CI/SfB

Date: May 1998

BRANZ

THE RESOURCE CENTRE FOR BUILDING EXCELLENCE

REPRINT

No 149 (1998)

REFERENCE

A Room-Corner Fire Model including Fire Growth on Linings and Enclosure Smoke-Filling

Colleen Wade, Jonathan Barnett

From: Journal of Fire Protection Engineering,
Vol.8, No.4, 1997

Funding for the work presented here was provided by the Building Research Levy and the Foundation for Research, Science and Technology.

ISSN: 0111 7459

J. of Fire Prot. Engr., **8** *(4), 1997, pp 183-193*

A ROOM-CORNER FIRE MODEL INCLUDING FIRE GROWTH ON LININGS AND ENCLOSURE SMOKE-FILLING

COLLEEN WADE
Building Research Association of New Zealand
Private Bag 50908 Porirua, New Zealand

JONATHAN BARNETT
Center for Firesafety Studies
Worcester Polytechnic Institute Worcester, MA USA

SUMMARY

This paper describes the development of a computer fire model *BRANZFIRE* intended for evaluating the performance and hazards associated with combustible room lining materials. It comprises a single-room zone model fully integrated or coupled with a concurrent flow flame spread and fire growth model applicable to a room-corner fire scenario. The fire growth model uses fire property data obtained from a cone calorimeter as input.

The computer model is compared with some available experimental data, with reasonable agreement. It is concluded that the model has the potential to differentiate the fire hazards associated with different combustible walls and ceilings in enclosures using a sound scientific approach.

INTRODUCTION

The purpose of this paper is to describe a model for predicting the fire environment *in* an enclosure resulting from a room-corner fire involving combustible wall and ceiling linings. The model combines a fire growth model for a room-corner fire scenario with a conventional zone model based on mass and energy conservation for a room. A complete description of the model physics is described by Wade.[1]

Most existing fire zone models[2,3,4] generally do not account for the ignition and burning of wall and/or ceiling lining materials and thus may underestimate the actual rate of fire development and hazard in cases where combustible room linings are present. Furthermore, unlike many computer models that have been developed, emphasis has been placed here on developing a user-friendly interface for this model, based on the Microsoft Windows environment, thus making it more accessible to fire designers and fire protection engineers, as well as other researchers.

The model described here couples a flame spread and fire growth model with a zone model. The advantage of this is that the effect of the developing hot layer on the lining flame spread rate can be considered. As a hot layer develops, the room surfaces are heated and therefore the energy required to raise the temperature of the wall and ceiling lining materials to ignition is lower. This means the lining is more easily ignited and the flame will spread more readily across the surface, resulting in a higher heat release rate. Ventilation to the room will also have an influence as the total heat release rate allowable in the room will be restricted by the available oxygen supply. The interaction between the fire growth and zone models is illustrated in Figure 1.

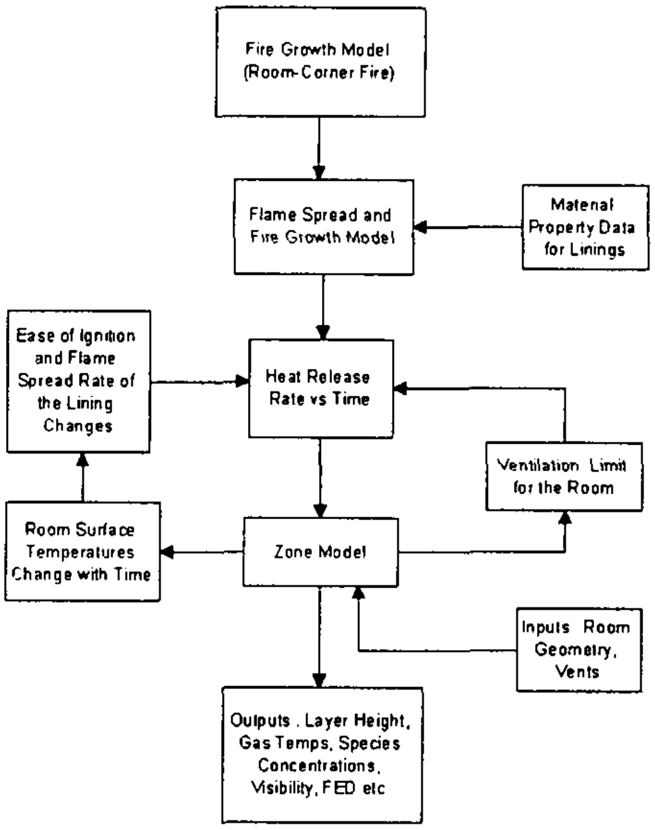

Figure 1. Structure of BRANZFIRE Model.

THE FIRE GROWTH MODEL

The fire growth model described here is taken from the work of Karlsson.[5,6,7] This model considers concurrent flow flame spread for a combustible lining material present in both the walls and ceiling. The actual time-dependent heat release rate measured in the cone calorimeter is used in a numerical solution of the velocity spread rate. Lateral or downward spread is not accounted for since the total heat release rate is dominated by concurrent flow flame spread in this configuration.

There are four sub-models to calculate different parameters which need to be determined to enable the total heat release curve to be determined. They are:

1. Ignition of the wall lining
2. Temperature of the hot gas layer and room surfaces
3. Ignition of the ceiling lining and subsequent flame spread
4. Calculation of the total heat release rate.

The only required input to the fire growth model is the heat release rate per unit area curve from the cone calorimeter (Karlsson used data at an irradiance of 50 kW/m²), thermal inertia $k\rho c$ and surface ignition temperature T_{ig} for the lining material also derived from cone calorimeter[8] or Lift[9] tests. The relevance of each of the sub-models is discussed here.

Ignition of the Wall Lining

The time to ignition of the wall lining is derived from the general equation for transient heat conduction for a semi-infinite solid exposed to a constant net surface heat flux[10] and is given as follows:

$$\tau_w = \frac{\pi k \rho c \left(T_{ig} - T_o\right)^2}{4\dot{q}_w''^2} \qquad (1)$$

$\dot{q}_w''$ is the net heat flux from the burner flame. Karlsson used 45 kW/m² for the ISO 9705 test.[5] T_o is the initial temperature of the wall.

Temperature of the Hot Gas Layer and Room Surfaces

In Karlsson's Model A, correlations by McCaffrey, Quintiere and Harkleroad[11] were used to determine the gas temperature in a compartment fire. However, this will not be necessary here since this fire growth model will be coupled to a zone model based on energy and mass conservation for the compartment fire. The zone model calculates the time-dependent upper layer gas temperature. The surface temperatures of the wall and ceiling are also obtained from the zone model, which considers the heat transfer processes between the hot upper gas layer and the surfaces in the compartment.

Ignition of the Ceiling Lining and Subsequent Flame Spread

Similar to the ignition of the wall lining, time to ignition of the ceiling lining is given by:

$$\tau_c = \frac{\pi k \rho c \left(T_{ig} - T_s\right)^2}{4\dot{q}_f''^{\,2}} \tag{2}$$

$\dot{q}_f''$ is the net heat flux from the flame. Karlsson used 35 kW/m² for the ISO 9705 test.[5] T_s is the surface temperature of the wall as obtained from the zone model solution and takes into account pre-heating of the ceiling lining.

The velocity of the pyrolysis front (expressed in area terms) is given by Karlsson[5] as:

$$V_a(t) = \frac{1}{\tau}\left[A_o + K\left(A_o\dot{Q}_c''(t) + \int_0^t \dot{Q}_c''(t - t_p)V_a(t_p)dt_p\right) - \left(A_o + \int_0^t V_a(t_p)dt_p\right)\right] \tag{3}$$

The flame area constant K may be taken as 0.01 m²/kW.[5]

Calculation of the Total Heat Release Rate

Prior to ignition of the wall lining by the gas burner, the total heat release is $\dot{Q}_b$ After the wall ignites, but before the ceiling ignites (*i.e.*, $t_w < t < t$), the total heat release is given by:

$$\dot{Q}_{\mathrm{tot}}(t) = \dot{Q}_b + A_w\dot{Q}_c''(t - \tau_w) \tag{4}$$

where $\dot{Q}_c''(t)$ represents the heat release rate per unit area measured in a cone calorimeter test at an irradiance of 50 kW/m². Following ignition of the ceiling lining ($t > t_w + t$), the total heat release rate is given by:

$$\dot{Q}_{\mathrm{tot}}(t) = \dot{Q}_b + A_w\dot{Q}_c''(t - \tau_w) + A_o\dot{Q}_c''(t - (\tau_w + \tau)) + \int_0^{t-(\tau_w+\tau)} \dot{Q}_c''(t - (\tau_w + \tau) - t_p)V_a(t_p)dt_p \tag{5}$$

where $V_a(t_p)$ is the spread rate in area terms and is calculated numerically from Equation 3. The initial pyrolysis area in the ceiling is given by:

$$A_o = K\left[\dot{Q}_b + A_w\dot{Q}_c''(t - \tau_w) - 150\right] \tag{6}$$

The wall area behind the burner is represented by A_w and is taken as 0.65 m² in the room corner test. The heat output from the burner, $\dot{Q}_b$, is specified as 100 kW for the first 300 seconds.

In addition to the description of this model by Karlsson, an upper limit has been placed on the total heat release rate from the ceiling material due to the finite size of the ceiling. This maximum heat release rate is given by multiplying the ceiling area by the peak rate of heat release per unit area for the ceiling material (measured in the cone calorimeter).

THE FIRE ZONE MODEL

Conservation Terms

The zone model solves for the upper and lower layer temperatures, position of the layer interface and species concentrations. The pressure equation is not solved. The ordinary differential equations for the position of the smoke layer interface above the base of the fire, Z, and for the upper layer temperature, T_u, based on conservation of mass and energy for the upper layer are given by:

$$\frac{dZ}{dt}=\frac{-(1-\lambda_\tau)\sum \dot{Q}_f-\sum \dot{m}_p c_p T_l+\sum \dot{m}_o c_p T_u-\dot{q}_u}{\rho_\infty T_\infty c_p A_f} \tag{7}$$

$$\frac{dT_u}{dt}=\frac{T_u(c_p(T_u-T_l)\sum \dot{m}_p-(1-\lambda_\tau)\sum \dot{Q}_f-\dot{q}_u)}{\rho_\infty T_\infty c_p A_f(H-Z)} \tag{8}$$

The ordinary differential equation for the lower layer temperature, T_l, based on conservation of mass and energy applied to the lower layer is given by:

$$\frac{dT_l}{dt}=\frac{T_l}{Z}\left[\frac{c_p(T_\infty-T_l)\sum \dot{m}_o+\dot{q}_l}{\rho_\infty T_\infty c_p A_f}\right] \tag{9}$$

The ordinary differential equation for the upper layer species, $Y_{i,u}$ (O_2, soot, CO_2, CO and H_2O) concentration, based on conservation of energy applied to the upper layer is given by:

$$\Rightarrow \frac{dY_{i,u}}{dt}=\frac{T_u\left[\Sigma(\psi_i-Y_{i,u})\dot{m}_f+(Y_{i,l}-Y_{i,u})\Sigma \dot{m}_p\right]}{\rho_\infty T_\infty A_f(H-Z)} \tag{10}$$

These equations are solved using a fourth order Runge-Kutta technique. The routine comprises an adaptive driver which estimates the error and adapts the step size to achieve the specified accuracy.

Plume Entrainment

The mass flux entrained into the plume for the continuous flaming, intermittent, and buoyant plume regions respectively is given by McCaffrey,[13] with modifications for the room-corner environment as suggested by Mowrer and Williamson.[14]

For the corner fire, entrainment rate is taken as 0.59 ¥ the entrainment rate for the same fire in the center of the room.[14] The entrainment model used here is a simplification of the actual situation. This model assumes that the total heat release, including the burner/source, wall lining, and ceiling lining, can be represented by a single fire located at the position and height of the burner. In reality only the burner and part of the wall lining entrains air from the lower layer to the upper layer. The rest of the wall and the ceiling lining are already in contact with the upper gas layer, so they will entrain air and oxygen from the upper (not the lower) layer. Therefore, for the purpose of determining the mass flux entrained into the corner-plume, only the heat released by the burner/source is used in the entrainment correlation. This part of the model could be improved in the future.

Vent Flows

The mass flow of air and hot gases through a wall vent is driven by buoyancy. Bernoulli's equation can be used to calculate the flows. For two-way flow, the expressions given by Rockett[15] are used. The model permits multiple vents to be specified, and determines the total vent flow by adding the two-way vent flow for each. Therefore, the calculation is acceptable where the vents are approximately at the same elevation in the walls, but will not correctly model the case where there is predominantly in-flow through one vent and out-flow through another.

The mass flow of hot gases flowing out of, and cooler gases flowing in through, a rectangular vent is given by the following equations.[15]

$$\dot{m}_o = \frac{2}{3} C_d W_o \frac{\rho_\infty T_\infty}{T_{\text{ext}}} \left[2g \frac{T_{\text{ext}}}{T_u} \left(1 - \frac{T_{\text{ext}}}{T_u}\right) \right]^{1/2} (H_o - Z_N)^{3/2} \tag{11}$$

$$\dot{m}_i = \frac{2}{3} C_d W_o \frac{\rho_\infty T_\infty}{T_{\text{ext}}} \left[2g \left(1 - \frac{T_{\text{ext}}}{T_u}\right) \right]^{1/2} (Z_N - Z)^{1/2} (Z_N + Z/2) \tag{12}$$

A mass balance for the compartment gives $\dot{m}_o = \dot{m}_i + \dot{m}_f$. If we assume that $\dot{m}_f << \dot{m}_i$, then the position of the neutral plane can be found by equating Equations 11 and 12. This is done by a process of iteration at each timestep after assuming an initial value for the location of the neutral pressure plane. A discharge coefficient of 0.68 is assumed as recommended by Prahl and Emmons.[16]

Heat Transfer

The model incorporates a four-wall radiation exchange algorithm following the method described by Forney.[17] This algorithm allows the ceiling, upper wall, lower wall, and floor to transfer radiation independently among each other. Radiant heating of these surfaces by the flames is also considered by treating the fire as a point source. The emission of radiation by soot particles in the upper layer and absorption by carbon dioxide and water vapor is also considered for both layers. The radiation exchange submodel is required to determine the net radiant heat flux emitted or absorbed by each room surface (*i.e.*, upper and lower walls, ceiling and floor). These radiant fluxes are combined with the convective heat flux and used as the boundary condition for the heat conduction calculations, while the gas layer absorption due to carbon dioxide and water vapor and emission due to soot particles are required for the energy source terms in the ordinary differential equations of the zone model. An implicit one-dimensional, 20-node finite-difference scheme was used to calculate heat conduction through the ceiling, upper walls, lower walls, and floor. This allows the temperature at any node to be calculated, by solving a set of simultaneous equations for the unknown nodal temperatures at each time step.[18] The detailed calculations for all the heat transfer processes are not given here, but can be found in Reference 1.

COMPARISON WITH EXPERIMENT

Description of Experiment

A full-scale room-corner fire test was carried out in an experimental house facility in order to gather experimental data for comparison with the predicted results obtained from *BRANZFIRE*. The test was carried out in a single room measuring 3.16 m long by 2.73 m wide by 2.37 m high, and including a vent opening in one wall which was 1.0 m high by 0.405 m wide. The sill was located 0.825 m above the floor. The room was lined with 25 mm of paper-faced gypsum plasterboard on the walls and ceiling, and the floor consisted of 20 mm thick flooring grade particleboard.

The ceiling was further lined with 3 mm thick medium density fiberboard spaced off the existing ceiling with timber battens. Two strips of medium density fiberboard, 600 mm wide, were also fixed to the walls each side of one of the corners in the room. An ignition source comprising a square pan (250 mm x 250 mm) of industrial grade hexane (Pegasol 1516) was placed in the room corner, and this was intended to provide an approximate heat output of 85 kW. The effective heat of combustion for this particular fuel was determined in a cone calorimeter to be 42.9 MJ/kg.

The room was instrumented with two thermocouple trees, which spanned floor to ceiling, and measured the gas temperatures in the room at discrete locations and heights above the floor. Each tree included eight thermocouples. A weigh-bridge based on a cantilevered beam was used to record the mass loss rate of fuel from the pan during the experiment. The deflection of the beam was measured by strain gauges and calibration done using known weights placed in the suspended tray. The mass loss data recorded during the experiment was used, together with the effective heat of combustion of the fuel (previously determined), to prescribe the time-dependent rate of heat release of the ignition source (*i.e.*, burner) used as input to the computer simulations.

Results and Computer Simulations

The gas temperature measurements from the thermocouple trees were used to calculate the height of the layer interface, average upper layer, and average lower layer gas temperatures, using the method developed by Cooper *et al.*[19]

The model *BRANZFIRE* was used to simulate the room-corner experiment. The net heat flux to the ceiling ahead of the pyrolysis front was assumed to be 30 kW/m², while two values for the wall heat flux were considered (25 and 30 kW/m²) as the ignition source was not in contact with the comer wall surfaces (offset by about 10 mm).

The simulation used heat release rate per unit area data from the cone calorimeter measured at an irradiance 35 kW/m², while the ignition temperature (285 °C) and thermal inertia (1.121 kW²s/m⁴K²) for the medium density fiberboard material were estimated using the method of Quintiere[20] based on a series of cone calorimeter experiments at irradiances in the range 10-75 kW/m².

The predicted rate of heat release is shown in Figure 2. The heat release rate from the room was not measured experimentally. The predicted average upper layer temperature compared to the experiment is shown in Figure 3. The sensitivity of the model to the net heat flux from the flame to the wall can be seen with the two values used bracketing the experimental results reasonably well. It is noted that the computer simulation predicted a transition to oxygen-limited burning at around 120–140 seconds. Following this time, the heat release rate was predicted to fall and be controlled by the available oxygen entrained into the corner plume. Although the model

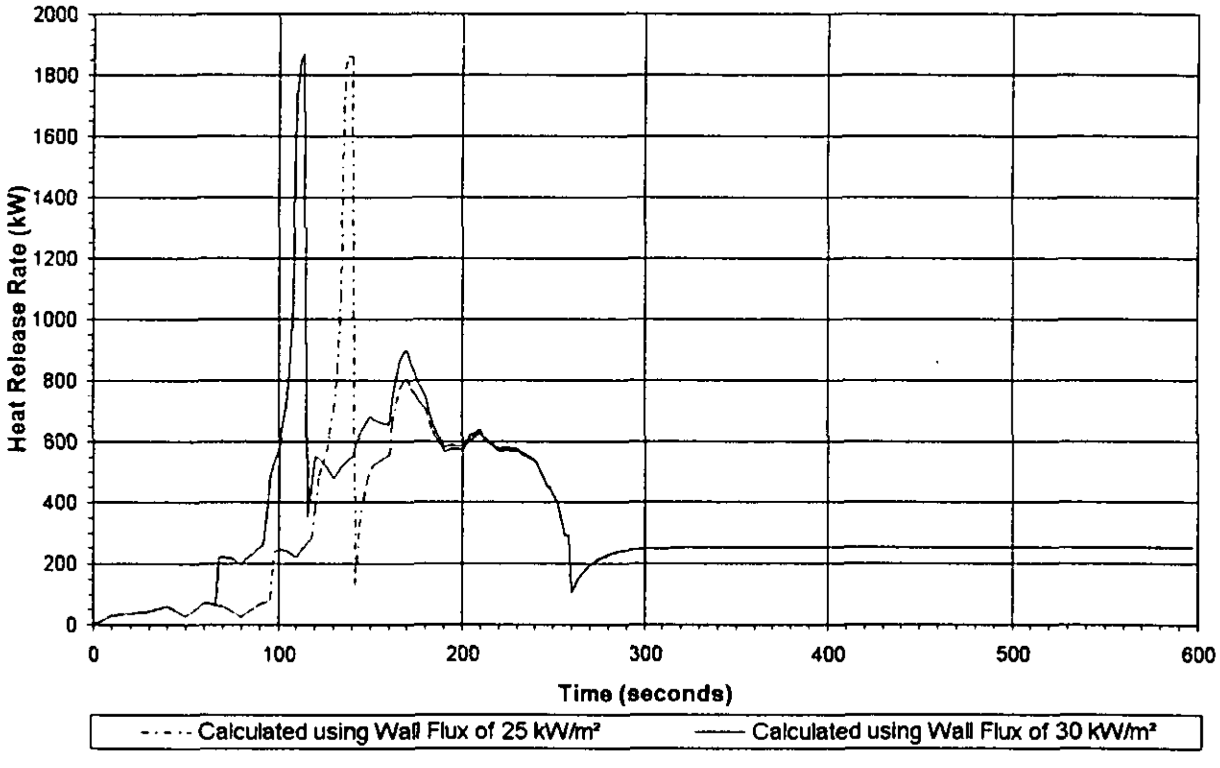

Figure 2. Rate of Heat Release - 3 mm MDF Linings.

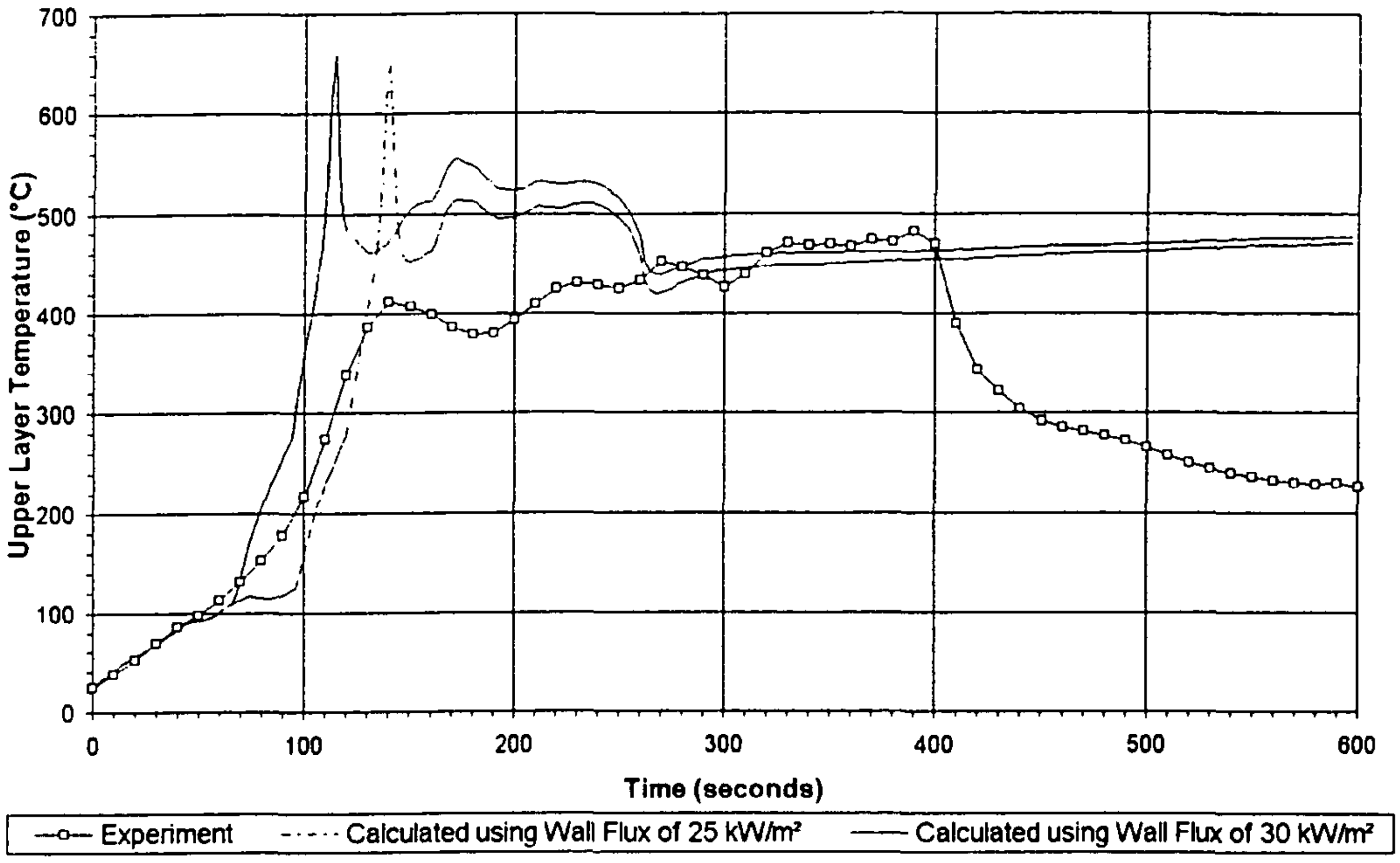

Figure 3. Upper Layer Temperature - 3 mm MDF Linings.

predicted a brief period at which temperatures exceeded 600 °C, a general transition to a fully-developed fire was not predicted. This was consistent with observations in that there was no distinct flashover of the room. The test observations also showed a period of intense burning and heat release which corresponds quite well with the time of rapid increase in predicted heat release. This level of intense burning then reduced slightly, which is also consistent with the transition to a ventilation-controlled fire. It can also be seen that agreement reduces over the latter stage of Figure 3. This may be a result of not modelling burnout of the lining material.

A comparison with a single test result has been described. Many more comparisons are required before the accuracy of the model can be evaluated.

SOFTWARE INTERFACE

The model described in this paper was programmed using Microsoft Visual Basic Version 3.0. The software is designed to run under the Microsoft Windows environment, and as a result the usual graphical user interface exists, as illustrated in Figure 4, for the opening screen. Data is input by the user through a series of menus, forms, and drop-down lists. Following completion of a model run, the results are immediately available to view in the form of graphs (see Figure 4), spreadsheet output, or a complete printed summary of input data and results. Context-sensitive on-line help is also available, although this has not yet been fully implemented for all parts of the software.

FUTURE WORK

The model described is under continuing development at the Building Research Association of New Zealand, in collaboration with Worcester Polytechnic Institute. It is intended to improve and expand on various parts of the model and its user interface, including the addition of improved flame spread and fire growth routines.

SUMMARY

The combined fire zone and fire growth model described here could be used to differentiate the fire performance and likely

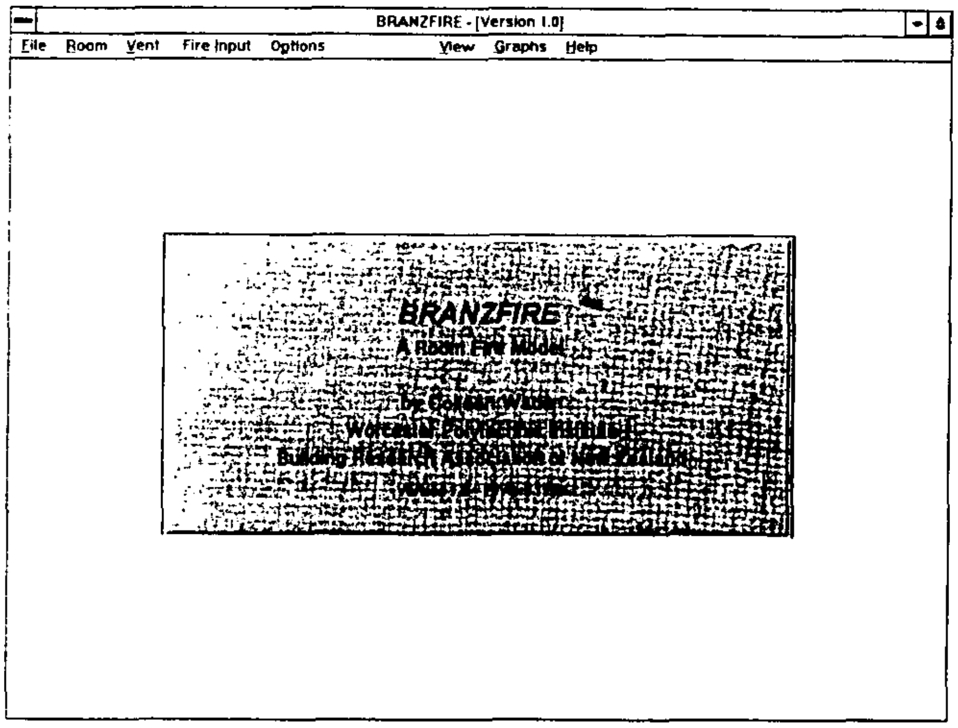

Figure 4. Main Menu and Screen.

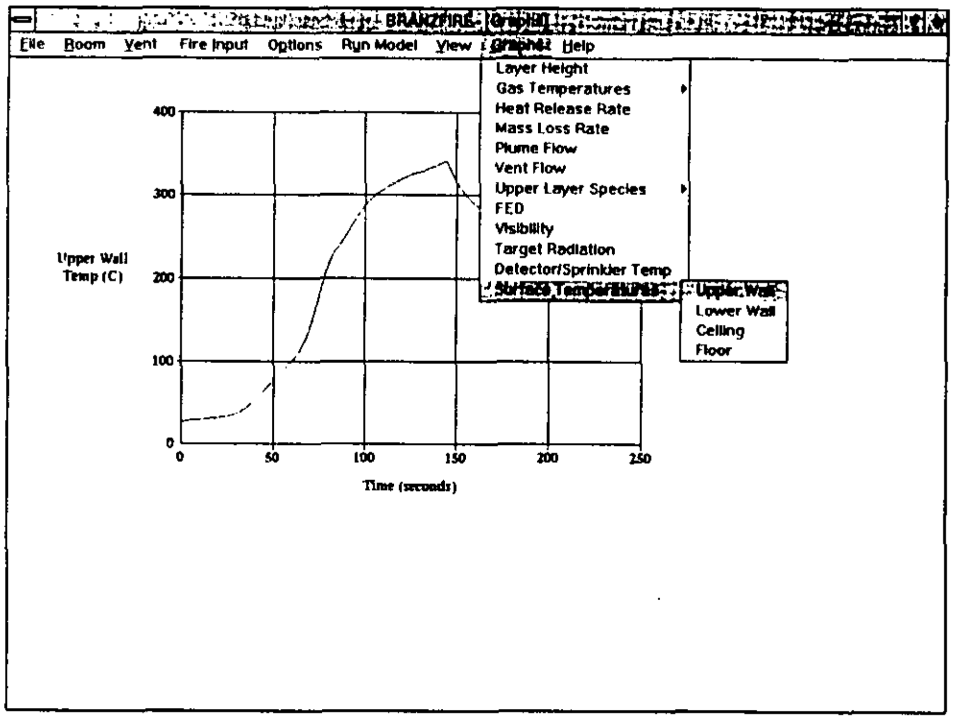

Figure 5. Graphical Output Available.

fire hazards associated with different room lining materials in a manner consistent with sound scientific and engineering principles. It provides a good basis for further development and enhancement because it has a very good user interface and has been well documented, making it more attractive to fire designers and fire protection engineers. Further comparisons with experiments are required.

ACKNOWLEDGMENTS

The authors wish to thank Professor N. Dembsey of Worcester Polytechnic Institute for valuable discussions regarding this work which contributed towards the first author's Master of Science degree. Thanks are also extended to Graham Cowles and Peter Collier of the Building Research Association of New Zealand for their help with the experiments. The work reported was jointly funded by the Building Research Levy and the Foundation for Research, Science and Technology (New Zealand).

NOMENCLATURE

A_f = floor area of the room (m^2)

A_w = wall area behind burner (m^2)

A_o = initial pyrolysing area in ceiling (m^2)

c_p = specific heat of air (J/kg K)

c_d = discharge coefficient

g = gravitational constant

H = height of the ceiling above the base of the fire (m)

krc = thermal inertia ($W^2 s/m^4 K^2$)

K = flame area constant (m^2/kW)

$\dot{m}_f$ = mass loss rate of the fuel (kg/s)

$\dot{m}_i$ = mass flow rate of cool gases in through the vent (kg/s)

$\dot{m}_o$ = mass flow rate of hot gases out through the vent (kg/s)

$\dot{m}_p$ = mass flow rate of air entrained into the plume (kg/s)

$\dot{q}_l$ = net heat transfer to the lower gas layer (kW)

$\dot{q}_u$ = net heat transfer to the upper gas layer (kW)

$\dot{Q}_f$ = total heat release from the fire (kW)

t = time (s)

t_p = dummy variable of integration

T = temperature (K)

T_{ext} = exterior ambient temperature (K)

T_{ig} = surface temperature for ignition (K)

T_l = temperature of the lower gas layer (K)

T_u = temperature of the upper gas layer (K)

$T_{\bullet}$ = reference temperature of ambient air (K)

$Va(t)$ = velocity of the pyrolysis front (m^2/s)

W_o = width of vent opening (m)

$Y_{i,l}$ = mass fraction of species i in the lower layer

$Y_{i,u}$ = mass fraction of species i in the upper layer

Z = height of the smoke layer from the base of the fire (m)

Z_N = height of the neutral plane (m)

r = density (kg/m^3)

$\lambda\tau$ = radiative fraction of energy loss by radiation from the flame/ plume

τ_c = time to ignition of the ceiling lining (s)

τ_w = time to ignition of the wall lining (s)

ψ_i = yield of species i from the pyrolysing fuel (kg species i/kg fuel)

REFERENCES

1. Wade, C., *A Room Fire Model Incorporating Fire Growth on Combustible Lining Materials,* Master's thesis, Worcester Polytechnic Institute, Worcester, MA, April 1996.

2. Peacock, R.D., Jones, W.W., Forney, G.P., Reneke, P.A., and Portier, R., *CFAST: The Consolidated Model of Fire and Smoke Transport,* Technical Note 1299, National Institute of Standards and Technology, Gaithersburg, MD, 1992.

3. Satterfield, D., and Barnett, J.R., *User's Guide for WPI Fire Version 2—Compartment Fire Model,* Master's thesis, Worcester Polytechnic Institute, Worcester, MA, 1990.

4. Nelson, H.E., *FPETOOL—Fire Protection Tools for Hazard Estimation,* NISTIR 4380, National Institute of Standards and Technology, Gaithersburg, MD, 1990.

5. Karlsson, B., *Modeling Fire Growth on Combustible Lining Materials in Enclosures,* Report TVBB 1009, Lund University, Department of Fire Safety Engineering, Lund, Sweden, 1992.

6. Karlsson, B., "Models for Calculating Flame Spread on Wall Lining Materials and the Resulting Heat Release Rate in a Room," *Fire Safety Journal,* pp. 365–386, 1994.

7. Karlsson, B., "Mathematical Models for Calculating Heat Release in the Room Corner Test," *Fire and Flammability of Furnishing and Contents of Buildings* ASTM STP 1233, pp. 216–236, American Society for Testing and Materials, Philadelphia, PA, 1994.

8. ASTM E 1354-92, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter,* American Society for Testing and Materials, Philadelphia, PA, 1992.

9. ASTM E 1321-90, *Standard Test Method for Determining Material Ignition and Flame Spread Properties,* American Society for Testing and Materials, Philadelphia, PA, 1990.

10. Saito, K., Quintiere, J.G., and Williams, F.A., "Upward Turbulent Flame Spread," *Fire Safety Science—Proceedings of the First International Symposium,* Hemisphere Publishing Corporation, 1985.

11. McCaffrey, B.J., Quintiere, J.G., and Harkleroad, M.F., "Estimating Room Temperatures and the Likelihood of Flashover using Fire Test Data Correlations," *Fire Technology,* Vol. **17**, pp. 98-119, 1981.

12. International Organization for Standardization. Room fire test in full scale for surface products (ISO DIS 9705). 1989.

13. McCaffrey, B.J., "Momentum Implications for Buoyant Diffusion Flames," *Combustion and Flame,* Vol. **52**, p. 149,1983.

14. Mowrer, F.W., and Williamson, R.B., "Estimating Room Temperatures from Fires along Walls and in Corners," *Fire Technology,* Vol. **23**, No. 2, pp. 133–145, 1987.

15. Rockett, J.A., "Fire Induced Gas Flow in an Enclosure," *Combustion Science and Technology,* Vol. **12**, pp. 165–175,1976.

16. Prahl and Emmons, H.W., "Fire Induced Flow through an Opening," *Combustion and Flame,* Vol. **25**, pp. 369–385,1975.

17. Forney, G.P., "Computing Radiative Heat Transfer Occurring in a Zone Model," *Fire Science and Technology,* 14:31–47, 1994.

18. Incropera, F.P. and De Witt, D.P., *Fundamentals of Heat and Mass Transfer,* John Wiley and Sons, 1990.

19. Cooper, L.Y., Harkleroad, M., Quintiere, J. and Rinkinen, W., "An Experimental Study of Upper Layer Stratification in

Full-Scale Multiroom Fire Scenarios," *Journal of Heat Transfer,* Vol. **104**, pp. 741–749, 1982.

20. Quintiere, J.G., and Harkleroad, M., *New Concept for Measuring Flame Spread Properties.* Technical Report NBSIR 84-2943, National Bureau of Standards, November 1984.

BRANZ
THE RESOURCE CENTRE FOR BUILDING EXCELLENCE

BRANZ MISSION

To be the leading resource for the development of the building and construction industry.

HEAD OFFICE AND RESEARCH CENTRE

Moonshine Road, Judgeford
Postal Address - Private Bag 50908, Porirua
Telephone - (04) 235-7600, FAX - (04) 235-6070

REGIONAL ADVISORY OFFICES

AUCKLAND

Telephone - (09) 526 4880
FAX - (09) 526 4881
419 Church Street. Penrose
PO Box 112-069, Penrose

WELLINGTON

Telephone - (04) 235-7600
FAX - (04) 235- 6070
Moonshine Road, Judgeford

CHRISTCHURCH

Telephone - (03) 366-3435
FAX (03) 366-8552
GRE Building
79-83 Hereford Street
PO Box 496