Measurement of the Specific Refractivities of CF_4 and C_2F_6

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In order to relate the measured fringe shift of an interferometer to density, the relation between density ρ and refractive index n must be known. For gases where the refractive index is close to unity, this relation between density and refractive index is very closely approximated by

$$(n - 1) = K\rho$$

where K is the specific refractivity, or the Gladstone-Dale constant. The specific refractivity, which is weakly dependent on wavelength and temperature, is readily available for a number of common test gases such as N_2 and air[1]. For more unique test gases such as CF_4 and C_2F_6 for which refractive index data at optical wavelengths is not readily available, the constants can be estimated from the atomic refractivities of carbon and fluorine[2]. In order to verify this estimation, a two-beam interferometer was used to experimentally determine the specific refractivities of CF_4 and C_2F_6. This data was required for holographic interferometric measurements made at the Langley Hypersonic CF_4 Tunnel[3].

A Twyman-Green interferometer with a He-Ne laser light source of vacuum wavelength λ equal to 633 nm was used to measure the constants. One beam of the two-beam interferometer passed through an optical cell of known inside length l which could be evacuated and slowly filled with the test gas to a density of 7.2 kg/m^3 for CF_4 or 5.7 kg/m^3 for C_2F_6. If the refractive index (and hence density) is constant along the optical path through the cell, the fringe shift M and density change $\Delta\rho$ are related by

$$M = 2Kl\Delta\rho / \lambda$$

for the double pass interferometer. Thus K can be determined by measuring the fringe shift as the density is changed.

The output of a photodiode used to detect the fringe shift was recorded on a strip chart recorder. The rate of pressure increase of the test gas in the cell was controlled such that the fringes shifted at a rate of 0.5 to 1 fringe per sec. The pressure in the test cell was measured with a high accuracy quartz crystal pressure transducer and recorded approximately every 20 fringe peaks. The temperature of the cell was measured with a thermocouple and recorded at the start, midpoint, and end of each test.

The densities corresponding to the fringe peaks were calculated from the measured temperatures and pressures using the real gas equations of state for CF_4 and C_2F_6[4,5]. The slope (specific refractivity) of fringe shift versus $2l\Delta\rho / \lambda$ was then determined by the method of least squares. The measured specific refractivities of CF_4 and C_2F_6 at a temperature of 300 K were 0.122 cm^3/g and 0.131 cm^3/g, respectively. These values were within 1% of the values computed from the atomic refractivities of carbon and fluorine. The systematic error of the measurement process was estimated to be $\pm$ 0.0003 cm^3/g.

The error due to measurement imprecision was ± 0.0006 cm^3/g for a 95% confidence interval as determined by computing the standard deviation of repeated measurements. Summing the systematic and imprecision errors gives ± 0.0009 cm^3/g as an estimate of the uncertainty of the measurement.

References

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