Review of Progress in the Fire and Smoke Physics Area

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A brief review of recent literature concerned with fire and smoke physics is given here for the period 1987 to 1989.

1. SCALING TECHNIQUES

Because of the great expense involved with full scale testing, the use of small scale test apparatus has intrigued most experimentalists involved with all types of fire tests and the development of standard tests. Unfortunately most subscaled tests have not proved to be convincingly useful because all scaling parameters can not be held constant simultaneously.

Quintiere addresses the general scaling problem and bases scaling laws on dimensionless parameters which he developes from the governing differential equations. He applies his results to a wide range of small scale tests under conditions for which many of the scaling parameters can be ignored and shows that satisfactory correlations can be obtained between small and large scale tests.

2. PROPERTIES OF SMOKE

CORROSION: The presence in smoke of trace species such as hydrochloric acid can produce corrosion in a wide variety of materials and on diverse surfaces which are exposed to the smoke, and the corrosive effects can cause considerable financial loss even though no serious thermal effects are present. Two examples are: smoke damage to computing equipment in the First Interstate Bank was a serious problem in areas which were 45 floors above the fire floor; and the Navy has developed a serious interest in the corrosion problem because of damage to computing equipment produced by smoke from fires involving cable insulation.

Papers by Hirschler and Smith, Galloway and Hirschler, and O'Neill discuss various aspects of the corrosion problem including the rate of transport and condensation of corrosive materials, and the rate of attack of these gases on various surfaces. Particular emphasis was placed on HCl formed from the combustion of halogenated materials. O'Neill was concerned that discriminatory standards might be developed to prevent some of these problems and that these standards would adversely effect the plastics industry.

A recent conference on this subject, (Corrosive Effects of Combustion Products, 13-14

October 1987, London), was organized by the Fire and Materials Center, QMC, in association with ISO, IEC, ASTM, and BSI.

COMPOSITION OF SMOKE: A number of recent papers have delt with the smoke or the products of combustion produced by fires burning in a variety of ambient conditions and with a wide range of fuels. These include literature surveys on the combustion products of polystyrenes by Gurman et al, and on polyvinal chloride by Huggett and Levin. The effects of various properties of the atmosphere which surrounds the fire on species production rates are discussed by Morikawa, Nakaya, Zhubanov and Gibov, McIlhagger et al, and Trzeszcynski et al.

Babrauskas has used the cone calorimeter to study the properties of smoke produced by combustion of fire-retarded plastics in the presence of external irradiance. Substantial effects on species production were observed as conventional fire retradants were added, and large differences in production rates of soot and species were observed for cable coverings which met the same military specifications. McIlhagger et al present interesting information on the effects of the oxygen mass fraction of the ambient atmosphere on the particle size of the soot produced in polystyrene fires in a small apparatus. Other papers on the properties of soot include several concerning experimental studies of the optical Habib and Vervisch, and by Charalampopoulos and Chang.

3. MODELING SMOKE MOVEMENT

CORRIDOR FLOWS: Gravity currents produced in corridors by hot gas supplied by a fire have been modeled with an $\epsilon - k$ field method by van de Leur et al which used the original constants proposed by Launder and Spalding. Buoyancy terms are included in the calculations and their effect is modeled with a Richardson number correlation based on the local values for the current depth and average velocity. Heat transfer between the current and the ceiling of the corridor are included is a dominant effect. Another paper by Liew et al describes in less detail computations with an $\epsilon - k$ model for a similar corridor like geometry. The results agree qualitatively with the experimental results of Chobotov and Zukoski. Both results emphasize the extreme importance of heat transfer between the hot gas current and the corridor ceiling in modeling these flows.

These papers clearly show the importance of heat transfer in corridor or tunnel flows. No one has yet explored the implications of this result in describing the development of the hot layer within the corridor subsequent to the arrival of the hot gas current at a closed end of corridor. Because of the large horizontal temperature gradient in the corridor, produced by heat transfer to the ceiling, the hot gas layer which develops later will certainly contain a large vertical temperature gradient. The presence of this gradient may make difficult or impossible the application of the usual two-layer zone model to flows in corridors.

4. PLUME MODELING

FIRE PLUMES: Continued interest in the structure of large buoyancy controlled diffusion flames has resulted in a number of papers. One of these by Hasemi attempts to correlate a number of the properties of the flow in the flame. He shows that correlations for the properties of large buoyant diffusion flames change as the heat release for a given diameter increases. These results emphasize that comparisons of data must be correlated with a Q^* like parameter and that data with different Q^* values should not be included in the same correlation.

Heskestad and Delichatsios have reexamined a large body of entrainment data for the flaming region using quite different approaches, and have suggested two correlations for entrainment into the flame. The Heskestad does make use of the Q^* dependence discussed above in developing his correlations.

A paper by Fisher et al concerns an experimental investigation of the distribution of soot within an ethanol pool fire and the radiant properties of the flame. Since up to 40% of the chemical energy released in these large flames is immediately radiated away, this is a key process. Heat release rates in the 10 to 40 KW range were studied.

Adiga et al use an $\epsilon - k$ numerical code to model pool-like gas flames of propane and show that the inclusion of radiant heat transfer has a large effect on their results.

Gross has measured the lengths of flames which impinge on a solid ceiling in the absence of side wall effects and in a corner geometry. He used large heat release rates, 100 to 400 KW, and fires generated by gas burners with diameters up to 0.54 m and wood cribs.

WALL PLUMES: Cooper, and Jaluira and Kapoor discuss the importance of natural convective flows arising on vertical surfaces during the early stages of a room fire and show that interactions of these currents with the interface between the hot and cold layer can cause considerable transport of gas between the layers.

5. COMPARTMENT FIRE MODELS

A number of papers concern the applications of various models for the prediction of the development of layers in the two-layer models for a single room. The room filling problem is discussed by Bengston and also by Fusegi and Farouk who considered very large spaces. Hinkley (1988), and Fusegi and Farouk show that the influence of radiant heat transfer must be considered in room filling models. Finally, Hinkley (1989) describes the results of the application of a zone model to the effect of smoke venting on the operation of arrays of sprinklers. A large number of examples are calculated and several are compared with experiments. A paper by Jamaluddin and Smith discusses the general problem of radiant heat transfer in a rectangular compartment and the application of the discrete ordinates method.

Keski-Rahkonen have developed a model to explain how windows break during a fire. Including a rational description of window breaking in models of fires in compartments when closed windows are initially present will be an important step.

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