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LETTER TO THE EDITORS

HEAT TRANSFER IN COLD WALL COMBUSTION CHAMBERS

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WE HAVE read with interest the paper by Leckner [1] on radiation from oil flames in cold wall combustion chambers. In particular we have noted that he dismisses methods in which flow patterns and burning rates are used to make heat balances [2] because the accuracy of the final result is out of proportion to the effort involved. Instead he advocates the "easier and more direct approach for radiation calculations assuming a temperature and an emissivity pattern from the general outlook of the burner arrangement and the geometry of the furnace". We would like to suggest a method that lies between these two approaches and which has been used by us in a study of water tube boilers, but which has not yet been reported in detail.

As Leckner has pointed out, temperature and emissivity (or the related absorption coefficient [3]) define the mathematical models. In order to arrive at a set of gas temperature (T_g) values isothermal models of about $\frac{1}{16}$th scale have been used with appropriate representation of the burners. The time [s] taken for combustion gases to reach various positions in the furnace were measured using a helium tracer technique [4]. Data on the average temperature/time history of the combustion products (which is determined by the rate of heat release and by radiant cooling) are then used to assign values of local gas temperature. This has been discussed by Anson, and a typical residence time–temperature curve is shown, in [4]. For specific cases flame temperatures and emissivities have been measured at increasing distances from the burner (i.e. at different stages of combustion), using established methods, on a single full scale flame of the type to be used in the boiler [3]. From these measurements empirical relationships between the stage of combustion and both the absorption coefficient k, and flame temperature were obtained.

Having predicted the pattern of flame temperatures and emissivities throughout the furnace chamber it is not difficult, using the Hottel and Cohen [5] method with modern computers, to calculate the heat flux at the furnace walls. The method involves dividing the furnace chamber into a number of radiating gas (flame) volume zones and receiving furnace zones. It can be shown [5] that for a cube of gas side B the energy radiated through the six bounding surfaces is given by:

$$E = 4kB^3\phi\sigma T_g^4$$

where k is the overall absorption coefficient referred to previously. ϕ is the fraction of energy within the cube that escapes and for which curves are available [5]. To arrive at an overall heat transfer solution it is necessary to evaluate the radiant emission and the interchange with other zones, making allowance for absorption between gas zones and for partial reflection and absorption of radiation at all surfaces. Thus a number of simultaneous equations can be set up although it must be remembered that the number of times they have to be solved is equal to the number of gas zones (cubes) plus surface zones (areas). There is a limit to the information that can be stored in a computer, thus setting a practical limit to the number of cubes and areas. In our computer programme this is 224 cubes and 204 wall areas. These water wall areas are considered to be all alike with a temperature T_w about 100°C above the saturated vapour temperature and a surface absorptivity α of 0·85. The problem is more complicated in coal fired furnaces where heavy variable ash deposits may affect T_w and α although if the pattern of ash coverage on the walls is predictable, the computer programme can cope with each surface zone having different values of T_w and α.

A comparison of the predicted and observed heat fluxes for the furnace chamber of an oil fired water-tube boiler producing 3500 klb/h of steam showed very reasonable agreement. For example, the maximum and minimum calculated heat fluxes were both within ± 13 per cent of the observed values. Furthermore, in practice they were located in the appropriate places on the boiler walls. It is perhaps surprising that the very simple approach adopted by Leckner gives a similar order of accuracy (i.e. within ± 15 per cent) but it must be remembered that he is dealing with a much simpler system. His furnace has a 1 m^2 cross-section and is 6 m long with a single linear, concentric flame; modern water-tube boiler furnaces can have a 200 m^2 cross-section and be 30 m high, with thirty or more flames giving, collectively, very complex flow patterns.

To sum up, we are in agreement with Leckner that calculating the heat transfer from combustion data and energy balances is difficult and unnecessarily complicated for most industrial systems. On the other hand, the method Leckner proposes of assuming a temperature and emissivity pattern from the general outlook of the burner arrangement and the geometry of the furnace may be too simple for large plant. An approach using isothermal models of the plant, a full scale burner in a test facility and a mathematical model to calculate the radiant heat transfer, has proved to be very effective for large modern water-tube boiler furnaces.

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