$$\text{Enhancement due to radiation} = \frac{q_{\text{conv(left)}} + q_{\text{rad(left)}}}{q_{\text{conv(left)}}} \quad (2)$$

At this point it needs to be emphasized that because of the predominantly boundary layer type of flow the convective heat flux from the left wall itself is relatively insensitive to radiation and remains more or less constant within the limits of numerical accuracy.

If one uses Eq. (1), spuriously low values of the enhancement factor would be obtained and this actually underplays the influence of radiation. The definition (2) is more meaningful because of the simple reason that when radiation is not there $q_{\text{conv(right)}}$ is also not there and hence the denominator that has been used in Eq. (1) is incorrect. We take an example from Lage et al. The results obtained with Eq. (1) have been plotted in Fig. 11 of their paper. Typically when $T_1 = 100°\text{C}$, $T_\infty = 25°\text{C}$, $L/H = 0.25$, and $\epsilon_1 = \epsilon_2 = 0.6$, the right wall temperature is around 56°C, as given in Fig. 10. Under these conditions Eq. (1) gives a value of 1.12 as the enhancement due to radiation. However, under these conditions, from the results reported in their paper the convection heat transfer from the right wall is 33 percent of the convective heat transfer from the left. Hence, Eq. (2) will give an enhancement factor of 1.49 and this is the actual effect of radiation. This directly disproves the statement of Lage et al. that ". . .in the temperature range considered in the example, the radiation contribution to the overall heat transfer rate is overshadowed by natural convection. . .". In fact radiation could contribute 50 percent of the total heat transfer as proved earlier by taking a simple example. Hence it is concluded that the interaction between radiation and convection is indeed strong.

References

Balaji, C., and Venkateshan, S. P., 1993a, "Interaction of Surface Radiation with Free Convection in a Square Cavity," *International Journal of Heat and Fluid Flow*, Butterworth, United Kingdom, in press.

Balaji, C., and Venkateshan, S. P., 1993b, "Interaction of Radiation With Free Convection in an Open Cavity," *AIAA Journal of Thermophysics and Heat Transfer*, submitted.

Authors' Closure

J. L. Lage,[10] J. S. Lim,[11] and A. Bejan.[12] We regret to say that the letter writers' observations add nothing to the comments we already included in many parts of our paper. It may be that these writers did not read our text carefully, or that they think that their forthcoming paper on the same problem will be received better if they publicize it ahead of time. To this point we will return in the last paragraph.

What the letter writers call "conceptual errors" are modeling decisions we made and discussed in detail, as part of a deliberate effort to construct the simplest model possible. We stated our objectives in Section 1, especially in the last three paragraphs. We set out to solve a real industrial problem (first paragraph, p. 479), not to calculate in the most accurate way possible the temperature distribution around an ash pit.

We recognized from the very beginning (p. 479) that "an alternative method that is well documented (e.g., Larson and Viskanta, 1976; Lauriat, 1980) consists of solving simultaneously the differential equations for natural convection and radiation, while the nonuniform temperature distribution of the three refractory surfaces is one of the unknowns." We discussed this further on p. 486. This alternative approach is apparently preferred by the letter writers. They are as free to choose their approach as we were when we chose ours. Their objectives are obviously not the same as ours.

Our decision to assign a single temperature (T_2) to the right wall and the bottom of the pit is one of the features of the simplest possible model. We analyzed the pluses and minuses of this decision in a long paragraph (see the bottom-left corner on p. 484); we did not hide it to be "discovered" now by the letter writers. We stated that the actual bottom wall acquires a temperature that varies between T_1 and T_2, and then we listed several *reasons* why we think our modeling decision "is a good *approximation*." To see the good approximations is not only an integral part of good engineering practice, but also the main mission of the *teaching* of engineering research.

Our estimate of the effect of radiation relative to a pure-convection model (Fig. 11) was meant to be qualitative, because it is impossible to separate the two mechanisms *after* they have been coupled in the radiation and convection model. The denominator in our ratio refers to a cavity in which *both* vertical walls are heated, as in the first part of our paper (the letter writers misunderstood our definition). We agree that there may be other ratios that can be looked at. The important point is that the letter writers' estimate (49 percent) agrees with our estimate (12 percent) in a qualitative sense, i.e., in that the dominant mechanism is natural convection. To attack this qualitative conclusion, as they have done, is to split hairs.

By the way, the best place to study the effect of radiation in an enclosure with natural convection is by looking at the *simplest* enclosure geometry, not at the open pit considered in our paper. That simplest geometry may be the square enclosure heated and cooled from the side: It makes a nice undergraduate textbook problem (Bejan, 1993), to which we direct the letter writers' attention.

In summary, we welcome Balaji and Venkateshan's interest in the problem we identified and solved, because it reminds us of what we felt: The problem is interesting. We would have thought, however, that a fairer way of commenting on our work would have been to submit the full-length paper (Balaji and Venkateshan, 1993b) to the JOURNAL OF HEAT TRANSFER, instead of a short letter. We question Professor Venkateshan's decision to (1) "criticize" our work in a letter to the original journal, and, simultaneously, (2) submit the long version of the same to a different journal.

[10] J. L. Embrey Assistant Professor, Mechanical Engineering Department, Southern Methodist University, Dallas, TX 75275-0335.

[11] Senior Researcher, Samsung Electronics, Co., Refrigeration & Living R&D Center, 416, Maetan-3 Dong, Paldal-Gu, Suwon City, Korea.

[12] J. A. Jones Professor of Mechanical Engineering, Department of Mechanical Engineering and Materials Science, Duke University, Box 90300, Durham, NC 27708-0300.

Reference

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