LAVENT
Link-Activated VENTs

A Compartment Fire Model For Sprinkler Activation

Research Today

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Computer fire modeling at the National Institute of Standards and Technology (NIST) began in 1976 when the Illinois Institute of Technology Research Institute developed a fire model called RFIRES. Subsequently the Harvard Fire Model, now known as FIRST, was developed at Harvard University. Computer modeling initially required main frame computers, severely restricting the use of these models by the fire community.

As main frame computers were improved and the personal computer was developed in the 1980s, additional fire models such as ASET-B, DETACT, FAST, and CCFM were developed at NIST to take advantage of the improving computer technology. Each of these models used a zone model approach, which divided each compartment or room into a hot upper layer and a cool lower layer. The entrainment of air by the fire was simulated by a plume model, and the time development of the fire was represented by a heat release rate. ASET-B and DETACT were single room models while the latter two models could handle multiple rooms. DETACT was the only one of these models that treated the heating of fusible links by a ceiling jet.

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LAVENT, Link Actuated VENTs, was conceived by L.Y. Cooper and supported by the AMAA Research Foundation in the middle 1980s to investigate the interaction of the ceiling jet with fusible links in a realistic fire scenario with ceiling vents and draft curtains. The major improvement that LAVENT introduced to zone fire modeling was to model the ceiling jet more accurately than was done in DETACT such that the distance below the ceiling as well as the radial distance from the center of the fire plume affected the activation of the fusible links. Also included in the computation was the effect of the hot upper layer on the ceiling jet. The thickness of the hot upper layer could be controlled by ceiling vents and draft curtains; the presence of the layer played a role in the rate of activation of the fusible links.

Using Cooper's theory, I wrote LAVENT using improved differential equations for the layer calculation. The model operates on an IBM PC or compatible, and an effort was made to make the model user friendly. LAVENT is designed to operate using either SI or English units—an extremely useful feature. Several publications about LAVENT, including a users' guide, are available from NIST.

A major challenge confronting a fire protection engineer with a new piece of software is learning how and when to use the model to simulate a fire problem. While many users have commented on how easy LAVENT is to use, there have been a number of questions about how to use LAVENT in particular situations. In the next few paragraphs, I will try to lead the reader through LAVENT's use, explaining problems that users have experienced.

The first question confronted by fire protection engineers is which tool(s) to use to analyze a fire problem. Problems in which LAVENT may be of use include: fusible link activation times in response to fire, smoke control by ceiling vents and draft curtains, the design and placement of heat sensitive elements to detect a fire, and the heating of a ceiling by the fire. This list may not include all of the applications for LAVENT, but it is certainly a good start.

Once LAVENT has been chosen, the fire protection engineer must first build the initial data file to represent the fire problem. LAVENT has a default data file, and probably the best choice a new user can make is to modify the default data file in order to build his own simulation.

In setting up an input file, room or enclosure geometry is the first data to input. LAVENT allows the fire room to be bounded by walls, walls and draft curtains, or draft curtains alone. While walls are fairly easy to understand, there is confusion about how to model draft curtains. Draft curtains hang from the ceiling and confine smoke in areas within a room. In LAVENT, the user must specify the length and width of the room and also the length of the draft curtain.

The length and width of the room may be misleading. Consider a large enclosure which has a length of 120 m and a width of 40 m. Three draft curtains span the width of the enclosures every 30 m dividing the space up into four separate enclosures each with a dimension of 30 m by 40 m. LAVENT would be used to model one of the four enclosures which would have a length of 30 m, a width of 40 m, and the draft curtain would have a length of 80 m (flow under two draft curtains) if the calculation is for one of the middle enclosures; the curtain length would be 40 m (flow under one draft curtain) if the enclosure borders one of the end walls. Notice that the length and width of the building are not used, only the length and width of the confined space over the fire. What happens to the smoke that pours under the draft curtain? LAVENT is not designed to be a multiple room model and so does not compute destination of the smoke lost under the draft curtain.

The other program input concerning the draft curtain is the height to the bottom of the curtain, i.e., the distance between the bottom of the curtain and the floor. Note that LAVENT assumes that the curtain is solid all the way to the ceiling, so that any space left between the top of the curtain and the ceiling in the actual space will affect the ability of LAVENT to simulate the smoke layer.

When there are no draft curtains but there is an open doorway, the draft curtain option can be used to simulate an open door. Set the height of the draft curtain equal to the height of the door soffit. The door width then is equal to the length of the draft curtain. The rest of the room would be enclosed using the length and the width of the room.

A window cannot be modeled using LAVENT since there is no provision made to close an opening at the floor. The final input for the room is the number of ceiling vents. A zone model approximation is used here in that the location of the ceiling vents with respect to the fire is not considered; the only effect the ceiling vents have is to remove smoke and enthalpy from the upper layer. There is no effect on the ceiling jet other than reducing the thickness of the upper layer by the ceiling vents. LAVENT does not include the physics necessary to calculate the disturbance of the ceiling jet due to the presence upstream of a ceiling vent.

Also included in the computation was the effect of the hot upper layer on the ceiling jet. The thickness of the hot upper layer could be controlled by ceiling vents and draft curtains; the presence of the layer played a role in the rate of activation of the fusible links.

The second set of input options presented to the user is the Physical Properties menu which allows the user to set the material properties for the ceiling. A zone model approximation is used in LAVENT which converts the user-prescribed rectangular room geometry to an equivalent cylindrical geometry with the fire located at the axis of the cylinder. The effective ceiling area includes not only the rectangular ceiling area, but the wall area and the area of the draft curtain as well. Thus, when the material properties are selected, it is assumed that the same material makes up the ceiling, walls and draft curtains.

Skipping over the straight-forward Output Parameter menu, and going to the Fusible Link Properties menu, a couple of comments are needed to clarify the model used to simulate the heating of fusible links. First, for a fusible link to heat, the link must be located in the ceiling jet such that the ceiling jet velocity is not zero. The model used for the ceiling jet velocity predicts a ceiling jet velocity which approaches zero at the ceiling and also a ceiling jet velocity which approaches zero far below the ceiling. This means that fusible links mounted flush with the ceiling and imbedded in the ceiling will not heat up.

Since the ceiling heats up, why don't the links heat up? The model calculating the fusible link heating requires a non zero ceiling jet velocity for link heating; the ceiling is heated by radiation and convection, neither of which depends on the local value of the ceiling jet velocity at the ceiling. The user should be cautious of using LAVENT to calculate fusible link heating when the links are closer than approximately 1 cm from the ceiling since (based on a single validation experiment) the link heating may be underestimated. Far from the ceiling LAVENT also seems to underestimate the fusible link heating, but this distance is quite large at 33 cm based on one validation experiment. Between these distances, LAVENT appears to do an excellent job in predicting fusible link response although more validation is needed to cover a variety of ceiling heights and fire sizes. This is particularly true for small fires where heat conduction from the fusible link to the ceiling (which LAVENT ignores) may slow the response of the link to the ceiling jet.

The only selection of the Fire Properties menu that has given users any problem is the Fire Power/Area selection. The plume model used in LAVENT requires two inputs — the fire's heat release rate and the fire's diameter — to determine entrainment. Two types of fires may be selected. The first fire has a constant diameter independent of the heat release rate and should therefore be used for burners and other geometrically confined fires. The diameter of the second fire is obtained by LAVENT from the user-specified material being burned and the fire's prescribed heat release rate. The fire's diameter will increase as the square root of the heat release rate and is an attempt to approximate the change of entrainment that a growing fire should experience.

One final note on fire properties . . . if too large a fire is chosen for a given ceiling height, the flame height could exceed the ceiling height. LAVENT will not warn the user if this occurs. LAVENT does not model flames running along the ceiling, so the user should not use LAVENT in these situations.

Further development of LAVENT will include a sprinkler algorithm which calculates the effects of sprinkler spray on the upper layer. LAVENT should prove to be a useful tool of the fire protection engineer in the 1990s.

The final menu selection to be discussed is the Solver Parameters selection. I made this menu available in case LAVENT was having trouble solving a particular problem and have extended the selections available in this menu since the Users' Guide was published. Generally the user does not need this menu since LAVENT rarely fails to complete a calculation. In the few cases that this has happened, the requirements placed on the fire room would never have occurred in the real world or were well outside of the limits of validity for the physical algorithms contained in LAVENT.

While the user will probably never change most of the menu selections, two selections are of interest. The first selection is the number of annuli or grid points that represent the ceiling in the radial direction along the ceiling. LAVENT will permit the ceiling to be represented by 2-50 grid points. The more grid points, the more detail available to the user on ceiling heating and the more accurate the calculation of link activation. Unfortunately, the more ceiling grid points, the slower LAVENT will run. Hence, the user may wish to adjust the number of grid points to a minimum number to speed up the calculation. I would recommend choosing at least six grid points and run LAVENT a second time with twice the grid points to estimate for the lack of accuracy introduced when using just a few grid points. One user has suggested that 25 grid points were necessary to accurately represent the ceiling for his application. This number of grid points may not always be required, but the user needs to be aware that reducing the number of grid points will affect the calculation accuracy.

The second input that a user may need to change is the Flux Update Interval. This variable is responsible for preventing the differential equation solver (which solves the layer and fusible link equations) from choosing time steps which are too large for the Gauss-Seidel solver (which handles the ceiling heat conduction and reradiation equations). If the time interval specified is too large, a growing oscillation can occur in the Gauss-Seidel solver which will prevent LAVENT from completing the calculation. This has happened once when a user put the default 33 megawatt fire in a small enclosure. LAVENT will print out a warning about the temperature going negative and stop. The user can recover by restarting the calculation and reducing the Flux Update Interval.

Most users of LAVENT have commented that the program is easy to use. Users with an early release of LAVENT (1.0) should get version 1.1 from the Fire Research Bulletin Board at NIST (modem telephone 301-921-6302). The new version incorporates improvements to the user interface, and the new program runs roughly three times faster than the older version.

LAVENT in its present form can only treat well-ventilated single room geometries. Even with this limitation, it provides the fire protection engineer with substantial improvements in calculating fusible link activation and smoke control in single room geometries over earlier models. Further development of LAVENT will include a sprinkler algorithm which calculates the effects of sprinkler spray on the upper layer. LAVENT should prove to be a useful tool of the fire protection engineer in the 1990s.