DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS
WASHINGTON 25, D.C.

National Bureau of Standards

Certificate of Viscosity Values

Standard Sample No. 710

Soda-Lime-Silica Glass

TABLE 1. *Comparison of viscosity vs temperature data from each participating laboratory*

$\log_{10}$ viscosity poise	Temperature, °C								
	Laboratories								Value from combined equation
	A	B	C	D	E	F	G	H	
2.00	--------	--------	--------	--------	--------	1455.7	--------	--------	1434.3
2.10	1403.3	--------	--------	--------	--------	1423.6	--------	--------	1402.9
2.25	1359.3	--------	--------	1358.7	--------	1378.5	--------	--------	1358.9
2.50	1293.0	1292.4	1297.3	1291.9	1291.0	1310.4	1303.7	1308.9	1292.7
2.75	1234.3	1234.1	1236.4	1232.8	1232.8	1249.9	1242.4	1245.8	1234.0
3.00	1182.0	1182.0	1182.4	1180.1	1181.0	1195.7	1188.0	1190.2	1181.7
3.50	1092.6	1093.0	1090.7	1090.3	1092.6	1103.1	1095.6	1096.6	1092.4
4.00	1019.1	1019.7	1016.0	1016.5	1020.0	1026.6	1020.0	1021.1	1019.0
4.50	957.6	958.4	953.8	954.9	959.4	--------	957.1	958.7	957.5
5.00	905.4	906.2	901.3	902.6	907.9	--------	904.0	906.4	905.3
5.50	860.5	861.4	856.4	857.8	863.7	--------	858.4	861.9	860.5
6.00	821.5	822.4	817.5	818.8	825.4	--------	819.0	823.6	821.5
6.50	787.3	788.2	783.5	784.7	791.8	--------	--------	--------	787.3
7.00	757.1	757.9	753.6	--------	--------	--------	--------	--------	757.1
8.00	706.0	706.8	703.2	--------	--------	--------	--------	--------	706.1
9.00	664.6	665.3	662.5	--------	--------	--------	--------	--------	664.7
10.00	630.3	630.9	628.9	--------	--------	--------	--------	--------	630.4
11.00	601.4	601.9	600.7	--------	--------	--------	--------	--------	601.5
12.00	576.8	577.2	576.7	--------	--------	--------	--------	--------	576.9

Viscosity of the Glass

The data received from each participating[a] laboratory was analyzed by the method of least squares to determine the constants for the Fulcher equation [1]. Using these equations a comparison of the temperatures obtained by each participating laboratory at nominal values of $\log_{10}$ viscosity are shown in table 1 above.

In an attempt to arrive at the best equation to represent the data from all of the participating laboratories, a plot of the difference between the observed viscosities and calculated viscosities from the general equation was made. Using this plot and a number of statistical tests it was obvious that the results submitted by Lab. F, and those of Lab. G and Lab. H in the temperature range 1100 to 1400 °C, were inconsistent with the rest of the data. The data from Laboratories F, G, and H were not used in calculating the values shown in the last column of table 1. The equation for the combined data is:

$$\log_{10}\eta = -1.626 + \frac{4236.118}{T-266} \quad (\pm 0.020).$$

[a] List of participating laboratories:
Armstrong Cork Co., Lancaster, Pa.
Bausch & Lomb, Inc., Rochester, N.Y.
Brockway Glass Co., Inc., Brockway, Pa.
Corning Glass Works, Corning, N.Y.
Emhart Manufacturing Co., Hartford, Conn.
General Electric Co., Cleveland, Ohio
Hazel-Atlas Glass Co., Plainfield, N.J.
Kimble Glass Co., Vineland, N.J.
National Bureau of Standards, Washington 25, D.C. (Lab. A)
Owens-Corning Fiberglas Corp., Granville, Ohio
Owens-Illinois, Toledo, Ohio
University of Rochester, Rochester, N.Y.

Softening, Annealing, and Strain Points of the Glass

These empirical points, as defined in the ASTM STANDARDS, were determined by several of the participating laboratories and are shown below in table 2.

TABLE 2. *Softening, annealing and strain points of standard glass No. 710 by participating labs.*

Log_{10} viscosity poise	Temperature, °C							
	Laboratories							
	A	B	D	E	F	I	J	Average
Softening point [1] ---7.6--	727	723	721	721	723	725	727	724
Annealing point [2] --13.00--	546	---	544	546	---	545	547	546
Strain point [2] -----14.50--	503	---	501	504	---	505	508	504

[1] Littleton softening point.
[2] The glass viscosity at the annealing temperature, as found by the ASTM test, is an apparent viscosity, and not, an equilibrium viscosity. This is also true for the strain point which is an extrapolation of the annealing point test.

Type of Glass

The sample is a soda-lime-silica glass having an index of refraction, after fine annealing, of $N_D = 1.52337 \pm 0.00010$, and a dispersion of $\gamma = 59.2 \pm 0.2$.

Composition of the Glass

The composition of the glass as calculated from the batch composition is as follows:

SiO_2 —70.5%
Na_2O— 8.7
K_2O — 7.7
CaO —11.6
Sb_2O_3— 1.1
SO_3 — 0.2
R_2O_3 — 0.2 (Fe_2O_3—0.02%)

Chemical analyses [b] were made by four of the participating laboratories and their results indicate that the glass conforms closely to the nominal composition.

Methods of Measuring Viscosity of Glass

The rotating concentric cylinder (Margules technique) was used by all the participating laboratories at high temperatures, i.e. above the softening point or in the viscosity range $\log_{10}6.0$ to $\log_{10}2.0$. At the lower temperatures, between the viscosity range $\log_{10}9.0$ to $\log_{10}15.0$, the fiber elongation method of measuring viscosities at equilibrium temperatures was employed by three of the laboratories. The test methods used by several laboratories in determining the softening, annealing, and strain points of glass are given in the ASTM Standards.

Listed below are references, which appear at the end of this certificate, pertaining to the apparatus and methods used by each participating laboratory in making their measurements.

Laboratory	*References*
A	2,3,4,5,6,9
B	2,3,6,8,9
C	2,6,7
D	2,9
E	4.9
F	7.9
G	2,4
H	2
I	9
J	9

[b] Chemical analyses. This glass is not intended as a standard for chemical analysis. The above composition is offered only for information purposes.

List of References

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5. J. Boow and W. E. S. Turner, Viscosity and working characteristics of glasses; I. Viscosity of some commercial glasses at temperatures between 500°C–1400°C, J. Soc. Glass Tech. **26**, No. 117, 215 (1942).
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8. C. L. Babcock, Viscosity and electrical conductivity of molten silicates, J. Am. Ceram. Soc. **17**, No. 11, 329 (1934).
9. a. ASTM Standard, Annealing point and strain point of glass, ASTM Designation C 336, 1961.
   b. ASTM Standard, Softening point of glass, ASTM Designation C 338, 1961.

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