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## REDUCING RADIATION FROM BUILDING FIRES WITH FIRE RESISTANT GLAZING

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# Reducing Radiation from Building Fires with Fire Resistant Glazing

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**Abstract**

Can glass be used to reduce radiation from building fires? This project involved measuring how effective fire resistant glass is at reducing radiation from building fires. Our results suggest that the previously assumed radiation reduction factor of 50% is seriously flawed. Georgian wired glass achieved the best result by reducing radiation by 45% radiation attenuated, with a ceramic glass 25%, a heat-strengthened borosilicate glass 25% and a toughened fire-resistant calcium silica float glass 30%. This report outlines how these new radiation reduction factors were measured and recommends how they can be used in building design.

## *Introduction*

It has traditionally been assumed that glass will reduce radiation from building fires by 50 percent. This assumption has been derived from the characteristics of standard glass and from tests conducted many years ago. A paper by Margaret Law[1] states that, for wired glass, about 50 percent of the radiation from a fire is transmitted through the glass. New Zealand's fire-resisting glazing standard[2] uses 50 percent for its value of radiation reduction through Georgian wired glass when it is used in fire-resisting glazing systems. The standard value has been taken from Law's work. There appears to be no experimental work in the literature that have specifically measured the ability of fire-resistant glazing systems to reduce radiation.

There is little information available to designers on the ability of fire-resisting glasses to reduce radiant heat from building fires. BRANZ has conducted many proprietary fire-resistance tests using various glass types and often radiation in front of the glass screen is measured. We could see that the radiation reduction abilities of different glasses varied. However for these tests the collection of information about radiation is secondary to the main purpose of the test. Also, fire-resistance tests are not required to measure or estimate the radiation emitting from the furnace, and this information is vital to determine the attenuation. If the radiation from a known radiation source can be modelled through a glass based on its spectral characteristics and its temperature only, then the determination of radiation attenuation can be reduced to a minimal computation.

Attenuation values have been applied to the design of external walls, and to glazed screens adjacent to escape routes, to prevent fire spread to a neighbouring building or to prevent evacuating occupants from being exposed to excessive radiation. Where fire-resisting glazing is used it is possible to decrease minimum separation distances because the radiant heat from the fire is reduced. The magnitude of the change in separation distance will be related to the degree to which the radiation from the fire can be reduced.

## *Background*

Despite the widespread use of glass as a building material, glass technology is still very much in the evolution stage. Until recently there were only three distinct types of fire-resistant glass: Georgian wired, borosilicate, and toughened fire-resistant calcium silica float glass. More recently insulating glasses and laminated systems have been made available.

The most basic fire-resistant glass is Georgian wired, made by a casting process which lays a thin wire mesh into the body of the glass. The result is a sheet which is effectively reinforced and able to support itself in fire conditions, but which requires polishing on both sides to achieve a satisfactory optical quality. Georgian wired glass will crack very early in a building fire and is held for the duration of the fire by the integral wire mesh. The performance of the glass is reliant on keeping a cool stiff edge clamped within a rebate to prevent slumping from the frame and allowing an integrity failure gap to develop.

Next are the borosilicate glasses, pioneered by Schott with its Pyran product. These have a much lower thermal expansion coefficient and a higher softening temperature than ordinary soda lime glass, which render them stable for longer periods in fire conditions. But this type of glass is not made by the float process. It has to be drawn flat, which can result in panes which are optically flawed.

There are also ceramic glasses. These expand rapidly on heating and can withstand an enormous thermal shock which occurs during the initial stages of a fire.

Last are the toughened fire-resistant calcium silica float glasses, originated by Swiss manufacturer Temperit but now made by Pilkington, Glaverbel and a number of other manufacturers. These fulfil the dual function of impact resistance and fire-resistance.

## *The Selection of a Fire Resisting Glazing System*

The final design selection of fire-resistant glazing usually comes down to application and cost. Borosilicate glasses are eight to ten times more expensive than wired glass but offer better optical and aesthetic design qualities. While calcium silica glasses can cost up to 20 times as much as wired glass, they can be used in larger panes than borosilicate because of their improved impact resistance.

## *Theory*

Not all of the radiation emanating from a building fire and striking a glass pane will pass to the other side. Without the glass, 100 percent radiation would be measurable on the other side. With the glass in place the level of radiation from the fire is reduced to 45 - 70 percent. A portion of the incident radiation is reflected and some is absorbed, while the rest passes through the glass. The level of radiation on the outside is also affected by re-radiation from the hot glass.

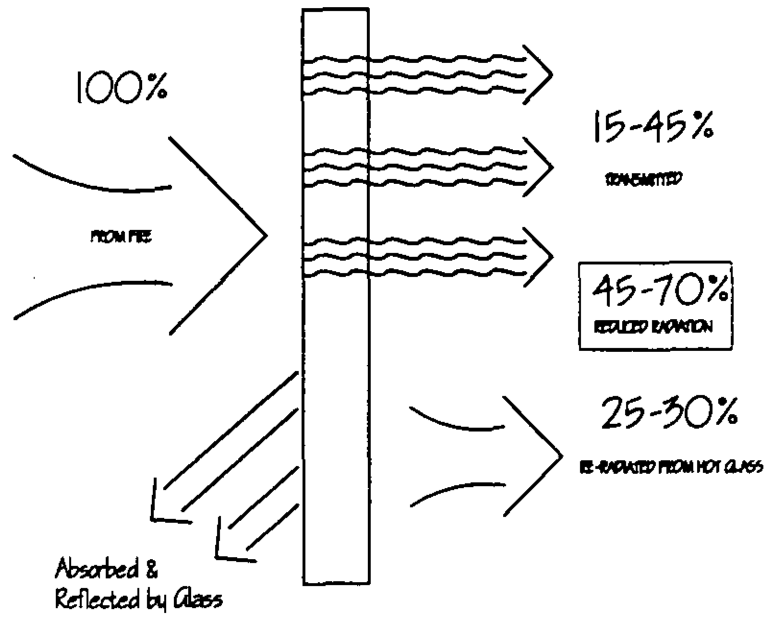


**Figure 1: Radiation model for fire-resistant glass exposed to a building fire.**

The spectral radiation characteristics of a real building fire will be complex and will vary for each and every fire. The standard fire-resistance test approximates a fully developed building fire and for this study a design fire radiation model was adopted. The model being based on the spectral radiation characteristics expected of the BRANZ pilot furnace. For this study a comparison of four different radiation sources was made. The four radiation sources studied were:

- black body radiation[3]
- a design fire[4]
- wooden cribs[4]
- a gas-fired radiant panel[5]

The spectral radiation characteristics of these radiation sources are illustrated in Figure 2.

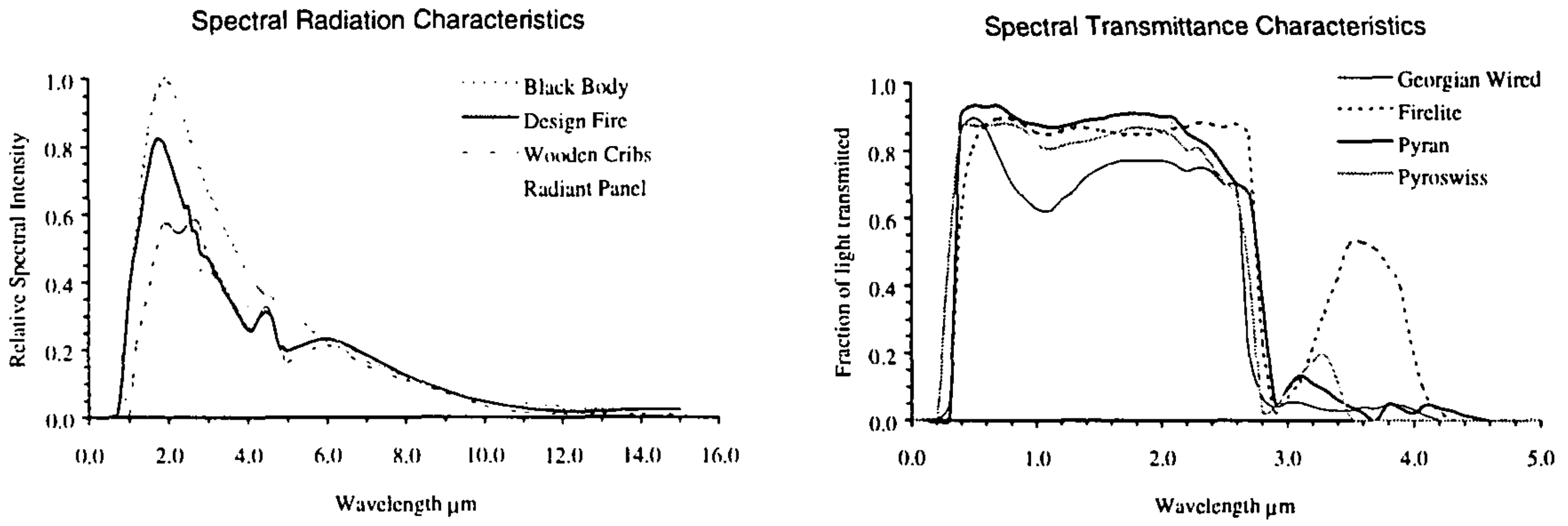


**Figure 2: The spectral radiation characteristic of the radiation sources studied and the spectral transmittance characteristics of each glass used.**

For this study it was clear that only a limited range of glasses could be tested to full scale. The fire testing was restricted to four glass types, each tested once in the BRANZ pilot furnace. Only two fire tests were carried out, with two glass systems per test (see Figure 3 and Experiment section). The four glasses chosen to best represent those available and most commonly used in New Zealand were:

- a wire-reinforced float glass, 6mm thick.
- a ceramic glass, 5mm.
- a heat strengthened borosilicate glass, 6.5mm.
- a toughened fire-resistant calcium silica float glass, 6mm.

Although it is recognised that this selection does not include the full range of glazing types available to resist heat and fire, it is acceptable given the intention of this study to examine glazing systems commonly used in New Zealand. Laminated insulating glasses are not yet widely used (in New Zealand) and are not commonly available.

An important part of this study was to consider the physical properties of the glass. It was necessary to be able to determine the level of radiation that is restricted from passing through the physical barrier that is the glass. The spectral transmittance of each glass, as illustrated in Figure 2, was sourced from manufacturers of the glass and from published literature. Each glass lets through electromagnetic radiation at different intensities at different wavelengths of radiation. The spectral transmittance characteristics of each glass type used are displayed in Figure 2. The differences between the glass types can be seen clearly and these have an influence on the ability of the glass to reduce radiation from building fires.

The radiation input into this new radiation attenuation model could be from a black body or from a radiant panel. The aim is to input the spectral radiation from an actual fire and determine the magnitude of attenuation for each glass based on the spectral transmittance characteristic of each glass and its temperature in the same fire.

The estimation of radiation attenuation has been considered as a function of two components: the *Spectral Transmittance* component and the *Radiation from hot glass* component.

The *Spectral Transmittance* component is given by the ratio of radiation intensity through the glass to the full radiation intensity from the radiation source. Georgian wired glass is able to reduce the radiation passing through by 68% of that emitted from the design fire.

The glass screen is heated by the fire and the hot surface of the glass radiates as a function of the temperature and the emissivity of the surface. For Georgian wired glass, after 60 minutes of the standard fire-resistance test, the glass is re-radiating at 26% of the incident radiation, as per the following equation:

$$\textit{Radiation from hot glass}\ \text{component} = \frac{(\mathrm{T_g})^4 \times \varepsilon_g}{(\mathrm{T_f})^4 \times \varepsilon_f} \times \frac{100}{1} = 26\%$$

**Equation 1: Determining the attenuation value for glazing systems based on the spectral transmittance characteristics of the glass and the radiation from the hot glass in the furnace test.**

The ability of the glass to reduce radiation from a fire can be estimated by summing the spectral transmittance component and the re-radiation component so that, for Georgian wired glass, the attenuation is equal to 100-(32+26) = 42%. See Table 1 for full results for other radiation sources and glass types.

## *Experimental*

The work of Moulens and Grubits[6] describes how fire-resistant glass sprayed with water can reduce radiation by up to 60 percent. Their approach unfortunately ignored the high temperatures experienced by glass in building fires and the radiation from the hot glass was much less than could normally be expected. This report was used as the basis for determining the need to do further experimental work.

Standard fire-resistance testing[7], to AS 1530 Part 4, was conducted in the BRANZ pilot fire-resistance furnace. The pilot furnace allows fire-resistance tests to be completed on smaller samples than for a full sized fire-resistance furnace. The BRANZ pilot furnace is diesel fired, and will have different radiation characteristics from gas-fired furnaces. This difference does not affect the ability of the glasses studied to attenuate radiation. The fire tests were planned to run to 90 minutes and a timber stud wall lined with 32 mm of fibre-reinforced gypsum plasterboard was used to support the glass frames.

Each glass sample was supported in a steel frame, suitable for 90 minutes fire-resistance. The exposed area of glass for each sample was 400 mm by 400 mm. The pilot furnace is 2.2 m high by 1.0 m wide. The windows were located in the timber framework as shown in Figure 3. Two fire tests were completed, with the first being of Georgian wired glass and ceramic glass and the second of the borosilicate glass and the calcium silica float glass. The frame for the calcium silica float glass specimen failed very early in the test and all results were lost for this glass type.

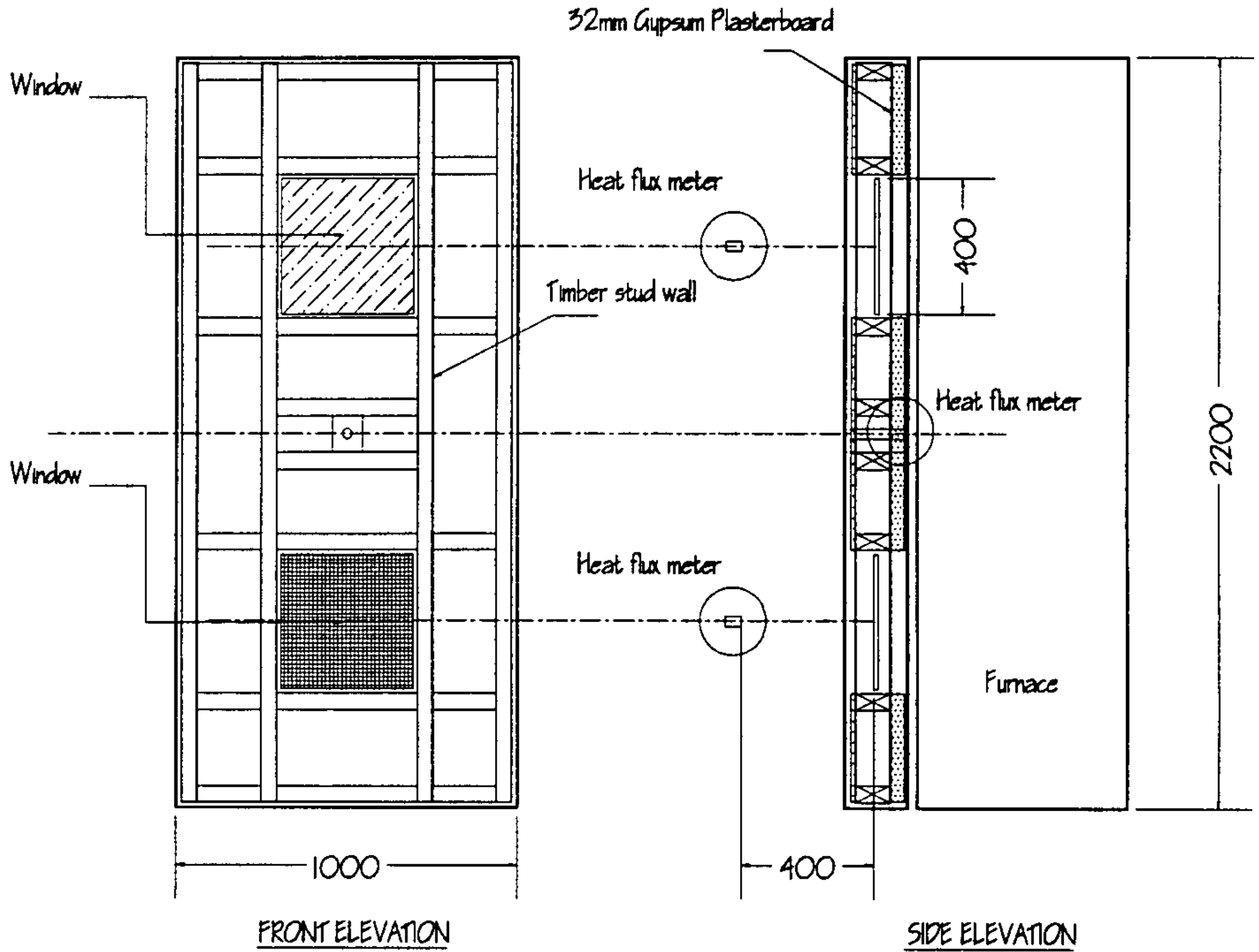


**Figure 3: Layout of fire-resistance test. The BRANZ pilot furnace was used to measure radiation from the furnace and radiation 400 mm in front of the glass windows. Note that only small panes of glass were needed for this test. Note also the locations of the heat flux meters.**

Radiation from the furnace was measured by placing a Gardon-type heat flux meter securely in the framing holding the windows in place. The heat flux meter was placed in the centre of the frame and continuously monitored the heat flux. The field of view of the heat flux meter was the interior walls of the furnace.

View factor for radiation from furnace = 0.64

View factor for radiation from window and measured at heat flux meter = 0.24

$$\text{Attenuation} = \left[ 1 - \left( \frac{\dot{q}''_{gm}/0.24}{\dot{q}''_{fm}/0.64} \right) \right] \times \frac{100}{1} = 45\% \text{ for Georgian wired glass}$$

**Equation 2: determining the attenuation value for glazing systems based on results from BRANZ fire test furnace.**

## *Results*

A method to determine the ability of fire-resistant glasses to attenuate radiation has been devised. The ability of any particular glazing system to reduce radiation from a building fire will be a factor of its thermal transmittance characteristics and of the surface temperature of the glass during the fire.

**Table 1: Results from analytical model, see Equation 1.**

| | | *Black Body* | *Design Fire* | *Wooden Cribs* | *Radiant Panel* |
|---|---|---|---|---|---|
| *Georgian wired* | through glass | 32% | 32% | 26% | 16% |
| | from glass | 26% | 26% | 26% | 26% |
| | total | 58% | 58% | 52% | 42% |
| | **attenuation** | **42%** | **42%** | **48%** | **58%** |
| *Ceramic glass* | through glass | 44% | 43% | 37% | 26% |
| | from glass | 32% | 32% | 32% | 32% |
| | total | 76% | 75% | 69% | 58% |
| | **attenuation** | **24%** | **25%** | **31%** | **42%** |
| *Heat strengthened borosilicate glass* | through glass | 40% | 39% | 32% | 20% |
| | from glass | 35% | 35% | 35% | 35% |
| | total | 75% | 74% | 67% | 55% |
| | **attenuation** | **25%** | **26%** | **33%** | **45%** |
| *Toughened calcium silica float glass* | through glass | 36% | 36% | 29% | 18% |
| | from glass | 35% | 35% | 35% | 35% |
| | total | 71% | 71% | 64% | 53% |
| | **attenuation** | **29%** | **29%** | **36%** | **47%** |

Table 1 lists the results from the analytical part of this study. The results are based on the conditions assumed at 60 minutes into the standard fire. The value of radiation passing through the glass is from the calculations undertaken in the Theory section. These calculations rely on the spectral radiation from the radiation source and the transmittance characteristics of the glass. The values for radiation from glass are based on the temperature of the glass achieved at 60 minutes into the fire-resistance tests. The temperature used has been estimated from the range of temperatures experienced in the experimental work. The total value is the sum of the through glass and from glass values. The percentage of radiation attenuation is therefore the ratio of the total radiation at the glass to the total radiation from the fire. The total radiation from the glass has been calculated from the expected radiation value from the standard fire at 60 minutes. The different radiation sources highlight the contribution of the spectral transmittance characteristics of each glass to the overall performance.

**Table 2: Results of experimental work.**

| *Glass* | *Time* (mins) | *Temperature of glass* (°C) | *Radiation from fire* $\dot{q}''_{fm}$ (W/m²) | *Radiation from glass* $\dot{q}''_{gm}$ (W/m²) | *Attenuation* ***Equation 2*** (%) |
|---|---|---|---|---|---|
| *Georgian wired* | 30 | 550 | 50,800 | 11,800 | 38% |
| | 60 | 680 | 96,800 | 20,100 | 45% |
| | 90 | 720 | 114,000 | 23,500 | 45% |
| *Ceramic glass* | 30 | 590 | 50,800 | 16,900 | 11% |
| | 60 | 730 | 96,800 | 27,800 | 23% |
| | 90 | 780 | 114,000 | 32,200 | 25% |
| *Heat strengthened borosilicate glass* | 30 | 670 | 41,900 | 10,900 | 31% |
| | 60 | 720 | 90,800 | 23,700 | 30% |
| | 90 | 650 | 26,500 | 6,700 | 33% |

Table 2 is a summary of the experimental results and shows 30, 60 and 90 minute time slices from the test results. The values $\dot{q}''_{gm}$ and $\dot{q}''_{fm}$ are the measured values from the fire test of the radiation by the heat flux meters 400 mm in front of the glass windows and by the heat flux meter in the furnace. It has been necessary to use configuration or view factors to equate the measured values to equivalent values at a common location. The plane of the window glass was used for this location and the view factors are described in Equation 2. Attenuation values vary over the duration of the test and the 60 minute values have been used for the recommendations that follow.

## Recommended Attenuation Values

The following recommendations, of design attenuation values for each glass type studied, can now be made:

- a wire-reinforced float glass 45%
- a ceramic glass 25%
- a heat strengthened borosilicate glass 25%
- a toughened calcium silica float glass 30%

These values will only apply to post-flashover compartment fires in buildings. It should not be assumed that the level of sophistication obtained here, in saying that a glass can reduce radiation by 25 percent, will apply in all building fires. At 60-90 minutes the glass will be at 650°C in a standard fire resistance test and a significant proportion of radiation is from the hot glass as well as from the fire. So the design attenuation values can only be applied for post-flashover compartment fires - as used in safe separation distance calculations[8]. The value of attenuation determined will not be applicable to other radiation sources, such as a radiant heater or from sunlight.

## *Conclusion*

The research project successfully developed a model of the radiation attenuation through glass from building fires. The model was used to compare four commonly available fire-resistant glazing systems. Two fire-resistance tests were completed as part of this project and a measurement of the radiation attenuation was made which compared favourably, as shown in Table 3, with the results from an analytical model. The model uses the spectral transmittance characteristics of the glass and the spectral radiation characteristics of a selection of radiation sources. The results clearly show that different glass types have varying abilities to attenuate radiation. All are less capable of reducing radiation from building fires than was previously assumed.

**Table 3: Comparison of analytical model and test results.**

| *Glass* | ***Analytical model*** *Attenuation* (%) | ***Test results*** *Attenuation* (%) |
|---|---|---|
| *Georgian wired* | 42 | 45 |
| *Ceramic glass* | 25 | 23 |
| *Heat strengthened borosilicate glass* | 26 | 30 |
| *Toughened calcium silica float glass* | 29 | na |

The specific results of attenuation abilities for the glass systems studied are outlined in the Results section. The values can be used immediately in calculations of safe separation distances between a burning building and its neighbour. The attenuation values can be used in the Heat Radiation module of FIRECALC[11] to determine safe separation distances between buildings or in the software developed as part of BRANZ Technical Recommendation 13[8].

The testing procedure adopted successfully avoided the limitations encountered by previous testing programmes, such as radiation losses due to the cooling of the glass. The model provides for different glass types and for different radiation sources.

The results from this work will also have input for calculations of safe screening distances for escape routes. NZS 4232[2] provides a nomogram for the width of escape routes bordered by wired-glass screens. Future work could involve updating this nomogram or providing an alternative method of determining the safe screening distance for different glass types.

## *Nomenclature*

$\dot{q}''_{gm}$ = heat flux measured at heat flux meter in front of window (kW / m$^2$)

$\dot{q}''_{fm}$ = heat flux measured at heat flux meter in fire test furnace (kW / m$^2$)

$T_g$ = Temperature of hot glass specimen in fire test furnace (K)

$T_f$ = Temperature of hot gases in fire test furnace (K)

$\varepsilon_g$ = Emissivity of glass

$\varepsilon_f$ = Emissivity of hot gases in fire

## *Acknowledgments*

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## *References*

1. Law, M. Safe Distances from Wired Glass Screening a Fire. *The Institute of Fire Engineers Quarterly*, Q.29.(73) 1969, pp.62-70.

2. SANZ, NZS 4232: 1988 Performance criteria for fire-resisting closures, Part 2 Fire-resisting glazing systems, *Standards Association of New Zealand, Wellington*, 1988, pp 29-31.

3. Rogers, G. F. C. & Mayhew, Y. R., Engineering Thermodynamics Work and Heat Transfer. *Longman Group Limited, London,* 1967, p 576.

4. Drysdale, D., An Introduction to Fire Dynamics. *John Wiley & Sons Ltd.*, 1985, pp 55-77.

5. Simms, D.L. & Coiley, J. E., Some radiation characteristics of a gas-fired panel. *British Journal of Applied Physics,* Vol. 14, 1963, pp 292-294.

6. Moulen, A. W. & Grubits, S. J., Water-curtains to shield glass from radiant heat from building fires. *Experimental Building Station TR 44/153/422.* Not dated.

7. Standards Australia, AS 1530.4 Methods for fire tests on building materials, components and structures. Part 4: Fire-resistance tests of elements of building construction. *Standards Association of Australia.* 1990.

8. Collier, P. C. R. Method for determining safe separation distances between buildings in the event of fire. *Technical Recommendation 13, Building Research Association of New Zealand.* To be published.

9. FIRECALC 2.3 Computer Software for the Fire Engineering Professional. *CSIRO div BCE, Australia.* June 1993.

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