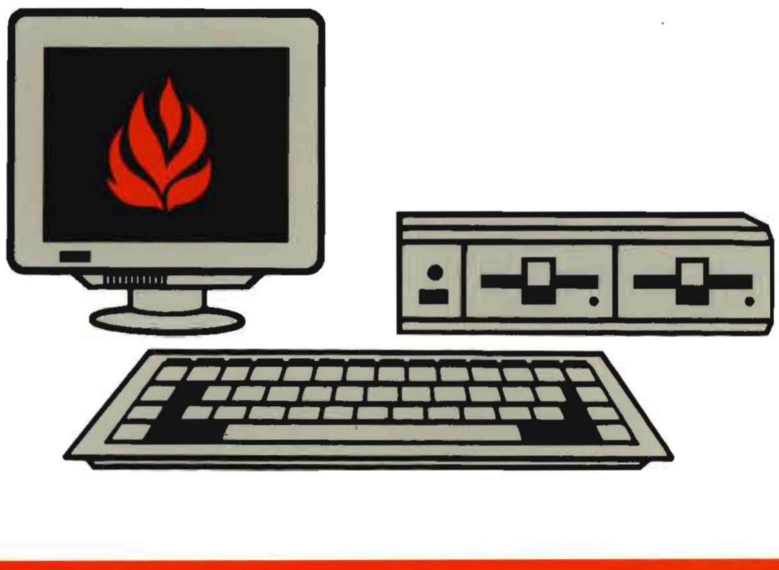
Central Fire Brigades Advisory Council
Scottish Central Fire Brigades Advisory Council
Joint Committee on Fire Research

Evaluation of Fire Models Summary Report



by B T HUME

Research Report Number 52

1992

Central Fire Brigades Advisory Council
Scottish Central Fire Brigades Advisory Council
Joint Committee on Fire Research

Evaluation of Fire Models Summary Report

By
B T HUME

Research Report Number 52

1992

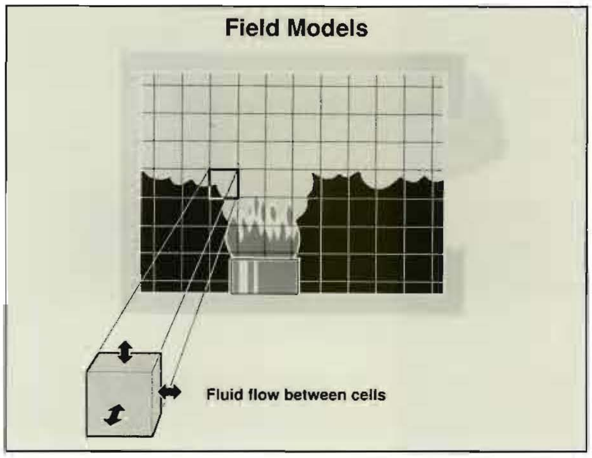
ISBN 0-86252-744-9

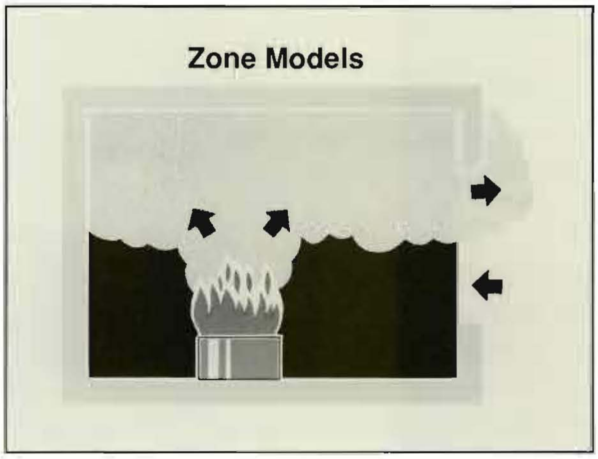
Evaluation of Fire Models Summary Report

Recent trends towards more complex buildings, with a greater variety of building materials and larger compartment sizes, have meant that we cannot always use past experience in the prediction of the likelihood and severity of fires.

To attempt to cope with the problem of predicting fire in modern buildings fire scientists in a number of countries have been developing computer models which attempt to show how fires and combustion products will behave and spread in a given situation and ultimately in a complex building.

Such models are already being used by building designers to demonstrate the level of fire safety and their use is likely to become more widespread. So that fire brigades can be advised of the reliability and accuracy of these models, the Fire Research and Development Group of the Home Office Fire and Emergency Planning Department have carried out an evaluation of some representative fire models.





THE MODELS SELECTED

Two types of model were considered, zone and field. The **zone** model is simpler than the **field** model; it divides the fire compartment up into a few large zones such as the plume and the hot smoky gas layer under the ceiling and relies on well established but empirical relationships for the transfer of heat and smoke between these zones. A field model divides the compartment into a large number of cells, and calculates heat and fluid flow between the cells using the fundamental equations of physics. For this reason, field models are likely to be more accurate but require more computing power and so are more expensive.

After a preliminary study, four fire models were selected for evaluation as well as a package of fire engineering calculations. These are listed in Table 1.

Since these models are still being developed and considerable further development may be expected, the results of the evaluations only apply to the versions of the models that were evaluated.

THE EVALUATION PROGRAMME

A contract was let to Edinburgh University to carry out the evaluations between November 1988 and June 1990. The evaluation of each model was split into two phases: qualitative and quantitative and a separate technical report was written on each. The **qualitative** phase considered:

TABLE 1 FIRE SOFTWARE EVALUATED			
Name	**Model Type**	**Originator(*)**	**Version No.**
ASET	Simple Zone model	NIST, USA	None given
HAZARD-I	Package containing zone model 'FAST'	NIST, USA	Evaluation copy (includes FAST version 17)
FIRST	Complex Zone model	NIST, USA	None given
JASMINE	Field model	FRS, UK	Version 1.2
ASKFRS	Package of fire engineering calculations	FRS, UK	1st Issue, 1988

* **Note:** NIST is the National Institute of Standards and Technology (formerly the National Bureau of Standards), Gaithersburg, USA. FRS is the UK Fire Research Station.

- the intended scope of fire situations which can be modelled
- the main assumptions and limitations of the model
- the input data required by the model
- the output data generated by the model
- the computer equipment required to run the model
- the extent of any studies already carried out to compare model predictions with experiment.

The **quantitative** phase considered the accuracy of the predictions made by each model for three different fire scenarios when compared with experimental test data. The fire scenarios were:

- **Single Room Fire** - polyurethane foam slab fire in domestic-sized room
- **House Fire** - armchair fire in lounge / dining-room of 2-storey house
- **Department Store Fire** - displayed furniture fire in centre of large sales area

Each model was run to predict the air temperature, smoke obscuration and carbon monoxide concentration as the fire progressed, and an assessment made of the time at which the conditions in the compartment became hazardous to life.

RESULTS OF THE QUALITATIVE PHASE

The key processes which make up a fire, approximately in the order in which they occur, are the following:

(i) Ignition

(ii) Fire growth (flame spread, secondary ignition, flashover)

(iii) Ventilation at doors and windows

(iv) Movement of heat, smoke and gases around the fire room

(v) Movement of heat, smoke and gases into other rooms

(vi) Fire detection

(vii) Evacuation of occupants

While all of these need to be predicted to enable an overall assessment of the fire safety of a building to be made, it was found that the models considered dealt mainly with stages (iii), (iv) and (v). With the exception of FIRST which can calculate the fire growth for certain simple fire types, the **fire growth** had to be calculated by the user and fed in to the computer as input data. In any event, the user must decide on the quantity, type and arrangement of combustible materials and this decision is critical to the result obtained from the model.

The user must also provide room dimensions and the location of the fire and in some cases factors used within the model's calculations which can have a critical effect on the result. In return the model will generate predictions of temperature, smoke density and gas concentrations.

The zone models studied will all run on personal computers while JASMINE requires a workstation or a larger computer.

Studies comparing model predictions with experiment have been reported on all of the models studied. However, these tend to demonstrate the accuracy of the model only in a very limited set of circumstances.

RESULTS OF THE QUANTITATIVE PHASE

In this phase of the work, the accuracy of each model was assessed by comparing the predictions with data from fire tests. Several difficulties were encountered:

(i) It was not possible to obtain perfectly repeatable fire test data so that the accuracy assessment depended on which fire test, in a supposedly identical series of tests, the model was compared with.

(ii) There are limits to the accuracy of the instrumentation used in the fire tests, and to the number of monitoring points. Smoke and gas measurements were particularly limited.

(iii) It was not always clear what numbers should be fed in to the model. The value that is used can have a critical effect on the result.

Temperature Prediction.

In a **zone** model the upper layer is assumed to be at the same temperature throughout whereas in reality the temperature near the ceiling is likely to be much greater than lower down. Therefore, all zone models will inevitably give large inaccuracies in predicting the air/gas temperature at any specific point.

None of the three zone models (ASET, FIRST and FAST) predicted consistently higher or lower temperatures than the others.

A **field** model divides the compartment up into a large number of cells and predicts a different temperature for each position, so that the results can be compared directly with the results of fire tests. As with the zone models, it was found that the field model JASMINE did not consistently over-predict or under-predict the experimental results.

In the test data used, the time from ignition until the maximum temperature is reached in some cases varied greatly between tests because of unaccountable variations in the growth of the fire. In these cases it was impossible to say how accurate the models were in predicting the time to maximum temperature.

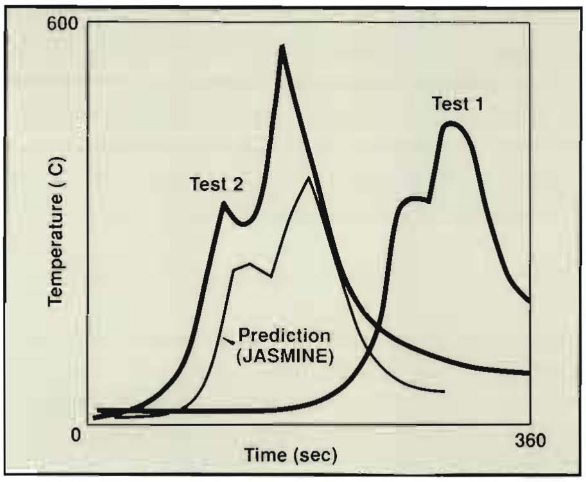


Figure 1 Comparison of test results with prediction by JASMINE

An example of temperature prediction is shown in figure 1 where the temperature prediction 75mm below the ceiling made by JASMINE for the House Fire test is compared with the measurements from two separate tests. The differences between the model and the test do not imply large inaccuracies in JASMINE, but are largely due to the inconsistency of the test and to the fire growth rate which was fed in to the model. This shows that the context in which a model is used is as important as the model itself.

Smoke Prediction.

The prediction of smoke obscuration should be treated with great caution and is probably of value only in qualitative terms. This is due to a lack of knowledge on smoke production and how it is affected by the fire conditions, and also to the difficulty in predicting the scattering and absorption of light by the smoke.

For the zone models tested, the user effectively decides how much smoke is produced and feeds this into the model. The result will rely heavily on whatever numbers are put in. Zone models also assume that the smoke layer is uniform whereas it will vary from place to place.

JASMINE, being a field model, can predict the smoke obscuration at different points in the room which can be compared directly with test results. The predicted smoke obscuration was found to be appreciably less than measured values but the Fire Research Station intend to improve the smoke obscuration predictions in future versions of JASMINE.

Carbon Monoxide Prediction

Prediction of carbon monoxide concentrations may be regarded as even more uncertain than smoke obscuration at the present time. As with smoke production, there is great uncertainty in estimating carbon monoxide production and how it is affected by the fire conditions, such as the ventilation of the fuel. For instance estimates for polyurethane have been found to vary by more than a factor of 80.

Prediction of Conditions in Secondary Rooms

The assumption made by zone models of a distinct upper smoke layer is even less likely to be valid in a secondary room than in the fire room because the smoke will tend to mix as it passes to another room, especially to a room on a different floor.

In the House Fire Test, the temperature predictions made by the field model JASMINE for secondary rooms were quite close.

Overall, predicting conditions in secondary rooms must be regarded as very problematic at the present time.

Prediction of Time Available for Escape

The time available for escape is usually based on the time to reach a defined level of smoke obscuration or toxic gas concentration. As the prediction of both of these is very uncertain, so too is the prediction of the time available for escape.

CONCLUSIONS AND RECOMMENDATIONS

It cannot be concluded that any model is simply good or bad, accurate or not, as its performance would depend on how the model was used and for what purpose.

The models considered have tended to concentrate on predicting movement of heat and smoke around the building and mainly within the fire room. They rely heavily on the user to supply information such as the fire growth rate, which can have a critical effect on the result. It is important, therefore, that adequate sources of data to define the fire should be available both to the modeller and to the assessor of a modelling study.

Furthermore, the results from the model may be very sensitive to small changes in the input data. It is therefore desirable that, when applying the model to a particular case, a series of runs of the model should be performed to show the sensitivity of the results to changes in the input data.

Other aspects of a fire, including human behaviour, evacuation and detection, need to be predicted if an overall assessment of fire safety is to be made.

It is important therefore, that where modelling studies are presented to brigades in support of building proposals they should be interpreted critically, bearing in mind the limitations of the model. Ideally an independent expert opinion should be obtained.

As a general rule, the results from fire models should not be taken to be quantitatively accurate, and quantitative results should be considered with great caution, and used in a supportive role with other knowledge and experience.

Field models have a better chance of being accurate than zone models since they can predict the variation in temperatures, smoke obscuration and gas concentrations around the room.

As fire models are developed and new versions are produced, there is a need for their continual assessment by independent parties. For this purpose, more data on repeatable fire tests in a variety of scenarios is needed.

A standard of practice for the authors of fire models would be desirable, to cover both the computer code itself and the associated documentation for the user. For instance, the computer code should be open to public scrutiny so that it is possible to see exactly what calculations are being made. Adequate warnings should be included in the documentation to make clear the limitations of the model.

FURTHER INFORMATION

The following reports provide more detail of the work carried out in this project:

A Beard,
"Evaluation of Fire Models: Report 1 -11",
Unit of Fire Safety Engineering,
University of Edinburgh,
October 1990.

Report 1 - ASET: Qualitative Assessment
Report 2 - ASKFRS: Qualitative Assessment
Report 3 - HAZARD-I: Qualitative Assessment
Report 4 - FIRST: Qualitative Assessment
Report 5 - JASMINE: Qualitative Assessment
Report 6 - ASET: Quantitative Assessment
(No report 7)
Report 8 - HAZARD-I: Quantitative Assessment
Report 9 - FIRST: Quantitative Assessment
Report 10 - JASMINE: Quantitative Assessment
Report 11 - Overview

B Hume, "A Review of Existing Fire Models", SRDB Publication 3/89, 1989.

For further information please contact:

Dr B T Hume
Fire Research and Development Group
Home Office
Horseferry House
Dean Ryle Street
LONDON
SW1P 2AW

Tel: 071-217-8008

Designed by Home Office Design and Illustration Branch

ISBN 0-86252-744-9