ON AN EXPERIMENTAL METHOD OF DETERMINING THE TOTAL RADIATION EXTINCTION COEFFICIENT OF FURNACE GASES

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In a recent paper [1] V. K. Mel'nikov and E. Ya. Blum have proposed a method of determining the total radiation extinction coefficient of furnace gases. The method is based on the assumption that in spectrally selective radiation the coefficients of absorption (extinction) and emission of the gas are identical and are determined by the physical properties of the gas at the given point. It is also assumed that this coefficient is inversely proportional to the absolute temperature ((7) in [1]). We intend to show that these assumptions may lead to errors.

The equation of radiative transfer is

$$\frac{dB}{dx} = kB_0 - kB, \qquad (1)$$

where B is the intensity of the beam, variable along its length (Q in [1]) and B_0 is black-body intensity at the local temperature.

Equation (1) holds for gray and monochromatic radiation. In the first case $B_0 = \sigma_0 T^4/\pi$, whereas in the second case B_0 is determined by Planck's function according to the wavelength and refers to unit wavelength.

In furnace gases radiation is due to carbon dioxide and water vapor. The radiation of these gases is highly selective, which makes Eq. (1) inapplicable. To generalize Eq. (1) so as to make it applicable to this case, we write it in its monochromatic form and integrate it over the whole spectrum. This yields

$$\frac{d}{dx} \int_0^\infty B_\lambda d\lambda = \int_0^\infty k_\lambda B_{0\lambda} d\lambda - \int_0^\infty k_\lambda B_\lambda d\lambda, \qquad (2)$$

where B_λ and $B_{0\lambda}$ are the local and black-body intensities, respectively, referred to unit wavelength.

We introduce the notation

$$B_c = \int_0^\infty B_\lambda d\lambda, \qquad B_0 = \int_0^\infty B_{0\lambda} d\lambda = \sigma_0 T^4/\pi,$$

$$k_{0c} = \int_0^\infty k_\lambda B_{0\lambda} d\lambda / B_0, \quad k_c = \int_0^\infty k_\lambda B_\lambda d\lambda / B_c. \qquad (3)$$

Substituting (3) in (2), we obtain

$$\frac{dB_c}{dx} = k_{0c}B_0 - k_c B_c. \qquad (4)$$

Equation (4) is of the form of Eq. (1). But from (3) we see that the coefficients k_{0c} and k_c are not equal.

The first of these is an emission coefficient, determined by the properties of the emitting gas at the given point, whereas the absorption coefficient k_c depends both on the physical properties of the gas at the given point and on the spectral composition of the incident beam of radiation. The latter varies along the path of the beam and depends on the spectral composition of the beam at its origin and on its history between the origin and the point under consideration. It can be easily seen that the values of the coefficients k_{0c} and k_c can be quite different and that the value of k_c itself can vary quite considerably along the beam.

From Figs. 62, 63, 66, and 67 of [2] we have: (a) For carbon dioxide at t = 1000° C—k_{0c} = 12 m^{-1}, k_c = 360 m^{-1} for px = 0.1 cm · atm and 230 m^{-1} for px = 1 cm · atm; (b) For water vapor at t = 600° C—k_{0c} = 4.1 m^{-1}, k_c = 92 m^{-1} for px = 0.1 cm · atm and 60 m^{-1} for px = 1 cm · atm.

This shows that in the case of a selectively radiating gas one cannot use the equation of radiative transfer with equal emission and absorption coefficients and with an absorption coefficient constant along the beam path. The concept of an emission-absorption coefficient has no physical meaning in this case.

The authors of [1] assume [equation (7)] that the absorption in the gas decreases with increasing gas temperature. It should be pointed out that this assumption contradicts experimental data for carbon dioxide, for which the absorption coefficient for a beam with constant spectral composition increases with temperature [3]. For water vapor the absorption coefficient increases with temperature in some ranges, and decreases in others [4].

The inconsistency of the method of determining the mean absorption (emission) coefficient along the beam which has been proposed in [1] can be seen if one uses Eq. (4) of [1], with data on the total emission of gases, to calculate the values of k for various beam lengths. Such calculations have been made by A. V. Kavaderov (Figs. 17 and 19 of [5]). These calculations show that the mean value of the coefficient k in an isothermal gas depends very strongly on the beam length. The reason for this is the variation of the spectral composition of the beam along its path.

At the end of their paper the authors point out the good agreement between the values of the coefficients k_0 obtained by them experimentally and the data of [6]. It should be noted that [6] does not present values of the coefficient k_0. Using the data of that paper to calculate these coefficients, one can obtain different values depending on the beam length assumed.

It remains unclear how Eq. (10) was obtained from (8) and (9) in [1]. In the writer's opinion instead of this equation one should obtain an expression which is gradratic in k_0. The dimensions of the left and right sides of (10) are not equal. It should also be noted that Eq. (8) has been derived, in slightly different form, by A. V. Kavaderov in 1956 [5].

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