# Computer Models
# For
# Fire and Smoke

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| *Model Name*: | FIRM-QB/FIRM-VB. |
| *Version*: | 1.0 (second edition.) |
| *Classification*: | Zone Model. |
| *Very Short Description*: | A zone model to predict the environment in a single compartment with a vent in a vertical wall. |
| *Modeler(s), Organization(s)*: | Marc L. Janssens, University of North Carolina at Charlotte. |
| *User's Guide*: | "An Introduction to Mathematical Fire Modeling, Second Edition," Technomic Publishing Co., July 2000, Chapter 6. |
| *Technical References*: | "An Introduction to Mathematical Fire Modeling, Second Edition," Technomic Publishing Co., July 2000, Chapter 5. |
| *Validation References:* | "An Introduction to Mathematical Fire Modeling, Second Edition," Technomic Publishing Co., July 2000, Chapter 7. |
| *Availability*: | Available from Technomic Publishing Company, Inc., 851 New Holland Avenue, Box 3535, Lancaster, PA, 17604 (http://www.techpub.com). |
| *Price*: | $149.95. |
| *Necessary Hardware*: | Intel architecture, running DOS 6.0 or later. Visual Basic version runs under Windows 95/98. |
| *Computer Language*: | QBasic/Visual Basic 6.0. |
| *Size*: | Approximately 2MB of disk space, and 16MB of RAM required. |
| *Contact Information*: | Marc L. Janssens, (704) 687-2930, mljansse@uncc.edu |

*Detailed Description*:

The FIRM model predicts the consequences of a user-specified fire in a compartment with a single vent in a vertical wall. It is a revised (second edition) extension of the ASET model, and comes in two versions: FIRM-QB written in QBasic and FIRM-VB developed in Visual Basic 6.0. The two versions are functionally identical, i.e., the same set of input variables will give the same results regardless of the version used. Figure 1 depicts the fire problem that is modeled. The main variables that are calculated as a function of time are upper layer temperature, layer interface height, and mass flows through the vent. These variables are pertinent to the fire hazard, which is quantified by the time to reach untenable conditions inside the compartment, or by the time to reach flashover. The fire is located in the center of the compartment, at a sufficient distance from the walls so that air is entrained uniformly over the entire perimeter of the flame and fire plume.

The assumptions used in the derivation of FIRM are as follows:

**1.** Two-zone (layer) approximation is considered acceptable.

**2.** The pressure within the compartment is constant and equal to atmospheric pressure.

**3.** Heat transfer from the floor and lower wall sections to the lower gas layer is neglected, and the temperature of the lower gas layer is constant and equal to ambient air temperature.

**4.** The specific heat at constant pressure is assumed to be constant for all gases, and is equal to the specific heat of dry air at 293 K, i.e., $c_p$ = 1.004 kJ/kg·K.

**5.** Zukoski=s point source plume model is considered to yield acceptable results in the flaming, intermittent, and plume regions. Entrainment occurs between the surface of the fuel and the layer interface. Virtual source corrections are considered negligible and are not included. Stratification does not occur, i.e., all heat and mass from the plume reach the hot layer located below the ceiling.

**6.** The transport time from the fire to the hot layer is negligible, i.e., quasi-steady state conditions are assumed. The plume occupies a negligible fraction of the lower layer.

**7.** The heat release rate of the fire is specified by the user. Compartment effects are ignored, but oxygen starvation due to vent or entrainment-controlled burning are accounted for.

**8.** A user-specified fraction, $L_r$, of the heat released by the fire consists of radiation.

**9.** The energy losses from the flame and plume, and the energy losses from the compartment through the bounding surfaces are described simply as a fraction, $L_c$, of the total heat release at any given time.

**10.** Venting occurs only through a rectangular opening in one of the vertical walls of the compartment.

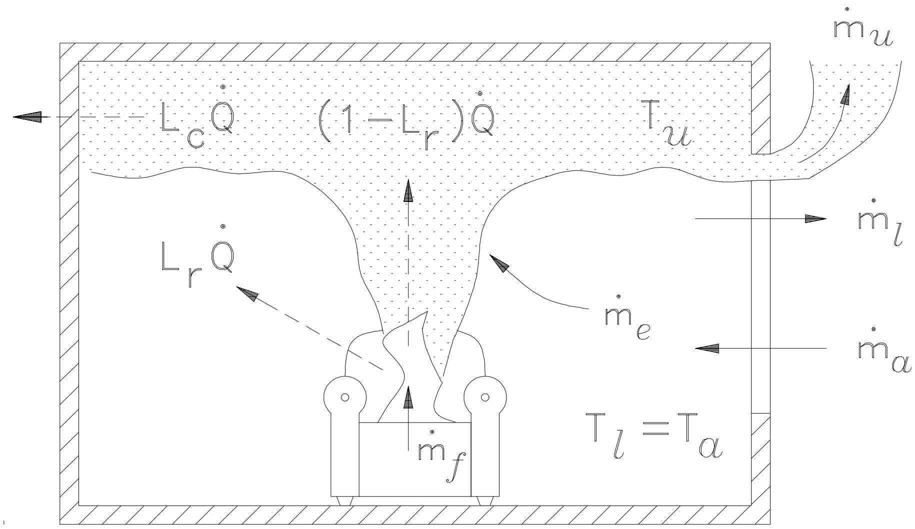


**Figure 1.** Fire problem modeled by FIRM

The main equations in FIRM express the conservation of energy in the upper layer, and the conservation of mass in the lower layer and form a set of two ordinary differential equations (ODE's). This set is solved at every time step to predict the upper layer temperature, $T_u$, and layer interface height, $Z_i$, at the next time step. A fourth-order Runge-Kutta method with stepsize control is used for this purpose. The stepsize control algorithm reduces the time step so that the estimated error of the solution vector is within certain tolerances. The maximum errors permitted are 0.3 K and 1 mm for $T_u$ and $Z_i$ respectively.

$\dot{Q}$ is supplied by the user, either interactively in the form of a series of time vs. heat release rate data pairs, or by specifying an existing fire file. HRR-QB and HRR-VB are convenient tools to create fire files that can be read by FIRM.

The heat loss fraction, $L_c$, is also specified by the user. However, FIRM uses an algorithm to estimate $L_c$ as a function of the height of the fuel, the geometry of the compartment, and the location of the vent soffit.

The entrainment rate, $\dot{m}_e$, is calculated on the basis of Zukoski=s plume model. If the air entrained into the flame and plume is insufficient to support complete combustion of the fuel volatiles, $\dot{Q}$ is adjusted to account for the lack of oxygen. This, in turn, affects the entrainment rate, because $\dot{m}_e$ is a function of $\dot{Q}$.

Vent flow are calculated on the basis of conservation of mass and hydrostatic pressure profiles inside and outside the compartment.

Documentation based on ASTM E 1472 and an evaluation of the predictive capability according to ASTM E 1355 are provided in Janssens, M., “An Introduction to Mathematical Fire Modeling,” Technomic Publishing Co., July 2000.