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SHORTER COMMUNICATIONS

RADIATION OF SPHERICALLY-SHAPED GASES

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THE purpose of this note is to present formulae and graphs from which thermal radiation from a spherically-shaped gas may be readily estimated. The body upon which the thermal radiation impinges may be inside or outside of the hot gas envelope. However, a line normal to the surface is assumed to pass through the center of the gas body. To obtain a closed form solution, the gases are taken to be isothermal.

Following the steps of reference [1] and using the sketch of Fig. 1, it may be shown that the emissivity of the hot gases with respect to the surface located inside of the hot gas body is:

$$\epsilon = 1 - 2 \int_0^1 t \exp\left\{-KS\left\{\sqrt{\left[2\frac{R}{S} - 1 + \left(1 - \frac{R}{S}\right)^2 t^2\right]} + \left(1 - \frac{R}{S}\right)t\right\}\right\} \mathrm{d}t \qquad (1)$$

where:

- ϵ, hemispherical emissivity $= q/\sigma T^4$;
- σ, Boltzmann constant;
- K, absorption coefficient;
- q, incident radiant flux;
- R, radius of sphere;
- S, gas layer "thickness";
- T, gas temperature.

Equation (1) is valid for total emission from a gray gas and for monochromatic emission from a non-gray gas. Equation (1) may be integrated to yield the following result:

$$\epsilon = 1 + \frac{1}{2\,[KS\,(R/S) - 1]^2}\left\{(1 + KS)\,\mathrm{e}^{-KS} - \left[1 + KS\sqrt{\left(2\frac{R}{S} - 1\right)}\right]\exp\left[-KS\sqrt{\left(2\frac{R}{S} - 1\right)}\right]\right\} - 2\left[\frac{(R/S) - (1/2)}{(R/S) - 1}\right]^2\left\{E_3\,(KS) - \frac{1}{2\,(R/S) - 1}\,E_3\left[KS\sqrt{\left(2\frac{R}{S} - 1\right)}\right]\right\} \qquad (2)$$

where

$$E_3\,(t) = \int_1^\infty \frac{\mathrm{e}^{-tx}}{x^3}\,\mathrm{d}x \quad [3] \qquad (3)$$

Thus, the hemispherical emissivity involves two dimensionless parameters, KS and R/S. Equation (1) has been used to compute the emissivity for a wide range of these two parameters and the results are presented in Fig. 1.

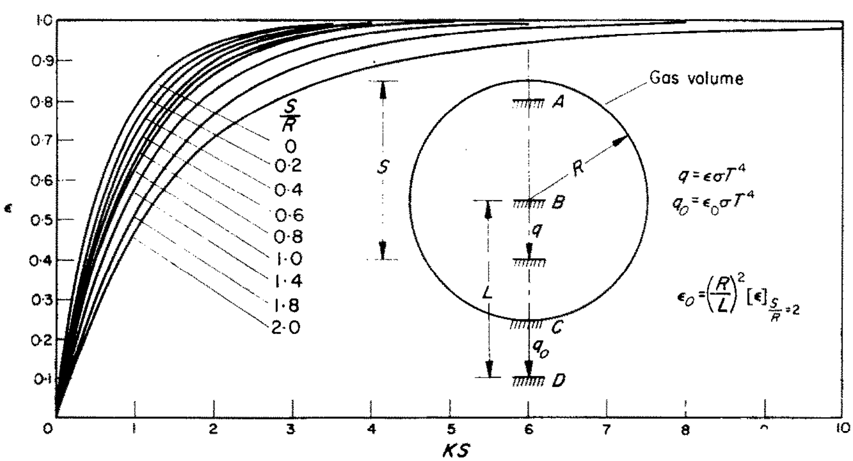

FIG. 1. Emissivity of spherically-shaped gases.

Several special cases where the hemispherical emissivity may be expressed in simple forms are:

(a) $(S/R) \to 0$ (location A in Fig. 1): When $(S/R) \to 0$, equation (3) reduces to:

$$\epsilon = 1 - 2E_3(KS) \quad (4)$$

(b) Hemispherical gas (location B in Fig. 1): For a hemispherical gas volume $[(S/R) = 1]$, equation (1) may be integrated to give:

$$= 1 - e^{-KS} \quad (5)$$

This expression can be also found in reference [4].

(c) Spherical gas (location C in Fig. 1): For a body situated at the inner surface of a spherical gas envelope $[(S/R) = 2]$, the emissivity as found from equation (1) is

$$\epsilon = 1 - \frac{1}{2(KR)^2}\,[1 - (1 + 2KR)\,e^{-2KR}] \quad (6)$$

Equation (6) was also derived by Schmidt [5]. For optically thin gas, $KR \ll 1$, equation (6) is reduced to

$$\epsilon = \frac{4}{3}KR \quad (7)$$

Equation (7) was also given in references [4] and [6].

(d) Body outside of gas volume (location D in Fig. 1): When a body is located outside of the hot gas volume, the emissivity may be computed from:

$$\epsilon_o = \left(\frac{R}{L}\right)^2 \left\{1 - \frac{1}{2\,(KR)^2}\,[1 - (1 + 2KR)\,e^{-2KR}]\right\} \quad (8)$$

where the subscript o indicates that the body is located outside of the gas volume $[(R/L) \leqslant 1)$.

Incident thermal radiation

With Fig. 1, the calculation of thermal radiation becomes very simple. For a given gas dimension (R), surface location (S), and radiation property (K), one can read the emissivity ϵ directly from Fig. 1. The incident thermal radiation from the gas body at a temperature T to a surface is simply $q = \epsilon\sigma T^4$.

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COMMENTS ON THE PREDICTION OF PRESSURE DROP DURING FORCED CIRCULATION BOILING OF WATER

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NOMENCLATURE

- G, mass velocity (lb/ft^2 s);
- v_g, specific volume of gas phase (ft^3/lb);
- v_1, specific volume of liquid phase (ft^3/lb);
- $\bar{X}_a$, fraction of cross section occupied by gas phase;
- X_m, weight fraction gas in mixture;
- α, specific volume ratio (v_g/v_1);
- γ, dimensionless slip factor;
- σ, slip ratio (α/γ).

J. R. S. Thom has recently proposed correlations for prediction of pressure drop for the circulation of boiling water [1]. He proposes to fit curves of the type

$$\bar{X}_a = \frac{\gamma \,.\, X_m}{1 + X_m(\gamma - 1)} \quad (1)$$

by using a slip factor γ which is a constant at any given pressure. This simplifying assumption would be expected to have limited application and should be used with knowledge of these limitations.