

Computer Models For Fire and Smoke

<i>Model Name:</i>	SmokePro
<i>Version:</i>	02
<i>Classification:</i>	Consolidated zone model
<i>Very Short Description:</i>	A zone model to predict smoke interface and smoke layer properties for deterministic time-line analysis for a single compartment.
<i>Modeler(s), Organization(s):</i>	SimCo Consulting
<i>User's Guide:</i>	Integrated in Help File
<i>Technical References:</i>	Help File
<i>Validation References:</i>	<p>The program uses established engineering relationships as given in references listed at the end of the program's Help file.</p> <p>A two-zone model is assumed and used for the purpose of analysis</p> <p>The SmokePro results have been compared for a range of 't-squared' fires and room geometries against the results obtained from the experimentally derived formula by Klote.</p> <p>Program provides two case-studies to verify the program's results by explicit calculations, following the used mathematical relationships</p>
<i>Availability:</i>	SimCo@alphalink.com.au
<i>Price:</i>	\$ 150
<i>Necessary Hardware:</i>	Intel architecture running Windows 95 or higher

Computer Language: Delphi (pascal)

Size: -----

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Detailed Description:

SmokePro is a computer program structured to assist fire safety engineers in assessing the impact of smoke under user-specified fire scenarios. The scenarios must be expressed in terms of 't-squared' fires, i.e. as slow, moderate, fast or ultra-fast fires initially, but can be capped at selected heat release rates, optionally at the time of sprinkler/detector system activation (automatically).

The SmokePro program can be used to calculate either:

1. the time necessary for the smoke interface to descend to a selected height, or alternatively
2. the smoke interface height reached at a selected time after ignition.

The effects of mechanical smoke exhaust and/or natural roof venting can be simulated and used as an estimation of the smoke exhaust requirements needed to keep the smoke interface at a given height.

The program calculates the smoke temperature, mass and volume generation rates, toxicity, optical density, visibility and radiating flux to the floor level. The information may be used for estimating the time available for evacuation and the required natural/mechanical smoke ventilation rate to maintain a given depth of a smoke layer within the room.

Fire Detection Time

The program calculates the detection time of heat detectors/sprinklers or smoke detectors in continuous growth t-squared fires, based on the Haskestad differential equations. It uses the detection time for one or all of the following:

1. Automatically caps the fire's HRR at time of activation
2. Opens the natural vents for smoke venting
3. Starts mechanical smoke exhaust

The procedure assumes the detector is located such that it is exposed to both the maximum ceiling jet velocity and temperature. Correlation for ceiling jet temperature and velocity are used as documented by referenced sources (no beam or truss ceilings, no cathedral ceilings, only smooth, horizontal unconfined ceilings).

Printed Report with Graphs

The program prints a A4 report which provides four diagrams, each representing two parameters as a function of time (HRR, interface height, flame height, visibility, smoke exhaust rate, etc). A printed table providing all smoke parameter values in 30 s intervals is also provided.

Smoke Calculations

The accumulated smoke volume is determined by summing up smoke production rates during a selected number of 1 second intervals with the smoke exhaust and roof venting rates – if applicable - deducted following the sprinkler/detector system activation. After each interval the smoke layer height, smoke gain/loss rates and temperature are adjusted to new conditions and then used in the next time interval. The smoke flow entering the smoke layer is calculated for the selected axisymmetric plume type, i.e. point, area, line, or window source.

The following important assumptions and limitations may have an influence on the results.

The routine calculates the smoke filling time with a fixed assumption that 1/3 of the energy released by fire is lost by radiation. This has an impact on the calculated temperature of the hot gas layer and on the calculated position of the bottom of that layer. Further, only half of the calculated adiabatic heat of combustion is assumed to remain in the smoke mass generated. This approach follows the NFPA 204M advise - based on the experimental evidence by Hinkley - that a fraction of 50% is a representative value of the convective heat contributing to the smoke layer's temperature – see discussion on smoke temperature calculations.

For smooth ceilings or ceilings of limited extent the entrainment is small during horizontal flow and can usually be neglected. However, when the smoke flows around obstacles (e.g. beams) or through apertures (e.g. a doorway), the rate of entrainment increases.

The routine assumes that there is some type of floor level vent sufficient to prevent any buildup of pressure due to the expansion of hot gases.

Smoke Temperature

The smoke temperature is calculated by dividing the total generated smoke mass after ignition with the total convective heat released by fire. The convective part is taken as 2/3 of the released fire power at any time. The heat transfer from the smoke layer to the surrounding walls is not considered explicitly. However the recommendation given in the NFPA 204M 97 (Clause 6-1.3.4) is followed and the smoke layer temperature is reduced by a factor of 0.5 to account for these losses. Consequently, the program may overestimate the smoke temperatures where heat transfer is a significant factor (high smoke temperatures and low thermal insulation of the ceiling) and underestimate where the smoke temperatures are low and the thermal insulation is of high value. The applied simplification may become an important limitation.

Smoke Flow

The smoke flow into the smoke layer is calculated by using the available engineering formulas for smoke flow by air entrainment for the selected plume source. The formulas are taken from Technical Memoranda TM19, NFPA 92B, and NFPA 204M.

The rate of the smoke mass supplied to the smoke layer is calculated from two complementary sets of formulas – where applicable. One set is used for flame heights smaller than the smoke clear height, and the second set of formulas otherwise.

For each 1second time interval - for which the smoke generation rate is calculated the limiting elevation (i.e. flame tip or intermittent flame height) is first calculated and compared with the smoke clear height. The appropriate set of equation is then selected.

Smoke Flow Through Roof Vents

Natural smoke vents can be used to prevent the smoke from descending below the design level of the smoke interface.

The smoke mass flow through the roof vents is calculated by the formula (recommended in TM19 and NFPA204M):

The equation calculates the smoke mass flow based on the pressure produced by the hot gas layer developed by a fire, based on the average temperature and the depth of the layer. It does not calculate the pressure produced by other pressure sources such as wind pressure or stack effect. It also assumes that the space has sufficient venting so that there is no increase in pressure other than that produced by the reduction in density due to the expansion of hot gases. However, the formula incorporates the multiplier to account for the inlet area effects.