U. S. Department of Commerce
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Secretary

National Bureau of Standards
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National Bureau of Standards

Certificate

Standard Reference Material 731

Borosilicate Glass – Thermal Expansion

T. A. Hahn

Thermal Expansion as a Function of Temperature

T	Expansion $\Delta L/L_{293}$	Expansivity α	T	Expansion $\Delta L/L_{293}$	Expansivity α
80 K	-819×10^{-6}		293 K	0×10^{-6}	4.78×10^{-6}/K
90	−797		300	34	4.82
100	−771	2.64×10^{-6}/K	320	131	4.91
110	−744	2.86	340	230	4.99
120	−714	3.07	360	330	5.06
130	−683	3.25	380	432	5.11
140	−649	3.43	400	535	5.15
150	−614	3.58	420	638	5.19
160	−578	3.72	440	742	5.21
170	−540	3.85	460	847	5.23
180	−501	3.97	480	952	5.25
190	−460	4.08	500	1057	5.26
200	−419	4.17	520	1162	5.26
210	−377	4.26	540	1267	5.27
220	−334	4.34	560	1372	5.27
230	−290	4.41	580	1478	5.27
240	−246	4.48	600	1583	5.27
250	−201	4.54	620	1689	5.28
260	−155	4.60	640	1794	5.29
270	−109	4.66	660	1900	
280	− 62	4.71	680	2007	

This SRM is available as a square rod with 6.4 mm (1/4 in) sides; L1 is 51 mm (2 inches) long, L2 is 102 mm (4 inches) long, and L3 is 152 mm (6 inches) long. This borosilicate glass is from the same lot as SRM 717, Borosilicate Glass Viscosity Standard, with a nominal composition of 70% SiO_2, 17% B_2O_3, 8% K_2O, 3% Al_2O_3, 1% Na_2O, and 1% Li_2O. The index of refraction after fine annealing is N_D=1.4874. These rods were annealed at 789 K, cooled to 743 K at a rate of 2 degrees per hour, and then cooled to 523 K at a rate of 5 degrees per hour.

The above values of expansion and expansivity were calculated from equations based on a least squares analysis of the expansivity data from six specimens taken from various positions of the stock. A description of the experimental method, fitting procedure, and estimate of uncertainties is given in this certificate.

The overall coordination and evaluation of data leading to certification of this Standard Reference Material was performed by T. A. Hahn.

The technical and support aspects involved in the preparation, certification, and issuance of this Standard Reference Material were coordinated through the Office of Standard Reference Materials by R. E. Michaelis.

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J. Paul Cali, Chief
Office of Standard Reference Materials

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PROCEDURE

The apparatus used for the expansion measurements was a Fizeau interferometer with a 1-cm specimen length. Above room temperature, the measurements were made with the interferometer in a controlled atmosphere furnace using a Pt vs Pt-10% Rh thermocouple. Below room temperature, a cryostat operating with liquid nitrogen was used with a platinum resistance thermometer. The green spectral line of a mercury light source was used to produce the interference fringes. Fringe motion was measured with a filar-micrometer eyepiece. Each test specimen was made by fastening three 1-cm rods of the SRM to a Kovar ring to form a three point contact for the interferometer plates. With the uncertainties in temperature and fringe measurements, the expansivity was determined with an uncertainty of $\pm 0.03 \times 10^{-6}$/K.

Values of expansivity were calculated between equilibrium temperatures and corrections[1] were made so that α represents $\frac{1}{L_{293}} \frac{dL}{dT}$.

Tests on the six specimens indicated no appreciable differences. All of the data were pooled and the following third-order spline polynominals were obtained by the method of least squares using an Omnitab routine:

$100 \leq T \leq 293$

$$\alpha \times 10^6 = -0.8194 + 4.7611 \times 10^{-2} T - 1.4753 \times 10^{-4} T^2 + 1.7153 \times 10^{-7} T^3$$

$293 \leq T \leq 640$

$$\alpha \times 10^6 = 0.8651 + 2.3569 \times 10^{-2} T - 4.2277 \times 10^{-5} T^2 + 2.5408 \times 10^{-8} T^3$$

The standard deviation of this fit is 0.06 with 88 data points. These equations and their integrals were used to calculate the values listed in the table. A comparison of the experimental expansion data with values predicted from the equations gives a standard deviation of 8×10^{-6}. All of the data for both the expansion and expansivity were within two standard deviations of the values predicted by the equations.

[1]Hahn, T.A., Thermal Expansion of Copper from 20 to 800 K – Standard Reference Material 736, J. Appl. Phys. **41**, 5096 (1970).