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Fire Spread from Openings in Sprinkler Protected Buildings – V2

Fire and Security Consulting Services (FSCS) is frequently consulted on the effects of fire spread from openings in buildings. A companion paper by FSCS entitled "Protection of Openings in Buildings" addresses buildings generally and specifically those without sprinkler protection which should be referenced when reading this paper.

This paper addresses Class 2, 3 and 9c buildings and other residential buildings such as class 9a where Quick Response residential sprinklers are installed. The rationale here is that with a properly designed and maintained Residential Sprinkler System in accordance with AS2118.4, the fire will be suppressed to such a degree that fire spread within the fire compartment will not emit sufficient heat flux from openings to ignite materials in adjoining buildings or detrimentally impact on persons passing by or located near the openings. That is, the opening in the building is not a *fire source feature* as defined in the BCA.

Note that this paper addresses the subject buildings as "emitters" of heat flux and only where buildings on the same lot where both the emitter and receiver buildings are sprinkler protected and is especially relevant to BCA Clauses C3.2 (a) (iii), C3.3, D1.7(c) and Verification Method CV2 and demonstrates that exposure from openings in sprinklered buildings are not considered as a fire source feature.

This paper also addresses the location of fire fighting equipment near openings in buildings under Australian Standard AS2419.1 – the Hydrant Code.

Where the buildings or fire compartments are sprinkler protected in accordance with the section on sprinklers below, this paper considers that a "Performance Based Alternative Solution" by a Fire Engineer can be substantiated and meet the following Performance Requirements of the BCA:-

- CP2 in respect to fire spread; and
- CP3 in respect to fire spread and evacuation in a Class 9a and 9c building; and
- EP1.3 in respect to the operational requirements of the Fire Brigade; and
- EP2.2 in respect to protection of evacuation routes.

Background - BCA

BCA clause C3.2 and C3.3 require protection of openings in external walls of buildings to prevent fire spread from one fire compartment to another. Compliance with these clauses is detailed in BCA C3.4 and Specification C3.4, including the use of "internal or external wall wetting sprinklers as appropriate". The functional objectives of the requirement are listed in BCA CF2 (d) and (e). CV2 in the BCA is cited as an acceptable verification method. The FSCS paper entitled "Heat Flux Calculations and Assessment" provides further information on this subject.

The BCA also, in Clause D1.7(c) requires that where a path of travel in open space passes closer than 6m to an external wall of the same building, that wall shall have an FRL of 60/60/60. As discussed in the FSCS companion paper "Protection of Openings in Buildings", protection of openings in a non sprinkler protected building with wall wetting sprinklers will not eliminate heat flux from the openings.

The concept for protection is that either the distance from the fire source and/ or the sprinkler discharge on the receiver building surfaces will attenuate the heat flux (radiation) such that ignition of materials in or on the surface of the receiver building will be prevented. The guide to the BCA under CV1 lists the radiant heat levels that materials will ignite is between 10kw/m^2 and 35kw/m^2 dependant on various circumstances and is considered relevant to CV2.

A typical arrangement is shown in Figure 1 below where the fire source is either a fire in an adjoining building or fire compartment. In this instance ether Buildings A or B can be either an emitter or a receiver, and under BCA C3.4 the openings in both buildings or fire compartments would need to be protected.

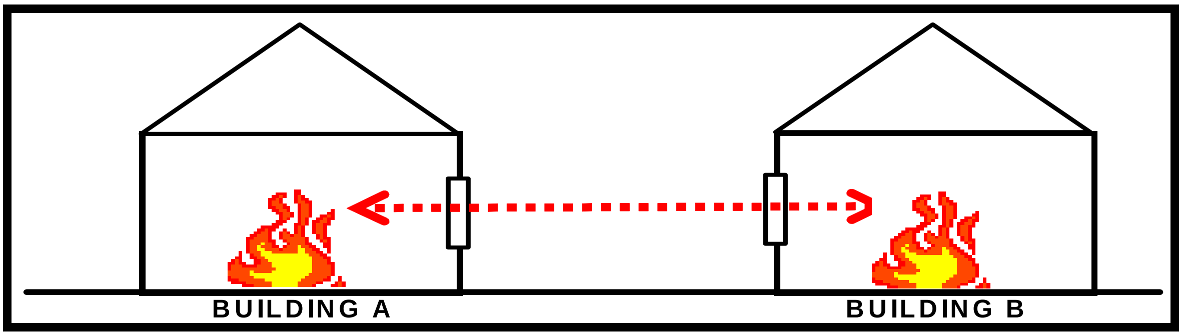


Figure 1 – BCA Compliance

Background – AS 2419.1

AS2419.1, the Fire Hydrant Code, requires that where external fire hydrants are used, the fire hydrant is required to be located greater than 10m from an opening in the building or fire compartment being protected by that hydrant. This 10m requirement also applies to Brigade Booster assemblies.

Figure 2 below shows the radiant heat flux from a typical building opening (large balcony sliding door of 2.1m high and 3.0m wide) where with a temperature of 1,000^{o}C and a clearance of 10m, calculations show that the radiant heat flux on the fire fighter is 2.92kW/m^2 and this is implied to be acceptable under the Standard.

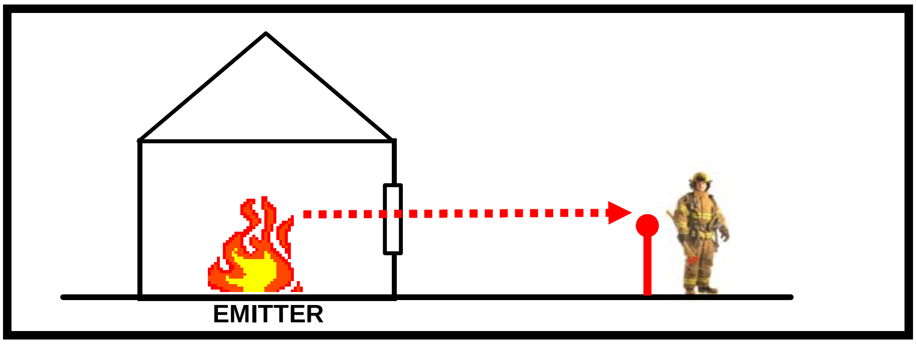


Figure 2 – Heal Flux on Fire Fighter

Where hydrants or the Booster is less than 10m from openings in a building, AS2419 requires that a wall with an FRL of 90/90/90 be used for protection. This wall is required to extend 2m either side of the hydrant or booster connections, 3m above the ground for hydrants and 3m above the uppermost booster connections. Figure 3 below shows the required arrangement.

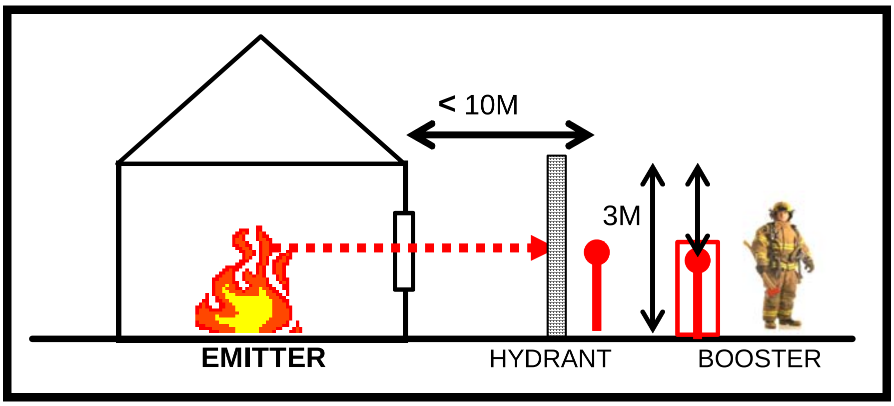


Figure 3 – Hydrant or Booster Protective Wall

Sprinkler System Design Reliability

The preface to AS2118.4, the Australian Standard on residential fire sprinkler systems states *"This Standard is intended to provide a degree of life safety and property protection for the inhabitants of low rise Class 2 and Class 3 together with Class 9a, excluding hospitals, buildings as defined in the BCA."* FSCS also considers that Class 9c should be included because the BCA in Specification E1.5 also requires a sprinkler system to be installed in accordance with AS2118.4.

In a building with a properly designed and maintained Residential Sprinkler System in accordance with AS2118.4, the fire will be suppressed to such a degree that fire spread within the fire compartment will not emit sufficient heat flux from openings to ignite materials in adjoining buildings or detrimentally impact on persons passing by or located near the openings.

The key here is that the sprinkler system must be (1), properly designed, (2) properly installed, (3) properly maintained and (4) be effective in achieving fire suppression.

In relation to requirements 1, 2 and 3 above, the current Regulatory requirements are such that under the Building Regulations the design and installation of the sprinkler system must be certified and under the Building Fire Safety Regulation 2008, the sprinkler system must be maintained in accordance with AS1851-2005. Accordingly there is a high degree of reliability.

On the question of reliability of design and performance, data on sprinkler operation can be found in the publication 'Fire – A Century of Automatic Sprinkler Operation in Australia and New Zealand, 1886 - 1986' by H W Marryatt.

Data from this publication, with reference to residential occupancies, is reproduced in Table 1. Examination of this data indicates that the average number of sprinkler heads operating across all occupancy types is less than the design number of sprinklers. Note that this data reflects the reliability of "Light Hazard" systems prior to the advent of specific residential systems.

AS2118.1 Classification and Design Data				Marryatt Data Table 15 1			
Occupancy	Classification	Number of sprinklers to operate	Design Flow l/s	No of Fires	Minimum / maximum / Average sprinklers operated	Controlled - loss of life	Maximum Flow l/s **Note 1**
Residential	Light Hazard	6 **Note 2**	5.5	55	1 / 4 / 1.3	100% - Nil	4.6

Table 1 – Sprinkler Performance Data

Note 1 – AS2118.4 residential systems require a flow of 5l/s.

Note 2 - Residential systems designed to AS2118.4 are based on 4 sprinklers operating.

Accordingly the statistics show 100% reliability in respect to design and performance.

Sprinkler Effectiveness Citations

The following articles published by researchers are cited as supporting evidence and reviewers are encouraged to download the referenced articles. The first citation (BCA) relates to the BCA acceptance of sprinkler suppression effectiveness, the second citation is from the Board of Fire Commissioners NSW – now NSW Fire Brigades, the third and fourth (BFRL) and (UL) relate to the effectiveness of sprinkler suppression in residential occupancies, the fifth (FM) relates to the heat flux at openings.

1 - BCA Recognition of Sprinkler System Effectiveness

The BCA, in Clause C2.6, requires that certain openings in external walls of Type A construction buildings, the only buildings being required to provide fire separation between floors, have compliant spandrels to prevent vertical fire spread. However where the building is sprinkler protected, this vertical separation is not required.

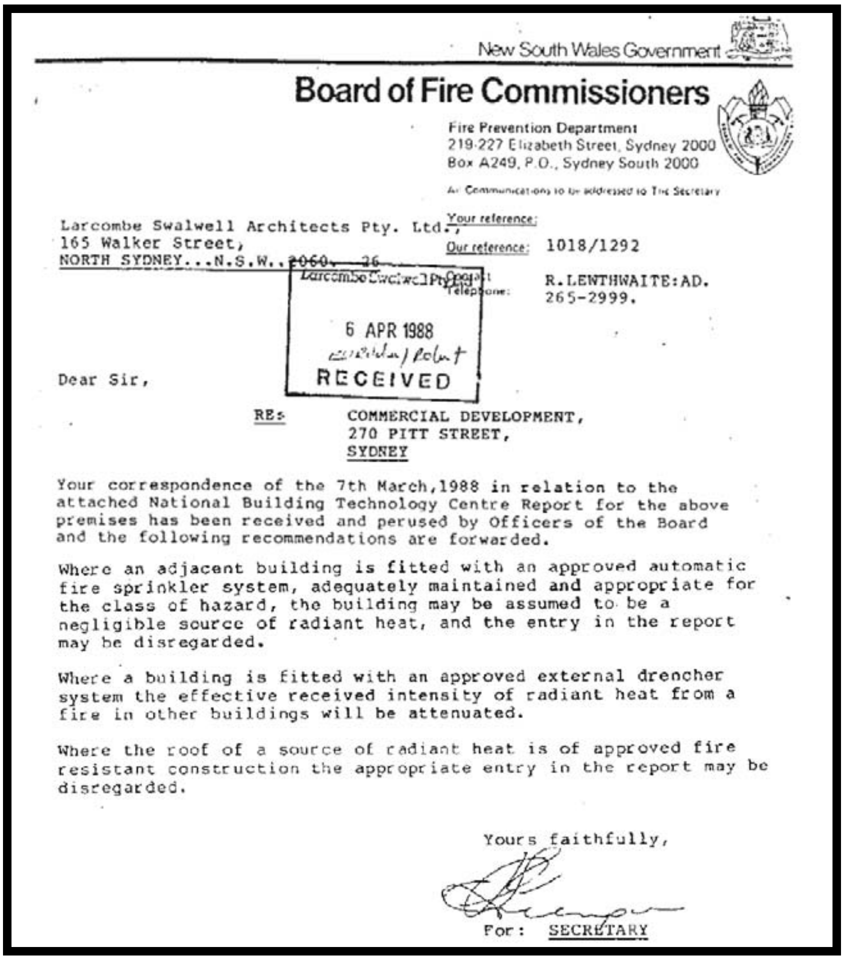
This demonstrates that the BCA recognises that sprinkler protection is effective in preventing fire spread.

2 - NSW Fire Brigade

The author of this paper, whilst Director of Eagle Consulting Group in Sydney, had a project in the Sydney CBD where two adjacent buildings had openings opposite and within 4m of each other. Both buildings were sprinkler protected and the author worked with the Architect, Sydney City Council and the Board of Fire Commissioners (now NSW Fire Brigades) to resolve the issue.

The outcome was an assessment by the National Building Technology Centre (now CSIRO) which was submitted to the Brigade and Council. Both agreed that radiant heat from a sprinkler protected building was negligible.

The BOFC letter is reproduced below.



New South Wales Government

Board of Fire Commissioners

Fire Prevention Department
219-227 Elizabeth Street, Sydney 2000
Box A249, P.O., Sydney South 2000

All Communications to be addressed to The Secretary

Larcombe Swalwell Architects Pty. Ltd.,
165 Walker Street,
NORTH SYDNEY...N.S.W.. 2060.

Your reference:
Our reference: 1018/1292
Telephone: R.LEWTHWAITE:AD. 265-2999.

6 APR 1988
RECEIVED

Dear Sir,

RE: COMMERCIAL DEVELOPMENT,
270 PITT STREET,
SYDNEY

Your correspondence of the 7th March,1988 in relation to the attached National Building Technology Centre Report for the above premises has been received and perused by Officers of the Board and the following recommendations are forwarded.

Where an adjacent building is fitted with an approved automatic fire sprinkler system, adequately maintained and appropriate for the class of hazard, the building may be assumed to be a negligible source of radiant heat, and the entry in the report may be disregarded.

Where a building is fitted with an approved external drencher system the effective received intensity of radiant heat from a fire in other buildings will be attenuated.

Where the roof of a source of radiant heat is of approved fire resistant construction the appropriate entry in the report may be disregarded.

Yours faithfully,

For: SECRETARY

3 - US Fire Administration – Building Fire Research Laboratory (BFRL)

BFRL - NIST was the first organisation to develop and test residential sprinklers and cited the following in their Report. Videos (MPG) are available for download from:-

http://www.fire.nist.gov/fire/sprink/ .

The following is an extract from their Report.

Residential fire sprinkler systems have proven themselves to be effective life safety systems. BFRL, with support from the U. S. Fire Administration, conducted experiments to quantify the effectiveness of residential sprinkler systems designed in accordance with NFPA 13.

An example of these experiments is the following comparison of a "living room" fire, with and without residential sprinklers. Two rooms, each 3.7m X 2.4m high, were built in the Large Fire Research Facility at NIST. Both of the "living rooms" were furnished with a sofa, love seat, end table, lamp and carpeting. Room A had a smoke detector installed and Room B had both a smoke detector and a residential sprinkler system. A match was used to ignite the sofa. Within 40 seconds after ignition, the smoke detectors in each room activated. The *fires in both rooms continued to grow. At 85 seconds the residential sprinkler activated in Room B.*

As a result of the water spray from the sprinkler in Room B, the fire is suppressed and safe conditions are maintained. The fire in Room A continues to grow. Flash over occurs in Room A, 195 seconds after ignition, with temperatures exceeding 600oC.

4 - Underwriters' Laboratories (UL) – Redmond (USA) Fire Department

Videos are not available on line but FSCS can provide a copy of the test videos.

On September 9th, 2006 three live fire exercises were conducted on a home scheduled for demolition in Woodinville, WA. USA. The Redmond Fire Department and the Woodinville Fire and Life Safety District conducted these exercises cooperatively. The primary goal for this project was to gather data to support the adoption of a local ordinance requiring sprinkler systems in all new residential occupancies.

The live fire exercises compared the fire development and temperature rise characteristics of an unprotected typical living room and bedroom to identical rooms that included a single UL Listed residential sprinkler installed in accordance with NFPA 13. This research consisted of a side-by-side simultaneous comparison of two living room fire scenarios, followed by two separate bedroom fire scenarios.

Underwriters Laboratories supported this effort by refining and testing the ignition scenarios in their laboratories prior to the actual fires, and reviewing the proposed sprinkler installation to ensure it was appropriate. UL staff also attended the burn site to setup an instrumentation package, record the actual time/temperature data, and film all of the live fire scenarios.

Of particular interest in this Report are the results from the bedroom fire which is considered to be representative of typical furnishings found in accommodation units in Australia. Note that the walls in the test rooms were combustible wall panelling. Figure 4 below shows the comparison between the maximum temperatures of the sprinklered and unsprinklered tests. Note that where the 1800°F temperature at 5'3" (1,6m) above the floor equated to 982°C for the unsprinklered tests, the maximum temperature in the sprinklered test was 110°F at 5'3" (1,6m) above the floor, equating to 56°C.

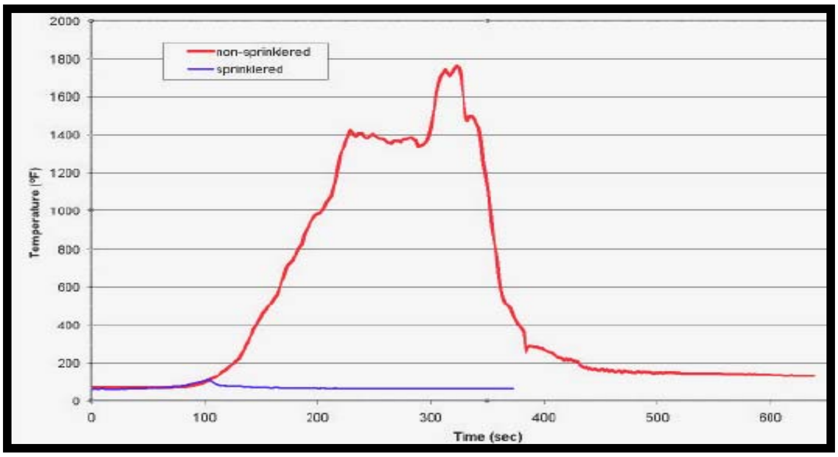


Figure 4 – UL Test Results – Sprinklered vs Unsprinklered

UL reported that:-

The fire in the unprotected bedroom raced from the point of origin to the draperies and bedding, escalating rapidly in intensity. The smoke alarm activated almost immediately, but was quickly destroyed by the fire. The temperature in the bedroom reached 1,769°F at 5 feet-3 inches above the floor, and the room flashed over in less than five minutes, well before the average local fire department response time. The fire completely consumed all of the fabric materials in the room, including the mattress and box spring.

The sprinkler-protected bedroom also saw rapid initial fire growth at the point of origin, with quick moke-alarm activation. In stark contrast, however, the sprinkler activated quickly to contain the flames and fire damage near the point of origin. The maximum temperature recorded at 5 feet-3inches above the floor was 110° F.

5 - Factory Mutual (FM Global)

An article by Hsiang-Cheng Kung of Factory Mutual was published in the "Fire Technology" Journal Volume 12 No. 2 reporting on tests to demonstrate the effectiveness of residential sprinkler protection. The full text of the article is available from http://www.springerlink.com/content/f730114106l76582/ .

The following are extracts from that Report.

A study of residential sprinkler protection sponsored by the National Bureau of Standards NBS), has recently been completed. The objective has been to study sprinkler control of residential fires by the cooling mechanism in support of the development of design criteria for residential sprinklers. The experiments were conducted in the 10-ft by 12-ft (3.05-m by 3.66~m) room with a window and a door. The room was furnished with a bed with representative bedding, an upholstered chair, a desk and hardwood chair, a bureau, and wall-to-wall carpeting.

FSCS note – the window dimension was 4'4'' high and 6'0'' wide being 25ft^2 or 2.416m^2 in area.

The results have demonstrated that the sprinkler, operating at the selected conditions, is capable of controlling a realistic bedroom fire, protecting the structure, and preventing fire spread to the adjacent area.

Total convective heat flux through the window opening is plotted in Figure 5, [FSCS Note – Reproduced in Figure 5] *which shows that the convective flux dropped sharply after sprinkler operation. The total convective heat flux at the commencement of sprinkler operation was 12,000 Btu/min (12,871 kJ/min), dropping to 2,900 Btu/min (3059.5 kJ/min) 30 sec later. After 4 min of sprinkler operation, the total convective heat flux through the window opening became negligible. In addition, the highest measured gas temperature in the window outflow dropped from 450 ° F (232 ° C) to 212 ° F (100 ° C) within 40 sec and to 100 ° F (37.8 ° C) within 3 min after sprinkler operation. Since cellulosic and plastic materials usually start to pyrolyze vigorously at temperatures near 570 ° F (299 ° C), the outflow was not considered likely to cause ignitions in other parts of a building. These results demonstrated that the sprinkler operating at the selected condition did limit the fire to its room of origin and hence would prevent fire spread to other parts of the building.*

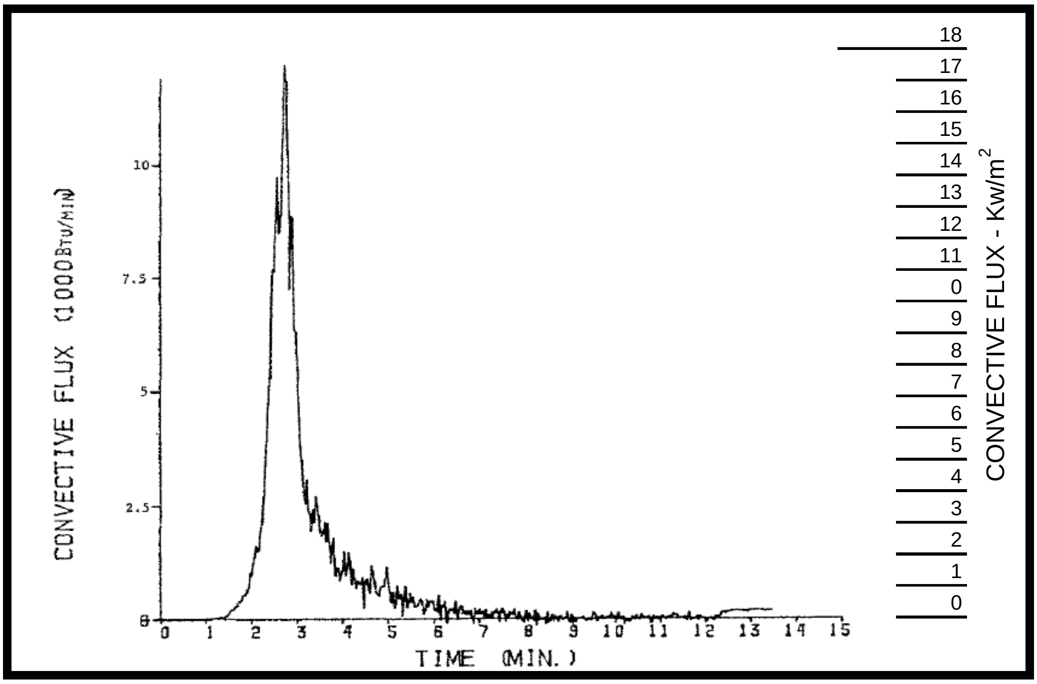


Figure 5 – Total convective heat flux through the window opening – *Figure 5* – FSCS has added Y2 axis in kW/m^2

Worked Example of Compliance

From the data in citation 5 (FM) and Figure 5, the results of the heat flux at the window in kW/m^2 are plotted in Figure 6.

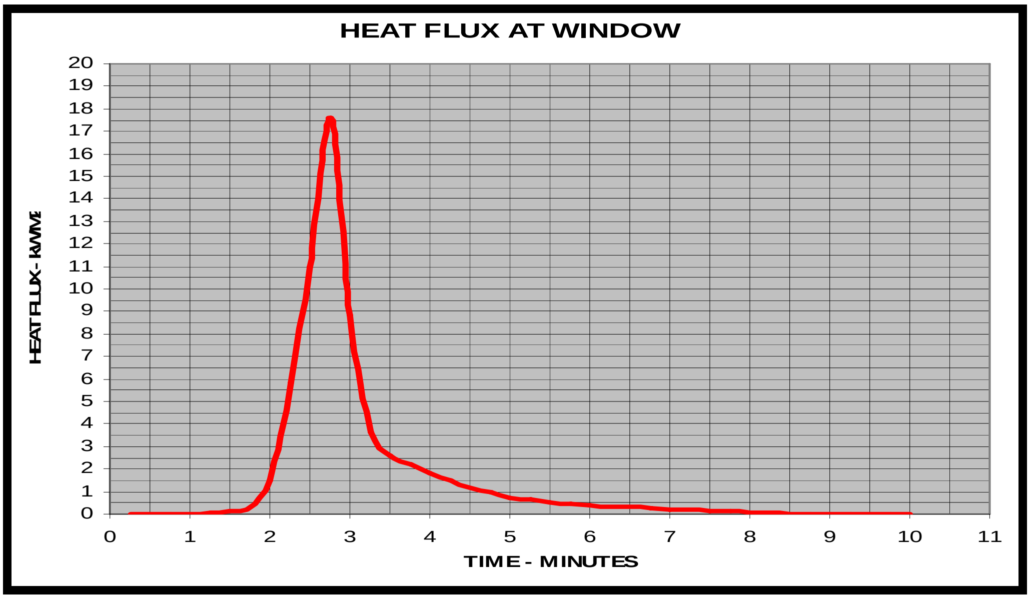


Figure 6 – Total convective heat flux through the window opening – kW/m^2

Using these resultant heat flux values, a performance Based Alternative Solution can now be carried out using the programme "Rad Parll Surf.xls" as described in the FSCS companion paper "Heat Flux (Radiation) Calculations for Performance Based Alternative Solutions".

Firstly, from Figure 6 the maximum window temperature can be calculated using the maximum heat flux of 17.605kW/m2, this is calculated as 473.5^{o}C as shown in Figure 7. This is the maximum radiant temperature as opposed to the gas temperature of 450 ° F (232 ° C) in citation 5. Note that this temperature is the peak and is reduced as the fire is suppressed.

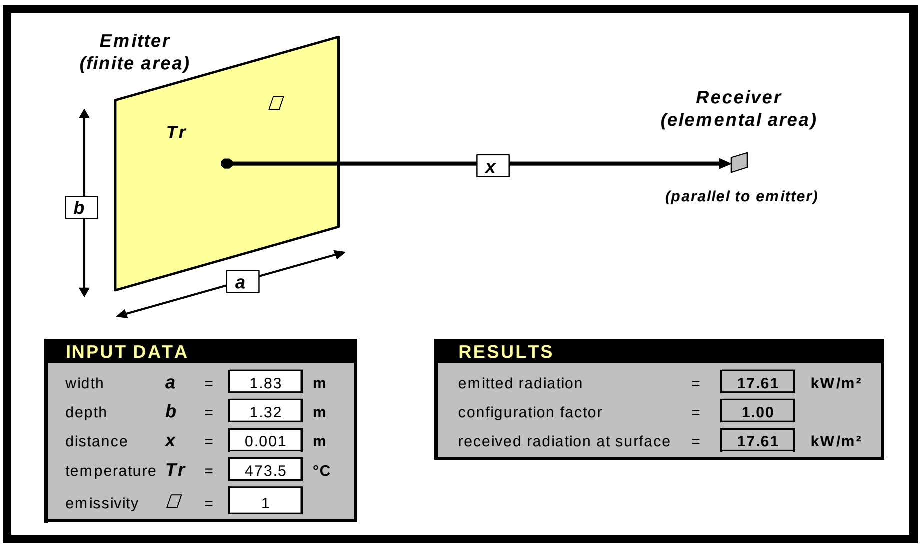


Figure 7 – Maximum Window Temperature Calculation

Now, further calculations can be carried out using the maximum (conservative) window radiant temperature for any selected scenario as follows:-

For example, with a window size of 2.7m high and 3.0m width:-

1. Addressing BCA Clauses C3.2 (a) (iii) and C3.3 for ignition of materials, where the maximum 17.6kW/m^2 heat flux occurs at 2.75 minutes as shown in Figure 6, the resultant heat flux on an opposite surface 1.4m away is less than 10kW/m^2 thus satisfying CV2 for readily ignitable materials such as curtains.

2. Addressing BCA D1.7(c) for a path of travel past the opening, data from the paper *Techniques for Assessing Industrial Hazards*, World Bank Technical Paper Number 55, World Bank, Washington, D.C., 1988 downloaded from www.fireriskforum.com advises that an incident radiant exposure of 1.6kW/m^2 causes no discomfort for long exposure.

   However because heat flux from the window only exceeds 1.6kW/m2 between 2 and 4 minutes as shown in Figure 6, it is unlikely that occupants will have commenced evacuation and would not likely to be passing the window during that time period.

3. Addressing the AS2419.1 requirement for hydrants and boosters to be greater than 10m from openings:-

   - Where a fire hydrant is 6.5m from the opening and using the maximum 17.6kW/m^2 heat flux occurring at 2.75 minutes as shown in Figure 6, the resultant heat flux is 1kW/m^2 thus meeting the Fire Brigade Intervention Model limit of 1kW/m^2 for "Routine Conditions".
   - Where a fire hydrant is 3.3m from the opening and using the maximum 17.6kW/m^2 heat flux occurring at 2.75 minutes as shown in Figure 6, the resultant heat flux is 3kW/m^2, the same heat flux expected from an unsprinklered building opening where the hydrant is 10m from the opening.

   The 2008 Commonwealth of Australia Productivity Commission Report on Government Services (Emergency Management in Table 10.12A, (http://www.pc.gov.au/__data/assets/pdf_file/0008/74672/attachment09.pdf recorded 90th percentile Fire Brigade response times in Queensland urban areas of between 10.9 and 13.1 minutes for the period 2002 to 2007. Accordingly it is unlikely that the Brigade would be in attendance within 10 minutes of fire start so it can be argued that the heat flux at the window would be negligible at that time – see Figure 6, and that a fire hydrant adjacent to the opening would be available for safe use.

Conclusion

It is the opinion of FSCS that considering the information provided in this paper and that where a building is sprinkler protected, the radiant heat flux emanating from a compartment fire can be considered to be negligible. However this paper considers that a "Performance Based Alternative Solution" by a Fire Engineer should be formulated in every case to meet the following Performance Requirements of the BCA, as appropriate, when addressing BCA Clauses C3.2 (a)(iii), C3.3, D1.7(c) and Verification Method CV2; and the location of fire fighting equipment near openings in buildings under Australian Standard AS2419.1:-

- CP2 in respect to fire spread; and
- CP3 in respect to fire spread and evacuation in a Class 9a and 9c building; and
- EP1.3 in respect to the operational requirements of the Fire Brigade; and
- EP2.2 in respect to protection of evacuation routes.

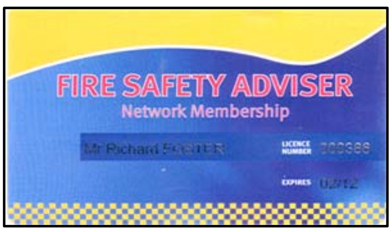
I trust that this paper provides information that you will find helpful.

Prepared by:

Richard A Foster Dip Mech Eng; Dip Mar Eng; MSFPE

Fire Safety Engineer,

Principal – Fire and Security Consulting Services



Version 2, April 2014. Section 4 title corrected from "Richmond" to "Redmond"