Thermal Expansion of Five Selected Optical Glasses [1]

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Coefficients of linear thermal expansion of five optical glasses were determined by a strain gage method for the range between room temperature and 60° C. The coefficients of expansion of two crown glasses are 7.6×10^{-6} per deg C. A rare-earth glass was found to have a slightly lower coefficient of expansion, but the coefficients of expansion of two flint glasses are 10 percent larger than the other glasses.

This paper gives coefficients of linear thermal expansion of five samples of optical glasses. The chemical composition of these glasses are given in Research Paper 2504.

The diameter of each sample of glass was 30 mm. The length of each sample was 105 mm, except sample DF (table 1), which was 97 mm long. Determinations were made on the linear thermal expansion of these glasses on heating and cooling between 23° and 60° C. An electric-resistance strain-gage method was used. When a strain gage, consisting of a fine wire, is attached to a sample of solid material, changes in length of the wire accompanying thermal expansion of the sample are proportional to the changes in electrical resistance of the wire. Information about commercially available types of wire strain gages has been given by Ramberg.[2]

Two SR4 (type A 11) strain gages connected in series, were attached with a cellulose nitrate cement on opposite sides of each sample of glass and of each of three reference samples. These reference samples were duplicates of samples of invar, glass, and steel on which coefficients of linear thermal expansion had previously been determined by the precision micrometric method [3] of the Bureau. After the cement was sufficiently dried, the cemented gages were coated with wax. The glass and reference samples with their attached gages were then subjected to two cycles of heating and cooling between room temperature and 60° C, in order to allow the gages to adjust themselves to the samples before observations were made. During these cycles of heating and cooling, all samples were held at the maximum temperature for 2 hours.

The samples of glass and the reference samples with attached strain gages were supported vertically in an electrically controlled temperature cabinet. Two copper leads extended from each sample and from each reference sample to an SR4 strain indicator (type K). Four copper-constantan thermocouples placed symmetrically in the region of the glass samples and the reference samples were connected to a precision potentiometer.

Observations were made at room temperature and at 60° C, during three cycles of heating and cooling, on each sample of glass in conjunction with each reference sample of known expansion. These observations at constant temperatures, consisted of strain-indicator readings recorded to the nearest microinch per inch and of potentiometer readings recorded to the nearest microvolt. The latter readings were converted to temperatures to the nearest 0.1 deg C. The coefficients of linear thermal expansion of the five samples of glass given in table 1, were derived from the data. These coefficients of expansion are believed to be accurate to $\pm 0.1 \times 10^{-6}$.

TABLE 1. *Coefficients of linear thermal expansion of some optical glasses*

Glass [a]	Observed average coefficient of expansion per deg C between 23° and 60° C	Computed [b] coefficient of expansion per deg C
BSC, $n=1.517$, $\nu=64.5$	7.6×10^{-6}	7.6×10^{-6}
LBC, $n=1.574$, $\nu=57.7$	7.6	7.8
F , $n=1.620$, $\nu=36.2$	8.4	8.5
DF , $n=1.649$, $\nu=33.8$	8.3	8.5
Rare earth, $n=1.673$, $\nu=56.2$	7.5	(c)

[a] n=index of refraction for the sodium D line, and ν, the Abbe value=$(n-1)/(n_F-n_C)$, where n_F and n_C are refractive indices for the hydrogen F and C lines, respectively.
[b] From English and Turner's factors for oxides in glass for the range from 25° to 90° C (see footnote 4).
[c] No factor was given by English and Turner for La_2O_3 in this glass.

The last column in table 1 gives coefficients of expansion computed from English and Turner's [4] factors.[5] One-third of the sum of the products of the factors and the precentages of the corresponding constituent oxides of a glass gives a computed coefficient of linear thermal expansion. The agreement between the observed and computed coefficients of linear expansion of the glasses is good.

[2] W. Ramberg, Contributions of electricity to mechanics, J. Wash. Acad. Sci. **39**, 281 (Sept. 1949).
[3] P. Hidnert and W. Souder, Thermal expansion of solids, NBS Circular 486 (1950).

[4] S. English and W. E. S. Turner, Relationship between chemical composition and the thermal expansion of glasses, J. Am. Ceram. Soc. **10**, 551 (1927); Corrections on "Relationship between chemical composition and the thermal expansion of glasses," J. Am. Ceram. Soc. **12**, 760 (1929).
[5] For computing coefficients of cubical expansion.

The coefficients of expansion of the two crown glasses (BSC 1.517 and LBC 1.574) and the rare earth glass 1.673 are practically the same and about 10 percent smaller than the coefficients of expansion of the two flint glasses (F 1.620 and DF 1.649).

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