SAND2018-1971C

Thermal Transport Model Development of an Intumescing Fire Protection Coating

Larsen, M.E. and Babiniec, S.M.

Protective coatings are in wide use to limit damage to equipment and facilities at risk of fire damage. The effectiveness of a commercially-available intumescing material (IM) used as a fire-protection coating has been quantitatively assessed for a half-hour hydrocarbon fuel fire. The coating was applied to a stainless steel metal substrate and exposed to thermal radiation from a parallel plate driven to 1024°C to simulate the fire boundary. Chemical reactions occurring from approximately 200 to 600°C outgas and expand the material to approximately ten times its initial volume and one-third of its initial mass. The rates of chemical decomposition have been characterized through thermogravimetric analyses (TGA) and used to inform Arrhenius kinetics models. Simultaneous differential scanning calorimetry (DSC) measurements were used to infer thermodynamics of each reaction event incorporated into the Arrhenius kinetics model.

A finite element thermal model formulation incorporates the chemistry to describe the transient conversion of the layer to the expanded state. In the expanded/reacted condition the layer provides significant insulating benefit to slow the thermal insult to the substrate. The unreacted layer is opaque to radiation and of relatively high thermal conductivity. At elevated temperatures the reacted layer's heat transfer is dominated by thermal radiation which is represented by the diffusion method. Parameters in the transport model were developed based on laboratory experiments that varied the boundary temperature and the initial thickness of the unreacted coating. Tests were conducted on 2-foot (0.61 m) square test specimens with initial coating thicknesses from 0.07- to 0.18-inch (1.8 to 4.6 mm). Inconel shroud temperatures from 650 to 1024°C were used to implement varied heating rates. Finally, the resultant model is assessed against experimental data obtained by exposing a 7' by 10' (2.1 by 3.05 m) structure, protected by the IM, to a Jet-A fire.

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