Computer Models
For
Fire and Smoke

Model Name: SPREAD

Very Short Description: A computer program which predicts the burning rate and spread rate of a fire ignited on a wall using input data from bench-scale tests.

Modeler, Organization: H.E. Mitler, Building and Fire Research Laboratory, National Institute of Standards and Technology

References:
1. Mitler, H.E., “Algorithm for the mass-Loss Rate of a Burning Wall,” Fire Safety Science – Proceedings of the Second International Symposium (Eds., C.E. Grant and P.J. Pagni); Hemisphere Publishing Corp. (1989) p. 179.
2. Mitler, H.E., “Predicting the Spread Rates of Fires on Vertical Surfaces,” 23rd (International) Symposium on Combustion; The Combustion Institute, Pittsburgh, PA, (1990) p. 1715.

Availability: Not available until documentation has been completed.

Hardware: Will run on desk computers: MS-DOS, Intel 80286 chip (or better)

Language: FORTRAN

Size: Source code = 90 Kb; executable = 177 Kb

Detailed Description:

This model calculates the burning rate and upward spread rate of fires on flat walls; that is, the upward spread rate of pyrolysis front of a burning vertical slab. It has recently been generalized to include lateral (opposed-flow) spread as well; the algorithm takes into account the fact that the lateral spread rate in the upper region. The fact that a wall slab can burn out, and the resulting effects, have also been included.

Analytic models for upward spread have certain drawbacks: simplifying assumptions must be made, such as a linearized radiation loss, a constant heat flux in the pre-heating region up to the flame tip height, zero thereafter; a "characteristic shape" (i.e., time dependence) for the mass-loss rate per unit area; uniformity of oxygen concentration and gas temperature. Also, a number are valid only for semi-infinite slabs; use it for finite-thickness slabs; use it for finite-thickness slabs is an approximation which becomes worse as the slabs get thinner (which happens near burn-through). Perhaps the most severe restriction on the use of analytic formulations is that any external radiation is assumed to be uniform and constant (or zero!), whereas in enclosures, where external ("feedback") radiation to the wall can increase the burning rate by a factor of as much as seven over the open-burning rate, that radiation varies strongly with both position and time.

In this algorithm, the movement of the pyrolysis front is therefore calculated numerically rather than analytically: the pyrolysis front is assumed to move up as certain (fixed) points along the surface heat up to a critical temperature T_c, assumed to be the ignition temperature, T_{ig}. This approach is less elegant but more general and straightforward: the principal assumptions made are that there exists a well-defined ignition temperature T_{ig}, that there is no lateral diffusion of heat within the slab (even though it is being heated at different rates at different heights), that the slab material has uniform, isotropic properties, and that it has a well-defined heat of vaporization.

The slab (or wall) is assumed to be ignited with a flame from a line burner; it is of user-specified strength, $Q_b(t)$. It can, at the same time, also be exposed to external heating fluxes which can be time-varying as well as nonuniform with respect to vertical position on the wall; the other external conditions (gas temperature and oxygen concentration) can also vary both with time and along the surface.

The mass-loss rate is calculated as follows: a sample is placed in the Cone Calorimeter and exposed to a given irradiance level; the resulting mass-loss rate dependence is then transformed into what the rate would be at the levels found during the actual experiment. This approach automatically includes the effects of charring, intumescing, melting, etc., as well as of transient heating, to a good first approximation. Expressions for the heating flux from the flame to the wall are found for all cases of interest.

Validation of the model: Two versions of the model were written: one which assumes the "Classical" dependence of the flame height on the two-thirds power of the power output per unit width, and the another which assumes a square-root dependence. The results, using either mass-loss rate option, were in excellent agreement with experiment when the latter dependence was used.