foremost amongst these is the borosilicate glass S.B.N.124., similar in many respects to F.C.N. glass but made specifically to seal to Kovar and Nilo.K alloys in their electronic applications. It is produced in the form of hand-drawn tubing and mouth-blown bulbs, and like F.C.N. careful control of the melting conditions is essential to avoid excessive variation in composition and properties. Electrical properties of this glass are of particular importance in its electronic applications. It is the most durable of the borosilicate sealing glasses.

Chemical Composition

A typical composition is:

Silica (SiO_2)	65·4%
Boric Oxide (B_2O_3)	15·8%
Alumina (Al_2O_3)	5·7%
Zinc Oxide (ZnO)	1·9%
Barium Oxide (BaO)	2·5%
Calcium Oxide (CaO)	0·9%
Sodium Oxide (Na_2O)	4·3%
Potassium Oxide (K_2O)	3·0%
Fluorine (F)	0·3%
Antimony Oxide (Sb_2O_3)	0·2%

Coefficient of Linear Thermal Expansion

This glass is controlled for expansion over two temperature ranges:

20°C.–350°C.	$5{\cdot}1 \pm 0{\cdot}1 \times 10^{-6}$
20°C.–500°C.	$5{\cdot}5 \pm 0{\cdot}1 \times 10^{-6}$

Softening Temperature

Measured by the highest point reached on the thermal expansion curve:

Softening Temperature (Mg point) = 550°C. ± 10°C.

Measured by the rate of extension of a fibre under its own weight at a viscosity of $10^{7{\cdot}6}$ poises:

Softening Temperature = 740 °C. ± 10°C.

Electrical Resistivity

This is considerably greater than for ordinary soft soda glasses, typical values being:

Log_{10} Electrical Resistivity (ohm. cm.)

at 20°C.	16·8
100°C.	12·9
200°C.	9·9
300°C.	7·9

Dielectric Constant and Loss Angle (tan δ)

Typical values at room temperatures (20°C.) for various frequencies are:

Frequency cycles/second	*Dielectric Constant*	*Loss Angle (tan δ)*
10^6	5·2	0·0024
3×10^7	5·2	0·0026
$9{\cdot}4 \times 10^9$	5·2	0·0080

COPPER SEALING GLASS . . . C.S.G.3
NICKEL SEALING GLASS . . . N.S.G.2
IRON SEALING GLASSES . I.S.G.20., I.S.G.30.

A series of high expansion glasses have been developed for making matched seals to copper, nickel, alloy steels and irons. I.S.G.20. gives moderate compression seals with pure iron. I.S.G.30. gives stress-free seals with pure iron and moderate compression seals with iron alloys having thermal expansion coefficients between that of pure iron and that of nickel. All these glasses are durable to normal atmospheric weathering and to the acid solutions normally used for cleaning the metal or alloy subsequent to sealmaking. The glasses are free from lead and have good electrical and working properties.
The high thermal expansion makes these glasses more sensitive to thermal shock than, for example, X.8. soda glass and special care should be taken in quick transfer of the seals to the annealing ovens. Technical information sheets which cover the properties of these glasses in greater detail are available on request.

Coefficient of Linear Thermal Expansion

The thermal expansion coefficients ($\times$ 10^{-6}) of the glasses are:

	C.S.G.3	N.S.G.2	I.S.G.30.	I.S.G.20.
20°C.–350°C.	14·95 ± 0·15	12·7 ± 0·15	12·5 ± 0·15	11·7 ± 0·15
20°C.–Mg point	17·60 ± 0·20	14·7 ± 0·20	13·9 ± 0·20	13·0 ± 0·20

Softening Temperature (Mg) and (F.S.P.)

The highest point reached on the thermal expansion curve (Mg) and the fibre softening point (F.S.P.) measured by the rate of extension of a fibre under its own weight, corresponding to a viscosity of $10^{7 \cdot 6}$ poises, are:

	C.S.G.3	N.S.G.2	I.S.G.30.	I.S.G.20.
Mg.	485 ± 5°C.	520 ± 5°C.	520 ± 5°C.	525 ± 5°C.
F.S.P.	570 ± 10°C.	650 ± 10°C.	645 ± 10°C.	655 ± 10°C.

Electrical Resistivity

Although not so high as those of W.1 or L.1 glasses the electrical resistivities are ten times that of X.8. soda glass.

	C.S.G.3	N.S.G.2	I.S.G.30.	I.S.G.20.
	Log$_{10}$ Electrical Resistivity (ohm. cm.)			
50·C	12	13·2	13·1	13·1
100°C.	11·1	11·1	11·3	11·3
200°C.	8·0	8·3	8·5	8·5
300°C.	5·9	6·6	6·6	6·6

Density and Refractive Index

	C.S.G.3	N.S.G.2	I.S.G.30.	I.S.G.20.
Density at 25°C.	2·78	2·96	2·95	2·93
Refractive Index at 20°C. (for Sodium D. Lime)	1·616	1·564	1·565	1·564

Annealing Range

When annealing glass to metal seals made with these high expansion glasses it is desirable to place the seals immediately into an annealing oven at a temperature in the rapid annealing range quoted below where they should anneal in 5 to 10 minutes. The subsequent cooling may then be at a rate just sufficient to prevent any glass breakage.

	C.S.G.3	N.S.G.2	I.S.G.30.	I.S.G.20.
Rapid Annealing Range	430°C.–400°C.	490°C.–450°C.	500°C.–450°C.	500°C.–450°C.

SOFT SOLDER GLASSES

A range of lead borate glasses which have quite low melting and flow points is available for sealing together glass components of similar expansion characteristics. This is accomplished at temperatures well below the softening points of the component glasses which are thus joined without any deformation and the resulting seal is vacuum tight.

Three glass soft solders cover the range of most applications, and are supplied in a granular form, or alternatively as a powder suspension in methyl alcohol.

	G.SS.1	G.SS.34	G.SS.38
Glasses joined	L.1. to X.8.	L.1. to L.1.	X.8. or Mica to X.8.
Coefficient of linear thermal expansion (20°C.–220°C.)	$8{\cdot}9 \pm 0{\cdot}15 \times 10^{-6}$	$8{\cdot}0 \pm 0{\cdot}15 \times 10^{-6}$	$9{\cdot}4 \pm 0{\cdot}15 \times 10^{-6}$
Soldering Temperatures	450–500°C.	460–525°C.	450–480°C.

GRADED SEAL GLASSES

G.E.C.

In scientific apparatus and many technical applications it is often necessary to make a seal between vitreous silica (quartz glass) or a hard borosilicate glass and a soft soda glass or even a lead glass. Such a seal cannot be made directly due to the great difference which exists in the thermal expansion coefficients. To surmount this difficulty a 'graded seal' is made.

Thus, starting with vitreous silica, a seal is made using a small quantity of a glass of slightly higher expansion (WQ10) and on to this a small quantity of a second glass of slightly higher expansion than the first (WQ20) and this procedure is repeated using glasses of successively higher expansion in the list until the final join which may be to L.1. or X.8. glass.

As many as ten 'graded seal' glasses may be required if for instance the seal is between vitreous silica and X.8. soda glass. In this way the stresses in the seal are uniformly distributed from end to end so that nowhere do they reach such a level as could cause breakage of the seal under normal conditions of use.

The complete range of 'graded seal' glasses made by the Company's Glass Works and supplied in the form of rod is given in the table below, together with their coefficients of linear thermal expansion and softening temperatures.

Sealing Glass Type	*Coefficient of Linear Thermal Expansion*	*Softening Temperature 'Mg' point*
	Sealing Glasses for joining silica to hard glass.	
Vitreous Silica		
WQ.10 (previously known as WQ.31)	$1{\cdot}0 \times 10^{-6}$	815°C.
WQ.20	$2{\cdot}0 \times 10^{-6}$	775°C.
WQ.25 (previously known as WQ.41)	$2{\cdot}5 \times 10^{-6}$	730°C.
WQ.30 (,, ,, ,, WQ42)	$3{\cdot}0 \times 10^{-6}$	690°C.
The graded seal may then be made successively to Chemical Pyrex, W.1. glass, H.H. glass and:		
G.S.52 (previously known as G.S.1)	$5{\cdot}2 \times 10^{-6}$	625°C.
G.S.59 (,, ,, ,, G.S.2)	$5{\cdot}9 \times 10^{-6}$	625°C.
*G.S.66 (,, ,, ,, G.S.3)	$6{\cdot}6 \times 10^{-6}$	620°C.
G.S.72 (,, ,, ,, G.S.4)	$7{\cdot}2 \times 10^{-6}$	625°C.
G.S.78 (,, ,, ,, G.S.5)	$7{\cdot}8 \times 10^{-6}$	560°C.
G.S.84 (,, ,, ,, G.S.6)	$8{\cdot}4 \times 10^{-6}$	515°C.

The next glass used is L.1. and this may then be sealed to X.8., X.4. or X.4/3.

**Matched seals may be made between G.S.*66 *and sapphire or* 42% *nickel-iron* ('*Nilo* 42'.)

The above glasses are naturally expensive to produce since all have to be specially melted, the first three at temperatures up to 2000°C., and the compositions carefully controlled, and comparatively small quantities are required. However, the small amount of each glass used in making a graded seal forms only a small proportion of the cost of making the seal.

SOME OF THE USES FOR G.E.C. GLASS

LEAD GLASS TUBING & ROD

Standard length 4 ft. (1·2 metres). Lengths up to 10 ft. (3·0 metres) can be produced. Used for:—

Flanges, stems and rod for electric lamps and radio valves.
Neck tubes, flared and plain for radar and television tubes.
Rings for miniature valve bases.
Sheathing tubes for electrodes.
Miniature and auto lamp bulbs.

SODA GLASS TUBING & ROD

Standard length 5 ft. (1·5 metres). Lengths up to 10 ft. (3·0 metres) can be produced. Used for:—

Fluorescent tubes.
Tubes for 'striplite' lamps, clear and enamelled.
Miniature valve bulbs.
Separator tubes for storage batteries.
Fuse tubes.
Gauge glasses.
Dental cartridge tubes.
Neon signs, also in lead glass.
Cold cathode lighting, also in lead glass.
Depth tubes.
Mercury switch tubes.
Syringe barrels.
Tower packing.
Test tubes.
Pill and tablet tubes.
Chemical, medical ware.
Laboratory apparatus.
Rods for stirrers, road studs.
Etc, etc.

TRANSPARENT VITREOUS SILICA

(Fused Quartz)

Standard length 720 mm.: also cut to size and usedfor:—

Electric lamps.
Electric heaters.

MACHINE-BLOWN PRODUCTS

Bulbs for electric lamps up to 150 mm. diameter.
Bulbs for radio valves.
Inner and outer blanks for vacuum flasks up to 2-pint capacity.
Hurricane lamp globes.
Tumblers and vases.

HAND-MADE PRODUCTS

Bulbs for electric lamps in lead, soda, borosilicate, special and coloured glasses.
Bulbs for mercury vapour and sodium lamps.
Bulbs for transmitting and receiving valves,
radar, television, electronic and X-ray tubes,
photo-electric cells and oscillograph apparatus.
Tubing in clear and coloured glasses.
Tubing for sodium lamps.
Street lighting, aerodrome electrification and domestic lighting glassware, blown and pressed.
Industrial glassware, blown and pressed.
Chemical, medical and laboratory ware.
Oil lamp chimneys and well glasses.
Coffee percolators, drainers and spirit lamps.
Bulkhead glassware.
Domestic glassware.

NEUTRAL GLASS TUBING

Standard length 5 ft. (1·5 metres). Used for:—

Ampoules, vials.
Dental cartridge tubes.
Gauge glasses.

PACKING

Tubing and rod packed in strong cardboard cartons, mainly 6 in. (0·15 metres) and 9 in. (0·23 metres) square, quantity depending on diameter.
Export. Either in cartons or bundles if sent by ferry truck or container, or wooden cases.
Bulbs, vacuum flask blanks, tumblers, etc. in strong sectional cardboard cartons approx. 3½/4 cu. ft. (1·0/1·3 cu. metres).
Export. The inner flask blanks are wrapped and packed in the outer blanks.

TRIMMING AND GLAZING

Bulk quantities of soda or neutral glass tubing in standard lengths and of diameters 14 mm. and greater are supplied with ends trimmed and glazed.

GLASS TUBING & ROD

(MACHINE-DRAWN AND HAND-DRAWN)

APPROXIMATE NUMBER OF FEET TO THE *POUND* IN VARIOUS SIZES AND WALLS
THESE TABLES ARE CORRECT FOR WEMBLEY X8 TUBING AND ROD
IF USED FOR OTHER GLASSES, ADJUSTMENT SHOULD BE MADE ACCORDING TO THEIR SP.G.

	TUBING									ROD
Ext. Diam. mm.	Wall ·25mm.	Wall ·50mm.	Wall ·75mm.	Wall 1·0mm.	Wall 1·25mm.	Wall 1·50mm.	Wall 2·0mm.	Wall 2·5mm.	Wall 3·0mm.	
2	436	254	203	—	—	—	—	—	—	189
3	277	152	113	95·3	87·3	—	—	—	—	84
4	203	109	78·2	63·5	55·5	50·8	—	—	—	47
5	160	85	59·8	47·7	40·7	38·0	31·8	—	—	30
6	132	69	48·3	38·1	32·1	28·3	23·9	21·7	—	21
7	113	58·7	40·7	31·8	26·5	23·1	19·0	16·9	15·7	15·5
8	98	51	35·1	27·2	22·6	19·6	15·9	13·8	12·6	12
9	87	45	30·8	23·8	19·7	17·0	13·6	11·7	10·5	9·5
10	78·2	40	27·5	21·2	17·4	15·0	11·9	10·1	9·0	7·5
11	71·0	36·3	24·8	19·1	15·6	13·4	10·6	8·9	7·9	6·2
12	64·8	33·1	22·6	17·3	14·2	12·1	9·5	8·0	7·0	5·2
13	59·8	30·5	20·8	15·9	13·0	11·0	8·7	7·2	6·3	4·5
14	55·5	28·3	19·2	14·6	12·0	10·1	7·9	6·6	5·7	3·9
15	51·7	26·3	17·8	13·6	11·1	9·4	7·3	6·0	5·2	3·4
16	48·3	24·6	16·7	12·7	10·3	8·8	6·8	5·6	4·8	3·0
17	45·5	23·1	15·6	11·9	9·7	8·2	6·3	5·2	4·5	2·6
18	43·0	21·8	14·7	11·2	9·1	7·7	5·9	4·9	4·2	2·3
19	40·7	20·6	13·9	10·6	8·6	7·2	5·6	4·6	3·9	2·1
20	38·5	19·6	13·2	10·0	8·1	6·9	5·3	4·3	3·7	1·9
21	36·7	18·6	12·5	9·5	7·7	6·5	5·0	4·1	3·4	1·7
22	—	17·7	12·0	9·1	7·3	6·2	4·7	3·9	3·2	1·5
23	—	17·0	11·4	8·7	7·0	5·8	4·5	3·7	3·1	1·4
24	—	16·2	10·9	8·3	6·7	5·6	4·3	3·5	2·9	1·3
25	—	15·6	10·5	7·9	6·4	5·3	4·1	3·3	2·7	1·2
26	—	15·0	10·1	7·6	6·1	5·1	4·0	3·2	2·6	1·1
27	—	14·4	9·7	7·3	5·9	4·9	3·8	3·1	2·5	1·0
28	—	13·9	9·3	7·0	5·7	4·7	3·6	2·9	2·4	1·0
29	—	13·4	9·0	6·8	5·5	4·6	3·5	2·8	2·3	·9
30	—	12·9	8·7	6·6	5·3	4·5	3·4	2·7	2·3	·8

Tubing above the thick line in these columns is Capillary.

THE FORMULA FOR CALCULATING WEIGHT of Wembley Soda Tubing is

$$2{\cdot}98\ (D^2 - d^2) = x$$

Where:—D=Mean outside diameter.
d=Mean bore.
x=Weight in grammes per 5-foot run.
(454 grammes=1 pound).

(Lead Tubing and Rod is one-fifth heavier per unit length). (Borosilicate Tubing and Rod is approx. one-tenth lighter per unit length).

GLASS TUBING & ROD

(MACHINE-DRAWN AND HAND-DRAWN)

APPROXIMATE NUMBER OF FEET TO THE *POUND* IN VARIOUS SIZES AND WALLS
THESE TABLES ARE CORRECT FOR WEMBLEY X.8. TUBING AND ROD.
IF USED FOR OTHER GLASSES, ADJUSTMENT SHOULD BE MADE ACCORDING TO THEIR SP.G

TUBING

Ext. Diam. mm.	Wall ·50mm.	Wall ·75mm.	Wall 1·0mm.	Wall 1·25mm.	Wall 1·50mm.	Wall 2·0mm.	Wall 2·5mm.	Wall 3·0mm.
31	12·5	8·4	6·3	5·1	4·3	3·3	2·6	2·2
32	12·1	8·1	6·1	4·9	4·1	3·2	2·5	2·1
33	—	7·9	5·9	4·8	4·0	3·1	2·5	2·1
34	—	7·6	5·7	4·7	3·9	3·0	2·4	2·0
35	—	7·4	5·6	4·5	3·8	2·9	2·3	2·0
36	—	7·2	5·4	4·4	3·6	2·8	2·2	1·9
37	—	7·0	5·3	4·3	3·5	2·7	2·2	1·9
38	—	6·8	5·1	4·1	3·4	2·6	2·1	1·8
39	—	6·6	5·0	4·0	3·3	2·5	2·1	1·7
40	—	6·5	4·9	3·9	3·3	2·5	2·0	1·7
41	—	6·3	4·7	3·8	3·2	2·4	2·0	1·6
42	—	6·1	4·6	3·7	3·1	2·4	1·9	1·6
43	—	5·9	4·5	3·6	3·0	2·3	1·9	1·6
44	—	5·8	4·4	3·5	3·0	2·3	1·8	1·5
45	—	5·7	4·3	3·4	2·9	2·2	1·8	1·5
46	—	5·6	4·2	3·3	2·8	2·2	1·7	1·4
47	—	5·5	4·1	3·2	2·8	2·1	1·7	1·4
48	—	5·4	4·0	3·2	2·7	2·1	1·7	1·3
49	—	5·3	3·9	3·1	2·6	2·0	1·6	1·3
50	—	5·2	3·9	3·1	2·6	2·0	1·6	1·3
51	—	—	3·8	3·0	2·5	1·9	1·5	1·2
52	—	—	3·7	3·0	2·5	1·9	1·5	1·2
53	—	—	3·6	2·9	2·4	1·9	1·5	1·2
54	—	—	3·5	2·9	2·4	1·8	1·5	1·2
55	—	—	3·4	2·8	2·3	1·8	1·4	1·2
56	—	—	3·3	2·8	2·3	1·8	1·4	1·1
57	—	—	3·2	2·7	2·2	1·7	1·4	1·1
58	—	—	3·2	2·7	2·2	1·7	1·4	1·1
59	—	—	3·1	2·6	2·1	1·6	1·3	1·1
60	—	—	3·1	2·6	2·1	1·6	1·3	1·1

GAUGING TOLERANCES ON DIAMETER are normally: 1mm. overall up to 25mm.; 2mm. from 25mm. to 30mm.; and 3mm. over 30mm. Special selection can, however, be undertaken if required.

STANDARD BUNDLES of machine-drawn tubing and rod are: Up to 25mm., 14lb.; over 25mm., 10 lb. Hand-drawn tubing and rod can be supplied in any quantities.

The above table is correct for soda glass tubing.
To obtain the lengths appropriate to L.1. and M.6., multiply by the following factors, L.1. 0·81, M.6. 1·03.

GLASS TUBING & ROD

(MACHINE-DRAWN AND HAND-DRAWN)

APPROXIMATE NUMBER OF METRES TO THE *KILOGRAM* IN VARIOUS SIZES AND WALLS
THESE TABLES ARE CORRECT FOR WEMBLEY X.8. TUBING AND ROD.
IF USED FOR OTHER GLASSES, ADJUSTMENT SHOULD BE MADE ACCORDING TO THEIR SP.G

	TUBING									ROD
Ext. Diam. mm.	Wall ·25mm.	Wall ·50mm.	Wall ·75mm.	Wall 1·0mm.	Wall 1·25mm.	Wall 1·50mm.	Wall 2·0mm.	Wall 2·5mm.	Wall 3·0mm.	
2	293	170	136	—	—	—	—	—	—	127
3	186	102	75·9	64·0	58·6	—	—	—	—	56·4
4	136	73·2	52·5	42·7	37·3	34·1	—	—	—	31·6
5	107	57·1	40·2	32·0	27·3	25·5	21·4	—	—	20·1
6	88·7	46·4	32·5	25·6	21·6	19·0	16·0	14·6	—	14·1
7	75·9	39·4	27·4	21·4	17·8	15·5	12·7	11·3	10·5	10·4
8	65·8	34·3	23·6	18·3	15·2	13·2	10·7	9·27	8·47	8·06
9	58·5	30·2	20·7	16·0	13·2	11·4	9·14	7·86	7·05	6·38
10	52·5	26·9	18·5	14·2	11·7	10·1	8·0	6·79	6·05	5·04
11	47·7	24·4	16·7	12·8	10·5	9·0	7·12	5·98	5·31	4·16
12	43·5	22·2	15·2	11·6	9·54	8·13	6·38	5·37	4·70	3·49
13	40·2	20·5	14·0	10·7	8·74	7·39	5·84	4·84	4·25	3·02
14	37·3	19·0	12·9	9·81	8·06	6·79	5·31	4·43	3·83	2·62
15	34·7	17·7	11·9	9·14	7·46	6·32	4·90	4·03	3·49	2·28
16	32·4	16·5	11·2	8·53	6·92	5·91	4·57	3·76	3·22	2·01
17	30·6	15·5	10·5	8·0	6·52	5·51	4·23	3·49	3·02	1·75
18	28·9	14·6	9·9	7·52	6·11	5·17	3·96	3·29	2·82	1·54
19	27·3	13·8	9·3	7·12	5·78	4·84	3·76	3·09	2·62	1·41
20	25·9	13·2	8·87	6·72	5·44	4·64	3·56	2·89	2·48	1·27
21	24·6	12·5	8·40	6·38	5·17	4·37	3·36	2·75	2·28	1·14
22	—	11·9	8·06	6·11	4·9	4·16	3·16	2·62	2·15	1·01
23	—	11·4	7·66	5·85	4·7	3·9	3·02	2·48	2·08	·940
24	—	10·9	7·32	5·58	4·5	3·76	2·89	2·35	1·95	·873
25	—	10·5	7·05	5·31	4·3	3·56	2·75	2·22	1·81	·806
26	—	10·1	6·78	5·11	4·1	3·43	2·69	2·15	1·75	·739
27	—	9·67	6·52	4·90	3·96	3·29	2·55	2·08	1·68	·672
28	—	9·34	6·25	4·70	3·83	3·16	2·42	1·95	1·61	·672
29	—	9·00	6·05	4·57	3·69	3·09	2·35	1·88	1·54	·604
30	—	8·67	5·85	4·43	3·56	3·02	2·28	1·81	1·54	·537

Tubing above the thick line in these columns is Capillary.

THE FORMULA FOR CALCULATING WEIGHT of Wembley Soda Tubing is

$1{\cdot}96\ (D^2 - d^2) = x$

Where:—D=Mean outside diameter.
d=Mean bore.
x=Weight in grammes per metre.
(1,000 grams = 1 kilogram)

(Lead Tubing and Rod is one-fifth heavier per unit length). (Borosilicate Tubing and Rod is approx. one-tenth lighter per unit length).

GLASS TUBING & ROD

(MACHINE-DRAWN AND HAND-DRAWN)

APPROXIMATE NUMBER OF METRES TO THE *KILOGRAM* IN VARIOUS SIZES AND WALLS
THESE TABLES ARE CORRECT FOR WEMBLEY X.8. TUBING AND ROD.
IF USED FOR OTHER GLASSES, ADJUSTMENT SHOULD BE MADE ACCORDING TO THEIR SP.G.

TUBING

Ext. Diam. mm.	Wall ·50mm.	Wall ·75mm.	Wall 1·0mm.	Wall 1·25mm.	Wall 1·50mm.	Wall 2·0mm.	Wall 2·5mm.	Wall 3·0mm.
31	8·40	5·64	4·23	3·43	2·89	2·22	1·75	1·48
32	8·13	5·44	4·10	3·29	2·75	2·15	1·68	1·41
33	—	5·31	3·96	3·22	2·69	2·08	1·68	1·41
34	—	5·11	3·83	3·16	2·62	2·01	1·61	1·34
35	—	4·97	3·76	3·02	2·55	1·95	1·54	1·34
36	—	4·84	3·63	2·95	2·42	1·88	1·48	1·27
37	—	4·70	3·56	2·89	2·35	1·81	1·48	1·27
38	—	4·57	3·43	2·75	2·28	1·75	1·41	1·21
39	—	4·43	3·36	2·69	2·22	1·68	1·41	1·14
40	—	4·37	3·29	2·62	2·22	1·68	1·34	1·14
41	—	4·23	3·16	2·55	2·15	1·61	1·34	1·07
42	—	4·10	3·09	2·48	2·08	1·61	1·27	1·07
43	—	3·96	3·02	2·42	2·01	1·54	1·27	1·07
44	—	3·90	2·95	2·35	2·01	1·54	1·21	1·01
45	—	3·83	2·89	2·28	1·95	1·48	1·21	1·01
46	—	3·76	2·82	2·22	1·88	1·48	1·14	·940
47	—	3·69	2·75	2·15	1·88	1·41	1·14	·940
48	—	3·63	2·69	2·15	1·81	1·41	1·14	·873
49	—	3·56	2·62	2·08	1·75	1·34	1·07	·873
50	—	3·49	2·62	2·08	1·75	1·34	1·07	·873
51	—	—	2·55	2·01	1·68	1·27	1·01	·806
52	—	—	2·48	2·01	1·68	1·27	1·01	·806
53	—	—	2·42	1·95	1·61	1·27	1·01	·806
54	—	—	2·35	1·95	1·61	1·21	1·01	·806
55	—	—	2·28	1·88	1·54	1·21	·940	·806
56	—	—	2·22	1·88	1·54	1·21	·940	·739
57	—	—	2·15	1·81	1·48	1·14	·940	·739
58	—	—	2·15	1·81	1·48	1·14	·940	·739
59	—	—	2·08	1·75	1·41	1·07	·873	·739
60	—	—	2·08	1·75	1·41	1·07	·873	·739

GAUGING TOLERANCES ON DIAMETER are normally: 1mm. overall up to 25mm.; 2mm. from 25mm. to 30mm.; and 3mm. over 30mm. Special selection can, however, be undertaken if required.

STANDARD BUNDLES of machine-drawn tubing and rod are of 5 kgm. and 10 kgm. weight. Hand-drawn tubing and rod can be supplied in any quantities.

The above table is correct for soda glass tubing; to obtain the lengths appropriate to L.1. and M.6., multiply by the following factors:—L.1., 0.81; M.6., 1·03.

ANNEALING SCHEDULES

For articles made from tubing and rod the following annealing procedure is recommended:

	Important Temperatures		
	High	*Intermediate*	*Low*
X.8. Soda Glass	530°C.	460°C.	400°C.
M.6. Neutral Glass	575°C.	530°C.	470°C.
L.1. Lead Glass	430°C.	390°C.	340°C.

Operating Instructions

(1) Hold the glassware at the 'high' temperature for a period of 5 to 10 minutes.

(2) Cool the ware down from the 'high' to the 'Intermediate' temperature at the following rates:

(*a*) 3°C. per minute for tubing up to ½ mm. wall thickness.
(*b*) 2°C. " " " " " " 1 mm. " "
(*c*) 1°C. " " " " " " 3 mm. " "

(3) Cool down from the 'intermediate' to the 'low' temperature at double the above rates.

(4) Cool down from the 'low' temperature to room temperature at any reasonable rate which can be accomplished without cracking the ware by excessive thermal shock.

(5) Examine samples of the articles when cold and at a *uniform room temperature* in a strain viewer. The habitual use by glass blowers of a reliable strain viewer is strongly recommended.