FIRE AND SECURITY CONSULTING SERVICES
ABN 67 166 244 105

17 McKenna Court
NOOSAVILLE
QUEENSLAND, 4566
AUSTRALIA

Phone: +61 (0)7 5455 5148, Mobile: 0409 399 190, Email: rafoster@bigpond.net.au

DEVELOPING DESIGN FIRES FOR ALTERNATIVE SOLUTIONS

Fire and Security Consulting Services (FSCS) is frequently asked about the design fires it uses in the Fire Engineering process.

It is incumbent on the Fire Engineer to consider whether or not the fire hazards present are within the normal range for the classification of the building because generally the Building Code of Australia (BCA) assumes that all buildings of the same Classification exhibit similar hazards in construction and fire loading. BCA Clause E1.10 states:-

E1.10 Provision for special hazards

Suitable additional provision must be made if special problems of fighting fire could arise because of-

(a) The nature or quantity of materials stored, displayed or used in a building or on the allotment; or

(b) The location of the building in relation to a water supply for fire-fighting purposes.

Design fires are required to be defined and agreed in the Fire Engineering Brief (FEB). However the International Fire Engineering Guidelines [1], Section 1.2.11.2 states:

"From the potential fire scenarios, the FEB team has to decide which scenarios are to be subjected to analysis. Usually, a number of severe scenarios which have a reasonable probability of occurrence and significant potential for loss (life, property, etc.) are selected for analysis. Care and judgement should be used to avoid unnecessarily analysing events with a very low probability of occurrence, but where the scenario may have very high adverse consequences, due consideration should be given if not for the primary analysis at least in the sensitivity studies."

Consequently only credible fire scenarios should be considered.

1 - General

t^2 Fires

Over the past decade, persons interested in developing generic descriptions of the rate of heat release of accidental open flaming fires have used a "t-squared" approximation for this purpose. A t-squared fire is one where the burning rate varies proportionally to the square of time. Frequently, t-squared fires are classed by speed of growth, labelled fast, medium, and slow (and occasionally ultra-fast). Where these classes are used, they are defined on the basis of the time required for the fire to grow to a rate of heat release of 1000 Btu/sec. The times related to each of these classes are as follow:

The general equation is shown below

$$\mathbf{q = at^2}$$

Where:

q = rate of heat release (normally in Btu/sec or kW)

a = a constant governing the speed of growth

t = time (normally in sec)

"t" values for the fire classes are as below:

Ultra-fast = 75 sec; Fast = 150 sec; Medium = 300 sec; Slow = 600 sec

Figure 1 below is a graphical representation of all the fire classes.

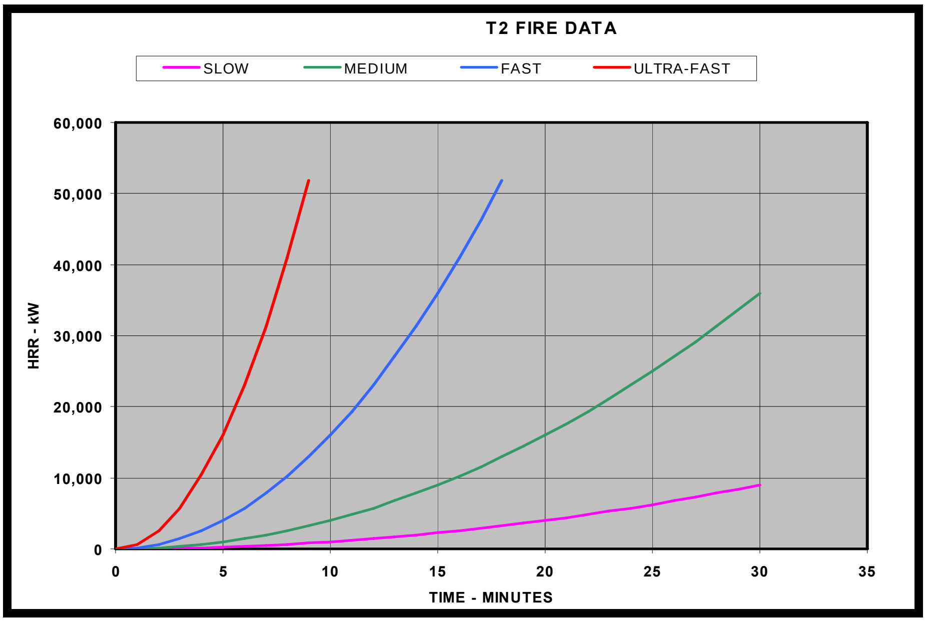

Figure 1 – All t^2 Fires

The fire growth characteristics are also influenced by the type of combustible material involved. NFPA 92B [2] provides guidelines on the fire growth characteristics for various combustibles. Generally the lighter the material such as plywood or polystyrene cups, the faster the growth rates whilst heavier materials such as solid hardwood, the slower.

Often the fire growth rate is expressed as the symbol α (from NFPA 92B) where, in relation to the graph above:-

- Ultra-fast fires have an α value of 0.18; and
- Fast fires have an α value of 0.045; and
- Medium fires have an α value of 0.015; and
- Slow fires have an α value of 0.0028.

2 - Maximum Convective Heat Output

AS1668.3 (2001) [3] – "*The Use of ventilation and air conditioning in buildings – Part 3 – Smoke control systems for large single compartments or smoke reservoirs*" provides design criteria to determine the maximum convective heat output (HRR).The approach is based on a modified fire curve (a sixth order polynomial function) initially generating a parabolic curve, which falls back into the t^2 fire curve for a time before it peaks and decays. After initial alignment with the selected fire load and curve, the rate of radial increase is adjusted so that the relationship of the family of curves generated more appropriately relates to the likely range of fire loads which may be encountered - Figure 2 below shows Figure B1 from AS1668.3.

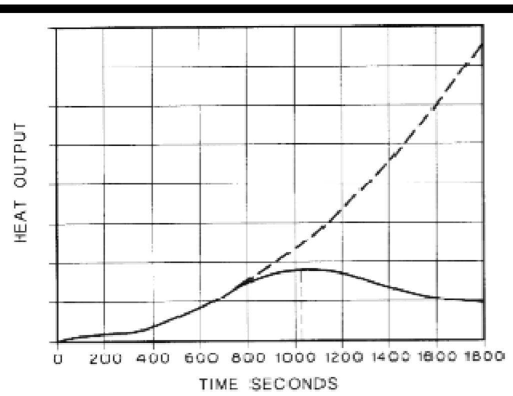

FIGURE B1 RELATIONSHIP BETWEEN A TYPICAL ALPHA TEE-SQUARED FIRE (DOTTED LINE) AND THE EQUATION (B2)1 POLYNOMIAL (SOLID LINE)

Figure 2 – Figure B1 from AS1668.3

Figure 3 below shows the results for storage of goods 2.5m high in an unsprinklered warehouse. The AS1668/3 algorithm results in an α value of 0.075 with a maximum HRR of 58.18 MW. Therefore the Fire Engineer can use a “medium” fire in a computer4 model and cap the HRR at 58.18MW.

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MAXIMUM FIRE SIZE CALCULATION IN ACCORDANCE WITH AS1668.3 FOR SINGLE COMPARTMENT FIRES

PROJECT	FUNNYFACE TOY IMPORTS
AREA ASSESSED	WAREHOUSE
STORAGE CONFIGURATION	BLOCK STORAGE - 2.5M HIGH - NO SPRINKLERS
NOTE - GENERAL STORAGE FIRE LOAD IS 1,000 MJ/M^2 PER METRE HEIGHT OF STORAGE	

STEP 1 - CALCULATE COEFFICIENT OF FIRE GROWTH		
FIRE LOAD DENSITY q_f MJ/M^2	2,500	FROM INTERNATIONAL FIRE ENGINEERING GUIDELINES
CONFIGURATION FACTOR c_f	1.5	GENERAL = 1; STORAGE >2.5M = 1.5,
FIRE GROWTH RATE α	**0.075**	FORMULA FROM AS1668.3 Apendix B3.1

INTERVENTION TIME - SECS	1020	FIRE BRIGADE OR SPRINKLERS "WATER ON FIRE"

STEP 2 - CALCULATE MAXIMUM FIRE SIZE		
CONVECTIVE HRR = Q_c Kw	58,184	FROM AS1668.3 APPENDIX B2.1
OR **Q_c MW**	**58.18**	t_m = FIRE BRGADE INTERVENTION OR MAX1,020 SECS

STEP 3 - CHECK FOR FLASHOVER		
t_f = TIME TO FLASHOVER - SECS	**881**	FORMULA FROM AS1668.3 Apendix B2.2.1

Figure 3 – HRR Calculation using AS1668.3

3 - Fuel and /or Ventilation Controlled Fires

The fire growth only represents the ‘rate of fire growth” assuming that the fuel load is unlimited and the fire is not constrained by limited ventilation, i.e. it reaches flashover.

Most fires are either limited by fuel load or ventilation so the next step in determining the design fire is to determine where the fire growth should be capped. This requires research and judgement considering the total fuel load and available ventilation.

Quantitative assessment is frequently used is in respect to the fire resistance of the bounding construction of compartment. The method of analysis, as described by Buchanan [4], calculates an actual fire time-temperature regime, dependent on compartment geometry, fire load, and ventilation characteristics. This is then compared to the standard time temperature regime as defined by AS1530.4 [5].

The majority of data inputs are determined by the building design (e.g. floor area) however the fire load must be assumed. The Fire Safety Engineering Guidelines nominates a fire loads for various occupancies.

Ventilation controlled fire sizes can be estimated using the formula $Q_v = 2.16 \times Av \times h_v^{1/2}$. [Formula from Fire Engineering Guidelines]. This is transposed on to an “Equivalent Fire Severity” calculation sheet as shown in Figure 5 below.

FIRE & SECURITY CONSULTING SERVICES	*EQUIVALENT FIRE SEVERITY CALCULATION* (Fire Engineering Design Guide method)	CLIENT	MOONSHINE BREWERY
		PROJECT	

Compartment Dimensions						
Floor Width	47.87	m	**NEW WAREHOUSE**			
Floor Length	79.245	m	Floor area	3793.46	m^2	
Height	7.9	m	Internal area	9595.33	m^2	
Ventilation						
Wall Openings			***Roof Openings***			
Mean Height	1.2	m				
Width	43	m	Length	81	m	
Area	51.60	m^2	Width	0.6	m	
			Area	48.60	m^2	
Calculated Factors						
alpha v	0.025		Av/Af			Buchanan Eqn 6.5
alpha h	0.013		Ah/Af			Buchanan Eqn 6.6
bv	15.62		12.5 (1 + 10 alpha v - alpha v^2)			Buchanan Eqn 6.7
Wf	1.94	m^ -0.3	(6.0 / H)^0.3 [0.62 + 90 (0.4 - alpha v)^4 / (1 + bv. alpha h)]			Buchanan Eqn 6.4
Fire Load Energy Density ef						
			FIRE ENGINEERING GUIDELINES DATA			
Fire Load Energy Density ef	1500	MJ/m^2	HOTEL B'ROOM 300	MANF STORAGE	1,180	
			DWELLING 500	LIBRARY	1,500	
FROM AS1668 USING 1.5 FACTOR			OFFICE 420	SCHOOL	285	
FOR STORAGE >2.5M			SHOP 600	CARPARK (2 CARS)	800	
			MANUFACTURING 300	CAR PARK STORAGE	700	
				Construction:		
Conversion Factor, k_b	Type Used			steel	0.045	
k_b	0.055	min m^2.3 /MJ		concrete / plasterboard	0.055	
				insulation	0.09	
Equivalent Fire Severity, t_e						
Equivalent Fire Severity	**te**		**159.8 mins.**	**ef . kb. wf**		Buchanan Eqn 6.3
Total Fuel Load	E		5,690,187 MJ	Af . ef		
Equivalent Average Heat Release Rate, Qe			593.6 MW	T / te		Buchanan Eqn 6.8
Temperature (AS 1530.4)			1092 °C			
Thomas' Flashover Correlation						
Total fuel load, E =			5,690,187	MJ		
Calorific value of wood, ha =			16	MJ/kg		
Wood equivalent mass of fuel, M=E/ha =			355,637	kg		
Area of vertical openings, Av =			51.6	m^2		
Height of vertical openings, h =			1.2	m		
Approximate burning rate, m'=5.5.Av.h^0.5 =			310.9	kg/min		
Internal suface area, At=2(Af+H(L+W))=			9595.3333	m^2		
Duration of burning, tb=M/m' =			1144	mins		
Ventilation controlled heat release rate, Qv =			4,974	MJ/min		
Qv =			82.9	MW		
Thomas Flashover Correlation, Q_{fo}=0.0078 At+0.378 Av h^0.5 =			96.2	MW		
	Flashover will not occur as Qv<Qfo					

Figure 5 – Typical Equivalent Fire Severity Calculation

4 - Flammable and/or Combustible Liquids

Where flammable (eg. petrol) or combustible (eg. diesel) liquids are involved, the growth rate is such that the closer the flash point is to the ambient temperature the faster the growth rate. Fuels such as petrol and diesel will exhibit ultra-fast characteristics. Goods such as rubber tyres will exhibit a slow initial growth rate but as the core temperature of the type increases the oil volatiles in the rubber will increase and the growth rate will change to fast or even ultra-fast.

Figure 6 below is the HRR calculation of a diesel oil spill from a vehicle in a warehouse. Note that the spreadsheet is based on US imperial units where 1 US gallon is 3.97 litres.

INPUT PARAMETERS

Fuel Spill Volume (V)	252.00	gallons
Fuel Spill Area or Dike Area (A_{dike})	1922.00	ft^2
Mass Burning Rate of Fuel (m")	0.045	kg/m^2-sec
Effective Heat of Combustion of Fuel (□$H_{c,eff}$)	44400	kJ/kg
Empirical Constant (k□)	2.1	m^{-1}

Calculate

Heat Release Rate Calculation

Reference: *SFPE Handbook of Fire Protection Engineering, 3rd Edition, 2002, Page 3-25.*

$Q = m''\Delta H_{c,eff}\,(1 - e^{-k\beta D})\,A_{dike}$

Where Q = pool fire heat release rate (kW)

m'' = mass burning rate of fuel per unit surface area (kg/m^2-sec)

$\Delta H_{c,eff}$ = effective heat of combustion of fuel (kJ/kg)

$A_f = A_{dike}$ = surface area of pool fire (area involved in vaporization) (m^2)

$k\beta$ = empirical constant (m^{-1})

D = diameter of pool fire (diameter involved in vaporization, circular pool is assumed) (m)

(Liquids with relatively high flash point, like transformer oil require localized heating to achieve ignition)

Pool Fire Diameter Calculation

$A_{dike} = \pi D^2/4$

$D = \sqrt{4A_{dike}/\pi}$

Where A_{dike} = surface area of pool fire (m^2)

D = pool fire diamter (m)

D = **15.078** m

Heat Release Rate Calculation

$Q = m''\Delta H_{c,eff}\,(1-e^{-k\beta D})\,A_{dike}$

Q = **356762.17** kW **338146.32** Btu/sec

Figure 6 – HRR Calculation for Diesel Oil Spill

5 - Real Fire Tests

Instead of relying solely on assumed fire growth rates and what cap to apply, FSCS in its standard assessment procedures researches fire test data from various International bodies which have conducted real fire experiments and live fire tests to be used a the basis of design fires. Sources of this research include:

- US National Institute of Standards and Technology (NIST) [6]
- SP Technical Research Institute of Sweden (SNTRI) [7]
- SINTEF NBL (Norwegian Fire Research Laboratory) [8]
- National Research Council Canada (NRC) [9]
- FM Global (Factory Mutual) [10]

These tests are usually conducted using full scale free burn testing under an “Industry Calorimeter” where the HRR and products of combustion are gathered and analysed.

Examples of the above are provided below.

a. For the first example, let’s say we have a call centre in an office building where an entire floor is taken up by 60 computer workstations.

The potential fire size for office workstations can be determined from available test data. As an example, NIST tests on a two panel workstation determined the following free burn characteristics.

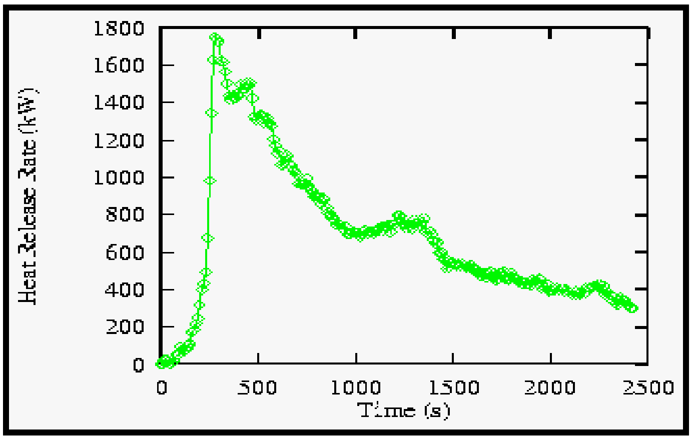

Figure 6 – Two Panel Workstation – Fire Growth

Figure 7 below shows real time photographs of the NIST test and it is interesting to see that from one minute onwards, how quickly the fire grows. Whilst some fire engineers would settle on a peak HRR of 1.8MW, this fire growth rapidly increases the convective and radiative effects, and ultimately the conductive effects of the fire which surely will cause adjacent workstations to become involved. Accordingly FSCS considers fire spread as discussed later.

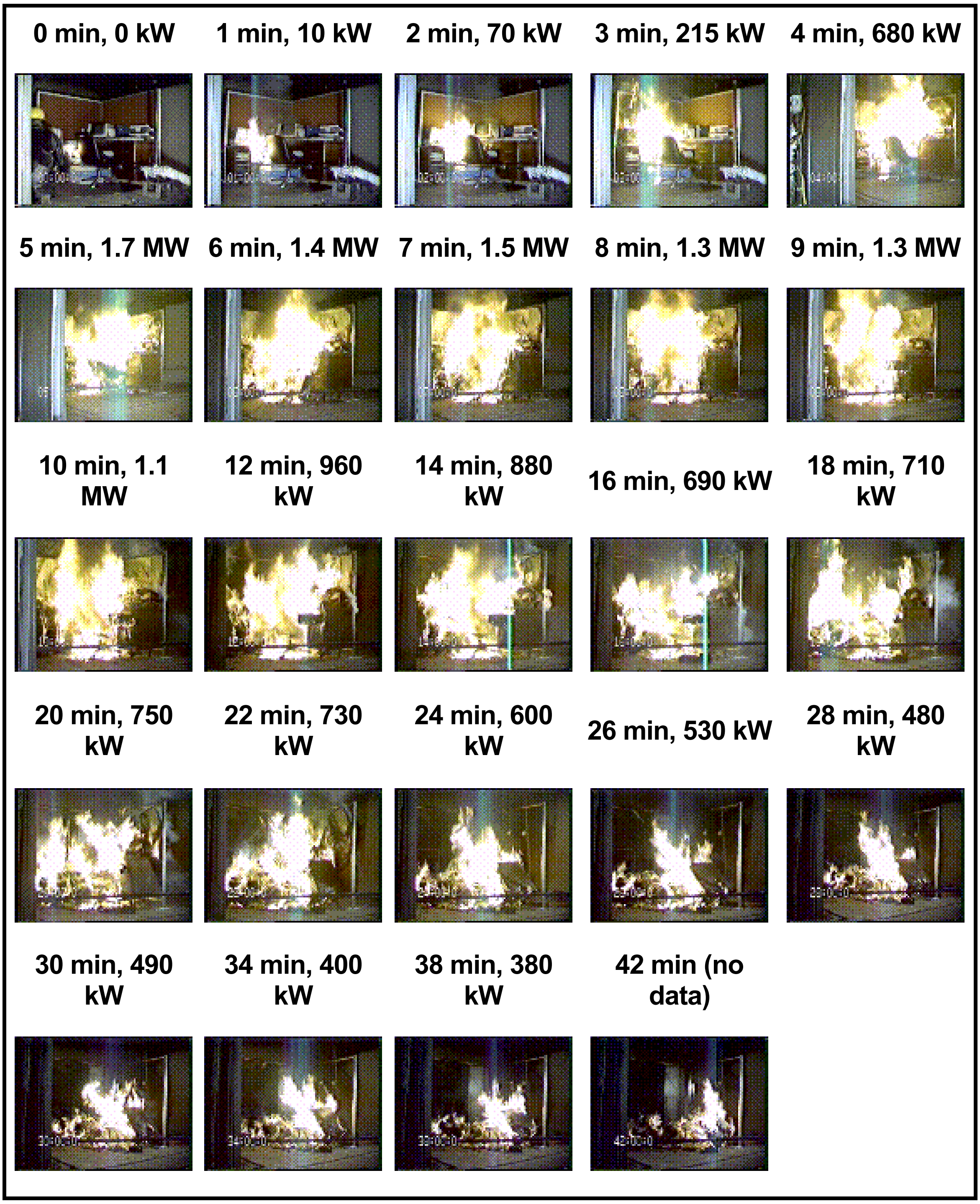

Figure 7 – NIST Tests of Two Panel Workstations

Note that the NIST fire test does not contemplate fire spread from the test array to other combustibles in a fire compartment but it is useful in providing data on fire spread and growth as discussed later.

Obviously fire will spread beyond the initial two panel workstation fire, and calculations should be carried out based on a conservative assumption that an adjoining workstation will become involved in the fire every 30 seconds. Figure 8 below represents this cumulative fire growth for a period of 30 minutes in which time a total of

60 workstations will be burning. Note that this scenario takes into account the burn-out and decay of the fire in each workstation as the fuel is consumed, and that the fire is not ventilation controlled.

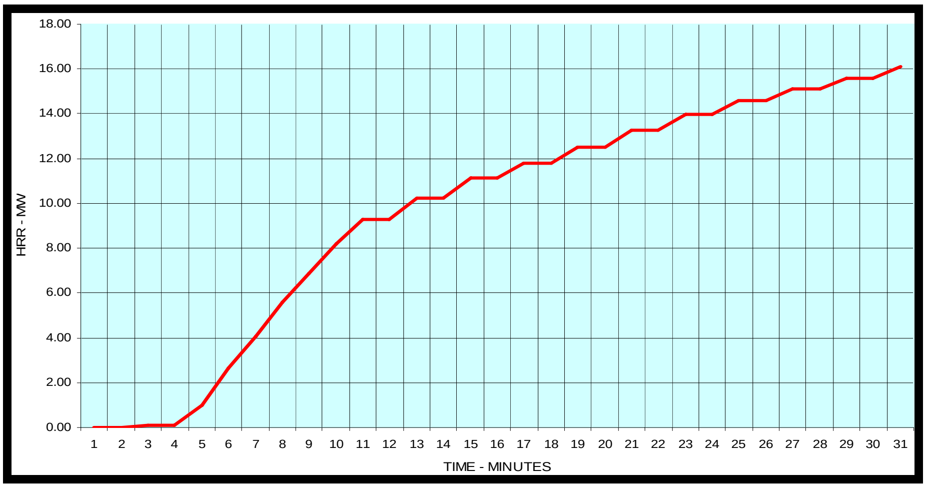

Figure 8 – Cumulative Fire Growth

A comparison of the fire growth data between the growth curves in Figure 6 and the extrapolated NIST test data for fire growth to additional workstations (Figure 8) is depicted in Figures 9 and 10 below

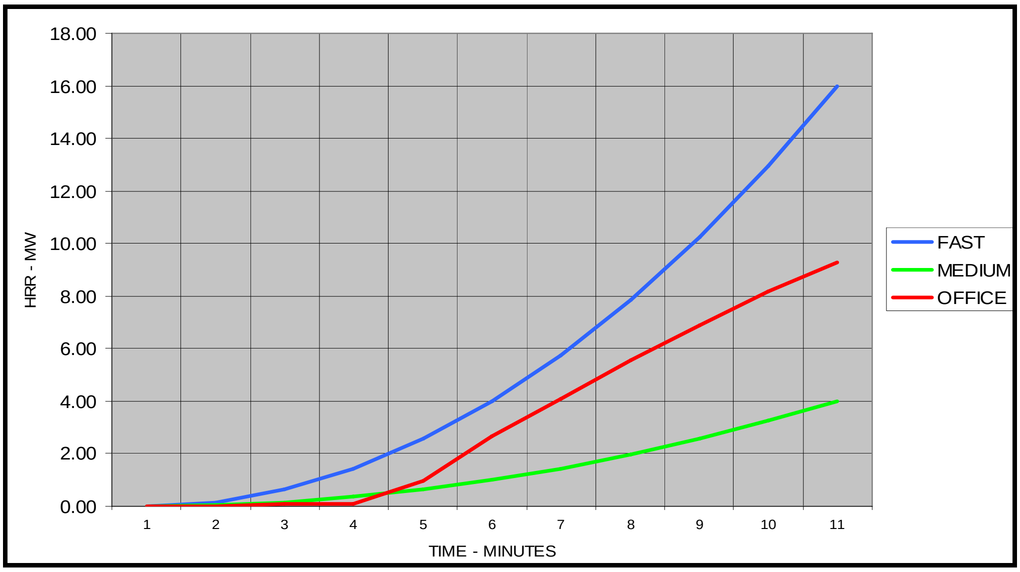

Figure 9 – Fire Growth Comparisons First 10 minutes

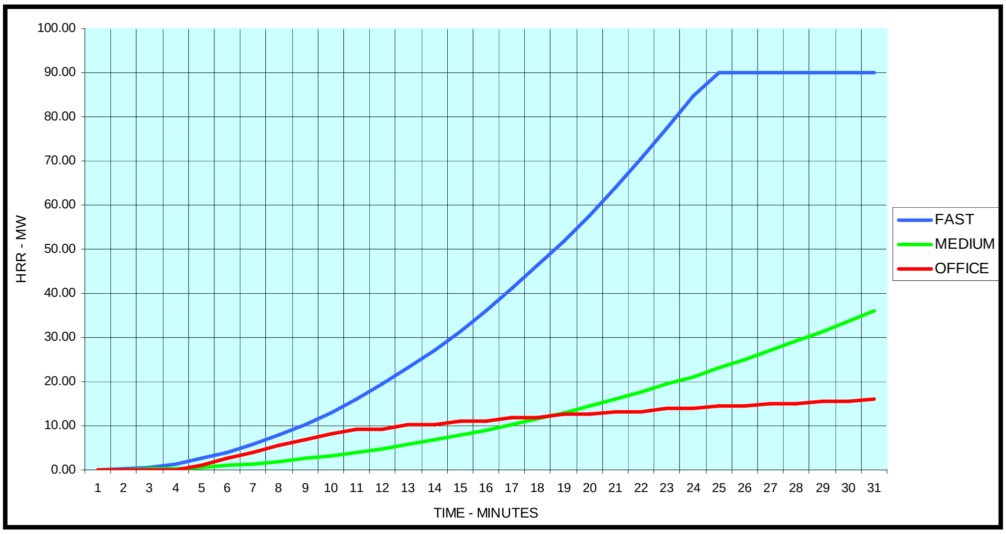

Figure 10 – Fire Growth Comparisons First 30 minutes

It can be seen that in the first four minutes the NIST test fire growth is slower than the 'medium' fire. At four minutes, the HRR of the NIST test fire grows at a rate somewhere between 'fast' and 'medium' fires. At six minutes the NIST test fire is decaying.

From the above, the fire growth would be somewhere between a 'medium' and a 'fast' fire.

Based on the preceding data, FSCS would formulate the following design fire using the following inputs.

- A fire growth equating to the NIST test data but extrapolated to include fire spread to adjoining workstations.

- After 30 minutes – fire continued at the same rate to a point where it reaches 20.8MW for flashover and thence to 23MW for a fully developed ventilation controlled fire is established and the HRR remains constant.

- Decay is not contemplated.

This approach is consistent with the Fire Engineering Guidelines.

The input data discussed results in a design fire represented in Figure 11 below, the values for the period beyond 30 minutes are considered to level off at between 14.6MW and 23.1MW dependant on fire spread and window breakage. As a conservative measure 23.1MW should be used as the maximum fire size.

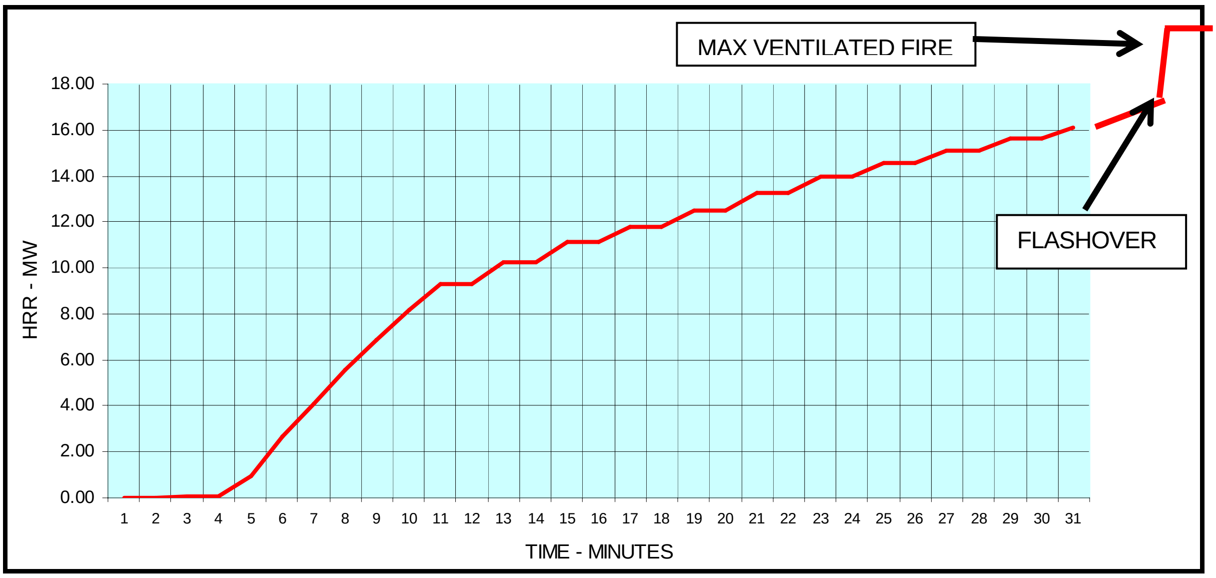

Figure 11 – Office Design Fire

From the input data and Figure 11 it is estimated that Flashover will occur at approximately 35 minutes and reach the maximum ventilated fire size at 40 minutes.

b. For the second example, let's say we have a warehouse where metal parts are stored in cardboard cartons on racking 4.0m high.

The SP Technical Research Institute of Sweden (SNTRI), in their publication "*Commodity Classification Tests of Selected Ordinary Combustible Products – Project 620 – 001"*[1] *tested* empty cardboard cartons to determine sprinkler application densities. Interestingly, a "free burn" test was conducted, the results of which are reproduced in Figure 12 below.

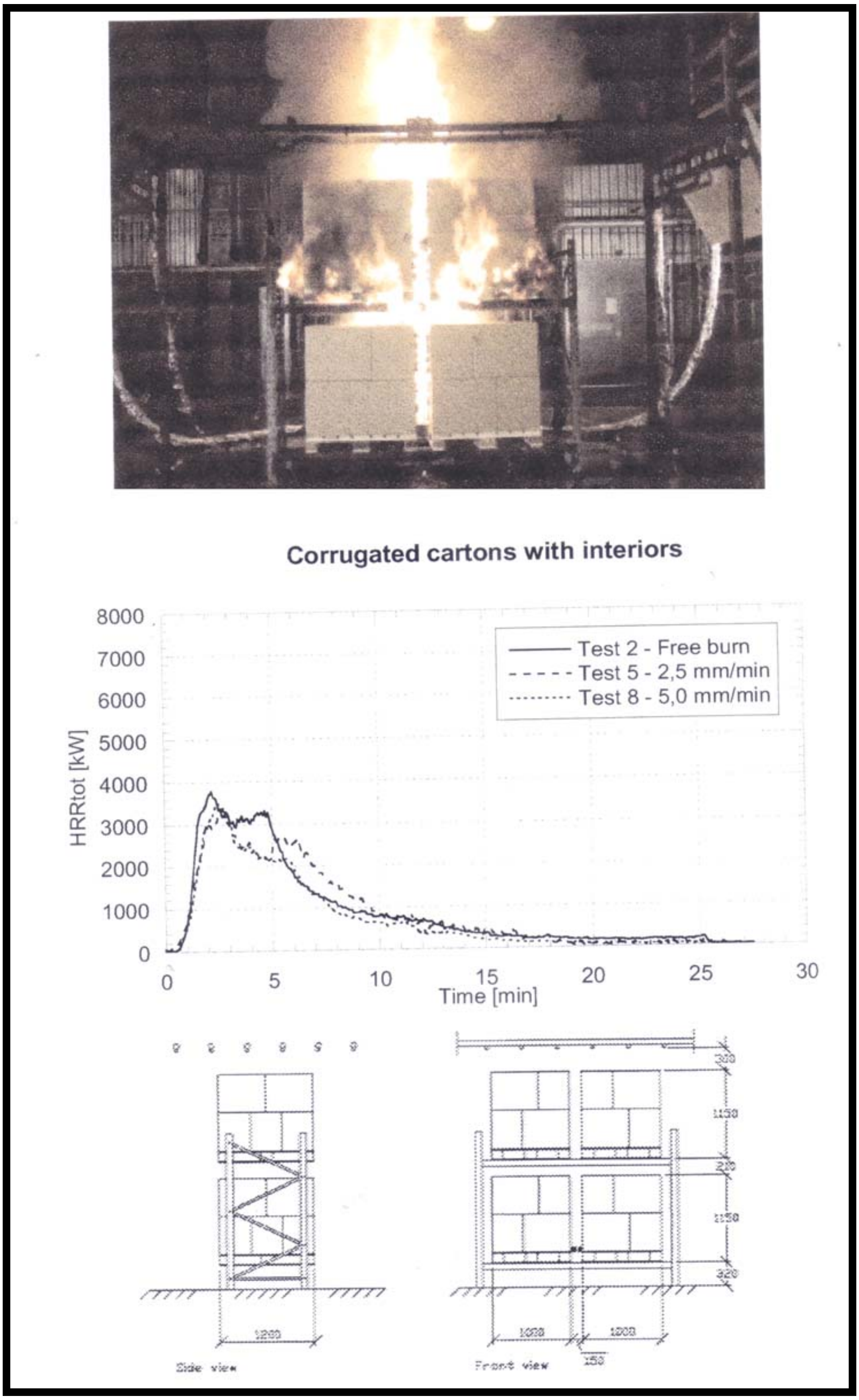

Figure 12 - SNTRI Free Burn Cardboard Cartons.

From these test results it is possible to develop a fire growth curve as shown in Figure 13. As a conservative measure, the HRR curve at 12MW is extended indefinitely. Note that this test is for storage of 2.3m in height.

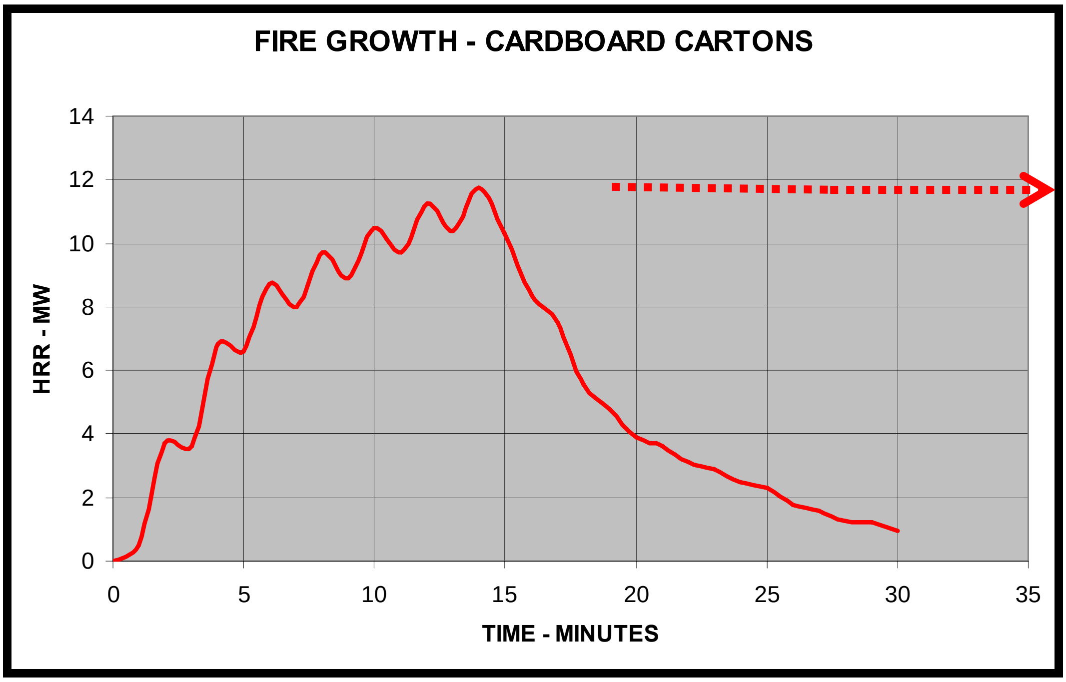

Figure 13 – Carton Fire HRR

c. For the third example, let's say we have a warehouse where goods with plastic wrappings are stored in cardboard cartons on racking between 4 and 6 pallets high. In this example it is assumed that the warehouse is protected by Storage Mode Sprinklers (previously known as Early Suppression Fast Response (ESFR) sprinklers) to FM Global requirements.

In this case, FSCS references tests by the Swedish National Testing and Research Institute (SNTRI) on rack storage of four (4) pallets (1,200 L x 1,000 w x 1,000 H)) of cardboard boxes containing plastics. During free burn a maximum fire intensity of 6MW was reached with the fire decaying to less than 1MW at 13 minutes due to fuel limitation. The total Heat Release Rate (HRR (tot)) results from the SNTRI tests are shown in Figure 14 below.

The objective of this selection is to determine the fire growth for use in the computer fire modelling. Note that the SNTRI "free burn" fire growth is consistent with the NFPA92B ultra-fast growth curves shown in Figure 9, the red and blue lines of the ultra-fast and fast growth rates superimposed on the SNTRI data.

This confirms the validity of the selection of an ultra-fast fire for modelling.

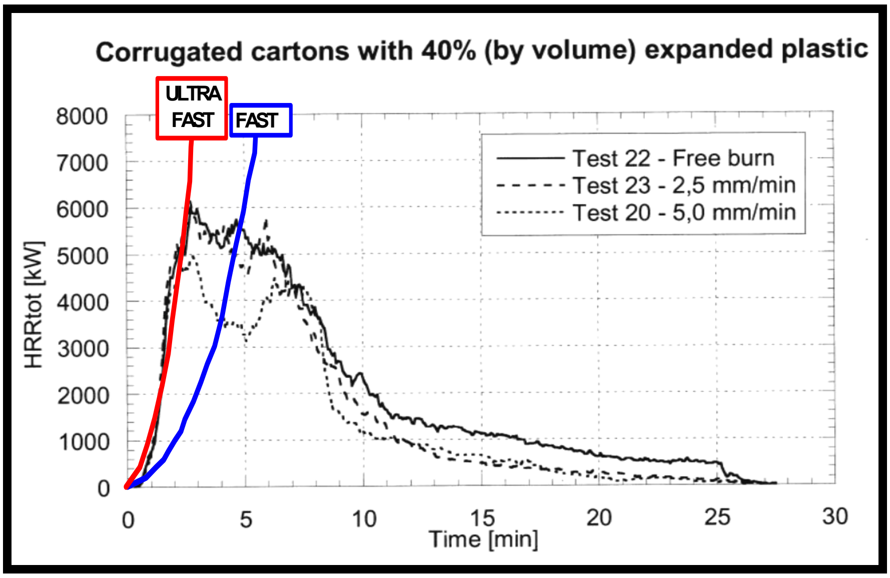

Figure 14 SNTRI HRR Data

Whilst this fire growth is valid for the rack storage, the general suppression algorithms use by Branz [11] and FDS [12] cannot model the rate and extent of fire suppression. In this case FSCS references actual fire tests carried out by FM Global. A typical FM Global test is shown in Figures 15 and 16 below. Note that the FM Global test hall uses a cone calorimeter to collect and analyse heat release rates and combustion products (species).

Figure 15 – FM Test

Figure 16 – FM Free Burn

A typical results sheet from a series of tests is reproduced in Figure 17 below. Certain portions have been obscured to protect the confidentiality of the supplier. You will also note that the RTI has been superimposed as "50" This is because the nominal RTI for ESFR sprinklers is 50 (28 metric), but the actual RTI of each manufacturer is somewhat systems is somewhat lower.

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FM APPROVALS
Project ID:

Data Table 2 Full Scale Fire Test Summary

	TEST #1	TEST # 2	TEST # 3	TEST # 4
Date				
Commodity or Type of Fuel	Standard Plastic	Standard Plastic	Standard Plastic	Standard Plastic
Arrangement or Storage Method	Double Row Rack	Double Row Rack	Double Row Rack	Double Row Rack
Array Size (W x L)	2 x 4	2 x 7	2 x 6	2 x 6
Number of Tiers	4	5	8	7
Stack Height (ft-in.)	19-8	24-8	39-8	34-8
Ceiling Height (ft)	30	30	45	45
Clearance to Ceiling (ft-in.)	10-4	5-4	5-4	10-4
Clearance to Sprinklers (ft-in.)	8-10	3-10	3-10	8-10
Aisle Width (ft)	N/A	4	4	N/A
Ignition Centered Below (Number of Sprinklers)	1	2[1]	2	1
Sprinkler Nominal Orifice Size (gal/min/psi$^{1/2}$)	25.2	25.2	25.2	25.2
Sprinkler Temperature Rating (°F)	165	165	165	165
Sprinkler Nominal RTI ((ft-sec)$^{1/2}$)	NOMINAL 50			
Sprinkler Spacing (ft x ft)	10 x 10	10 x 10	10 x 10	10 x 10
Constant Water Pressure (psi)	20	20	50	50
Minimum Discharge Density (gal/min/ft^2)	1.13	1.13	1.78	1.78
First Sprinkler Operation (min:sec)	0:32	0:49	0:54	0:45
Last Sprinkler Operation (min:sec)	0:32	0:56	1:01	0:45
Total Number of Sprinklers Opened	1	4	6	1
Peak/Maximum One Minute Average Steel Temperature (°F)	73/72	213/212	130/125	56/56
Peak/Maximum One Minute Average Plume Velocity (ft/sec)	16.52/6.06	23.14/14.73	21.74/10.52	18.29/5.33
Peak/Maximum One Minute Average Heat Flux (Btu/sec^2)	0.11/0.00	0.99/0.56	0.21/0.07	0.06/-0.02
Time of Aisle Jump (min:sec)	N/A	N/A	N/A	N/A
Equivalent Number of Pallet Loads Consumed	less than 1	3	5	less than 1
Test Duration (min)	5	20	9	4

(1) For test #3, one of the two sprinklers closest to ignition was rendered inoperative. The inoperative sprinkler was located over the aisle space that separates the test array from the target.

Figure17 – Typical ESFR Test Results.

There are a number of items of interest in the test results shown above and if we examine Test No.3, we can see that a total of six sprinklers operated; the first at 54 seconds and the last at 61 seconds. During that time period a total of five pallets of 'Standard Plastic" commodity was consumed.

From these test results it is possible to develop a fire growth and suppression curve as shown with the red graph in Figure 18. Note that as a conservative measure, the HRR is extended at 0.5MW for the duration of the modelling.

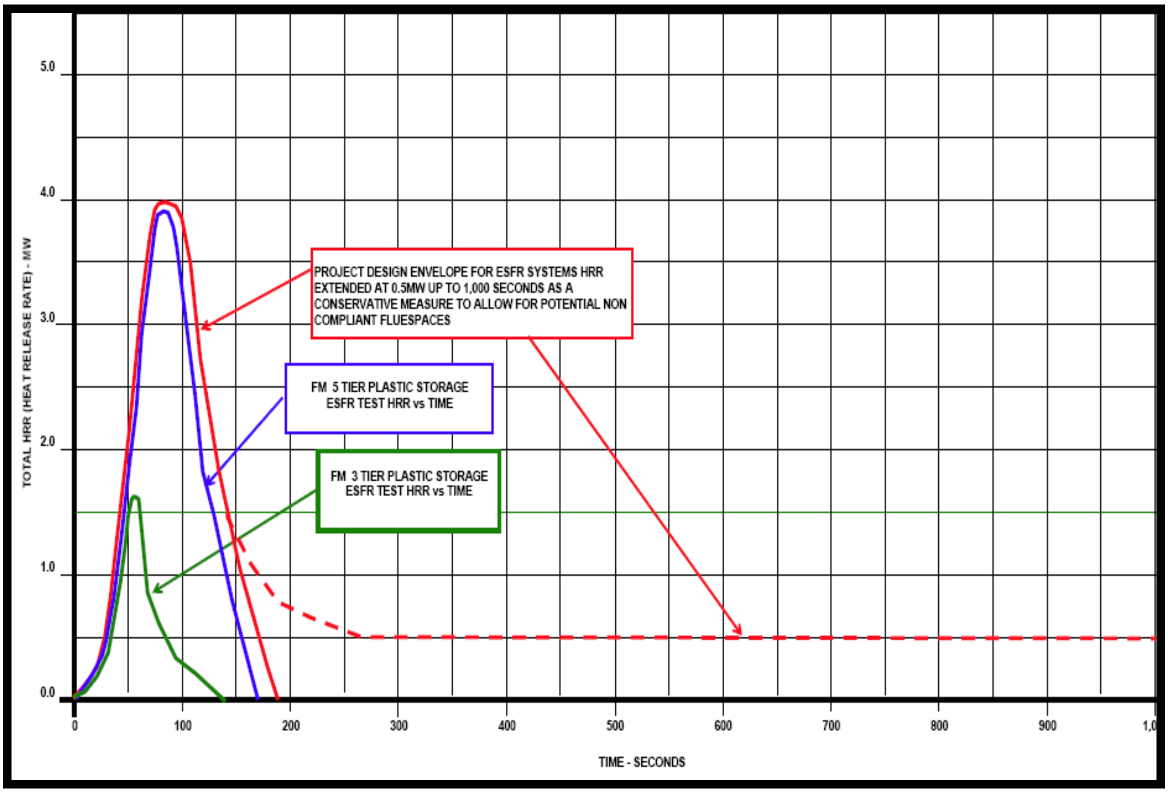


Figure 18 – ESFR Design Fire

6 - Car Park Fires

Figure 19 shows the BranzFire [11] database input for an Opel (Holden) Vectra with Figure 20 showing the burn test. This is a modern car with extensive external and internal thermoplastic body parts and trim, which is significantly more representative that many of the car fire test data hitherto used by fire engineers.

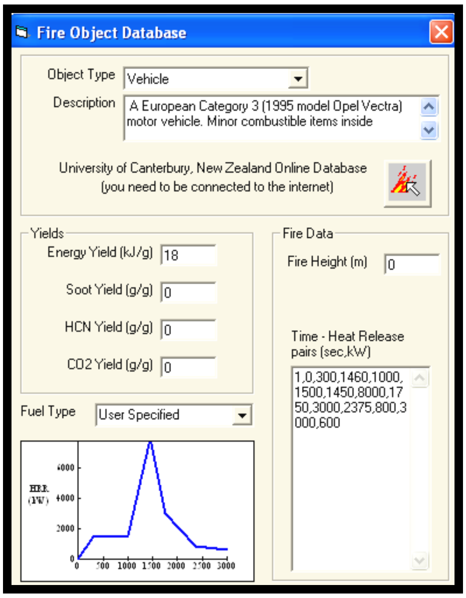


Figure 19 – Branz database

Figure 20 - Freeburn

Generally, the risk of fire spread within a car park is considered to be low. In most cases a fire will be a single car fire.

Fire spread between cars in a car park is a low probability event. Statistical data examined by Denda [8] for fires in USA car parks indicates that fire spread is of a low probability. The data examined was based upon 404 car park fires of which only 28 spread from the vehicle of origin to another vehicle (7%). The extent of fire spread indicated by Denda is:

- Spreads to 1 other vehicle (i.e. 2 cars) – 18 fires out of 404 (4.5%)
- Spreads to 2 other vehicle (i.e. 3 cars) – 8 fires out of 404 (2%)
- Spreads to 3 other vehicle (i.e. 4 cars) – 1 fire out of 404 (0.2%)
- Spreads to 4 other vehicles (i.e. 5 cars) – 1 fire out of 404 (0.2%).

Fire growth data for single cars data is transposed into Figure 21 representing a two car fire with ignition of the second car five minutes after ignition of the first car. This shows a 1-car fire peaking at 8MW and a 2-car fire peaking at 12MW. The standard "Medium" fire growth curve is also shown thus demonstrating the correlation between the Medium fire and the two car fire in terms of growth.

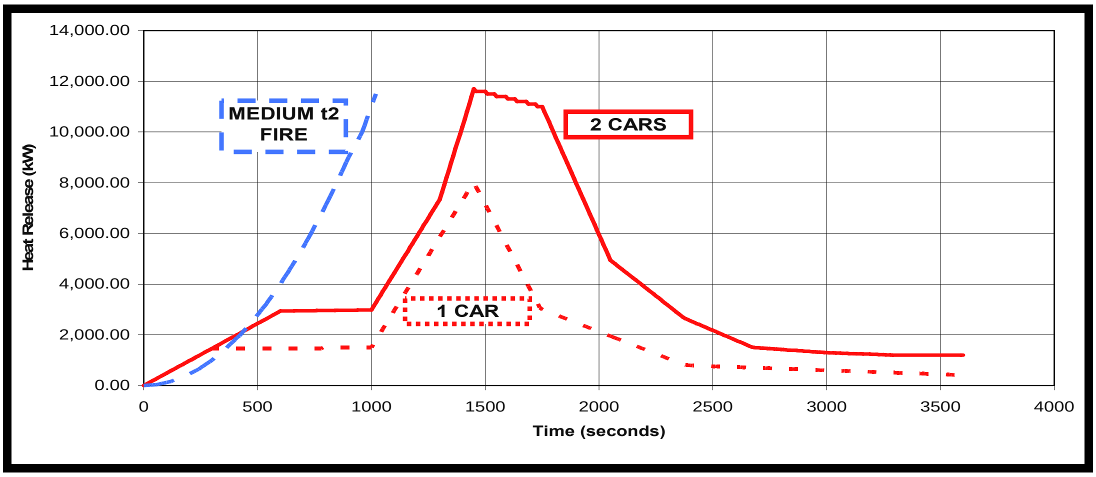


Figure 21 - Two car design fire

QFRS have indicated that their experience is that modern car fires involving the extensive use of thermo-plastics in external bumpers and trim necessitates the analysis of a potential 3 car fire. Accordingly FSCS has extrapolated the car fire data to involve a third car. The HRR profile for this scenario is shown in Figure 22 below. This shows a 3 car fire peaking at 21MW

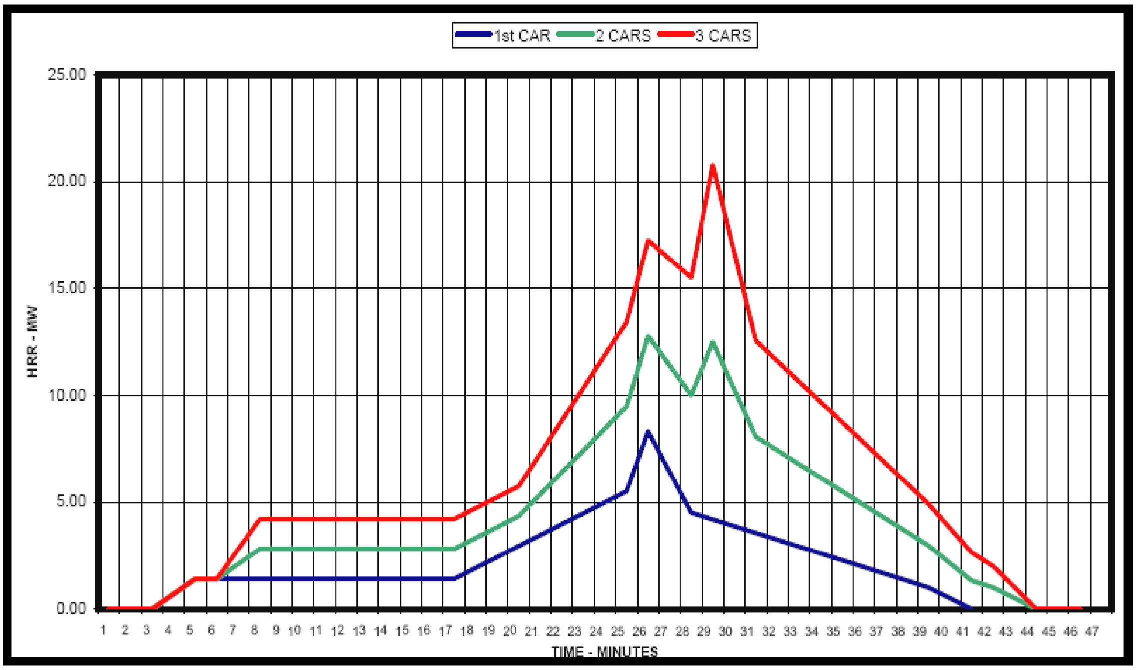


Figure 22 – 3 Car Fire

7 - Fire Control or Suppression

a - General

The Fire Engineering Guidelines for the control and/or suppression of fires in compartments where sprinkler systems are installed. This is shown diagrammatically in Figure 23 below:

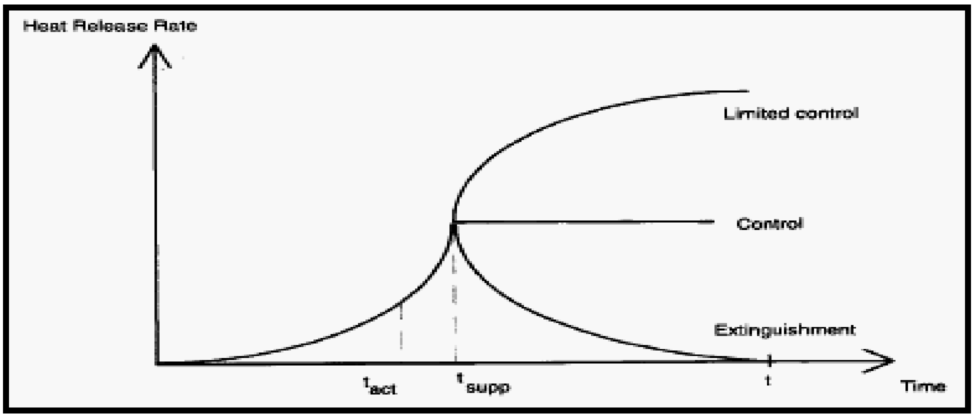


Figure 23 – Sprinkler Control and Suppression

For the Fire Engineer, the distinction between Control and Suppression may be important in the evaluation of such life safety features of large buildings including smoke control and egress.

b - Control Mode Sprinklers

Automatic sprinkler systems in accordance with AS 2118.1 [13] can be at least expected to control a fire at the time of the first sprinkler operation, at which point the fire size can conservatively be assumed to maintain a constant heat release rate (HRR) after sprinkler activation, see Figure 23. This is consistent with advice in both the Fire Engineering Guidelines and AS1668.3.

It is incumbent on the fire engineer however to moderate such sprinkler operating time by assuming that the nearest sprinkler to the fire is “skipped” (does not operate).

Sprinkler spacing for **Light Hazard and Ordinary Hazard Group 1** reproduced in Figure 24 below is based on AS2118.1. Based on this spacing and conservatively assuming that the nearest sprinkler to the fire source does not operate, the distance to the nearest operating sprinkler is to be modeled at 2.6m and 1.8 m respectively.

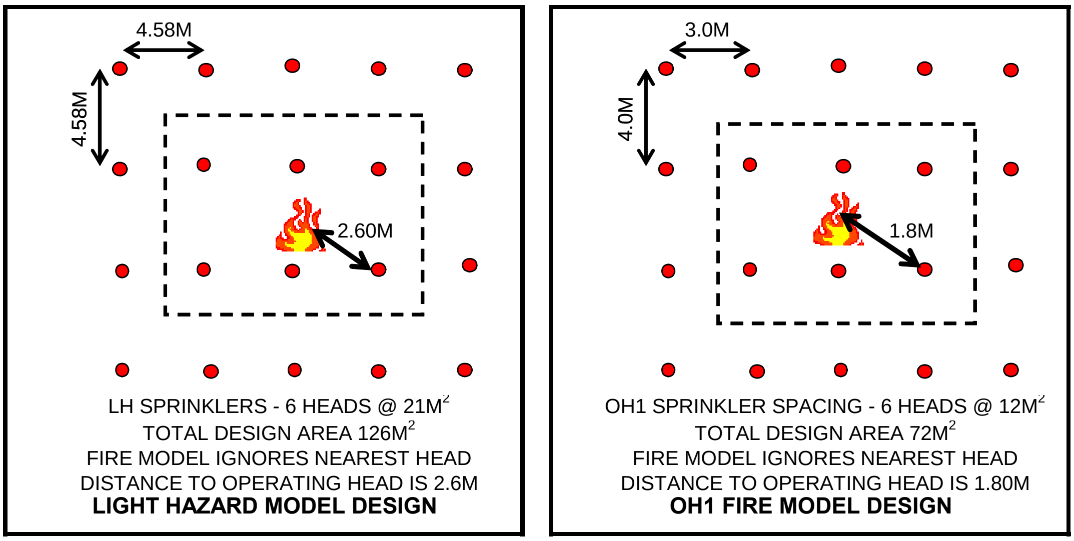


Figure 24 – Sprinkler Spacing – LH & OH1

Sprinkler spacing for **Ordinary Hazard Groups 2 and 3** reproduced in Figure 25 below is based on AS2118.1. Based on this spacing and conservatively assuming that the nearest sprinkler to the fire source does not operate, the distance to the nearest operating sprinkler is to be modeled at 1.8m.

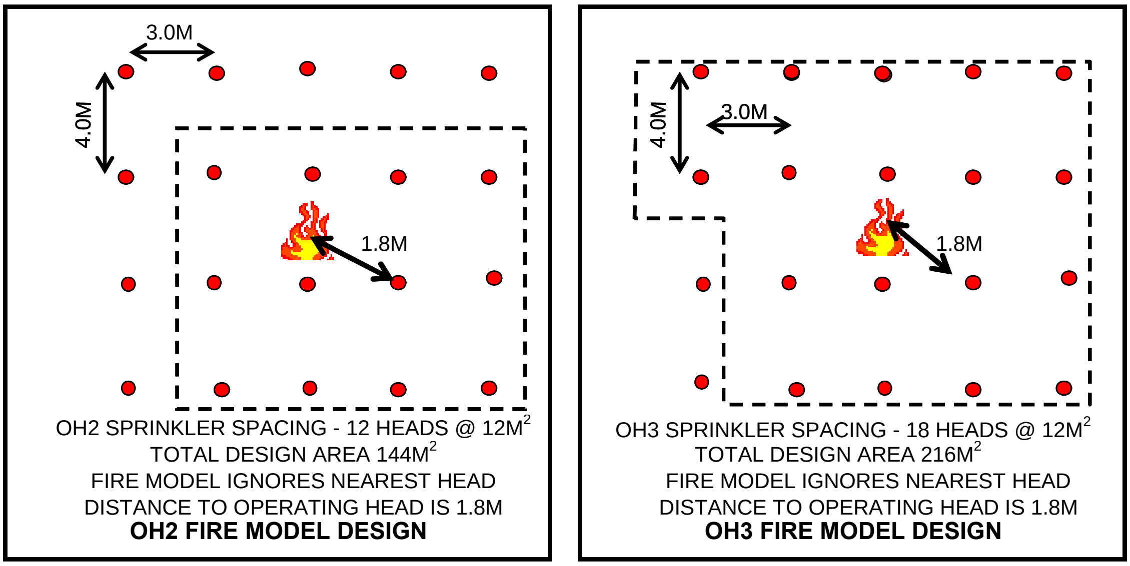


Figure 25 – Sprinkler Spacing – OH1 & OH3

Sprinkler spacing for **High Hazard and ESFR** reproduced in Figure 26 below is based on AS2118.1 and FM Global Data Sheets respectively.

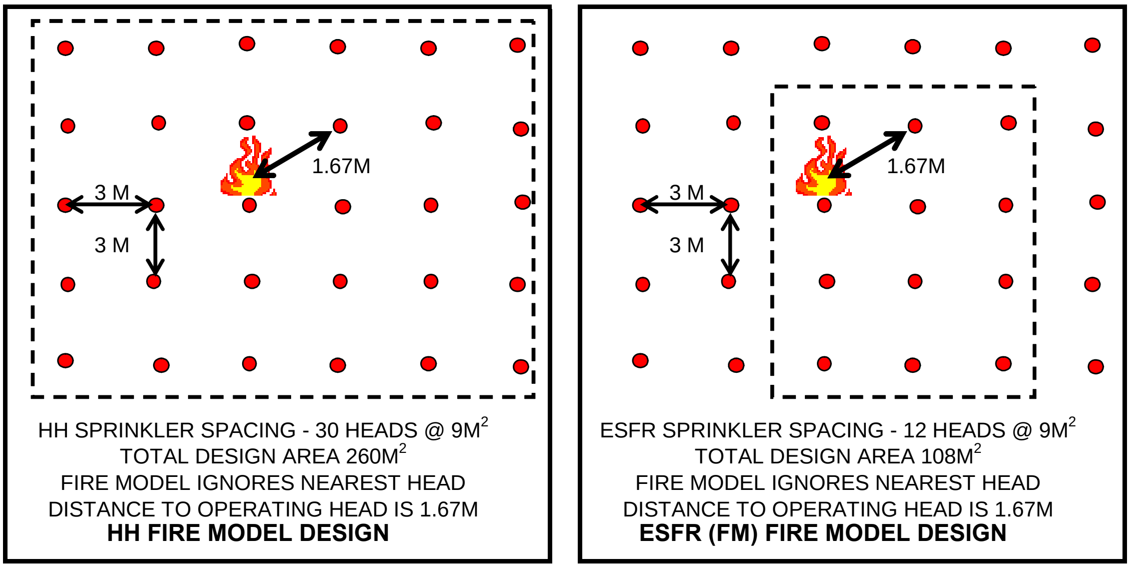


Figure 26 – Sprinkler Spacing – HH & ESFR

It is important to note that the reader should reference AS2118.1 Appendix A to determine the occupancy classification and the appropriate sprinkler design criteria (OH1 etc) to select the appropriate distance to the operating sprinkler.

c - Suppression Mode Sprinklers

AS2118.1 (1999) provides for the installation of an Early Suppression Fast Response (ESFR) system. AS2118.1 references both NFPA 13 and the FM Global Property Loss Prevention Data Sheets 2-0 and 8-9 which detail the design requirements.

FM Global has conducted literally hundreds of live fire tests and provided the system is installed properly, suppression is assured.

Summary

The development of design fires for Alternative Solutions requires considerable research and proper application of that research. This paper provides only a very small sampling of the many and varied fire research papers and tests that have been carried out worldwide.

FSCS has, and continues to research published journals and the results from testing laboratories and has an electronic library of hundreds of examples for use in its Alternative Solutions.

I trust that this Paper clarifies the development of design fires in Fire Engineering Reports prepared by FSCS.

Richard A Foster

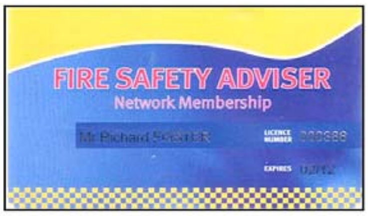
Dip Mech Eng; Dip Mar Eng; MSFPE; Member IE (Aust) SFS

RPEQ 7753

Fire Safety Engineer

QFRS Accredited Fire Safety Adviser under BFSR 2008

Principal – Fire and Security Consulting Services



References

[1] Australian Building Codes Board, Canberra ACT Australia - *International Fire Safety Engineering Guidelines – Edition 2005*,

[2] NFPA 1995, *NFPA 92B - Guide for Smoke Management Systems in Malls, Atria, and Large Areas – 1995 Edition*

[3] AS1668.3 (2001) – "*The Use of ventilation and air conditioning in buildings – Part 3 – Smoke control systems for large single compartments or smoke reservoirs*"

[4] Buchanan, A.H. 2001, *Fire Engineering Design Guide*, Centre for Advanced Engineering, University of Canterbury, Christchurch, NZ

[5] Standards Australia 1997, *AS1530.4 – Methods for fire tests on building materials, components and structures. Part 4: Fire-resistance tests of elements of building construction*, Standards Australia International, Sydney NSW Australia

[6] US National Institute of Standards and Technology (NIST) http://fire.nist.gov/bfrlpubs or http://www.bfrl.nist.gov

[7] SP Technical Research Institute of Sweden (SNTRI) http://www.sp.se http://www.sp.se/fire/br_reports.HTM

[8] SINTEF NBL (Norwegian Fire Research Laboratory) http://www.sintef.no

[9] National Research Council Canada (NRC) http://irc.nrc-cnrc.gc.ca

[10] FM Property Loss Prevention Data Sheets 2-0 & 8-9

[11] BRANZ http://www.branzfire.com

[12] FDS Fire Dynamics Simulator - US National Institute of Standards and Technology (NIST)

[13] AS2118.1 – 1999, *Automatic Fire Sprinkler Systems – Part 1 – General Requirements*

Version 4, June 2013 – Sections numbered, sprinkler spacing corrected & AS2118.1 Appendix A referenced.