Fused Quartz Products

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY
Quartz Products Department

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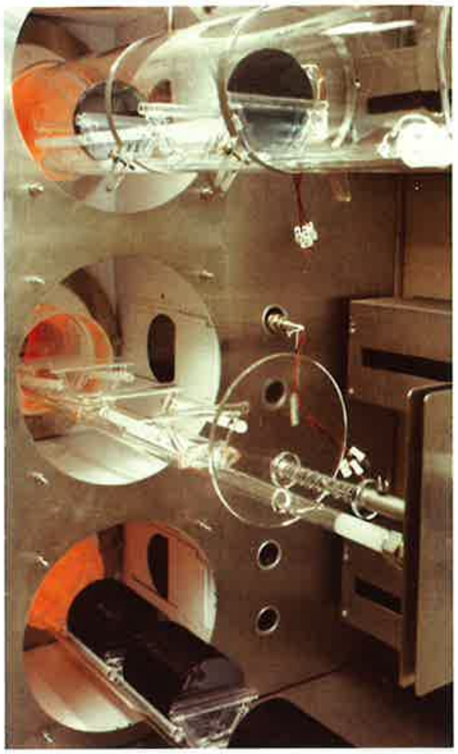
Introduction

FUSED QUARTZ PRODUCTS

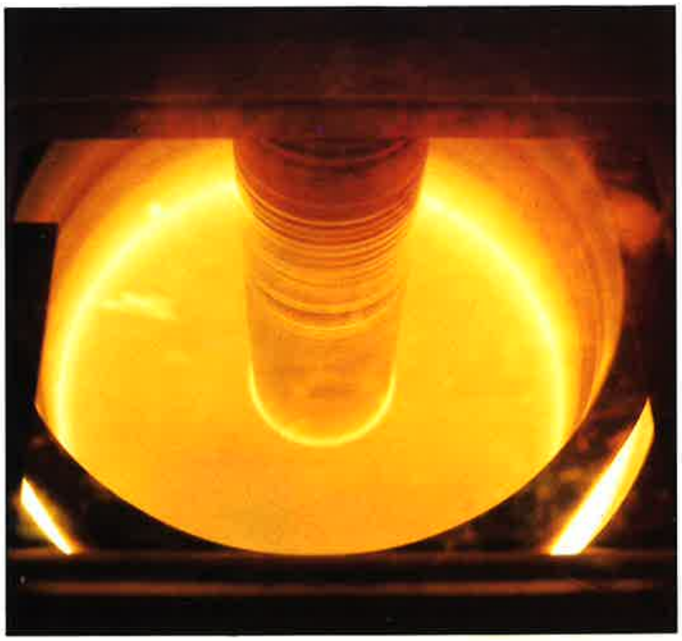
General Electric Company began producing fused quartz to meet the high temperature requirements of many of its lamp products. Over the years, fused quartz has become an important engineering material, with a variety of applications both inside and outside the lighting industry. GE is now a major producer of the material, with an extensive product line that is sold to users and quartzware fabricators throughout the world.

Fused quartz is still widely used in high temperature lighting devices such as quartz metal halide, quartz halogen, and mercury vapor lamps. But it is the fast-growing semiconductor and fiber optics industries which now claim an important share of General Electric's fused quartz capacity.

In electronics, the material has found a ready and growing market because it can tolerate the wide temperature gradients and high heat rates required for processing silicon wafers. The purity of fused quartz creates a low contamination environment needed for this type of processing.



GE Type 214LD fused quartz tubes are used for processing silicon wafers in diffusion furnaces that cycle between 300° and 1250°C. The material has the ability to withstand the high temperatures, thermal cycling and chemical environment required in this application. Other fused quartz parts shown here include loading sleeves, end caps, push rods, and boats.

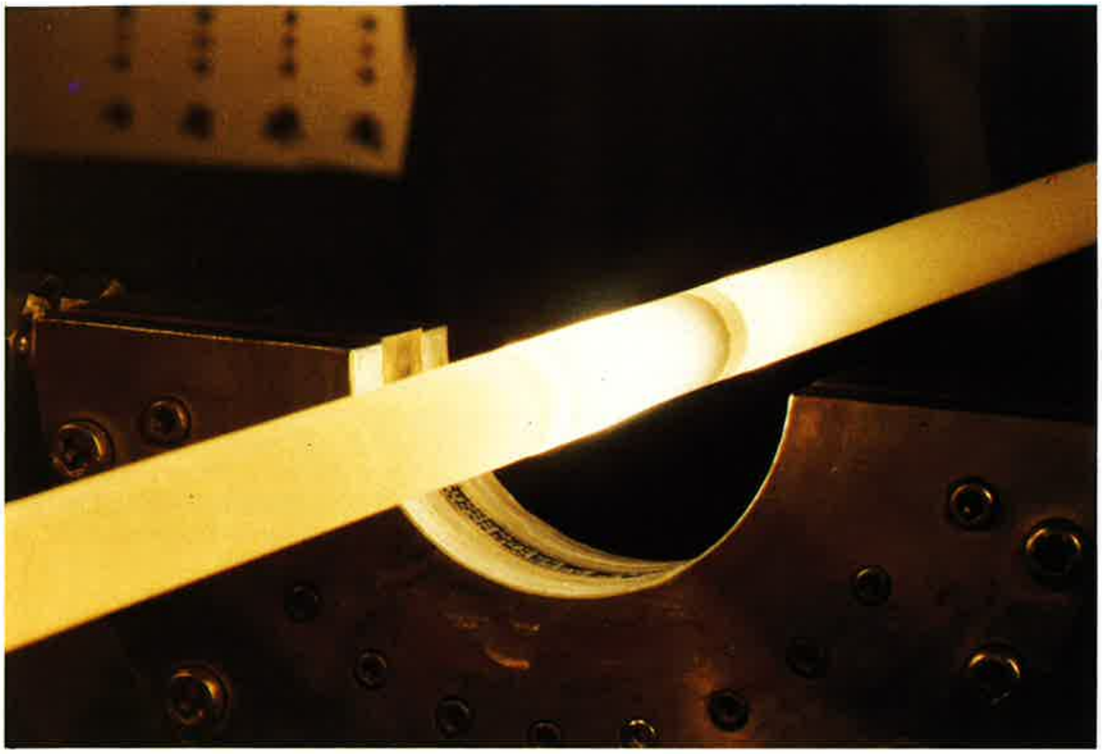


Type 510 crucibles are used by silicon single-crystal manufacturers to achieve extremely consistent results, and are given strong credit for the ultra-high purity of the melts.

General Electric has responded to the growing demand for fused quartz by finding new and better sources of raw materials, expanding and modernizing its production facilities, and continually upgrading its quality control functions to improve product reliability. All General Electric clear fused quartz is made from high purity silicon dioxide which is upgraded through the use of various proprietary processes.

A major factor in the development of new uses for fused quartz is General Electric's ability to provide the necessary engineering support as well as the resources for making and testing prototypes.

GE fused quartz products are supplied directly to users or through appointed quartzware fabricators who custom-make diffusion tubes, wafer carriers, and other products used in semiconductor processing.



GE Type 982WG tubing is used as cladding to make material for fiber optic preforms.

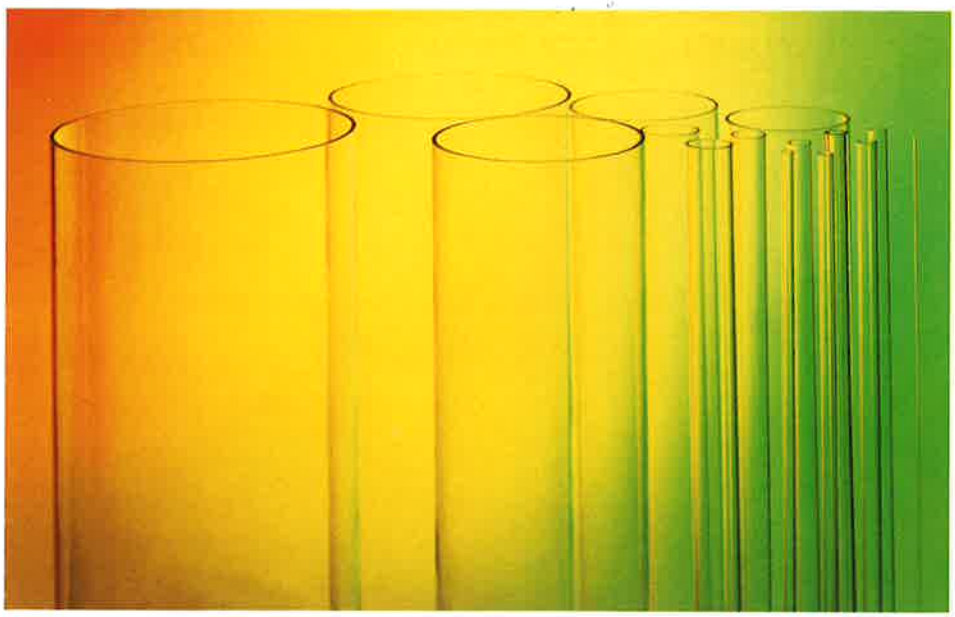
Fused quartz tubing is widely used in the lamp industry for high temperature lamps including quartz halogen, Multi-Vapor®, and mercury vapor types. These lamps are used for lighting stadiums and athletic fields, illumination of buildings and parking lots, interior lighting for stores, shopping malls and plants, special types of photographic lighting, and many other applications.

SECTION II

Fused Quartz Products

TYPES OF GENERAL ELECTRIC FUSED QUARTZ		
Type	**Description**	**Application**
214 Tubing	Clear fused quartz for high volume applications. Low cost and available in a wide range of stock sizes. This material is essentially free from hydroxyl.	Used as high temperature envelopes for mercury and halogen lamps, and semiconductor quartzware.
214A Tubing	Clear fused quartz which has the same excellent properties as Type 214 material. This material is essentially free from hydroxyl or other dissolved gas content.	Used as high temperature envelopes for metal halide lamps or other applications requiring essentially hydroxyl-free material.
214HV Tubing	This material may contain some relatively large air lines which tend to collapse and disappear when subjected to typical fabrication processing.	Generally intended for use as a low cost, high purity material for fabrication of custom quartzware and large diameter fused quartz bell jars.
214LD Tubing	Clear fused quartz for large diameter applications. This material is essentially air line free but may have some fine bubbles and a slightly rippled appearance.	Used by the semiconductor industry for diffusion, oxidation and LPCVD processing.
219 Tubing	Clear fused quartz tubing doped with titanium dioxide to reduce U.V. transmission. This material is essentially free from hydroxyl or other dissolved gas content. This U.V. filtering grade is commonly referred to as ozone-free fused quartz.	Used as lamp envelopes in applications where U.V. transmission is considered undesirable.
318 Tubing	Translucent fused quartz tubing with a satin surface and a higher impurity content than standard GE clear grades. Translucent appearance is derived from the many fine air lines inherent in this material.	Used as lamp envelopes for infrared heating lamps and as heating element protection tubes in diverse industrial and consumer infrared applications.
982 Tubing	Clear fused quartz made by a special General Electric proprietary process to provide tubing with minimal inclusions, air lines, and exceptional tolerance control.	Used as cladding material by the fiber optics industry for optical waveguide manufacture.
214 Rod	Clear fused quartz rod which has minimal air lines and inclusions, and excellent dimensional stability.	Used to fabricate silicon wafer carriers for the semiconductor industry.
124 Ingots	Clear fused quartz plate and window material which is produced in ingot form, 72-inch diameter × 26 inches thick. This material has high purity and will contain some fine bubbles. Various sizes and shapes are readily available.	Used to fabricate wafer carriers and flanges for the semiconductor industry and in a variety of optical applications where low cost commercial quality material is specified.
510 Crucibles	High purity, opaque crucibles with a high gloss internal surface and a white granular outside surface.	These crucibles are used by the semiconductor industry to grow single crystal silicon.

FUSED QUARTZ TUBING



Clear fused quartz tubing is available in a wide range of sizes with diameters ranging from 1.5mm OD through 330mm OD, and wall thicknesses from 1mm through 6mm.

TABLE I—TYPICAL SIZES, TYPE 214 FUSED QUARTZ TUBING

Designation (mm)	OD(mm)	ID(mm)	Wall (mm) Avg.	Min.	Max.	Max. Siding (mm)	Max. Ovality (mm)
1.00 × 2.00	2.00 ± .15	1.00 ± .12	—	—	—	.10	.10
2.00 × 3.00	3.00 ± .18	2.00 ± .18	—	—	—	.10	.10
2.00 × 6.00	6.00 ± .30	2.00 ± .16	—	—	—	.30	.10
2.35 × 3.65	3.65 ± .18	2.35 ± .18	—	—	—	.10	.10
2.35 × 3.80	3.80 ± .18	2.35 ± .18	—	—	—	.10	.10
2.35 × 4.00	4.00 ± .19	2.35 ± .18	—	—	—	.10	.10
2.35 × 4.35	4.35 ± .20	2.35 ± .18	—	—	—	.10	.10
3.00 × 4.00	4.00 ± .20	3.00 ± .24	—	—	—	.10	.10
3.00 × 5.00	5.00 ± .25	3.00 ± .24	—	—	—	.10	.15
4.00 × 6.00	6.00 ± .30	4.00 ± .32	—	—	—	.10	.15
4.75 × 7.25	7.25 ± .30	4.75 ± .25	—	—	—	.15	.22
5.00 × 7.00	7.00 ± .35	---	1.00	.85	1.15	.15	.20
6.00 × 8.00	---	6.00 ± .30	1.00	.87	1.13	.10	.15
6.00 × 10.00	10.00 ± .30	---	2.00	1.74	2.26	.20	.20
6.50 × 8.50	8.50 ± .26	---	1.00	.87	1.13	.10	.15
7.00 × 9.00	9.00 ± .27	---	1.00	.87	1.13	.15	.30
7.75 × 9.75	---	7.75 ± .25	1.00	.87	1.13	.15	.15
7.80 × 10.00	---	7.80 ± .30	1.10	.97	1.23	.15	.15
8.00 × 10.00	10.00 ± .30	---	1.00	.87	1.13	.15	.30
8.00 × 12.00	---	8.00 ± .32	2.00	1.70	2.30	.30	.30
9.00 × 11.00	11.00 ± .33	---	1.00	.87	1.13	.15	.30
9.00 × 11.80	---	9.00 ± .36	1.40	1.12	1.68	.28	.30
10.00 × 12.00	---	10.00 ± .45	1.00	.87	1.13	.15	.30
10.50 × 12.75	12.75 ± .30	---	1.13	1.00	1.26	.15	.35
11.00 × 13.00	13.00 ± .40	---	1.00	.87	1.13	.15	.35
12.00 × 14.00	14.00 ± .50	---	1.00	.87	1.13	.15	.50
12.75 × 15.00	15.00 ± .45	---	1.13	1.00	1.26	.20	.40
13.00 × 15.00	---	13.00 ± .50	1.00	.87	1.13	.15	.50
15.00 × 17.00	---	15.00 ± .60	1.00	.87	1.13	.15	.50
15.00 × 18.00	18.00 ± .55	---	1.50	1.30	1.70	.20	.45
16.00 × 18.00	18.00 ± .55	---	1.00	.87	1.13	.15	.50

Designation (mm)	OD(mm)	ID(mm)	Wall (mm) Avg.	Min.	Max.	Max. Siding (mm)	Max. Ovality (mm)
18.0 × 20.5	20.5 ± .60	---	1.25	1.08	1.42	.20	.55
18.0 × 21.6	---	18.0 ± .55	1.80	1.50	2.10	.25	.50
20.0 × 22.0	---	20.0 ± .60	1.00	.87	1.13	.15	.66
20.0 × 22.5	---	20.0 ± .70	1.25	1.08	1.42	.20	.50
22.0 × 25.0	25.0 ± .50	---	1.50	1.30	1.70	.20	.50
22.0 × 25.3	25.3 ± .50	---	1.65	1.43	1.87	.20	.50
22.0 × 25.8	25.8 ± .55	---	1.90	1.60	2.20	.25	.55
25.0 × 27.5	27.5 ± .55	---	1.25	1.08	1.42	.20	.55
25.0 × 28.0	28.0 ± .55	---	1.50	1.30	1.70	.20	.55
25.0 × 28.8	28.8 ± .60	---	1.90	1.60	2.20	.25	.60
27.0 × 30.0	30.0 ± .90	---	1.50	1.28	1.72	.20	.90
30.0 × 33.0	33.0 ± 1.00	---	1.50	1.28	1.72	.20	1.00
32.0 × 35.0	35.0 ± 1.05	---	1.50	1.28	1.72	.20	1.05
35.0 × 38.0	38.0 ± 1.15	---	1.50	1.28	1.72	.20	1.15
37.0 × 40.0	40.0 ± 1.20	---	1.50	1.28	1.72	.20	1.20
38.1 × 42.1	42.1 ± 1.25	---	2.00	1.70	2.30	.30	1.25
40.0 × 43.0	43.0 ± 1.30	---	1.50	1.28	1.72	.20	1.30
42.0 × 45.0	45.0 ± 1.35	---	1.50	1.28	1.72	.20	1.35
45.0 × 48.0	48.0 ± 1.45	---	1.50	1.28	1.72	.20	1.45
47.0 × 50.0	50.0 ± 1.50	---	1.50	1.28	1.72	.20	1.50
48.0 × 52.0	52.0 ± 1.55	---	2.00	1.70	2.30	.30	1.55
50.0 × 54.0	54.0 ± 1.60	---	2.00	1.70	2.30	.30	1.60
50.0 × 55.0	55.0 ± 1.65	---	2.50	2.13	2.87	.35	1.65
53.0 × 57.0	57.0 ± 1.70	---	2.00	1.70	2.30	.30	1.70
55.0 × 59.0	59.0 ± 1.75	---	2.00	1.70	2.30	.30	1.75
57.0 × 61.0	61.0 ± 1.85	---	2.00	1.70	2.30	.30	1.85
60.0 × 64.0	64.0 ± 1.90	---	2.00	1.60	2.40	.30	1.90
63.0 × 67.0	67.0 ± 2.00	---	2.00	1.60	2.40	.30	2.00
65.0 × 69.0	69.0 ± 2.10	---	2.00	1.60	2.40	.30	2.10
66.0 × 70.0	70.0 ± 2.10	---	2.00	1.60	2.40	.30	2.10

NOTE: Other sizes available upon request

Maximum Bow: 2 mm/1220 mm

TABLE II–GENERAL TOLERANCES, TYPE 214 FUSED QUARTZ TUBING

Designation	OD	ID	Wall
Up to 2mm ID	± 8%	± 12%	—
2mm up to 5mm ID	± 5%	± 8%	—
5mm up to 13mm ID	± 3%	—	± 13%
13mm up to 18mm ID	± 3%	—	± 13%
18mm up to 25mm ID	± 2%	—	± 13%
25mm up to 59.9mm ID	± 3%	—	± 15%
59.9mm up to 69.9mm ID	± 3%	—	± 20%
69.9mm ID and over	± 3%	—	± 25%

Length Tolerances

30mm OD and Under		Over 30mm OD	
Under 150mm	± .5mm	Under 305mm	± 1mm
150mm thru 304mm	± 1mm	305mm thru 4 ft.	± .125"
305mm thru 4 ft.	± .062"	4 ft. thru 8 ft.	± .250"
4 ft. thru 8 ft.	± .125"		

Maximum Siding: 14% of Nom.
Maximum Ovality: 3% of Nom. OD
Maximum Bow: 2mm/1220mm

TABLE III–TYPICAL SIZES & TOLERANCES, TYPE 214A FUSED QUARTZ TUBING

Typical Sizes (mm)	% Tolerances	
	OD	Wall
18 × 20.5	3	13
18 × 21.6	3	13
20 × 22.0	2	13
20 × 22.5	2	13
22 × 24.5	2	13
22 × 25.0	2	13
22 × 25.3	2	13
22 × 25.8	2	13
25 × 27.5	2	13
25 × 28.0	2	13
25 × 28.8	2	13
27 × 30.0	3	20

NOTE: Other sizes available upon request.

Length Tolerances:		
	Less than .3 meters	± .5mm
	.31 to 1.2 meters	± 1.5mm
	Over 1.3 meters	± 3.0mm

TABLE IV–TYPICAL SIZES, TYPE 214HV CLEAR FUSED QUARTZ TUBING

Designation (mm)	OD (mm)	ID (mm) Min.	ID (mm) Max.	Wall (mm) Avg.	Wall (mm) Min.	Wall (mm) Max.	Max. Siding (mm)	Max. Ovality (mm)
61.2 × 68	68 ± 2.00	—		3.4	2.9	3.9	.34	2.0
66.6 × 72	72 ± 2.00	—		2.7	2.3	3.1	.27	2.2
64.4 × 72	72 ± 2.00	—		3.8	3.2	4.4	.38	2.2
70.0 × 76	76 ± 2.00	—		3.0	2.5	3.5	.30	2.3
69.0 × 77	77 ± 2.00	—		4.0	3.4	4.6	.40	2.3
73.2 × 80	80 ± 2.00	—		3.4	2.9	3.9	.34	2.4
76.6 × 84	84 ± 2.50	—		3.7	3.1	4.3	.37	2.5
77.8 × 85	85 ± 2.55	—		3.6	3.1	4.1	.36	2.6
80.0 × 88	88 ± 2.60	—		4.0	3.4	4.6	.40	2.6
88.0 × 97	97 ± 2.90	—		4.5	3.8	5.2	.45	2.9

NOTE: Other sizes available upon request

Maximum Bow: 2 mm/1220 mm

TABLE V–GENERAL TOLERANCES, TYPE 214HV CLEAR FUSED QUARTZ TUBING

Size	Length	OD	ID*	Wall	Max. Siding	Max. Ovality	Max. Bow
All > 50mm ID	6' ± 1" 6'6" ± 1" 7' ± 1" 8' ± 1"	± 3%	± 3%	± 15%	10% of Nominal Wall	3% of Nominal OD	2mm/1220mm

*ID for reference only. Unless otherwise specified, material will meet OD wall tolerance.

TABLE VI—TYPICAL SIZES, TYPE 214LD FUSED QUARTZ CIRCULAR TUBING

Designation (mm)	OD (mm)	Max. Siding (mm)	Max. Ovality (mm)
65 × 69	69.0 ± 2.0	.50	.35
66 × 70	70.0 ± 2.0	.50	.35
70 × 74	74.0 ± 2.0	.50	.35
75 × 80	80.0 ± 2.0	.60	.40
80 × 84	84.0 ± 2.0	.50	.50
80 × 85	85.0 ± 2.0	.60	.40
85 × 90	90.0 ± 2.0	.60	.40
90 × 95	95.0 ± 2.0	.60	.50
92.5 × 98.5	98.5 ± 2.0	.75	.50
94 × 99	99.0 ± 2.0	.60	.50
95 × 100	100.0 ± 2.0	.60	.50
98.5 × 106.5	106.5 ± 2.0	.75	.50
101.6 × 106.6	106.6 ± 2.0	.60	.50
101.6 × 114.3	114.3 ± 2.0	1.00	.50
105 × 110	110.0 ± 2.0	.60	.55
105 × 112	112.0 ± 2.0	.75	.50
105 × 117.7	117.7 ± 2.0	1.00	.50
110 × 115	115.0 ± 2.0	.60	.60
115 × 120	120.0 ± 2.0	.60	.60
115 × 127.7	127.7 ± 2.0	1.00	.55
120 × 125	125.0 ± 2.0	.50	.60
125 × 130	130.0 ± 2.0	.60	.65
130 × 135	135.0 ± 2.0	.60	.70
130 × 136	136.0 ± 2.0	.75	.70
130 × 142.7	142.7 ± 2.0	1.00	.65
135 × 141	141.0 ± 2.0	.75	.70
135 × 147.7	147.7 ± 2.0	1.00	.65
140 × 146	146.0 ± 2.0	.75	.70
140 × 150	150.0 ± 2.0	1.00	.70
140 × 152.7	152.7 ± 2.0	1.00	.70
145 × 151	151.0 ± 2.0	.75	.80
145 × 157.7	157.7 ± 2.0	1.00	.70
150 × 156	156.0 ± 2.0	.75	1.00
150 × 162.7	162.7 ± 2.0	1.00	.75
155 × 161	161.0 ± 2.0	.75	1.00
160 × 166	166.0 ± 2.0	.75	1.00
165 × 171	171.0 ± 2.0	.75	1.00
170 × 176	176.0 ± 2.0	.75	1.80
170 × 182.7	182.7 ± 2.0	1.00	1.70
184 × 190	190.0 ± 2.0	.90	1.90
184 × 196.7	196.7 ± 3.0	1.00	1.80
190 × 196	196.0 ± 3.0	.60	1.90
192 × 200	200.0 ± 3.0	.80	1.90
195 × 201	201.0 ± 3.0	.60	1.90
200 × 206	206.0 ± 3.0	.60	2.00
203 × 211	211.0 ± 3.0	1.20	2.11
208 × 216	216.0 ± 3.0	1.20	2.20
215 × 221	221.0 ± 3.0	.90	2.20
225 × 235	235.0 ± 3.0	1.00	2.25
227 × 235	235.0 ± 3.0	1.20	2.40
240 × 246	246.0 ± 4.0	.90	2.50
250 × 260	260.0 ± 4.0	1.50	2.60
255 × 265	265.0 ± 4.0	1.00	2.50

Note: Other sizes available upon request.

Maximum Bow: .3mm/ft.

TABLE VII—GENERAL TOLERANCES, TYPE 214LD FUSED QUARTZ TUBING

Size	OD	Wall	Max. Siding	Max. Ovality	Max. Bow
Up to 131mm ID	± 2.0mm	± 20%	25% of Nom.	.5% of Nom.	.3mm/ft.
131mm to 165mm ID	± 2.0mm	±25%	25% of Nom.	.5% of Nom.	.3mm/ft.
165mm to 191mm ID	± 2.0mm	± 30%	30% of Nom.	1% of Nom.	.3mm/ft.
191mm to 245mm ID	± 3.0mm	± 30%	30% of Nom.	1% of Nom.	.3mm/ft.
246mm ID and over	± 4.0mm	± 30%	30% of Nom.	1% of Nom.	.3mm/ft.

Length Tolerances

Under 12″	± .040″
12 to 48″	± .062″
48 thru 72″	± .125″
72 thru 96″	± .250″
Over 96″	± .375″

TABLE VIII – TYPICAL SIZES & TOLERANCES, TYPE 318 TRANSLUCENT FUSED QUARTZ TUBING

Designation	OD (mm) Min.	OD (mm) Max.	ID (mm) Min.	ID (mm) Max.	Wall (mm) Avg.	Wall (mm) Min.	Wall (mm) Max.	Max. Siding (mm)	Max. Ovality (mm)	Max. Bow (mm per 6′ Lgth.)
6.55 × 8.35mm	8.0	8.7	—	—	.9	0.7	1.1	.300	.500	5
7.75 × 9.75mm	—	—	7.30	8.20	—	0.8	1.2	.300	.900	5
7.75 × 9.75mm	—	10.1	7.25	—	1.0	—	—	.300	.900	5
⅜″ × ½″	.480	.520	.345	.405	.063	—	—	.025	.030	5
½″ × ⅝″	.600	.650	.460	.540	.063	—	—	.025	.037	5
⅝″ × ¾″	.720	.780	5.75	.675	.063	—	—	.025	.045	5
¾″ × 1″	.960	1.040	.690	.810	.125	—	—	.050	.060	5
⅞″ × 1⅛″	1.085	1.170	.805	.945	.125	—	—	.050	.067	5

General Dimensional Tolerances

OD:	± 4%	Length:	Under 12″	± .040″
ID:	± 8%		12″ thru 48″	± 1/16″
Wall:	± 25%		48″ thru 73″	± 1/8″

TABLE IX – TYPICAL SIZES & TOLERANCES, TYPE 982 FUSED QUARTZ TUBING

Typical Sizes

Inside Diameter		Outside Diameter	Inside Diameter		Outside Diameter
17 mm	×	20 mm	16 mm	×	20 mm
18 mm	×	21 mm	17 mm	×	21 mm
21 mm	×	24 mm	22 mm	×	26 mm
22 mm	×	25 mm	20 mm	×	25 mm
24 mm	×	27 mm	19 mm	×	25 mm

Lengths are available up to 1.5 meters.

General Dimensional Tolerances

Within a Tube:

Outside Diameter	± 2%
Wall Thickness	± 5%
Ovality	2% Max.
Bow	.8mm/meter
Siding (Max. Wall - Min. Wall) / Nominal Wall	6% Max.
Length	± 3%
Cross Section Variation	≤ 4%

Among Tubes:

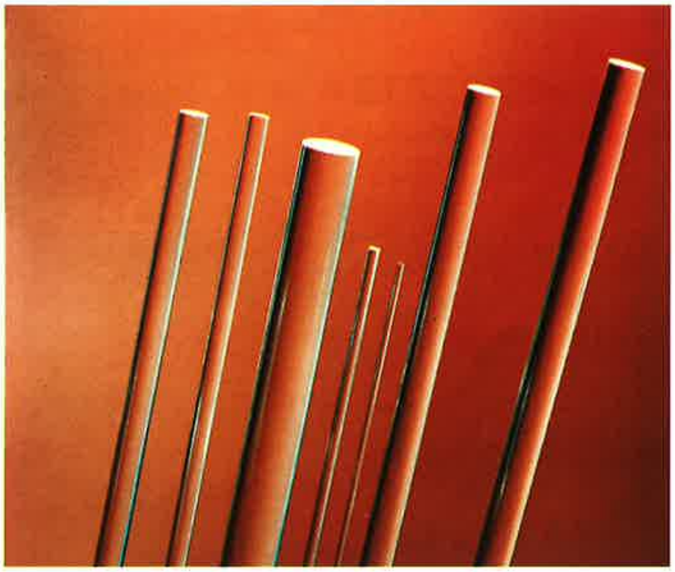
Sample results of average Cross Sectional Area (CSA) variations among tubes indicate:

50% of tubes are within 1% nominal CSA

85% of tubes are within 2% nominal CSA

100% of tubes are within 4% nominal CSA

FUSED QUARTZ ROD



Range of Sizes of GE Type 214 fused quartz rod.

Fused quartz rod and small diameter tubing are fabricated into boats, trays and carriers for holding silicon wafers during processing.

TABLE X–TYPICAL SIZES, TYPE 214 CLEAR FUSED QUARTZ ROD

Designation (mm)	Diameter (mm) Min.	Max.	Max. Ovality (mm)
1.0	.80	1.20	.10
1.5	1.20	1.80	.15
2.0	1.80	2.20	.15
2.5	2.25	2.75	.10
3.0	2.70	3.30	.10
3.5	3.15	3.85	.10
4.0	3.90	4.10	.10
5.0	4.85	5.15	.12
6.0	5.85	6.15	.15
6.4	6.25	6.55	.16
7.0	6.85	7.15	.18
8.0	7.75	8.15	.20
9.0	8.85	9.15	.23
10.0	9.85	10.15	.25
12.0	11.80	12.20	.30
13.0	11.80	12.20	.32
15.0	14.75	15.25	.38
19.0	18.50	19.50	.48

TABLE XI–LENGTH TOLERANCES, TYPE 214 FUSED QUARTZ ROD

Under 12″	± .040″
12″ thru 48″	± .062″
49″ thru 72″	± .125″

FUSED QUARTZ INGOTS

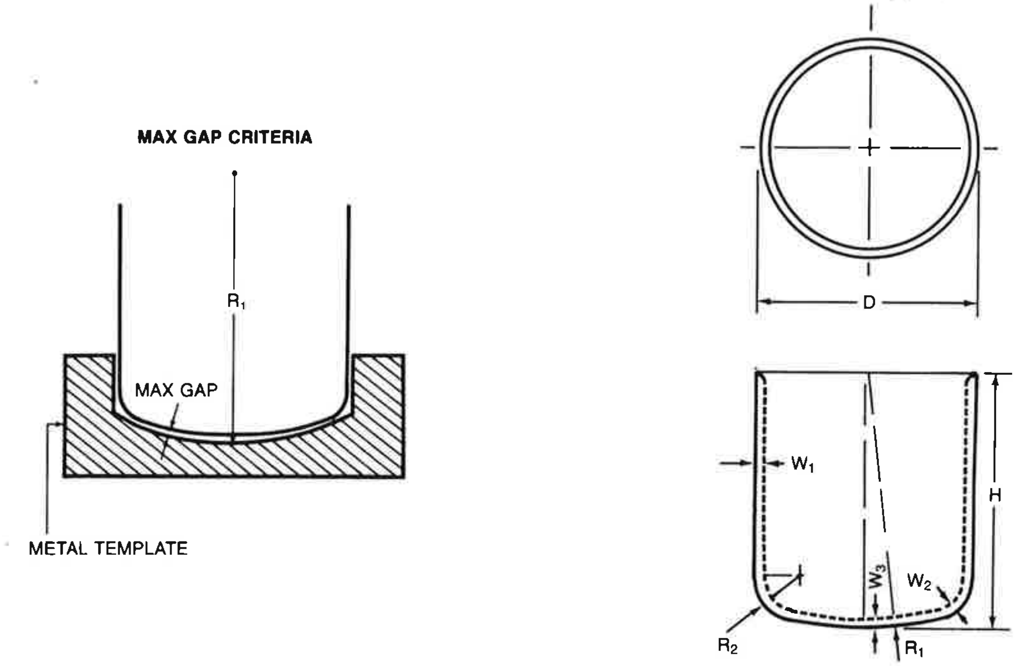
General Electric provides fused quartz ingots for fabricating a variety of quartzware products. Individual pieces are cut to specification by fabricators from six-foot diameter, two-foot thick ingots such as these, weighing approximately 9,000 lbs. Custom sizes, shapes and finishes are readily available from GE appointed fabricators (listing available upon request).

This delicate part illustrates the fine detail which can be achieved in parts fabricated from fused quartz. It is a core used in a mold to cast jet engine turbine blades, creating a tiny internal passage that permits circulating air to cool the blade.

Exposure to 2400-2800°F molten metal required a core material with high temperature properties. The ease of fabricating intricate shapes was also a factor in the selection of fused quartz for this application.

FUSED QUARTZ CRUCIBLES

Type 510 crucibles are used by silicon single-crystal manufacturers to achieve extremely consistent results, and are critical in maintaining the ultra-high purity of the melts.



Letter symbols in diagram above are keyed to the column headings in Table XII.

TABLE XII–TYPICAL SIZES & TOLERANCES, TYPE 510 FUSED QUARTZ CRUCIBLES

(Dimensions and Tolerances in Inches)

GE Number	Letter Symbols—Keyed to Diagram Above							Max. Gap
	D (Diameter)	H (Height)	W_1 (Wall)	W_2 (Wall)	W_3 (Wall)	R_1 (Radius)	R_2 (Radius)	
8601FP	7.990 ±.040	6.000 ±.125	.175 +.100 −.025	.100 Min.	.250 Max.	12.625	1.500 Reference	.062
10801FP	10.000 ±.050	7.500 ±.125	.170 +.100 −.030	.120 Min.	.300 Max.	14.000	2.000 Reference	.062
12801F	12.000 ±.075	7.500 ±.125	.200 ±.050	.160 Min.	.350 Max.	14.000	2.000 Reference	.125
12903F	12.000 ±.075	9.500 ±.125	.200 ±.050	.160 Min.	.350 Max.	14.000	2.000 Reference	.125
12906F	11.925 ±.075	9.000 ±.125	.300 ±.050	.200 Min.	.250 Min.	14.000	2.000 Reference	.125
13902F	13.062 ±.062	9.578 ±.078	.320 ±.080	.240 Min.	.400 Max.	12.000	3.000 Reference	.188
13905F	13.000 ±.118	9.450 ±.118	.276 ±.040	.220 Min.	.400 Max.	14.000	2.000 Reference	.188
14111F	14.000 ±.100	11.000 ±.125	.275 +.100 −.050	.220 Min.	.400 Max.	15.000	3.500 Reference	.188
14123F	14.000 ±.125	12.078 ±.078	.250 ±.075	.250 Min.	.500 Max.	16.000	3.500 Reference	.188
15121F	14.917 ±.080	12.000 ±.118	.335 ±.050	.430 ±.145	.430 ±.145	15.000	3.000 Reference	.188
16121F	16.000 ±.160	12.000 ±.120	.335 ±.100	.250 Min.	.500 Max.	16.000	3.000 Reference	.188
18141F	18.000 ±.118	13.500 ±.118	.335 ±.100	.250 Min.	.500 Max.	18.000	3.500 Reference	.188
24151F	24.000 ±.160	15.000 ±.125	.350 ±.100	.250 Min.	.500 Max.	24.000	3.500 Reference	.188

NOTE: Other sizes available upon request

SECTION III

Properties of Fused Quartz

While *vitreous silica* is the generic term used to describe all types of silica glass, some producers refer to this material as *fused quartz* or *fused silica*. Originally, there was a commercial distinction between transparent and opaque vitreous silica with fused quartz products being produced from quartz crystal into transparent ware and fused silica being manufactured from sand into opaque ware.

Today, however, advances in raw material beneficiation permit transparent fusions from sand as well. Consequently, if naturally occurring crystalline silica (sand or rock) is melted, the material is called *fused quartz.* If the silicon dioxide is synthetically derived, the material is often referred to as *synthetic fused silica.*

General Electric fused quartz products provide a wide range of useful properties. Individually or in combination, these properties are making important contributions in a number of specialized applications.

CHEMICAL PURITY

The performance of most fused quartz products is closely related to the purity of the material. Contaminants, even in parts per million, are controlled very closely in the manufacture of the product.

GE fused quartz typically contains less than 50 ppm by weight as the element total impurities. The clear varieties have a nominal purity of 99.995 W% SiO_2. Alumina (Al_2O_3) is the major impurity. The remaining impurity content is composed of Na_2O, Fe_2O_3, CaO, TiO_2, K_2O and Li_2O.

The translucent variety of fused quartz has a purity of 99.9 to 99.93 W +% SiO_2. Again, alumina represents about two-thirds of the total impurities. The Fe_2O_3 and TiO_2 contents are higher than in the clear materials. Remaining impurities consist of CaO, Na_2O, K_2O, MgO and Li_2O. Table XIII summarizes the typical trace level impurity content of General Electric fused quartz products.

Structural hydroxyl (OH^{-1}) impurities are also summarized in Table XIII. The strong IR absorption of OH^{-1} species in fused quartz provides a quantitative method for analysis.

The term *Beta Factor* is sometimes used to characterize the hydroxyl (OH) content of fused quartz tubing. This term is defined by the formula shown below.

BETA FACTOR = β

$$\beta = \frac{1}{t}\log_{10}\left(\frac{Ta}{Tb}\right), mm^{-1}$$

t = sample thickness in mm

Ta = actual % transmission at 2.6 micrometers

Tb = actual % transmission at 2.73 micrometers

To ascribe a composition value corresponding to a measured β requires knowledge of the extinction coefficient of hydroxyl ions, α. β = αC, where:

C = concentration, ppm

α = 58* l/mole•cm

For example, if β = 0.025 mm^{-1}, C = 0.0043 mole/l = 33 ppm OH.

**Intro and Removal of Hydroxyl Groups in Vitreous Silica*, Philips Res. Rpts. 30, 192-205,1975.

TABLE XIII–TYPICAL FUSED QUARTZ IMPURITIES* (ppm By Weight)

Type	Al	Ca	Fe	K	Li	Mg	Mn	Na	Ti	Zr	OH**
214, 214HV, 982	20.3	1.8	1.9	<3.0	1.0	0.5	0.1	1.3	1.4	2.4	<5
214A	20.3	1.8	1.9	<3.0	1.0	0.5	0.1	1.3	1.4	2.4	<1
124, 214LD, 510	20.3	1.8	1.9	<3.0	1.0	0.5	0.1	1.3	1.4	2.4	33
219	20.3	1.8	1.9	<3.0	1.0	0.5	0.1	1.3	<350	2.4	<1
318	170	34	58	31	2	8	1	17	49	53	280
*Analysis via Direct Reading Spectrometer with detection limits (ppm) of:											
	0.6	0.1	0.1	3	0.1	0.02	0.1	0.2	0.2	0.1	1

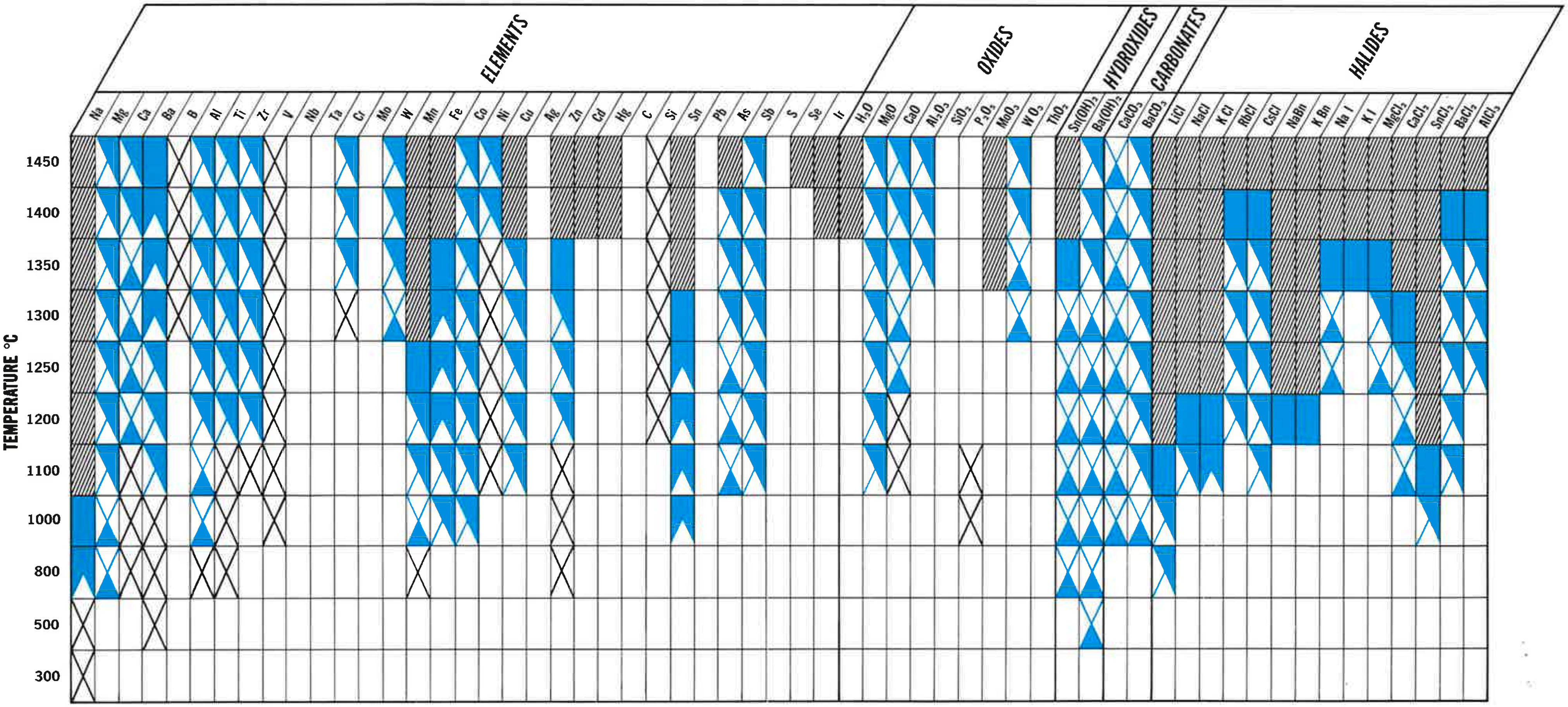
Detection limits for B and P are 2 and 3 ppm, respectively. No B or P is detectable using this technique.

**Type 214LD may contain a higher amount of surface hydroxyl (OH) ions, but the values represent a bulk average for the total tube thickness.

REACTIVITY

Most acids, metals, chlorine and bromine are unreactive with fused quartz at ordinary temperatures. It is slightly attacked by alkaline solutions, the reaction rate increasing with temperature and concentration of solution. Phosphoric acid will attack fused quartz at temperatures above about 150°C. Hydrofluoric acid alone will attack it at all temperatures. Carbon and some metals will reduce fused quartz; basic oxides, carbonates, sulfates, etc., will react with it at elevated temperatures. For general use it can be concluded that fused quartz is quite unreactive.

TABLE XIV – QUALITATIVE GUIDE TO FUSED QUARTZ REACTION WITH SELECTED ELEMENTS AND COMPOUNDS AT ELEVATED TEMPERATURES



VISUAL INSPECTION RESULTS:

LEGEND: NO CHANGE — NO DEVITRIFICATION–BUT COATED OR STAINED BY TEST MATERIAL — SOME SPOTS OF DEVITRIFICATION — SURFACE DEVITRIFICATION — SEVERE DEVITRIFICATION — FAILURE DUE TO DEVITRIFICATION — NOT TESTED AT THIS TEMPERATURE

Effect of various elements and compounds on silica glass at elevated temperatures, reactions observed in a vacuum. Each sample held at lowest temperature for one hour, then at the next higher temperature for one hour, and so on. The extent of reaction at temperature is, of course, also time-dependent. Analysis: *visual inspection*

Most acids, metals, chlorine and bromine do not react with silica at ordinary temperatures. Phosphoric acid will attack fused silica at temperatures above 150°C while hydrofluoric acid will attack it at all temperatures. It is slightly attacked by alkaline solutions, the reaction rate increasing as temperatures and concentration of solution increase. Carbon and some metals will reduce silica glass; basic oxides, carbonates and sulfates will react with it at elevated temperatures. At temperatures in excess of 1000°C most other materials in contact with silica will accelerate devitrification.

MECHANICAL PROPERTIES

Mechanical properties of fused quartz are much the same as those of other glasses. The material is extremely strong in compression, with design compressive strength of better than 160,000 psi.

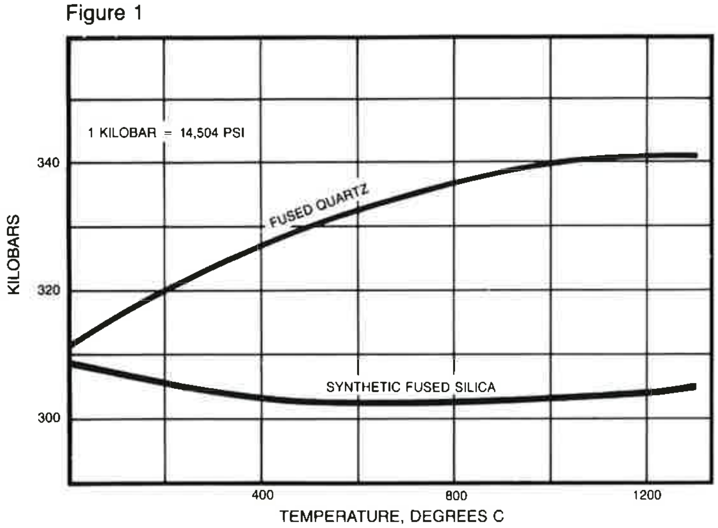
Surface flaws can drastically reduce the inherent strength of any glass, so tensile properties are greatly influenced by these defects. The design tensile strength for fused quartz with good surface quality is in excess of 7,000 psi. In practice, a design stress of 1,000 psi is generally recommended. Typical mechanical data are shown in Table XV.

Temperature dependence for various mechanical properties are illustrated in Figures 1 to 7.

TABLE XV – TYPICAL PHYSICAL PROPERTIES, CLEAR FUSED QUARTZ

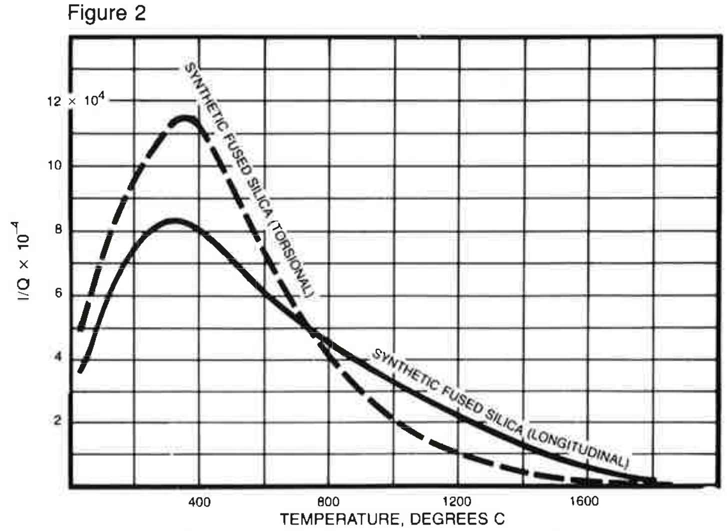
PROPERTY	ENGLISH & METRIC SYSTEM VALUE	INTERNATIONAL SYSTEM OF UNITS (SI) VALUE
Density	2.2 gm/cm^3	2.2 × 10^3 kg/m^3
Hardness	5.5–6.5 Mohs' Scale 570 KHN_{100}	
Design Tensile Strength	7,000 psi	4.8 × 10^7 Pa (N/m^2)
Design Compressive Strength	Greater than 160,000 psi	Greater than 1.1 × 10^9 Pa
Bulk Modulus	5.3 × 10^6 psi	3.7 × 10^{10} Pa
Rigidity Modulus	4.5 × 10^6 psi	3.1 × 10^{10} Pa
Young's Modulus	10.5 × 10^6 psi	7.2 × 10^{10} Pa
Poisson's Ratio	.17	.17
Coefficient of Thermal Expansion	5.5 × 10^{-7} cm/cm•°C (20°C - 320°C)	5.5 × 10^{-7} m/m•°K (293°K - 593°K)
Thermal Conductivity (20°C)	3.3×10^{-3} gm cal•cm/cm^2•sec•°C	1.4 W/m•°K
Specific Heat (20°C)	.16gm cal/gm	670 J/kg•°K
Softening Point	1683°C	1956°K
Annealing Point	1215°C	1488°K
Strain Point	1120°C	1393°K
Electrical Resistivity	7(10^9) ohm•cm (350°C)	7(10^7) ohm-m
Dielectric Properties	(20°C and 1 Mc)	(293°K and 1 MHz)
Constant	3.75	3.75
Strength	1270 volts/mil	5 × 10^8 V/m
Loss Factor	Less than 4 × 10^{-4}	Less than 4 × 10^{-4}
Dissipation Factor	Less than 1 × 10^{-4}	Less than 1 × 10^{-4}
Index of Refraction	1.4585	1.4585
Constringence (Nu value) Fused Quartz	67.56	67.56
Velocity of Sound-Shear Wave	3.75 × 10^5 cm/sec	3.75 × 10^3 m/s
Velocity of Sound/ Compressional Wave	5.90 × 10^5 cm/sec	5.90 × 10^3 m/s
Sonic Attentuation	Less than .033 db/ft•Mc	Less than .11 db/m•MHz
Permeability Constants	(cm^3•mm/cm^2•sec•cm of Hg—700°C/973°K)	
Helium	210 × 10^{-10}	
Hydrogen	21 × 10^{-10}	
Deutrium	17 × 10^{-10}	
Neon	9.5 × 10^{-10}	

Figure 1



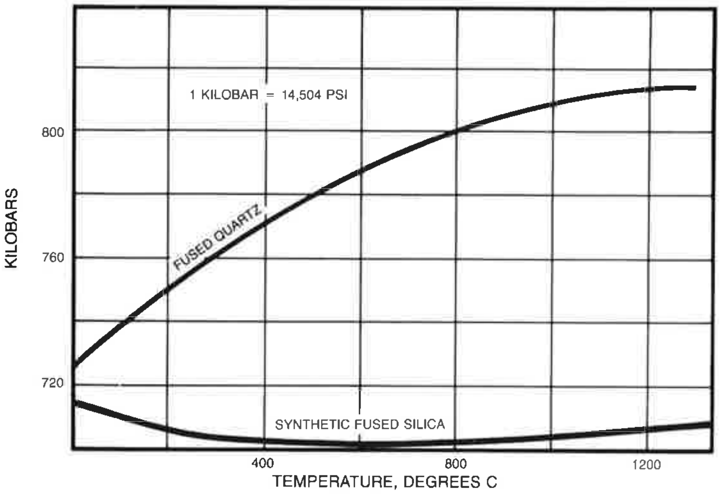
Representative shear (rigidity) modulus values for silica glass. Source: National Bureau of Standards.

Figure 2



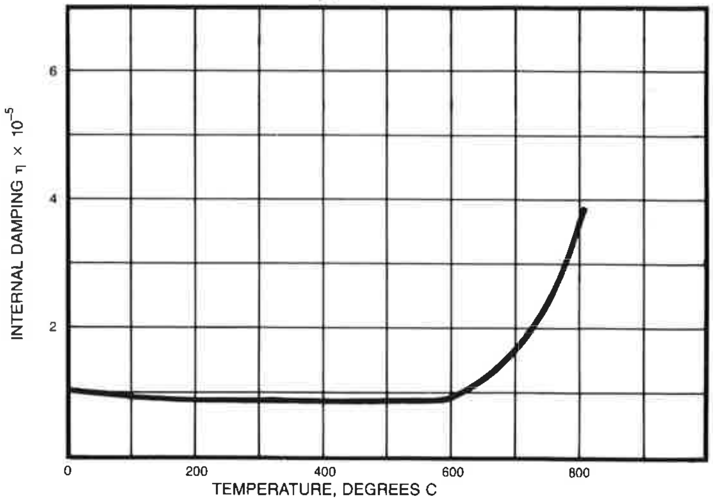
Representative longitudinal and torsional internal friction values for silica glass. Source: Ibid.

Figure 3



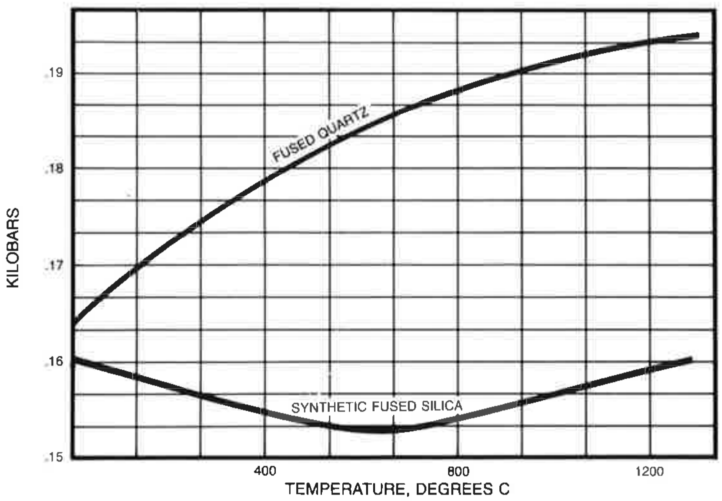
Representative elastic (Young's) modulus for silica glass.
Source: Ibid.

Figure 4



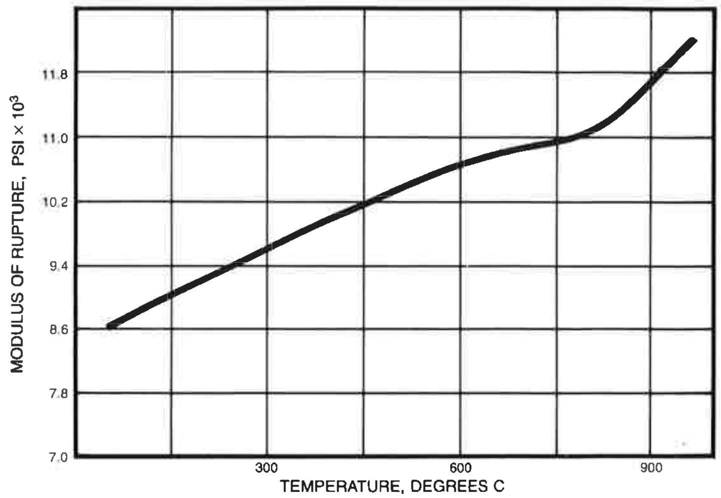
Representative internal damping values for silica glass.
Source: Published manufacturer's data.

Figure 5



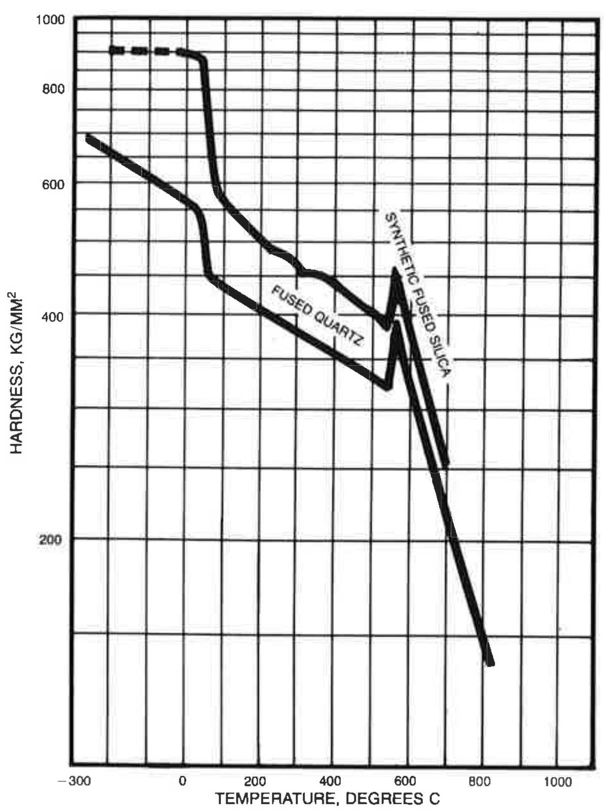
Poisson's ratio for silica glass. Source: Ibid.

Figure 6



Representative modulus of rupture values for silica glass.
Source: Published manufacturer's data.

Figure 7



Representative hardness values for silica glass. Source: J. H. Westbrook *Physics and Chemistry of Glasses*, Vol 1, 1960.

INTERNAL PRESSURE DETERMINATION

Since fused quartz is utilized in applications involving internal pressures, it is sometimes helpful to know the maximum pressure which can be applied to a certain size tube. The following formula will approximate this information at room temperature.

CFQ RUPTURE FORMULA FOR TUBING

Formula: $S = \frac{pr}{t}$

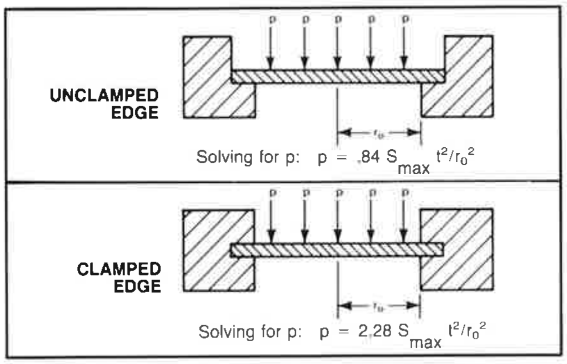
Where: S = Hoop Stress in Pa
p = Working pressure (Pa)
r = Inside Radius of Tube (mm)
t = Wall Thickness (mm)

This formula is not applicable when the internal pressure exceeds 100 psi ($7 \cdot 10^5$ Pa).

CFQ RUPTURE FORMULA FOR DISCS AND PLATES

Calculating pressure differential is also required for many applications of stressed fused quartz discs, plates, and sight glasses.

The formulae which follow can be used for room temperature applications of circular parts with either clamped or unclamped edges.

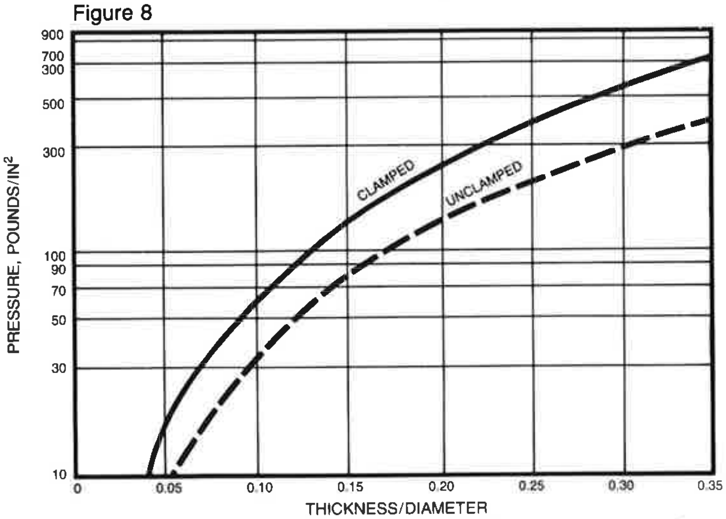


Where: P = Pressure differential, Pa
r° = Unsupported disc radius, mm (for plates substitute width)
S_{max} = Maximum stress (approx. 7 to 1 safety factor) 7.0×10^6 Pa
t = Disc thickness, mm

However, the following factors will affect the strength of these parts and must be considered when using the formulae:

a. Surface should be highly polished and free of scratches.
b. Means by which a sample is clamped into a pressure device.
c. The gasketing material used.
d. The thermal gradients expected across the surface and between the surfaces.
e. The rate of pressure increase which will be applied.
f. Temperature of specimen.

Figure 8

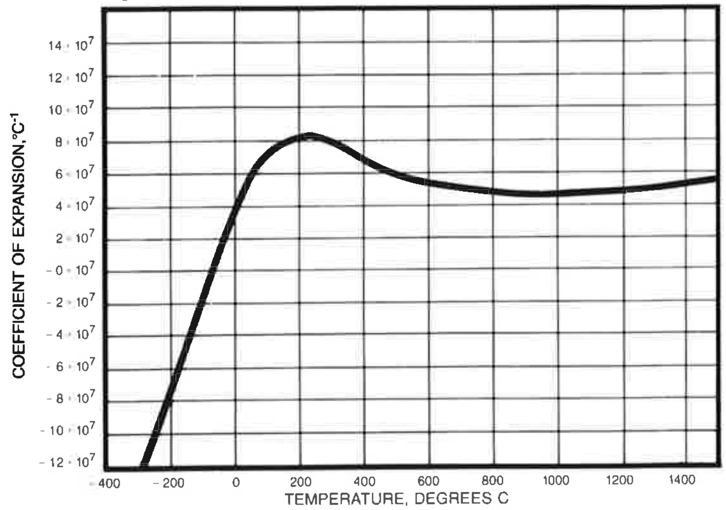


Maximum pressure versus ratio of thickness to diameter for clamped and unclamped plates. To determine required thickness, multiply diameter of disc by the factor at the bottom corresponding to required pressure. Source: General Electric Company.

THERMAL PROPERTIES

One of the most important properties of fused quartz is its extremely low coefficient of expansion—0.55×10^{-6}cm/cm°C (0-300°C). Its coefficient is $^1/_{34}$ that of copper and only $^1/_7$ of borosilicate glass. This makes the material particularly useful for optical flats, mirrors, furnace windows and critical optical applications which require minimum sensitivity to thermal changes. A related property is its unusually high thermal shock resistance. For example, thin sections can be heated rapidly to above 1500°C and then plunged into water without cracking.

Figure 9



Representative values of the coefficient of expansion of silica glass. Source: Published manufacturer's data.

EMPIRICAL ANNEALING RATES, FUSED QUARTZ

Cooling From Two Sides:

$$\text{Rate, °C/minute} = .4\, \frac{\text{residual stress, psi}}{(\text{thickness, inches})^2}$$

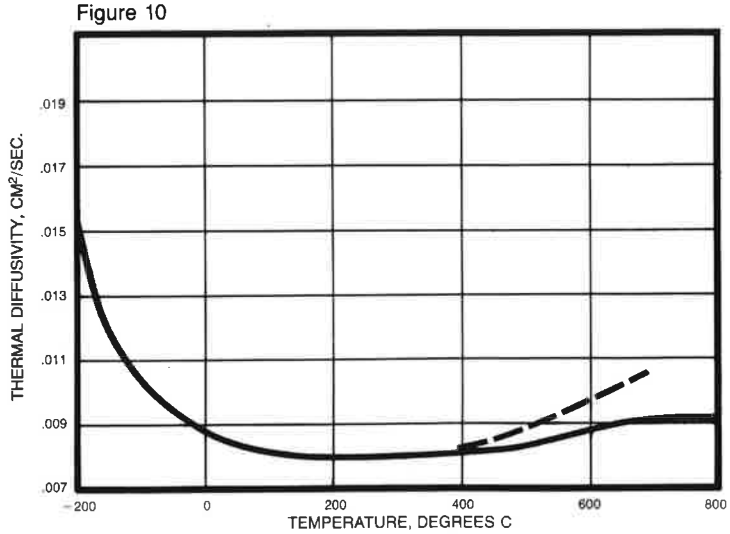
Cooling From One Side:

$$\text{Rate, °C/minute} = .4\, \frac{\text{residual stress, psi}}{(2 \times \text{thickness, inches})^2}$$

The residual stress or design, depending on the application, may be in the range of 25 to 300 psi.

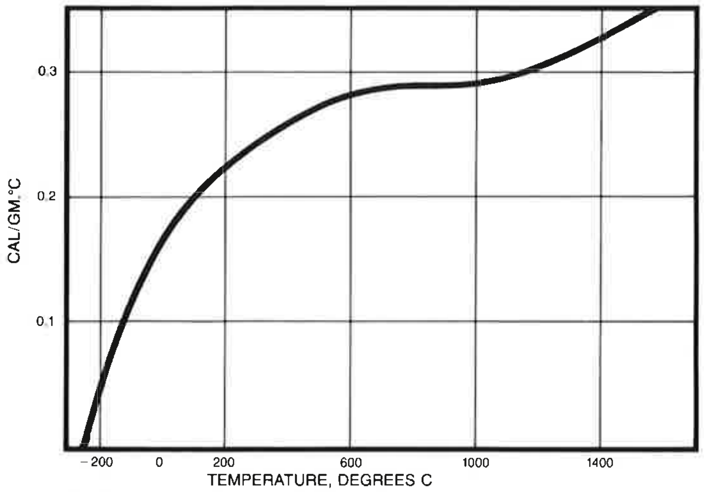
As a general rule, it is possible to cool up to 100° C/hour for sections less than 1" thick.

Figure 10



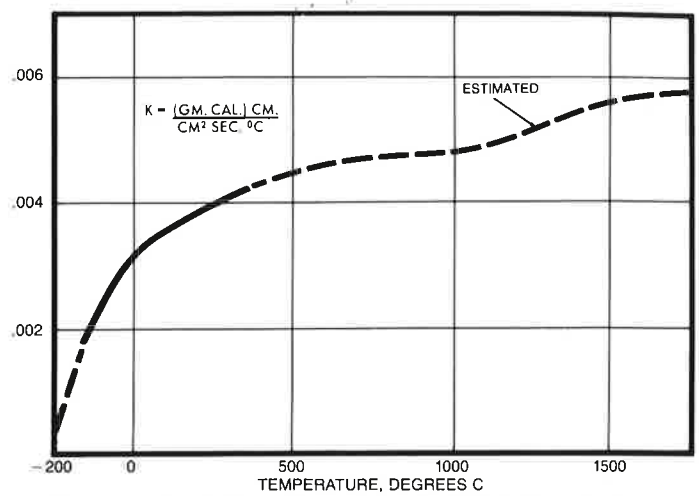
Representative values of thermal diffusivity of silica glass. Source: Ibid.

Figure 11



Representative values of heat capacity of silica glass.
Source: R. B. Sosman, *The Properties of Silica*, 1927.

Figure 12



Representative values of thermal conductivity of silica glass.
Source: Published manufacturer's data.

EFFECTS OF TEMPERATURE

Fused quartz is a solid material at room temperature, but at high temperatures, it behaves like all glasses. It does not experience a distinct melting point as crystalline materials do, but softens over a fairly broad temperature range. This transition from a solid to a plastic-like behavior, called the transformation range, is distinguished by a continuous change in viscosity with temperature.

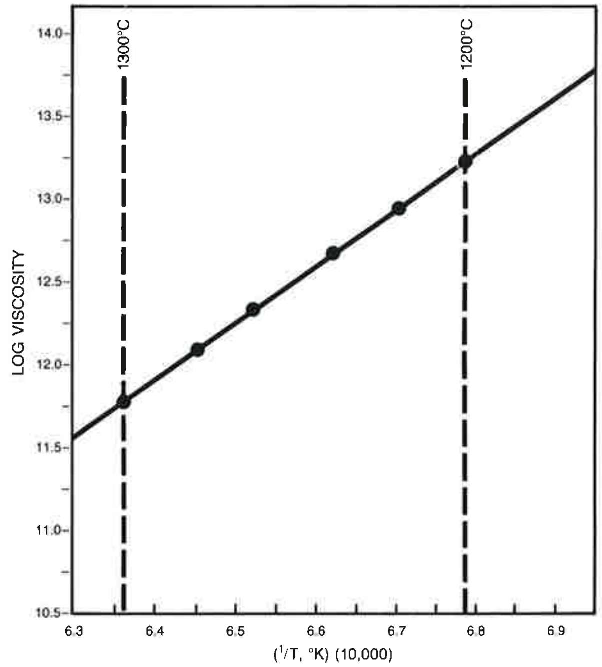
Viscosity is the measure of the resistance to flow of a material when exposed to a shear stress. Since the range in "flowability" is extremely wide, the viscosity scale is generally expressed logarithmically. Common glass terms for expressing viscosity include: strain point, annealing point, and softening point, which are defined as:

Strain Point: The temperature at which the internal stress is substantially relieved in four hours. This corresponds to a viscosity of $10^{14.5}$ poise, where poise = dynes/cm^2 sec.

Annealing Point: The temperature at which the internal stress is substantially relieved in 15 minutes, a viscosity of $10^{13.0}$ poise.

Softening Point: The temperature at which glass will deform under its own weight, a viscosity of approximately $10^{7.6}$ poise. The softening point of fused quartz has been variously reported from 1500°C to 1670°C, the range resulting from differing conditions of measurement.

TYPICAL FUSED QUARTZ VISCOSITY TEST



LOG VISCOSITY:
@ 1100°C = 14.8818
@ 1200°C = 13.2209
@ 1300°C = 11.7634

ANNEAL. POINT = 1213.83°C

STRAIN POINT = 1122°C

ACTIV. ENERGY = 155.11 kcal/mole

TEMP. °K	1/T $\times 10^{-4}$	VISC. LOG
1393	7.18	13.40
1433	6.98	13.30
1473	6.79	13.24
1493	6.70	12.91
1513	6.61	12.59
1533	6.52	12.29
1553	6.44	12.05
1573	6.36	11.77

TABLE XVI – TYPICAL FUSED QUARTZ VISCOSITY DATA

		Types 214, 214LD Tubing	Type 510 Crucibles
Log_{10}Viscosity	@ 1100°C	14.9	14.7
	@ 1200°C	13.3	13.0
	@ 1300°C	11.9	11.5
Annealing Pt. °C		1215	1200

EFFECTS OF TEMPERATURE
(Cont'd)

For applications at elevated temperatures, viscosity is an important parameter as the sagging rate of an article of a given geometry is inversely proportional to viscosity. Sagging, however, is often not the limitation to high temperature performance of fused quartz. Devitrification, or recrystallization, is frequently the limiting factor. The phase transformation to β-cristobalite, which generally does not occur below 1000°C, is particularly detrimental if the fused quartz article must be thermally cycled below the β to α cristobalite transformation temperature (~ 250°C). This inversion is accompanied by a large specific volume change which results in spalling and, possibly, mechanical failure. Devitrification in fused quartz, or in any glass for that matter, is a two-step event comprising nucleation (formulation of a stable crystal seed nucleus) and crystal growth. For fused quartz, nucleation is typically initiated at the surface and in general the nucleation rate is to a large extent determined by surface cleanliness. The mechanism and nature of this problem is the same for all types of fused quartz and fused silica glasses, translucent, clear, and opaque. However, there are significant differences in the rate and, therefore, in usable life of the fused quartz, depending upon purity of the grade used. For example, most opaque grades, with the exception of General Electric Type 510 are less pure than the clear grades. As a result, they will devitrify more rapidly in a given environment. Likewise, those grades containing water impurities will tend to devitrify faster.

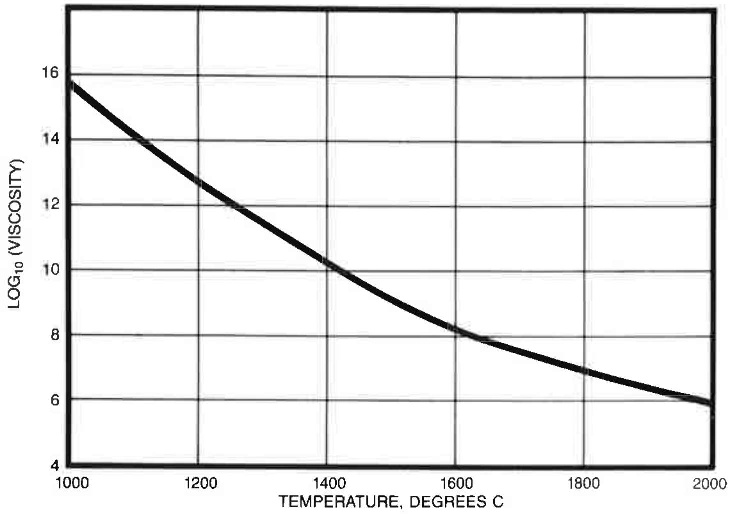
Contamination in almost any form is detrimental. Alkaline solutions, salts, or vapors are particularly deleterious. Handling of fused quartz with the bare hands deposits sufficient alkali from perspiration to leave clearly defined fingerprints upon devitrification. Drops of water allowed to stand on the surface will collect enough contamination from the air to promote devitrified spots and water marks.

Surface contamination affects devitrification in two ways. First, the contaminant promotes nucleation of the cristobalite. Second, it acts as a flux to enhance the cristobalite to β (high) tridymite transformation. Under some conditions, the tridymite devitrification will grow deeply and rapidly into the interior of the fused quartz.

Heating fused quartz to elevated temperatures (ca. 2000°C) causes the SiO_2 to undergo dissociation or sublimation. This is generally considered to be: $SiO_2 = SiO \times \frac{1}{2} O_2$

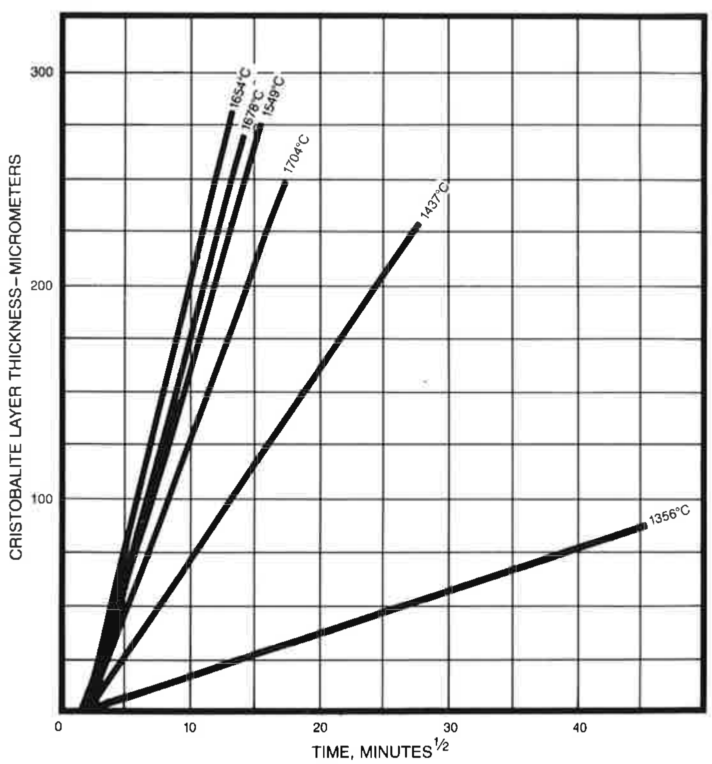
Consequently, when flame-working fused quartz, there is a band of haze or smoke which forms just outside the intensely heated region. This haze presumably forms because the SiO recombines with oxygen from the air (and perhaps water) and condenses as extremely small particles of amorphous SiO_2. The haze can be removed from the surface by a gentle heating in the oxy-hydrogen flame. The dissociation is greatly enhanced when the heating of fused quartz is carried out in reducing conditions. For example, the proximity or contact with graphite during heating will cause rapid dissociation of the SiO_2.

Figure 13



Representative values of viscosity of silica glass.
Source: General Electric Company.

Figure 14



Devitrification rate versus temperature, General Electric Type 204 fused quartz. Qualitatively similar behavior is observed for Type 214.

PERMEABILITY

Fused quartz is essentially impermeable to most gases, but helium, hydrogen, deuterium and neon may diffuse through the glass. The rate of diffusion increases at higher temperatures and differential pressures.

The selective diffusion of helium through fused quartz is the basis for a method of purifying helium by essentially "screening out" contaminants in passing the gas through thin-walled quartz tubes.

The diffusion of helium, hydrogen, deuterium and neon through fused quartz is accelerated with increasing temperature. According to the General Electric Research Laboratory, the permeability constants for these gases through fused silica at 700°C are estimated to be:

Helium	2.1×10^{-8} cc./sec./ cm^2/mm./cm.Hg
Hydrogen	2.1×10^{-9}
Deuterium	1.7×10^{-9}
Neon	4.2×10^{-10}

ELECTRICAL PROPERTIES

As electrical conductivity in fused quartz is ionic in nature and alkali ions exist only as trace constituents, fused quartz is the best glass for electrical insulation and low loss dielectric properties. In general, the electrical insulating properties of the clear types are superior to those of the opaque or translucent types. The superior electrical insulation and microwave transmission properties are retained even at very high temperatures and over a wide range of frequencies.

Typical electrical property values for clear fused quartz include:

Electrical Resistance:
$7(10^9)$ ohm-cm at 350°C

Dielectric Loss Factor:
Less than .0004 at 20°C 1 Mc

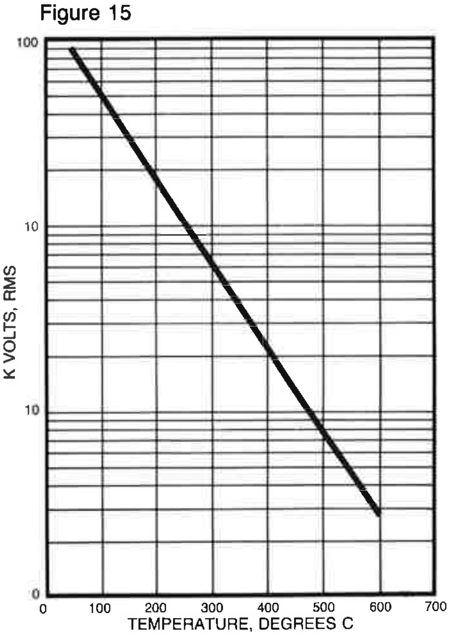
Dielectric Constant:
3.75 at 20°C 1 Mc

Specific Resistivity:
10^{18} ohms/cm^3 at 20°C

Dissipation Factor:
Less than .0001 at 20°C 1 Mc

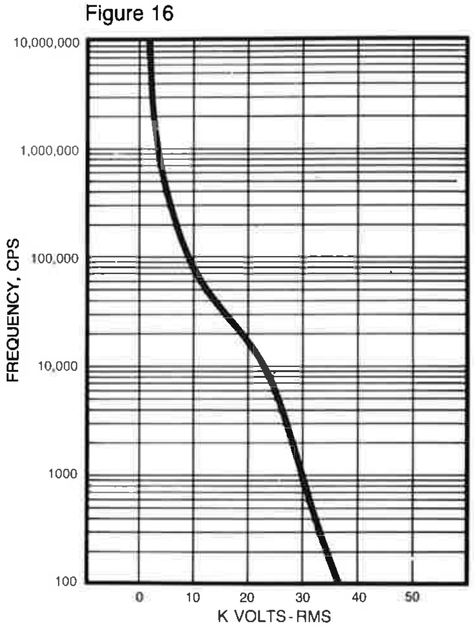
The temperature dependencies of many of these properties are shown in Figures 15, 17, 18 and 19.

Figure 15



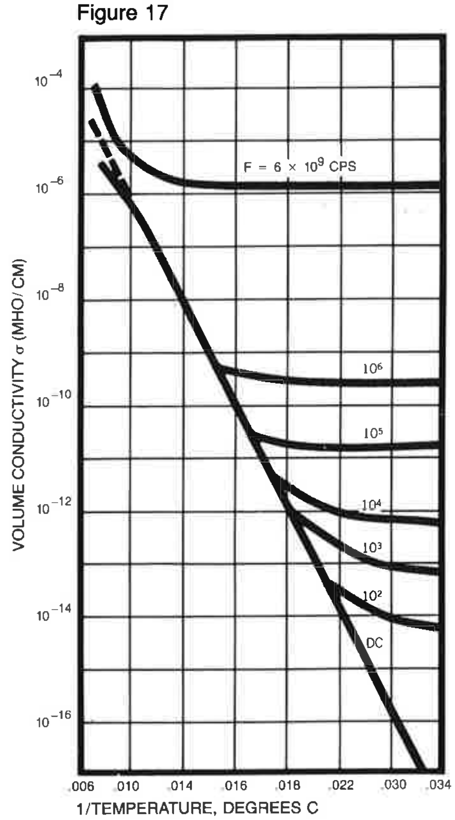
Representative values of the dielectric strength of silica glass, 2mm thick samples at 60 cps. Source: Ibid.

Figure 16



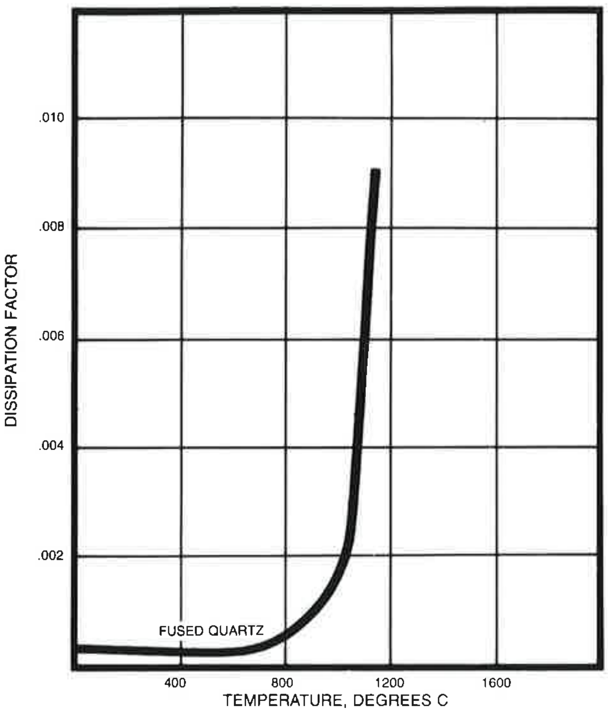
Representative values of the dielectric breakdown voltage of silica glass, .030 in. thick samples. Source: Ibid.

Figure 17



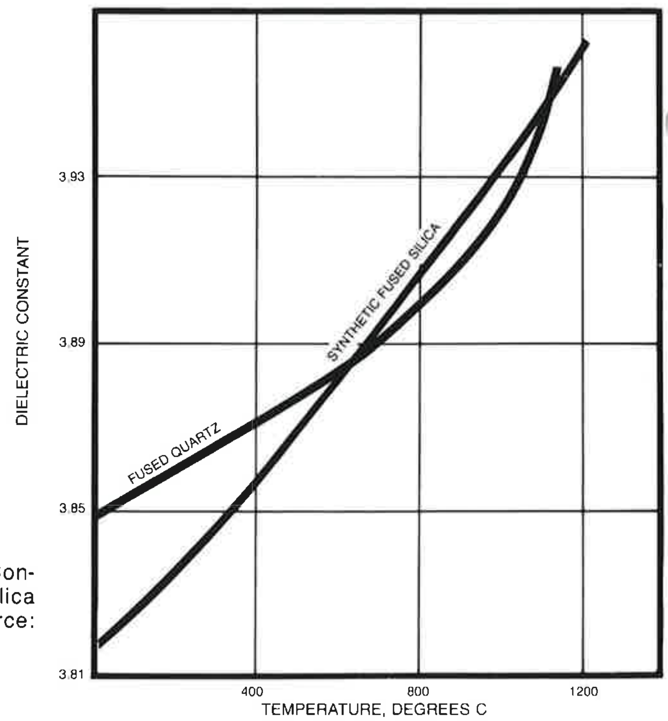
Volume conductivity of silica glass. Source: Ibid.

Figure 18



Dissipation factor of silica glass. Source: Ibid.

Figure 19



Dielectric Constant of silica glass. Source: Ibid.

OPTICAL PROPERTIES

Optical transmission properties provide a means for distinguishing among various types of vitreous silica as the degree of transparency reflects material purity and the method of manufacture.

Specific indicators are the UV cutoff and the presence or absence of bands at .245 μm and 2.73 μm. The UV cutoff ranges from ~ .155 to .175 μm for a 10 mm thick specimen and for pure fused quartz is a reflection of material purity.

The presence of transition metallic impurities will shift the cutoff toward longer wavelengths. When desired, intentional doping, e.g., with Ti in the case of Type 219, may be employed to increase absorption in the UV. The

Figure 20

FUSED QUARTZ AVERAGE TRANSMITTANCE CURVES

(Includes Surface Reflection Losses)

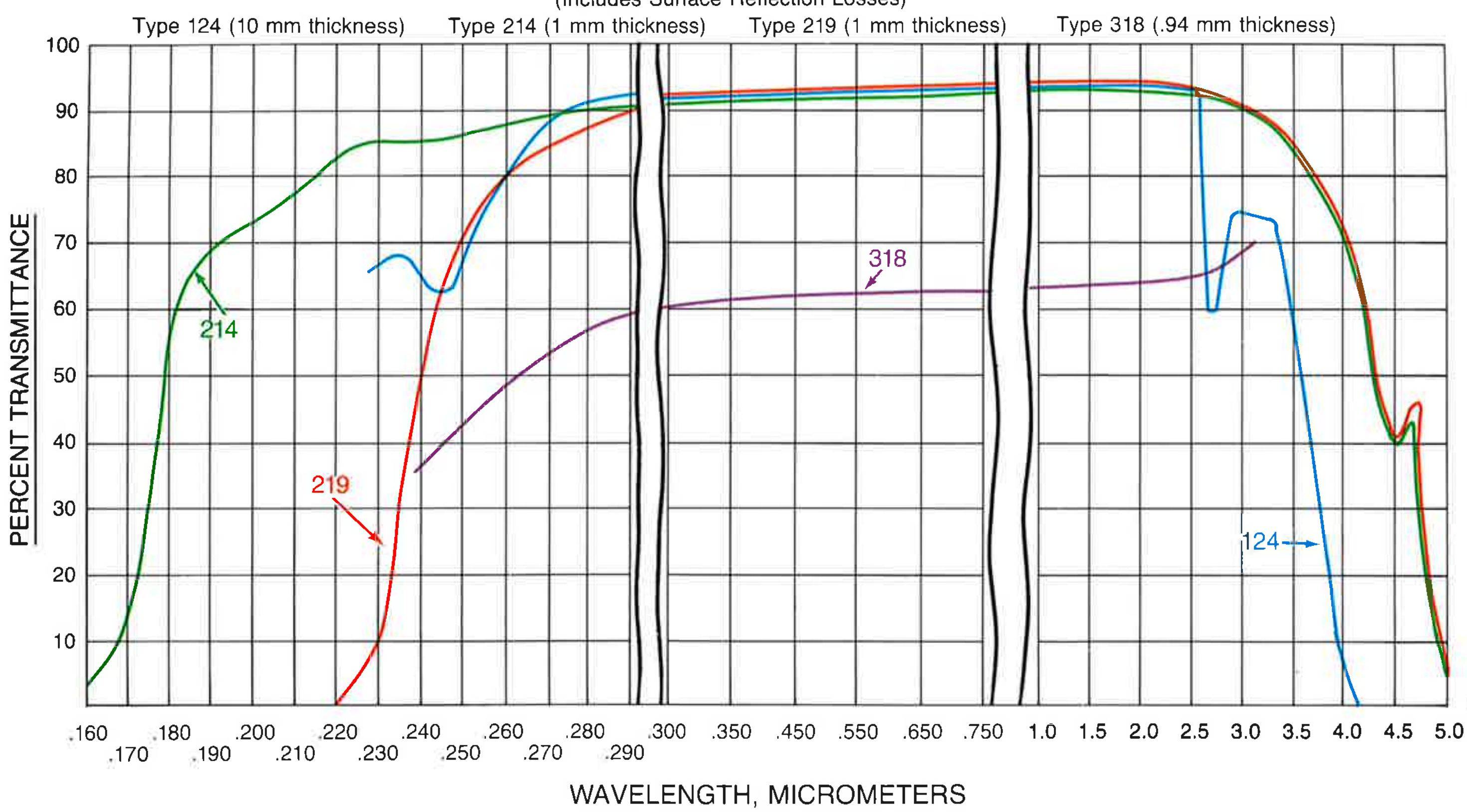


TABLE XVII – TYPE 124 FUSED QUARTZ INGOTS, TRANSMITTANCE STANDARD

THICKNESS–10MM
(Includes Surface Reflection Losses)

WAVELENGTH IN MICROMETERS	AVERAGE TRANSMITTANCE IN PERCENT
.225	65.0
.230	67.4
.240	62.6
.250	69.5
.270	89.0
.300	91.2
.350	91.9
.450	92.5
.550	92.3
.650	92.9
.750	92.8
1.00	93.2
1.50	93.4
2.00	93.6
2.50	93.2
2.60	92.9
2.73	59.3
2.90	85.2
3.00	83.3
3.17	82.5
3.32	83.6
3.60	48.3
3.80	17.2
3.88	17.5
4.14	1.7
4.27	1.5
4.31	0

TABLE XVIII – TYPE 214 FUSED QUARTZ TUBING, TRANSMITTANCE STANDARD

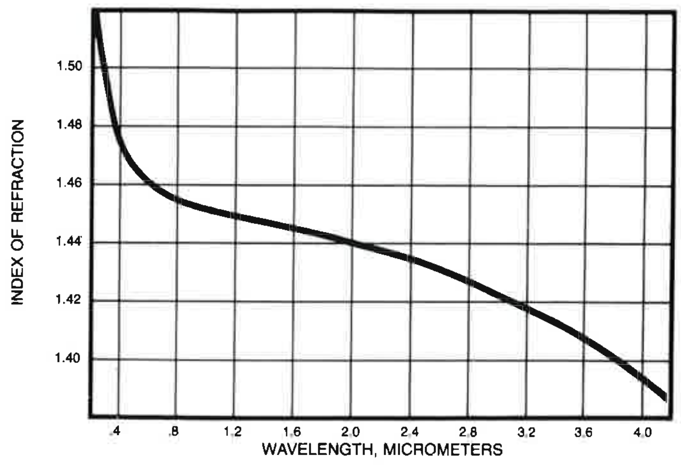
THICKNESS–1MM
(Includes Surface Reflection Losses)

WAVELENGTH IN MICROMETERS	AVG. TRANSMITTANCE IN PERCENT	TRANS-MITTANCE $+3\sigma$ VALUE	TRANS-MITTANCE -3σ VALUE
.160	4.6	7.5	1.6
.162	5.8	9.6	2.0
.164	7.4	12.1	2.7
.166	8.4	14.1	2.6
.168	10.9	19.4	2.4
.170	18.5	30.9	6.1
.175	43.6	56.6	30.7
.180	60.4	64.8	56.1
.185	66.1	69.5	62.8
.190	70.4	73.3	67.5
.195	71.3	74.8	67.9
.200	73.4	77.5	69.5
.205	76.1	79.7	72.4
.210	79.4	82.2	76.6
.220	85.3	87.1	83.6
.230	87.3	89.0	85.5
.240	86.5	88.8	84.3
.245	86.6	90.0	84.5
.250	87.7	91.3	83.9
.260	89.5	91.9	87.1
.270	90.2	92.2	87.8
.280	90.7	92.2	88.6
.290	90.9	92.4	88.8
.300	91.1	92.5	88.9
.350	91.7	92.7	90.0
.450	92.2	93.0	90.6
.550	92.5	93.1	91.1
.650	92.7	93.2	91.0
.750	92.9	93.3	91.6

absorption band at .245 μm characterizes a reduced glass and typifies material made by electric fusion. If a vitreous silica is formed by a "wet" process, either flame fusion or synthetic material, for example, the fundamental vibrational band of incorporated structural hydroxyl ions will absorb strongly at 2.73 μm.

As the transmission curve in Figure 20 illustrates, GE Type 214 fused quartz has a UV cutoff (1mm thickness) at <.160μm, a small absorption at .245μm, and no appreciable absorption due to hydroxyl ions. Type 219, which contains approximately 350 ppm Ti has a UV cutoff at ~.230μm for a 1mm thick sample. The IR edge falls between 4.5 and 5.0μm for a 1mm thick sample. Tables XVII and XVIII detail the percent transmittance for Types 214 and 124 fused quartz with values representing a 1mm thick Type 214 sample and a 10mm thick Type 124 sample.

Figure 21



Index of refraction of fused quartz. Source: Rodney and Spindler. *Journal of the Optical Society of America*, Sept., 1954

SECTION IV

Guidelines For Users Of Fused Quartz

Like any material that is expected to provide a design life at high temperatures, fused quartz demands some care in handling and use to achieve maximum performance from the product.

STORAGE

Space permitting, fused quartz should be stored in its original shipping container. If that is not practical, at least the wrapping should be retained. In the case of tubing, the end coverings should be kept in place until the product is used. This protects the ends from chipping and keeps out dirt and moisture which could compromise the purity of the tubing.

CLEANING

For applications in which cleanliness is important, General Electric recommends the following procedure:

The product, particularly tubing, should be washed in deionized or distilled water with a degreasing agent added to the water. The fused quartz should then be placed in a 7% (maximum) solution of ammonium bifluoride for no more than ten minutes, or a 10 vol % (maximum) solution of hydrofluoric acid for no more than five minutes. Etching of the surface will remove a small amount of fused quartz material as well as any surface contaminants. To avoid water spotting which may attract dirt and cause devitrification upon subsequent heating, the fused quartz should be rinsed several times in deionized or distilled water and dried rapidly.

To further reduce the possibility of contamination, care should be used in handling fused quartz. The use of clean cotton gloves whenever possible is highly recommended.

Washing of translucent tubing is not recommended because the water or acid solution tends to enter the many capillaries in the material. This can cause problems if the pieces are subsequently heated rapidly or to very high temperatures.

ROTATION PROCEDURES FOR FUSED QUARTZ FURNACE TUBES

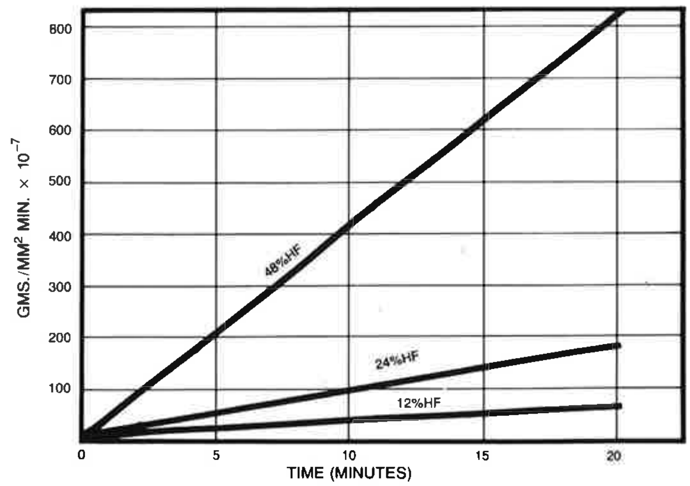
In certain applications, devitrification can be put to the user's advantage since the cristobalite material will tend to inhibit sag of the fused quartz. For example, if a diffusion furnace tube is to be used at high temperatures for extended periods of time, and is not subject to thermal cycling below the β-αcristobalite transformation, the following procedure has been used to create an even layer of cristobalite on diffusion tubes in order to increase any resistance:

Place the tube in a furnace at 1200°C, and rotate the tube 90° every two hours for the first 30 hours. If the working schedule does not permit adherence to this procedure, the following suggestion is offered. Place the tube in a furnace at 1200°C and rotate the tube 90° every two hours for the first 8 hours, then reset the furnace to operating temperature.

IRRADIATION

Irradiation of fused quartz by high energy radiation (such as X-rays, gamma rays, or neutrons) can induce certain absorption bands. Generally, three absorption bands occur; these are at about 215, 303 and 540 nm. When absorptions are induced, they can be thermally bleached by heating to about 500°C. Irradiated fused quartz will exhibit thermoluminescence on heat bleaching.

Figure 22



Rate of dissolution of fused quartz in hydrofluoric acid. Source: General Electric Company.

SECTION V

Manufacturing & Quality Control

As a leading supplier of fused quartz in its major forms, General Electric maintains highly modern and efficient manufacturing facilities, supported by well equipped laboratories and highly-qualified engineering personnel.

At these plants, concern with quality starts with raw materials. The silica sand comes from a single source, virtually eliminating lot-to-lot variations. The raw material is then further processed by General Electric to increase the purity level.

During and after the manufacturing, the product is constantly inspected for visual defects and dimensional accuracy. An infrared spectrophotometer is used to detect residual hydroxyl ion content in fused quartz products. The viscosity of the material is routinely measured in a beam bending viscometer following ASTM procedure C598. In addition, fused quartz samples are routinely analyzed for trace impurities with a direct reading spectrometer. This instrument is computerized and utilizes an induction coupled argon plasma for determining the concentrations of 36 different elemental impurities.

Fused quartz tubing, rod, crucibles and other engineered shapes are produced to exceedingly high quality standards at General Electric manufacturing plants in Willoughby, Ohio, and Newark, Ohio. Fused quartz is also manufactured and fabricated at General Electric's affiliate, Westdeutsche Quarzschmelze, GmbH, in Geesthacht, West Germany.

TECHNICAL ASSISTANCE

General Electric offers a number of engineering services to assist customers in their fused quartz applications. This includes consultation on design, laboratory studies, prototype development and tests, and application in the field.

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