Computer Models For Fire and Smoke

Model Name:	FIRST (FIRe Simulation Technique)
Version:	3.0
Classification:	Zone Model
Very Short Description:	Predicts the fire environment in a single compartment based on either a user prescribed fire or a fire dominated by radiation feedback.
Modeler(s), Organization(s):	H. E. Mitler, J. A. Rockett, and W. D. Davis; National Institute of Standards and Technology, Gaithersburg, MD, USA. (H. E. Mitler is currently at the University of Maryland, College Park, Maryland, and J. A. Rockett is Retired.)
User's Guide:	Users' Guide to FIRST, A Comprehensive Single-Room Fire Model, National Institute of Standards and Technology, NBSIR 87-3595 (1987).
Technical References:	Emmons, H.W., "The Prediction of Fires in Buildings," *17th Symposium (International) on Combustion*, The Combustion Institute, Pittsburgh, PA (1979) p. 1101.
	Mitler, H.E., "The Physical Basis for the Harvard Computer Fire Code," Harvard University, Home Fire Project Technical Report No. 34; (1978).
	Mitler, H.E. and Emmons, H.W., "Documentation for CFC V, the Fifth Harvard Computer Fire Code," Home Fire Project Technical Report No. 45, Harvard University and National Bureau of Standards GCR 81-344 (1981).
	Mitler, H.E., and Rockett, J.A. (1981), "How Accurate is Mathematical Fire Modeling?" Presented at US-USSR Joint Seminar on Mathematical Modeling of Fire, Tbilisi,

USSR, July 1981; National Bureau of Standards (U.S.), NBSIR 86-3459 (1986).

Mitler, H.E., "Zone Modeling of Forced Ventilation Fires," *Combustion Science and Technology* 39 (1984) p. 83.

Mitler, H.E., "The Harvard Fire Model," *Fire Safety Journal* 9 (1985) p.7.

Mitler, H.E., and Rockett, J.A., "Users' Guide to FIRST, a Comprehensive Single-Room Fire Model," National Bureau of Standards, NBSIR 87-3595, (1987).

Gross, D., and Davis, W. D., "Burning Characteristics of Combat Ship Compartments and Vertical Fire Spread," National Institute of Standards and Technology, NISTIR 88-3897, 1988.

Validation References: Mitler, H.E., and Rockett, J.A. (1981), "How Accurate is Mathematical Fire Modeling?" Presented at US-USSR Joint Seminar on Mathematical Modeling of Fire, Tbilisi, USSR, July 1981; National Bureau of Standards, NBSIR 86-3459 (1986).

Mitler, H.E., "Zone Modeling of Forced Ventilation Fires," *Combustion Science and Technology* 39 (1984) p. 83

Availability: Available from the NIST/BFRL web site http://fire.nist.gov/. The software and documentation is found under the selection Fire Modeling Software Online.

Price: Free

Necessary Hardware: Personal computer running Windows 3.1, 95, 98, or 2000. Runs in the DOS window.

Computer Language: FORTRAN 77

Size: The program requires 540 KB of memory running in an MSDOS window..

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Detailed Description:

The needed inputs are the geometry of the room, the primary fire source, and the targets, as well as thermophysical data pertaining to the walls/ceiling, and to the fuels. FIRST can access a data file giving the needed (thermophysical) properties of materials. The associated program MASBANK can produce this file.

The outputs are the temperature of the upper and lower layers, the rate of mixing between them, the mass and enthalpy flow rates at each vent and from the plume into the upper layer, the temperature of the walls and targets, the time of ignition (if it occurs) of targets, the various species concentrations, and the various radiative and convective energy fluxes among the gas volumes and relevant surfaces in the enclosure.

FIRST, an enhanced and improved version of Harvard Mark 5, is a deterministic single-room fire model; it yields the time-dependent solutions to the equations describing the mass and energy transfer processes which take place when there is a fire in a vented compartment. It is a lumped-parameter, or “zone,” model’ some of these zones are volumes, some are areas, and others are functional units (such as an unspecified place where combustion takes place). The volumes are the upper and lower gas layers, the boundaries of the compartment (i.e., the ceiling, floor, and walls), the flames, and any object which is pyrolyzing or heating up. The areas are the vent areas.

Three types of fire may be simulated: A fire growing on a horizontal surface, a pool fire, and a burner fire. The spread rate of the growing fire, normally the result of heat feedback from its own flame, is augmented by the heat feedback from the room (hot layer, hot ceiling, etc.). The pool fire has a fixed area, but the pyrolysis rate depends on the total heat feedback. The burner fire has a fixed radius, and the heat feedback is irrelevant to the fuel flow rate. However, this is a very flexible option, in that it permits the user to specify a gas flow rate that is an arbitrary (within limits) function of time. This permits one to simulate the burning of furniture items, wood cribs, etc. Note that if the open-air burning rate is used to simulate them the radiation feedback effects will be neglected. The burnout rate can be user-specified. The combustion rate is limited when oxygen starvation occurs.

Each burning item generates heat that depends on the heat of combustion and the combustion efficiency. It also produces various species, whose production rates are fractions of the pyrolysis or gas evolution rate. These species are soot (as C), CO, CO_2, H_2O, and hydrocarbons. The concentrations of these and of O_2 in the upper layer are calculated. From these concentrations, the program calculates the absorption coefficient and radiative emission/absorption of the layer as a function of time.

A fire produces a thermal plume that carries mass and energy into the upper layer. This plume is modeled in several ways, and the user can choose among these plume models; the default is an area-source (virtual point source) plume, as given by Morton, Taylor, and Turner. The model then permits the calculation of the rates of heat and mass transfer into the upper layer.

The possibility of having forced ventilation at a vent is one of the features of the model. The algorithm is simple, in the sense that the user must specify the (time-dependent) volumetric flow rate into or out of each vent, rather than that being determined by the fan setting and the fan characteristic. Since the pressure in the room must remain essentially ambient, there must be at least one free (natural) vent for the room.

A vent may be opened, at either a predetermined time or a predetermined upper layer temperature. Mixing of some of the outgoing gases with the incoming ones occurs at vent openings; this results in heating, pollution, and oxygen vitiation of the lower layer. The program calculates the mixing rate and the resulting species concentrations in, and the temperature of, the lower layer.

Radiative and convective fluxes from various sources (e.g. hot layer, hot surfaces, flames) heat objects in the room (including walls and floors). The heating of an object is calculated in a one-dimensional (slab geometric) approximation. The object can be either thermally thick or thin and is heated on the side facing the fire by flame and layer radiation and convection. On the far side, the object is heated or cooled by radiation and convection. The far side of the object may be either inside or outside the room. The object's orientation can be either vertical or horizontal. The object is assumed to ignite when its surface reaches some "ignition temperature" T_{ig}. T_{ig} is user-specified for the particular material. The flame then rapidly spreads over the entire object.

Upper layer burning has been included in the model. Unburned fuel entering the upper layer will burn provided that the temperature of the layer is above the ignition temperature of the fuel and the oxygen concentration is above a user specified mass ratio.

A photoelectric detector of user specified sensitivity may be placed anywhere in the room.