SFPE (NZ) TECHNICAL PUBLICATION - TP 2005/2

CALCULATION METHODS FOR STORAGE WATER USED FOR FIRE FIGHTING PURPOSES

(Refer to TP 2004/1 for "Calculation Methods for Water Flows Used for Fire Fighting")[1].
(Refer to TP 2005/3 for "Comparison of Methods used for Determining Water Used for Fire Fighting Purposes") (to be published).

1. INTRODUCTION

The previously published TP 2004/1 sets out design methods for calculating required flow rates from water mains used for fire fighting purposes. TP 2005/2 sets out design methods for determining how much water should be provided in storage to back up the required flow rates. A useful way of comparing the different methods used for calculating the required storage volumes is to assume the water is stored over an area equal to the floor area of the firecell. This gives an "*equivalent water depth*" which provides a very simple comparison of different design methods. As will be demonstrated, the "*ratio of the storage volume divided by the total fire load*" (S/E ratio) also provides a useful ranking factor of the design methods.

Five Methods are described below. The first is based on arbitrary times. The second is based on arbitrary fire intensities. The third is based on firecell volume. The fourth is based on the time taken to reach the peak temperature of the fire, and the fifth is based on total fire load. Methods 4 and 5 are based on fire engineering and use the properties of the water, fuel, and the behaviour of the fire, whereas Methods 1, 2 and 3 do not.

To assist in comparing the design methods, the same firecell has been used in each worked example having a floor area of 625 m^2 and a total fire load E of 500,000 MJ. This represents a fire load energy density (FLED) of 800 MJ/m^2.

2. METHOD 1 – ARBITRARY TIME METHOD

Some fire authorities use un-scientific methods of calculating the required water storage by adopting quite arbitrary times of flow t_a which increase as the hazard increases but have no obvious basis that relates to the behaviour of a fire. The primary disadvantage of such methods is that they can introduce overly large safety factors into the system. A typical equation for determining the water storage volume by such a method is :-

$$S = F \times t_a \quad \text{litres} \quad \text{(Eq. 1)}$$

where S = required storage in litres
F = required flow rate in litres/sec
and t_a = arbitrary time for which the flow is required in seconds (see below).

An example of this type of approach can be seen in Table 2 from the NZFS Code of Practice SNZ PAS 4509:2003. [2]. This document sets out the required storage volumes as follows:-

W Water Supply Classification	F Required Flow Rate (litres/second)	t_a Assumed Time of Flow (minutes)	S Required Storage Water (litres)
W2	12.5	30	23,000
W3	25	30	45,000
W4	50	60	180,000
W5	100	90	540,000
W6	150	120	1,080,000
W7	200	180	2,160,000

Table 1: Fire fighting water supply from Table 2 of SNZ PAS 4509 [2].

Table 2 of SNZ PAS NZFS 4509 [2] can in some cases require an equivalent water depth of 2.7 meters over the floor area of the firecell. (Refer to Appendix A). This is more than 4 times the value derived from specific fire engineering. (Refer to Appendix C). No provision appears to have been made for exposure situations in Tables 1 and 2 of SNZ PAS NZFS 4509.

Example 1.1

Assume a retail shop has a total fire load of 500,000 MJ over a floor area A_f of 625 m^2. The fire load energy density (FLED) is therefore 800 MJ/m^2 which corresponds to a Fire Hazard Category of 2 (FHC2). Use Tables 1 and 2 of SNZ PAS NZFS 4509 to determine the required fire fighting water storage volume. From Table 1 and FHC2 the required water classification is W6. From Table 2 the required flow rate F for W6 is 150 l/s, and the required flow time tf is 120 minutes. From this the storage volume S, the equivalent depth dw, and the S/E ratio can be calculated as follows:-

$S = F \times t_f$ = 150 l/s x120 mins x 60 s=1,080,000 litres

$d_W = S / A_f$ = 1,080000 litres/ 625 m^2= 1,728 mm

S / E = 1,080,000 litres/ 500,000 MJ = 2.16

thus S = 2.16 E litres

3. METHOD 2 – ABITRARY FIRE INTENSITY METHOD (E/Q).

An alternative arbitrary method is to determine the time of flow t_f by dividing the total fire load E by an arbitrary value of the maximum fire intensity Q_{max}. Thus:-

$E = A_f \times FLED$……………………………………………………MJ

$Q_{max} = A_f \times q_{max}$…………………………………………………..MW

$tf = E / Q_{max}$ ………………………………………………..seconds (Eq. 2)

where q_{max} = arbitrary assumed unit fire intensity in MW/m^2

However because E and Q_{max} both depend on the floor area A_f, the floor area can be eliminated resulting in a simpler equation as follows:-

$tf = FLED / q_{max}$…………………………………………………seconds (Eq. 3)

NZFS 4509 [2] is an example of this type of method. Table E2 of SNZ PAS NZFS 4509 sets out arbitrary values of q_{max}. Table E2 has been modified below by adding Cols. (2), (3) and (5) as shown below:-

(1)	(2)	(3)	(4)	(5)
Occupancy	Fire Hazard Category	Fire Load Energy Density FLED	Assumed Unit Fire Intensity q_{max}	Time of Flow t_f
	FHC	MJ/m^2	MW/m^2	minutes
Office	2	800	0.25	53
Retail	2	800	0.50	27
Warehouse	3	1200	1.00	20

Table 2: Unit fire intensities of fuel controlled fires from Table E2 of SNZ PAS NZFS 4509 [2].

Example 2.1
A retail shop has a total fire load of 500,000 MJ over a floor area Af of 625 m^2. The FLED is therefore 800 MJ/m^2 and the fire hazard category classification of FHC2. From Table 1 of SNZ PAS NZFS 4509 and FHC2 the corresponding water classification is W6. From Table 2 of SNZ PAS NZFS 4509, the corresponding flow rate for W6 is 150 l/s. From the modified Table E2 (Table 2 above), the time of flow tf is 27 minutes. The required storage volume S, the equivalent depth d_W, and the S/E ratio can be calculated as :-

S = F x t_f = 150 l/s x 27 min x 60 s = 243,000 litres

d_W = S / A_f = 243,000 litres/ 625 m^2= 389 mm

S / E = 243,000 litres/ 500,000 MJ = 0.49

thus S = 0.49 E litres

The disadvantage of Method 2 is that for a fuel surface controlled fires the value of t_f may be less than that of the time t_m taken to reach Q_{max}. Also provision for exposure has to be made in accordance with Clause F4 of Appendix F of SNZ PAS NZFS 4509 but this calculation cannot be done without first doing an on-site survey of the details of any existing adjacent buildings. If there are no adjacent buildings the required exposure allowance is nil. The assumed unit fire intensity values in Column (4) of modified Table E2 (Table 2 above) are higher than would be derived from specific fire engineering calculations. Typical calculated results for office, retail and warehouse using specific fire engineering would respectively be in the region of 0.16, 0.18 and 0.25 MWm^2 or less. The flow times in Column (5) would then become longer namely 67, 67 and 80 minutes respectively creating much higher water storage values than derived from Table 2 of SNZ PAS NZFS 4509. Example 2.2 demonstrates this.

Example 2.2
Assume a retail shop has a total fire load of 500,000 MJ over a floor area A_f of 625 m^2. The fire load energy density (FLED) is therefore 800 MJ/m^2 which corresponds to a fire hazard category of 2 (FHC2). The total fire load E is therefore 500,000 MJ. A realistic value of the unit fire intensity would be 0.18 MW/m^2. From Table 1 and FHC2 the required water classification is W6. From the modified Table E2 of SNZ PAS NZFS 4509 (Table 2 above) the required flow rate F for W6 is 150 l/s. Calculate the required flow time t_f. From this the storage volume S, the equivalent depth d_W, and the S/E ratio can be calculated as :-

t_f = E / Q = 500,000 MJ / (0.18 MW/m^2 x 625 m^2) = 4,444 s =74min)

S = F x t_f = 150 l/s x 4,444 s= 666,700 litres

d_W = S / A_f = 666,700 litres / 625 m^2= 1,067 mm

S / E = 666,700 litres/ 500,000 MJ = 1.33

thus S = 1.33 E litres

4. METHOD 3 – FIRECELL VOLUME METHOD

In Method 3, the water storage volume is considered to be proportional to the volume of the firecell, an arbitrary value for the type of occupancy in the firecell, and an arbitrary value for the occupancy hazard classification. The following discussion uses NFPA 1142 [3] as an example of this method. For imperial values the water storage volume is :-

S = 0.2 x kn x V ……………………………………………..US gallons (Eq. 4)

For metric values the equation is :-

S = 26.733 x kn x V ………………………………………………..litres (Eq. 5)

where kn = nominal factor based on arbitrary values used for Construction Class (CC) and Occupancy Hazard Classification No. (OHC) (see Table 3 below)
and V = firecell volume in either ft^3 or m^3

Construction Class (CC) >		0.5	0.75	1.0	1.5
Construction Type >		FR Const	Non Comb	Ord Const	Wood Const
Occupancy Hazard Description	Occupancy Hazard Class No. (OHC)	Nominal Factor kn			
Light	7	0.36	0.54	0.71	1.07
Low	6	0.42	0.63	0.83	1.25
Moderate	5	0.50	0.75	1.00	1.50
High	4	0.63	0.94	1.25	1.88
Severe	3	0.83	1.25	1.67	2.50

Table 3: Values of nominal factor kn as per arbitrary values for CC and OHC from NFPA 1142 [3].

Example 3.1 – Imperial System

Determine what water storage volume would be required for a 54,000 ft^3 firecell (82 ft W x 82 ft L x 8 ft H). Assume the building is wood construction (CC = 1.5), and it has a “low” occupancy hazard class number (OHC) of 6. Table 3 above shows the value of kn = 1.25.

V = 82 ft x 82 ft x 8 ft = 54,000 ft^3

S = 0.2 x1.25 x 54,000 ft^3 = 13,500 US gallons

Example 3.2 – Metric System

Determine what water storage volume would be required for a retail shop having a total fire load of 500,000 MJ and a floor area of 625 m^2 firecell (25 m W x 25 m L x 2.44 m H). Assume the building is of wood construction (CC = 1.5), and it has a low occupancy hazard class number (OHC) of 6 (which corresponds to a FLED of 800 MJ/m^2). From Table 3 above the value of kn = 1.25.

V = 25 m x 25 m x 2.44 m = 1,525 m^3

S = 26.733 x1.25 x 1,525 m^3= 51,000 litres (= 13,500 US gallons)

d_w = S / A_f = 51,000 litres/ 625 m^2= 82 mm

S / E = 51,000 litres/ 500,000 MJ= 0.10

thus S = 0.10 E litres

The above-calculated values are for non-exposure situations. For exposure situations, Clause 7.3.1 of NFPA 1142 [3] recommends adding 50% to the above calculated storage values.

5. METHOD 4– FIRE ENGINEERING METHOD BASED ON PEAK TEMPERATURE TIME (t_m)

In Method 4, the water storage volume is related to t_m which is the point in time when the maximum fire temperature occurs in a fire. The time of flow t_f is taken as the time tm plus a safety margin of 1.5. Fig 2. from Ref [4] is shown as Fig. 1 below. It shows the difference in t_m for a fuel surface controlled fire and a ventilation controlled fire.

While the unique properties of water as set out in TP 2004/1 [1] are used therein to determine fire fighting water flows, the same properties can be used to determine the required storage volume. Fig. 1 in TP 2004/1 shows that 1 kg of water when boiled at 100°C from an initial temperature of 18°C can absorb 2.6 MJ. Put another way, for each MJ of fuel in the firecell, and if the cooling efficiency is 100%, a fire fighter theoretically needs 1/2.6 or 0.385 ℓ water as steam at 100°C to absorb the heat output of each MJ of fuel as it burns in a fire.

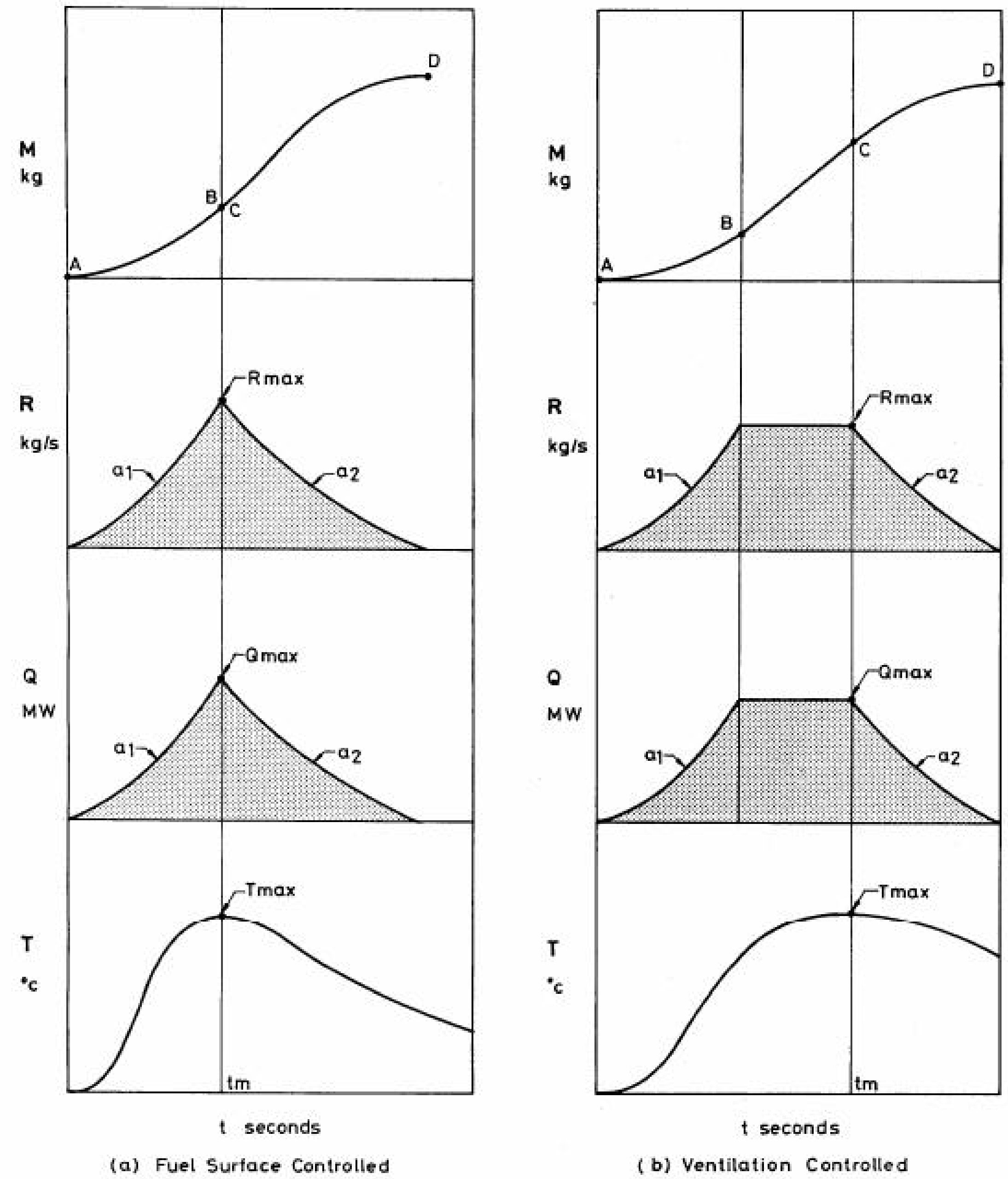

Fig. 1 : Fire design curves showing the difference in location of T_{max} and t_m for fuel surface controlled and ventilation controlled fires [4].

The same firecell was used in the three following examples being 25 m W x 25 m D x 2.4 m H with openings 1.5 m H. Widths of the openings were adjusted to give opening areas equal to 11%, 4% and 1% of the floor areas respectively. As in the previous worked examples the floor area is 625 m^2, the FLED is 800 MJ/m^2 and the total fire load E is 500,000 MJ. The fire growth coefficient was chosen as 225 s/1MW being midway between a moderate (300) and fast (150) fire. The fire decay coefficient was chosen as 4 times the value of the growth coefficient value or 900 s/1MW .[4].

The Heat of Combustion H'n was taken as 18 MJ/m^2 to represent a fire load of mostly wood but with some plastic. The input data for each example thus consisted of 9 items and were used in the same manner to that set out in Table 5 of Ref [4]. The calculated fire intensities of the three examples are 120, 80 and 40 MW respectively as shown in Fig. 2 which follows. To derive the time of flow tf a safety margin (SM) of 1.5 is applied to the peak temperature time tm. Flow is calculated as F = 0.385 Q_{max} as per Eq 3 in Ref [1].

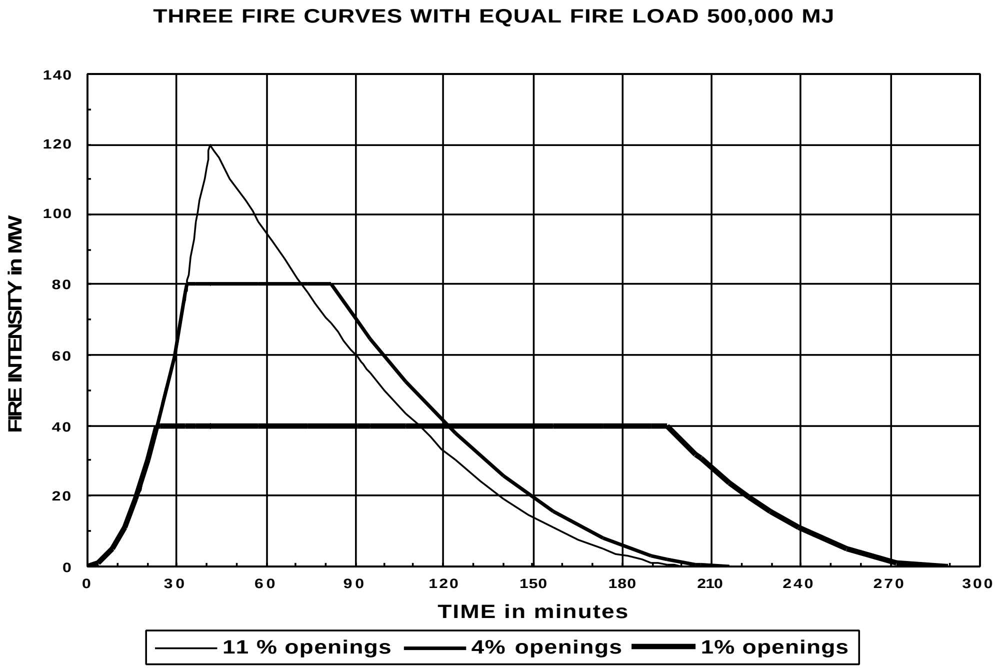

Fig 2: Fire design curves for three different opening situations in a firecell having a floor area of 625 m^2. The area under each curve is the same and is equal to 500,000 MJ.

Example 4.1

In Example 4.1 the firecell has 11% openings resulting in a fuel surface controlled fire (at the FC/VC point) [1], Q_{max} = 120 MW, and t_m = 41 min. as illustrated in Fig. 2 above.

t_m = 41 min x 60 = 2,460 s

t_f = t_m x SM = 2460 s x 1.5 = 3,690 s (= 62 min)

F = 0.385 Q_{max} = 0.385 x 120 MW = 46.2 litres/sec

S = F x t_f = 46.2 l/s x 3,690 s = 170,000 litres

d_w = S/A_f = 170,000 litres/ 625 m^2= 273 mm

S / E = 170,000 litres / 500,000 MJ = 0.34

thus S = 0.34 E litres

Example 4.2

In Example 4.2 the firecell has 4% openings resulting in a ventilation controlled fire, Q_{max} = 80 MW, and t_m = 82 min. as illustrated in Fig. 2 above.

t_m = 82 min x 60 = 4,920 s

t_f = t_m x SM = 4,920 s x 1.5 = 7,380 s (= 123 min)

F = 0.385 Q_{max} = 0.385 x 80 MW = 30.8 litres/sec

S = F x t_f = 30.8 l/s x 7380 s = 227,000 litres

d_w = S/A_f = 227,000 litres/ 625 m^2 = 364 mm

S / E = 227,000 / 500,000 = 0.45

thus S = 0.45 E litres

Example 4.3

In Example 4.3 the firecell has 1% openings resulting in a ventilation controlled fire, Q_{max} = 40 MW, and t_m = 195 min. as illustrated in Fig. 2 above.

t_m = 195 min x 60 = 11,700 s

t_f = t_m x SM = 11,700 s x 1.5 = 17,550 s (= 293 min)

F = 0.385 Q_{max} = 0.385 x 40 MW = 15.4 litres/sec

S = F x t_f = 15.4 l/s x 17,700 s = 270,000 litres

d_w =S/A_f = 270,000 litres / 625 m^2 = 432 mm

S / E = 270,000 litres / 500,000 MJ = 0.54

thus S = 0.54 E litres

6. METHOD 5 – FIRE ENGINEERING METHOD BASED ON TOTAL FIRE LOAD (E)

In Method 5, the water storage volume is related to the total fire load E in the firecell. In other words the cooling potential of the water is balanced against the heating potential of the fuel. Examples 5.1 to 5.2 use the same figures for openings and intensities as in Examples 4.1 to 4.3. The time of flow is determined from t_f = E/ Q_{max} plus a safety margin of 1.3. Q_{max} is derived using the 9 input items as per the fire engineering method set out in Ref [4].

Example 5.1

As in Example 4.1 above, the firecell has 11% openings and Q_{max} = 120 MW as illustrated in Fig. 2 above.

t_f = E/ Q_{max} = 500,000 MJ / 120 MW = 4167 s (= 69 min)

F = 0.385 Q_{max} = 0.385 x 120 MW = 46.2 litres/sec

S = F x t_f x SM = 46.2 l/s x 4167 s x 1.3 = 250,000 litres

d_w = S/A_f = 250,000 litres/ 625 m^2= 400mm

S / E = 250,000 litres / 500,000 MJ = 0.50

thus S = 0.50 E litres

Example 5.2

As in Example 4.2 above, the firecell has 4% openings and Q_{max} = 80 MW as illustrated in Fig. 2 above.

t_f = E/Qmax = 500,000 MJ /80 MW = 6250 s (= 104 min)

F = 0.385 Q_{max} = 0.385 x 80 MW = 30.8 litres/sec

S = F x t_f x SM = 30.8 l/s x 6250 s x 1.3 = 250,000 litres

d_w = S/A_f = 250,000 litres/ 625 m^2 = 400 mm

S / E = 250,000 / 500,000 = 0.50

thus S = 0.50 E litres

Example 5.3

As in Example 4.3 above, the firecell has 1% openings and Q_{max} = 40 MW as illustrated in Fig. 2 above.

t_f = E/Qmax = 500,000 MJ /40 MW = 12500 s (= 209 min)

F = 0.385 Q_{max} = 0.385 x 40 MW = 15.4 litres/sec

S = F x t_f X SM = 15.4 l/s x 12,500 s X 1.3 = 250,000 litres

d_W = S/A_f = 250,000 litres / 625 m^2 = 400 mm

S / E = 250,000 litres / 500,000 MJ = 0.50

thus S = 0.50 E litres

As will be seen above, all three examples end up requiring the same water storage volume namely 250,000 litres. If the fire fighting system is designed to cater for the worst Q_{max} case, namely at the FC/VC changeover point for this firecell [1], than all other ventilation cases will be automatically catered for. If the ventilation is greater than the FC/VC value then the fire will not burn at any greater intensity. If the ventilation is less than the FC/VC case, the fire will burn for a longer time and at a lower fire intensity as demonstrated by the 4% and 1% ventilation cases in Fig. 2 but the required fire flow will also be lower.

However because each worked example produces the same value for the equivalent depth of water d_W namely 400 mm, this indicates that the S/E ratio is constant. This produces the very simple formula with a built safety margin of 1.3 is as follows :=

S = 0.50 E……………………………………………………...…….……….litres (Eq. 6)

The same formula can also be derived from the general equation Eq. 2 in TP2004/1:-

$$F = \frac{k_F \times Q_{max}}{k_W \times Q_W} \quad \ell/s \text{......(Eq. 2 from TP 2004/1) [1]}$$

where F = fire fighting water flow in ℓ/s
k_F = heating efficiency of fire (conservatively 0.50 for a typical firecell)
k_W = cooling efficiency of available water (conservatively 0.50 for a water main)
Q_{max} = maximum heat output of fire in MW
Q_W = heat absorptive capacity of water at 100°C = 2.6 MW/ℓ/s.

In simple terms this means that for each MW of Q_{max} in a fire, the fire fighting water flow, will need to be 0.50 / (0.50 x 2.6 MJ/kg) = 0.385 ℓ/s/MW of Q_{max}.

As an equation this becomes:-

F = 0.385 Q_{max} .... (Eq. 3 from TP 2004/1) [1]

If S = F x t_f and t_f = E / Q_{max}
then S = F x (E / Q_{max}) = 0.385 Q_{max} x E / Q_{max} = 0.385 E ……….. litres

Applying a safety margin of 1.3 to S results in the same equation as Eq. 6 above namely :-

S = 1.3 x 0.385 E = 0.50 E…………………………..……………..……….litres

The primary advantage of this equation is that the need to calculate Q_{max} has been eliminated.

7 USE OF STORAGE WATER IN PRACTICE

In practice the flow of water does not start until the fire engines arrive, the attack point decided upon, and the hoses are run out and connected. The fire attack time may typically be 10 to 15 minutes after the fire start time. Fig 3 (a) below shows the fire flow starting at time zero, whereas Fig. 3 (b) shows a time shift to the right to allow for the fire attack start time. Fig 3 (c) shows what happens when fire engines arrives one after the other. Fig 3 (d) shows the same as (c) but with a fire efficiency of only 50%. Similar arrangements apply to the ventilation controlled examples in (e) to (h) below except that the Fire Commander can select lower flows to suit the lower intensity fires.

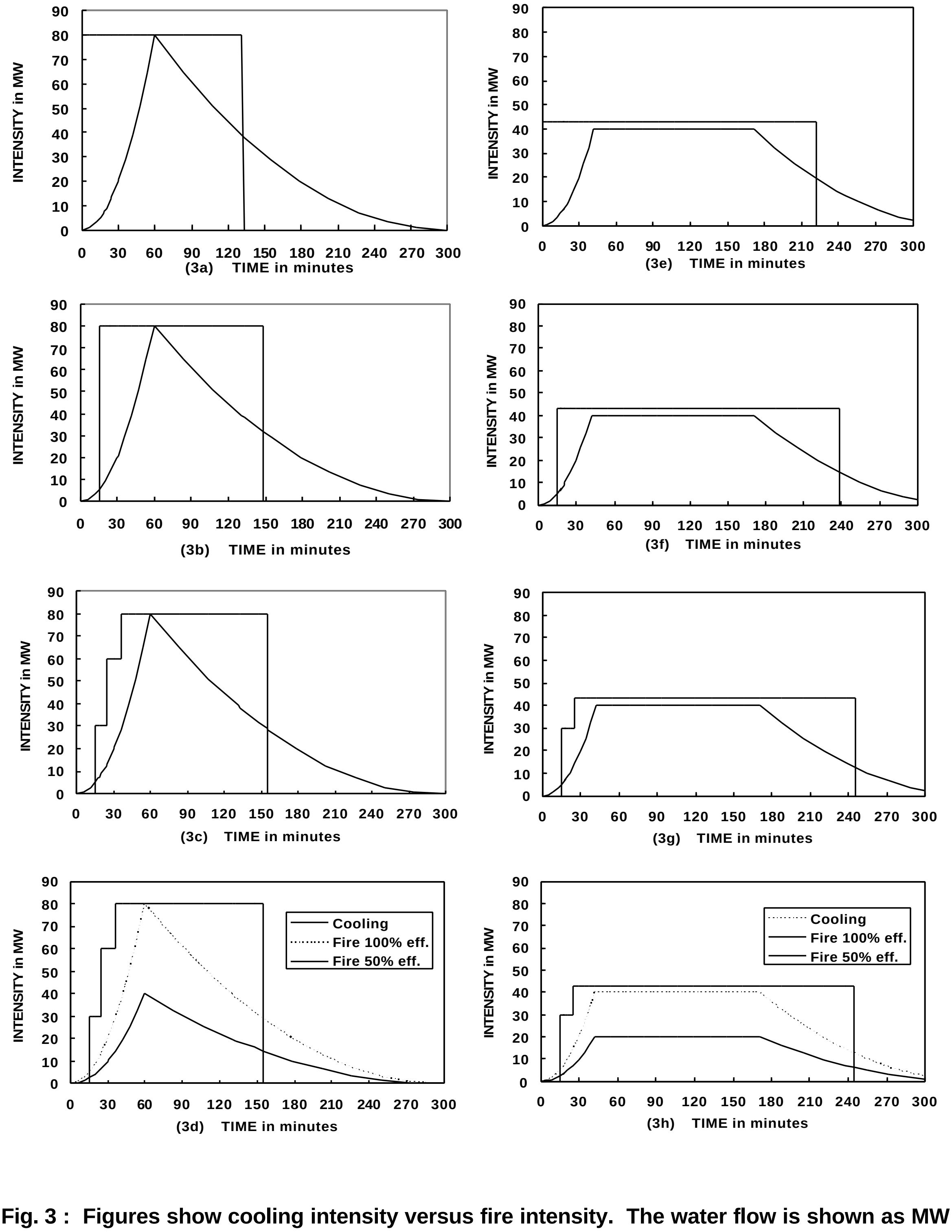

Fig. 3 : Figures show cooling intensity versus fire intensity. The water flow is shown as MW of cooling capacity instead of flow in litres/s. The area under each water curve represents the storage volume of water in MJ of cooling capacity. The area under each fire curve represents the total fire load in MJ of heating capacity.

8 SUMMARY

Five design methods were discussed above. These are :-

(a) Method 1 $S = F \times t_a$
(b) Method 2 $S = F \times t_q$
(c) Method 3 $S = kn \times V$
(d) Method 4 $S = F \times t_m \times SM$
(e) Method 5 $S = 0.385 \times SM \times E$

A summary of the results from the worked examples is set out in Table 5 below.

Design Method	Worked Example	Storage S litres	Equivalent Depth d_w mm	Safety Margin SM	S/E Ratio
1	1.1	1,080,000	1,728	-	2.16
2	2.1	243,000	389	-	0.49
2	2.2	666,700	1067	1.0	1.33
3	3.2	51,000	82	1.0	0.15
4	4.1	170,000	273	1.5	0.34
4	4.2	227,000	364	1.5	0.45
4	4.3	270,000	452	1.5	0.54
5	5.1	250.000	400	1.3	0.50
5	5.2	250,000	400	1.3	0.50
5	5.3	250,000	400	1.3	0.50

Table 4: Summary of results from Worked Examples for a 625 m^2 firecell using Design Methods 1 to 5.

Method 4 gives required volumes based on specific fire engineering, but the geometry of the firecell needs to be known along with estimates of the fire growth and fire decay coefficients which need to selected on the basis of engineering judgement.

For general use however Method 5 is recommended because of its sheer simplicity. The geometry of the firecell is not required. The minimum volume of storage water for fire fighting purposes shall be al least equal to 0.385 l/MJ of fire load. If a safety margin of 30% is added to this minimum, the volume of storage water needed to deal with the fire when it reaches it's peak temperature, the equation becomes :-

$S = 0.5\,E$ litres…………………………………………………………………..(Eq. 6)

In closing it could be said that to date, few if any fire codes appear to have based their required water storage volumes on fire engineering logic. TP 2005/2 may be the first time this subject has been approached from a fire engineering point of view.

As mentioned in the Summary of TP 2004/1, there are extra bonuses not included in the above storage calculations. These are the extra heat absorbtion capacity of water from 100 to 300 ºC, the modern fog nozzle versus the traditional jet nozzle, and the extra steam volume produced when heated to 600 ºC rather than just 100 ºC.

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(1) Barnett, C R – "Calculation Methods for Water Flows used for Fire Fighting Purposes", SFPE (NZ) Technical Publication, TP2004/1 (2004).
(2) SNZ PAS 4509; – "NZ Fire Service Fire Fighting Water Supply Code of Practice" (2003).
(3) NFPA 1142 :- "Standard on Water Supplies for Suburban & Rural Fire Fighting". Edition 2001.
(4) Barnett, C R – "BFD Curve" – Fire Safety Journal 37 (2002) pp 437-463

Floor Area m^2	Storage in Litres 400 MJ/m^2	800 MJ/m^3	1200 MJ/m^4	Equivalent Water Depth in mm 400 MJ/m^2	800 MJ/m^3	1200 MJ/m^4
0	45,000	180,000	540,000			
200	45,000	180,000	540,000	225	900	2700
400	180,000	540,000	1,080,000	450	1350	2700
600	540,000	1,080,000	1,080,000	900	1800	1800
800	540,000	1,080,000	1,080,000	675	1350	1350
1000	540,000	1,080,000	2,160,000	540	1080	2160
1200	1,080,000	2,160,000	2,160,000	900	1800	1800
1400	1,080,000	2,160,000		771	1543	
1600	1,080,000	2,160,000		675	1350	
1800	1,080,000			600		
2000	1,080,000			540		
2200	1,080,000			491		
2400	1,080,000			450		
2600	1,080,000			415		
2800	2,160,000			771		

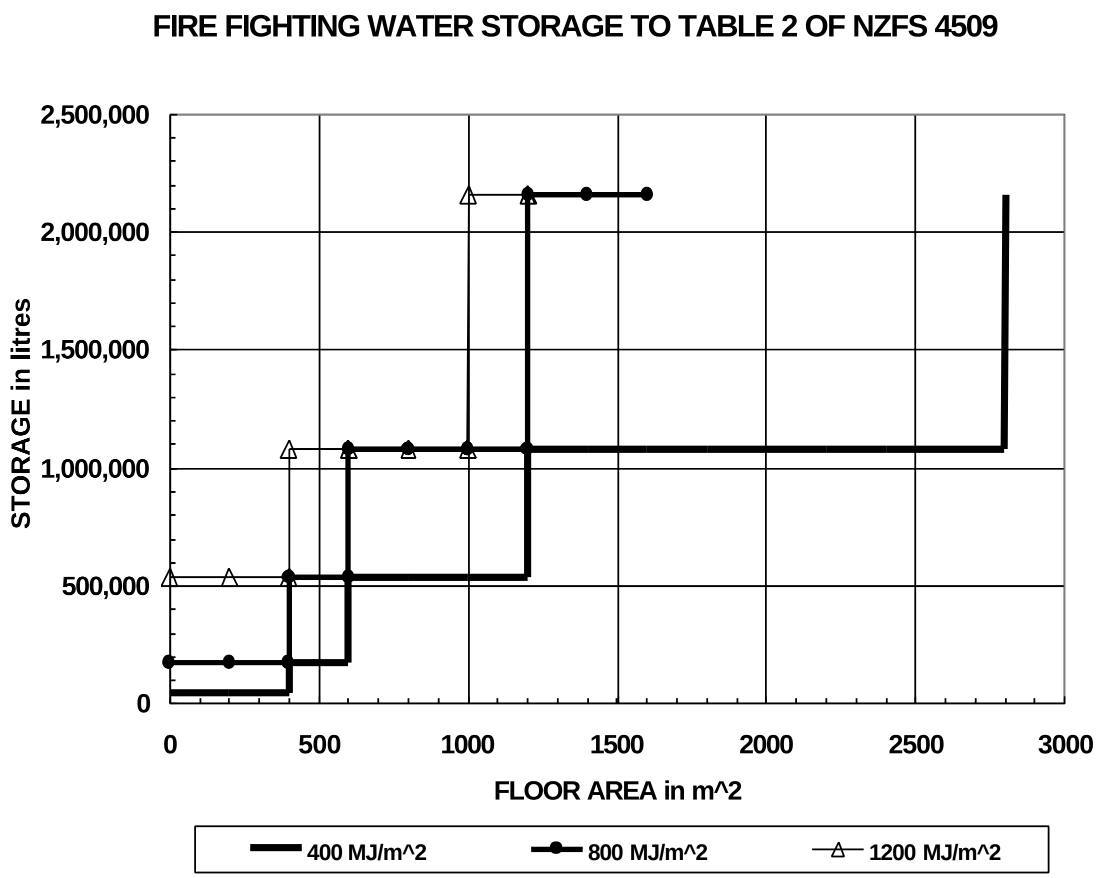

Fig. 4 : Fire fighting water storage calculated as per Eq. 1. Storage values are for suppression only. No allowance is made for exposure.

Floor Area Af m^2	Firecell Volume V m^3		Storage in Litres 400 MJ/m^2	800 MJ/m^2	1200 MJ/m^2	Equivalent Water Depth in mm 400 MJ/m^2	800 MJ/m^2	1200 MJ/m^2
		CC =>	1.0	1.0	1.0	1.0	1.0	1.0
		OHC =>	7	6	5	7	6	5
		k_m =>	0.75	0.85	1	2.79	3.16	3.72
200	488		9,778	11,082	13,037	49	55	65
400	975		19,556	22,163	26,074	49	55	65
600	1,463		29,334	33,245	39,111	49	55	65
800	1,951		39,111	44,326	52,149	49	55	65
1000	2,438		48,889	55,408	65,186	49	55	65
1200	2,926		58,667	66,489	78,223	49	55	65
1400	3,414		68,445	77,571	91,260	49	55	65
1600	3,901		78,223	88,653	104,297	49	55	65
1800	4,389		88,001	99,734	117,334	49	55	65
2000	4,877		97,779	110,816	130,371	49	55	65
2200	5,364		107,556	121,897	143,409	49	55	65
2400	5,852		117,334	132,979	156,446	49	55	65
2600	6,340		127,112	144,061	169,483	49	55	65
2800	6,828		136,890	155,142	182,520	49	55	65
3000	7,315		146,668	166,224	195,557	49	55	65

Storage = k_m x V ………………………………………………………litres……..Eq. 5

FIRE FIGHTING WATER STORAGE TO NFPA 1142 FOR ORDINARY CONSTRUCTION (CC = 1.0)

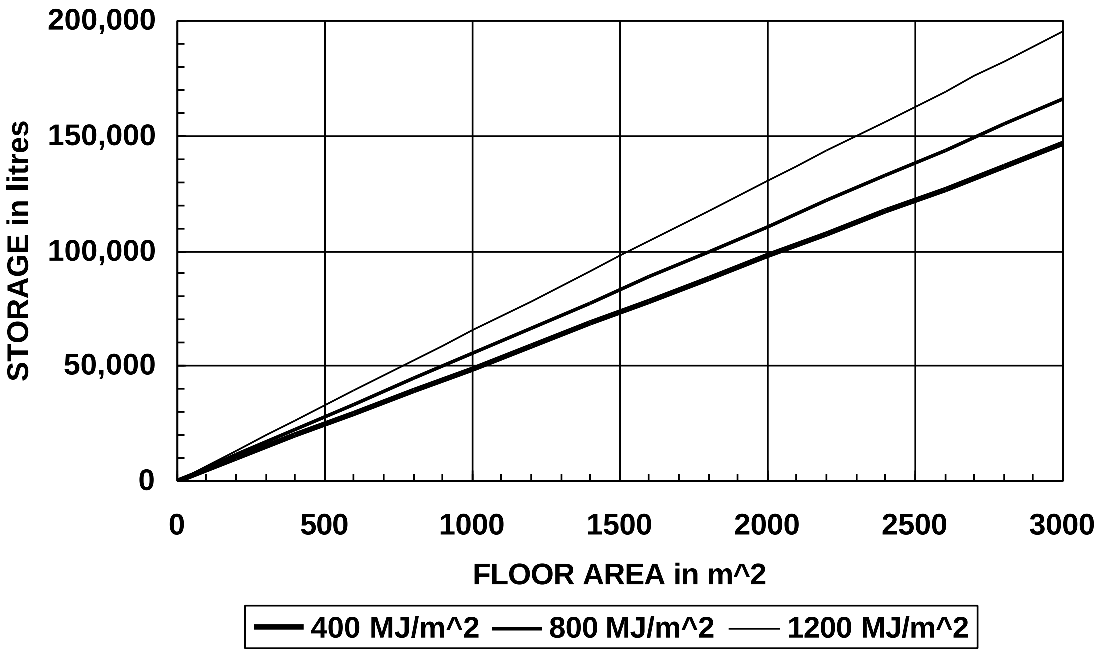

Fig 5: Fire fighting water storage calculated as per Eq. 5. Add 50% for exposure if required as per Clause 7.3.1 of NFPA 1142.

Floor Area m^2	Storage in Litres 400 MJ/m^2	800 MJ/m^2	1200 MJ/m^2	Equivalent Water Depth in mm 400 MJ/m^2	800 MJ/m^2	1200 MJ/m^2
200	40,000	80,000	120,000	200	400	600
300	60,000	120,000	180,000	200	400	600
400	80,000	160,000	240,000	200	400	600
500	100,000	200,000	300,000	200	400	600
600	120,000	240,000	360,000	200	400	600
800	160,000	320,000	480,000	200	400	600
1000	200,000	400,000	600,000	200	400	600
1200	240,000	480,000	720,000	200	400	600
1400	280,000	560,000	840,000	200	400	600
1600	320,000	640,000	960,000	200	400	600
1800	360,000	720,000	1,080,000	200	400	600
2000	400,000	800,000	1,200,000	200	400	600
2200	440,000	880,000	1,320,000	200	400	600
2400	480,000	960,000	1,440,000	200	400	600
2600	520,000	1,040,000	1,560,000	200	400	600
2800	560,000	1,120,000	1,680,000	200	400	600
3000	600,000	1,200,000	1,800,000	200	400	600

Storage = 0.50 E ……………………………………litres…… Eq. (6)

FIRE FIGHTING WATER STORAGE TO METHOD 5 IN TP 2005/2

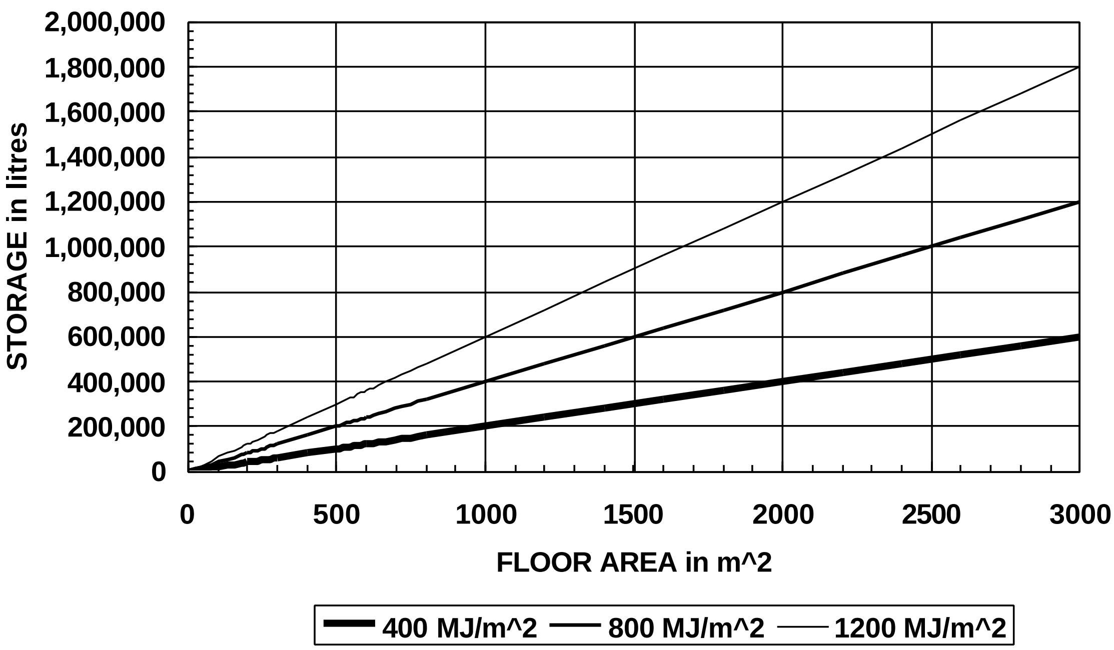

Fig 6: Fire fighting water storage calculated as per Eq. 6. Allows 50% for suppression and 50% for exposure.