LOCAFI+

Temperature assessment of a vertical member subjected to LOCAlised FIre
Dissemination

5. Worked examples

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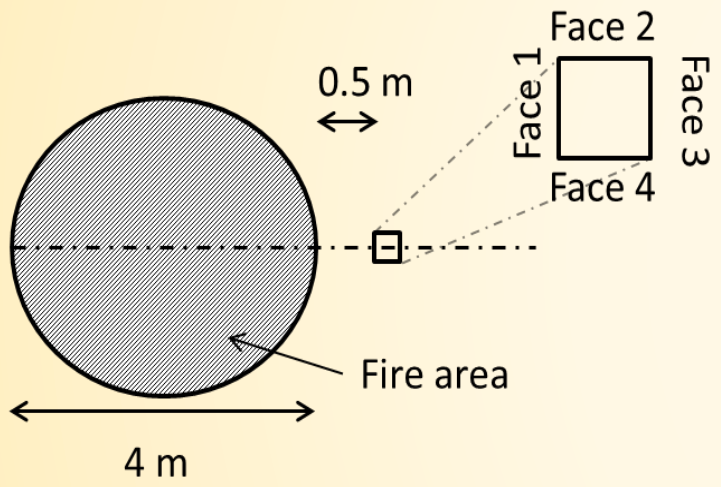
5. Worked examples

5.1. Example 1 : Radiation fluxes under localised fire



Column section : HEB 300

Diameter of the fire source : 4m

Distance between the fire and the column : 0.5m

Rate of heat release : 1000 kW.m^{-2}

Conic flame

Column situated outside the fire and the smoke layer

No ceiling

Calculation is made for z = 1.0m

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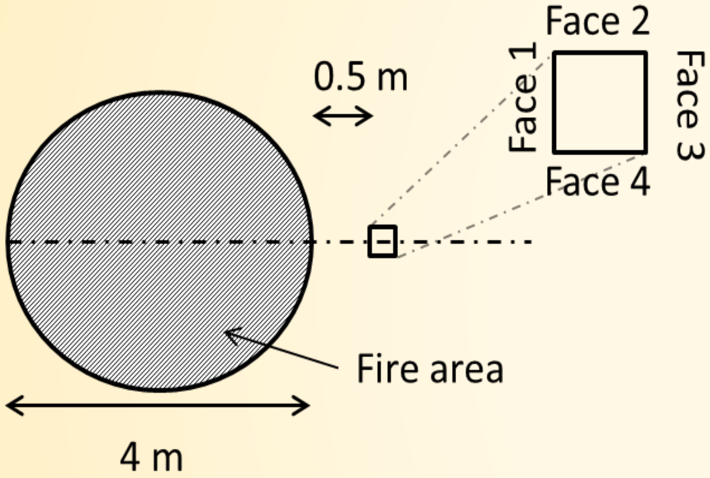


$D = 4\ m$

$Q = RHR * \frac{\pi}{4} * D^2 = 12566371\ W$

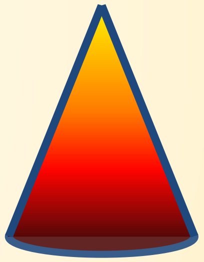
$L_f = -1.02\ D + 0.0148\ Q^{0.4}$ = 6.15 m

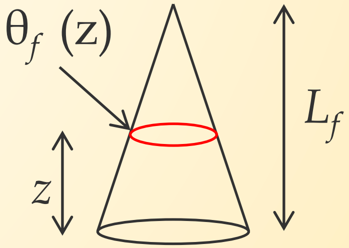
$z_0 = \ -1.02\ D + 0.00524\ Q^{0.4}$ = -0.48 m

Flame temperature

$$\theta_f(z) = \min\left(900; 20 + 0.25\left(0.8Q(t)\right)^{2/3}(z - z_0)^{-5/3}\right)$$

z (m)	T (°C)
0	900
0.5	900
1	900
1.5	900
2	900
2.5	900
3	900
3.5	900
4	900
4.5	827.9
5	708.4
5.5	614.8
6	540.0
6.5	479.3
7	429.1
7.5	387.2

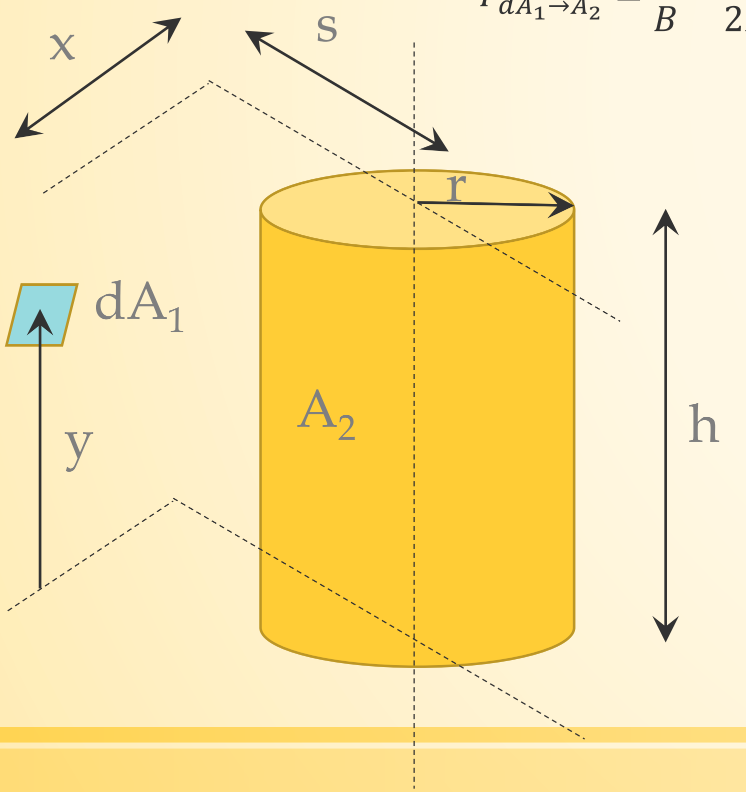




5. Worked examples

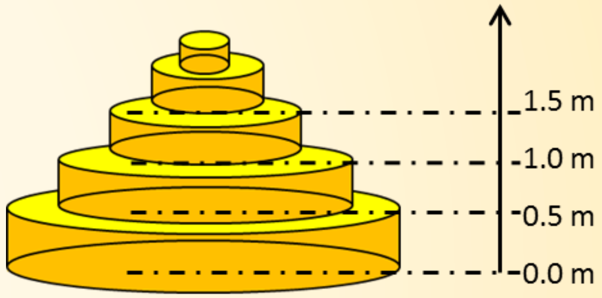
5.1. Example 1 : Radiation fluxes under localised fire

Face 1



$$F_{dA_1\rightarrow A_2} = \frac{S}{B} - \frac{S}{2B\pi}\left\{\begin{array}{l} cos^{-1}\left(\frac{Y^2 - B + 1}{A - 1}\right) + cos^{-1}\left(\frac{C - B + 1}{C + B - 1}\right) \\ -Y\left[\frac{A + 1}{\sqrt{(A - 1)^2 + 4Y^2}} cos^{-1}\left(\frac{Y^2 - B + 1}{\sqrt{B}(A - 1)}\right)\right] \\ -\sqrt{C}\frac{C + B + 1}{\sqrt{(C + B - 1)^2 + 4C}} cos^{-1}\left(\frac{C - B + 1}{\sqrt{B}(C + B - 1)}\right) \\ +H cos^{-1}\left(\frac{1}{\sqrt{B}}\right) \end{array}\right\}$$

$$S = s/r$$
$$X = x/r$$
$$H = h/r$$
$$A = X^2 + Y^2 + S^2$$
$$B = S^2 + X^2$$
$$C = (H - Y)^2$$



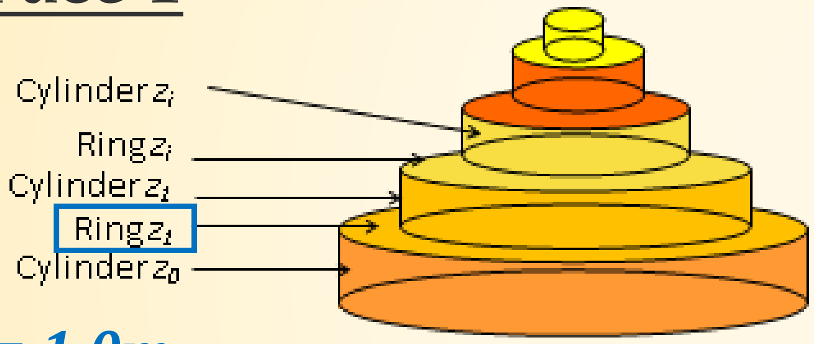
$$F_i = F_{dA_1\rightarrow A_2}\left(s = s_f, x = x_f, r = r_i, h = |z_i - z_f|\right)$$
$$F_{i+1} = F_{dA_1\rightarrow A_2}\left(s = s_f, x = x_f, r = r_i, h = |z_{i+1} - z_f|\right)$$

$$\left| \begin{array}{l} if\ z_i \geq z_f\ then\ F = F_{i+1} - F_i \\ else\ F = F_i - F_{i+1} \end{array}\right.$$

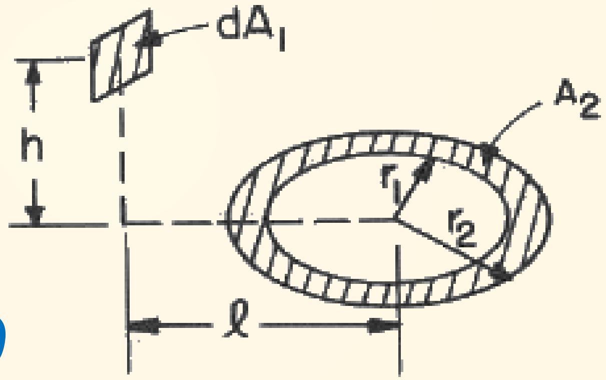
5. Worked examples

5.1. Example 1 : Radiation fluxes under localised fire

Face 1



$$F_{dA_1 \to A_2} = \frac{H}{2}\left(\frac{H^2 + R_2^2 + 1}{\sqrt{(H^2 + R_2^2 + 1)^2 - 4R_2^2}} - \frac{H^2 + R_1^2 + 1}{\sqrt{(H^2 + R_1^2 + 1)^2 - 4R_1^2}}\right)$$



$$H = h/l = (1 - 0.5)/2.5 = 0.2$$
$$R_2 = r_2/l = 2/2.5 = 0.8$$
$$R_1 = r_1/l = 1.84/2.5 = 0.73$$

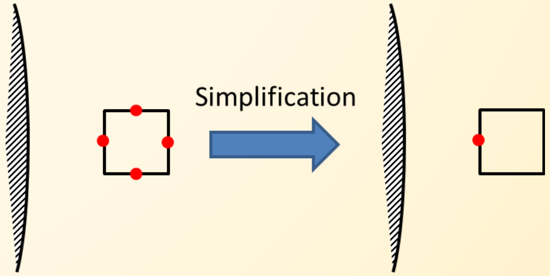
z_f = 1.0m

→ Only one ring to consider (z_i = 0.5m)

External radius r_2 = 2.0m

Internal radius r_1 = (6.15-0.5)/6.15*2.0m = 1.84m

Simplification : l = 2.5m



5. Worked examples

5.1. Example 1 : Radiation fluxes under localised fire

Face 1

Input data				
HRR	Dfire	Q	Q	hf
kW/m²	m	W	MW	m
1000	4	12566370.6	12.57	6.15

Constant	
σ	Tabs
5.67E-08	273.15

Section coordinate		
sf	xf	zf
m	m	m
2.5	0	1

Intermediate variables	
z_{virt}	l
-0.46	2.5

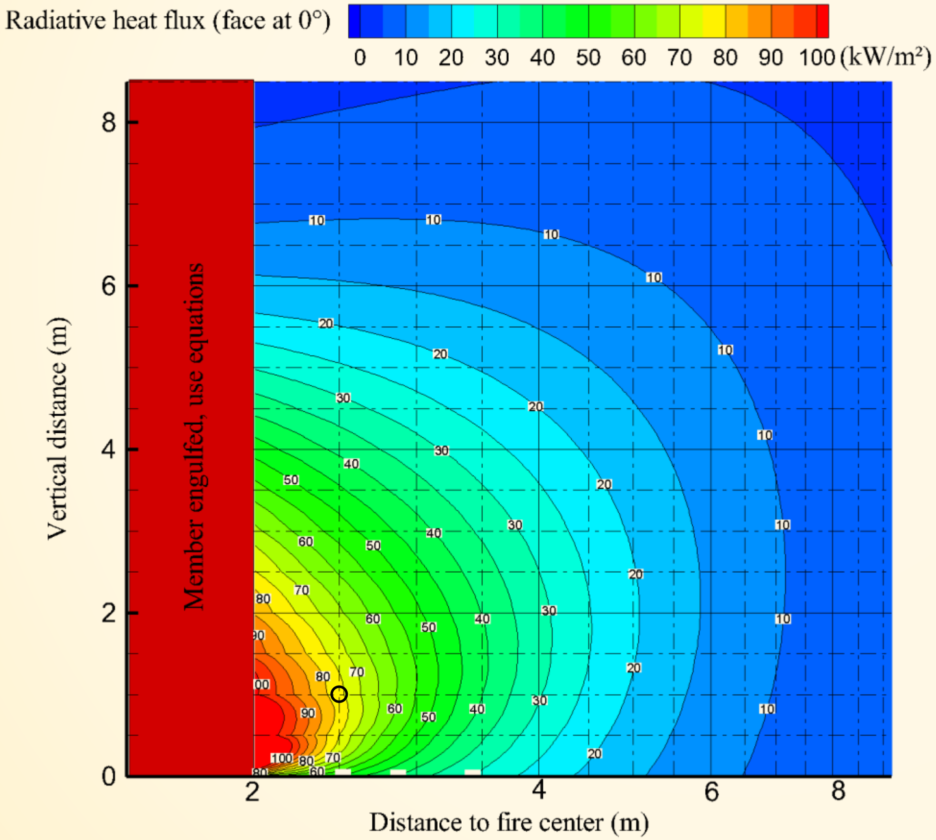
						Cylinder									Ring		
zi	Tf	ri	$F_{cylinder\_zi}$	F_{ring_zi}	$Flux_{face1}$	Fi	Fi+1	S	X	A	Hi	Hi+1	|zi-zf|	|zi+1-zf|	H	Ri	Ri+1
m	°C	m	-	-	kW/m²	-	-	-	-	-	-	-	m	m	-	-	-
0	900	2.00	0.0726	0	7.79	0.3705	0.2979	1.25	0	1.56	0.50	0.25	1.00	0.50	0	0.00	0.00
0.5	900	1.84	0.2374	0.0555	31.45	0.2374	0.0000	1.36	0	1.85	0.27	0.00	0.50	0.00	0.20	0.80	0.73
1	900	1.67	0.1893	0	20.33	0.0000	0.1893	1.49	0	2.23	0.00	0.30	0.00	0.50	0	0.73	0.67
1.5	900	1.51	0.0823	0	8.84	0.1514	0.2337	1.65	0	2.73	0.33	0.66	0.50	1.00	0	0.67	0.60
2	900	1.35	0.0361	0	3.88	0.1953	0.2315	1.85	0	3.43	0.74	1.11	1.00	1.50	0	0.60	0.54
2.5	900	1.19	0.0177	0	1.91	0.1958	0.2136	2.11	0	4.43	1.26	1.68	1.50	2.00	0	0.54	0.47
3	900	1.02	0.0095	0	1.02	0.1797	0.1893	2.44	0	5.95	1.95	2.44	2.00	2.50	0	0.47	0.41
3.5	900	0.86	0.0054	0	0.58	0.1564	0.1618	2.90	0	8.41	2.90	3.48	2.50	3.00	0	0.41	0.34
4	900	0.70	0.0031	0	0.34	0.1296	0.1328	3.57	0	12.77	4.29	5.00	3.00	3.50	0	0.34	0.28
4.5	828	0.54	0.0018	0	0.15	0.1009	0.1027	4.66	0	21.68	6.52	7.45	3.50	4.00	0	0.28	0.21
5	708	0.37	0.0010	0	0.05	0.0711	0.0720	6.68	0	44.58	10.68	12.02	4.00	4.50	0	0.21	0.15
5.5	615	0.21	0.0004	0	0.02	0.0405	0.0409	11.80	0	139.24	21.24	23.60	4.50	5.00	0	0.15	0.08
6	540	0.05	0.0001	0	0.00	0.0095	0.0096	50.71	0	2571.11	101.41	111.55	5.00	5.50	0	0.08	0.02
6.5	479	0	0	0	0	0	0	0	0	0	0	0	5.50	6.00	0	0.02	0
7	429	0	0	0	0	0	0	0	0	0	0	0	6.00	6.50	0	0	0
7.5	387	0	0	0	0	0	0	0	0	0	0	0	6.50	1.00	0	0	0

Incident heat flux on face 1	76.36	kW/m²
Absorbed heat flux on face 1	53.45	kW/m²

5. Worked examples

5.1. Example 1 : Radiation fluxes under localised fire

Face 1

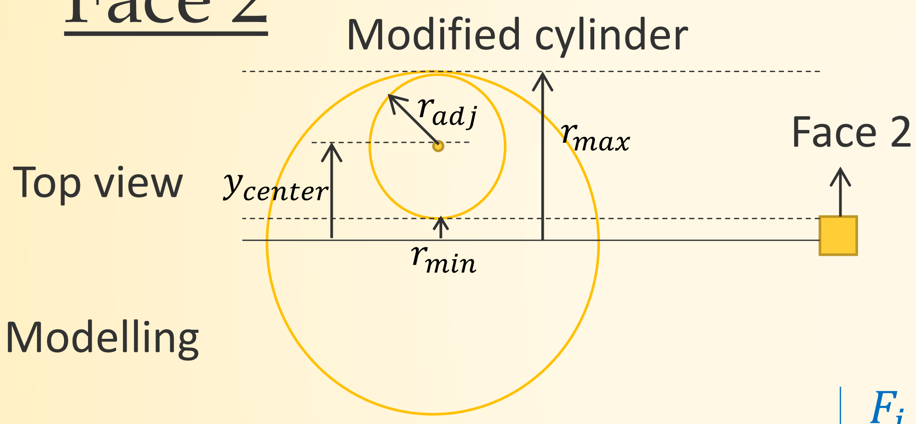


$$\text{Received flux} = \varepsilon * \varphi_{tot}$$
$$= 0.7*77 \text{ kW/m2}$$
$$= 53.9 \text{ kW/m2}$$

5. Worked examples

5.1. Example 1 : Radiation fluxes under localised fire

Face 2



z = 0

$$r_{min} = max(-r_i, x_f) = 0$$

$$r_{max} = r_i = 2.0 \text{ m}$$

$$y_{center} = \frac{r_{min}+r_{max}}{2} = 1.0 \text{ m}$$

$$r_{adjusted} = \frac{r_{max}-r_{min}}{2} = 1.0 \text{ m}$$

$$F_i = F_{dA_1 \rightarrow A_2}(s = y_{center} - x_f, x = s_f, r = r_{adjusted}, h = |z_i - z_f|)$$

$$F_{i+1} = F_{dA_1 \rightarrow A_2}(s = y_{center} - x_f, x = s_f, r = r_{adjusted}, h = |z_{i+1} - z_f|)$$

5. Worked examples

5.1. Example 1 : Radiation fluxes under localised fire

Face 2

						Ring		
zi	Tf	ri	$F_{cylinder\_zi}$	F_{ring_zi}	$Flux_{face2}$	H	Ri	Ri+1
m	°C	m	-	-	kW/m²	-	-	-
0	900	2.00	0.0175	0	1.88	0	0.00	0.00
0.5	900	1.84	0.0193	0.0060	2.71	0.20	0.40	0.37
1	900	1.67	0.0160	0	1.72	0	0.37	0.33
1.5	900	1.51	0.0103	0	1.10	0	0.33	0.30
2	900	1.35	0.0056	0	0.60	0	0.30	0.27
2.5	900	1.19	0.0028	0	0.30	0	0.27	0.24
3	900	1.02	0.0014	0	0.15	0	0.24	0.20
3.5	900	0.86	0.0006	0	0.07	0	0.20	0.17
4	900	0.70	0.0003	0	0.03	0	0.17	0.14
4.5	828	0.54	0.0001	0	0.01	0	0.14	0.11
5	708	0.37	0.0000	0	0.00	0	0.11	0.07
5.5	615	0.21	0.0000	0	0.00	0	0.07	0.04
6	540	0.05	0.0000	0	0.00	0	0.04	0.01
6.5	479	0	0	0	0	0	0.01	0.00
7	429	0	0	0	0	0	0	0
7.5	387	0	0	0	0	0	0	0
		Incident heat flux on face 2			8.57	kW/m²		
		Absorbed heat flux by face 2			6.00	kW/m²		

Input data				
HRR	Dfire	Q	Q	hf
kW/m²	m	W	MW	m
1000	4	12566370.6	12.57	6.15

Section coordinate		
sf	xf	zf
m	m	m
2.5	0	1

Constant	
σ	Tabs
5.67E-08	273.15

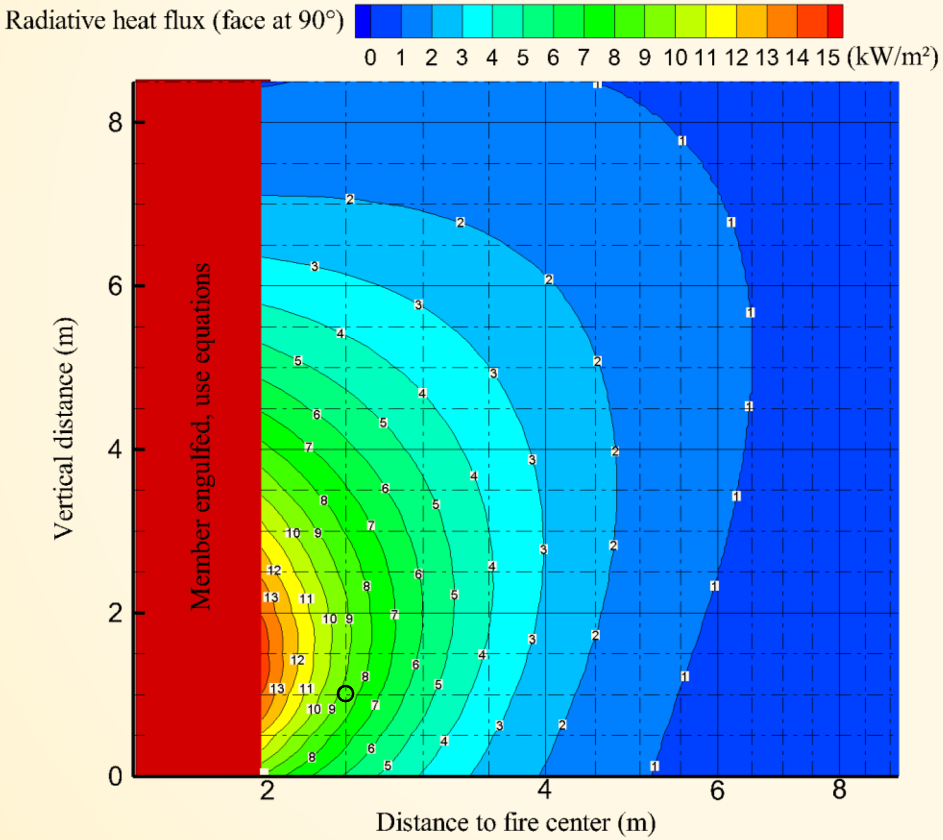
Intermediate variables	
z_{virt}	l
-0.46	2.5

Modified cylinder / ring				Cylinder									
rmin	rmax	$ri_{\_adjusted}$	y_{center}	Fi	Fi+1	s	S	X	A	Hi	Hi+1	$\|z_i-z_f\|$	$\|z_{i+1}-z_f\|$
m	m	m	m	-	-	-	-	-	-	-	-	m	m
0	2.00	1.00	1.00	0.0403	0.0229	1.00	1.00	2.50	7.25	1.00	0.50	1.00	0.50
0	1.84	0.92	0.92	0.0193	0.0000	0.92	1.00	2.72	8.40	0.54	0.00	0.50	0.00
0	1.67	0.84	0.84	0.0000	0.0160	0.84	1.00	2.99	9.91	0.00	0.60	0.00	0.50
0	1.51	0.76	0.76	0.0130	0.0233	0.76	1.00	3.31	11.93	0.66	1.32	0.50	1.00
0	1.35	0.67	0.67	0.0185	0.0241	0.67	1.00	3.70	14.72	1.48	2.22	1.00	1.50
0	1.19	0.59	0.59	0.0187	0.0215	0.59	1.00	4.21	18.74	2.53	3.37	1.50	2.00
0	1.02	0.51	0.51	0.0161	0.0174	0.51	1.00	4.88	24.81	3.90	4.88	2.00	2.50
0	0.86	0.43	0.43	0.0124	0.0130	0.43	1.00	5.80	34.64	5.80	6.96	2.50	3.00
0	0.70	0.35	0.35	0.0086	0.0089	0.35	1.00	7.15	52.09	8.58	10.01	3.00	3.50
0	0.54	0.27	0.27	0.0053	0.0054	0.27	1.00	9.31	87.70	13.04	14.90	3.50	4.00
0	0.37	0.19	0.19	0.0026	0.0027	0.19	1.00	13.35	179.33	21.37	24.04	4.00	4.50
0	0.21	0.11	0.11	0.0009	0.0009	0.11	1.00	23.60	557.97	42.48	47.20	4.50	5.00
0	0.05	0.02	0.02	0.0000	0.0000	0.02	1.00	101.41	10285.43	202.82	223.11	5.00	5.50
0	0	0	0	0	0	0	0	0	0	0	0	5.50	6.00
0	0	0	0	0	0	0	0	0	0	0	0	6.00	6.50
0	0	0	0	0	0	0	0	0	0	0	0	6.50	1.00

5. Worked examples

5.1. Example 1 : Radiation fluxes under localised fire

Face 2



Received flux $= \varepsilon * \varphi_{tot}$
$= 0.7*8.7$ kW/m2
$= 6.1$ kW/m2

5. Worked examples

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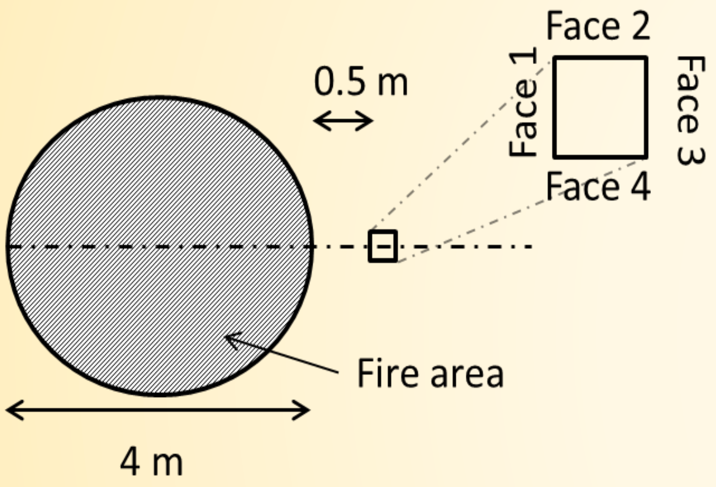

Heat flux received by each face (assuming $\varepsilon = 0.7$)

Face 1 : 53.45 kW/m²

Face 2 : 6.00 kW/m²

Face 3 : 0.00 kW/m²

Face 4 : 6.00 kW/m²

→ Mean heat flux = 16.36 kW/m²

$$0 = \underbrace{h(T-20)}_{\text{Emitted net convective flux}} + \underbrace{\sigma\varepsilon[(T+273)^4 - (20+273)^4]}_{\text{Emitted radiative flux}} - \underbrace{\varepsilon * \varphi_{tot}}_{\text{Received flux}}$$

$$h = 35\, W.m^{-2}.K^{-1};\ \sigma = 5.67 * 10^{-8}\, W.m^{-2}.K^{-4}$$

T (°C)	Emitted flux W/m²
20	0
30	392.03
40	788.42
50	1189.49
…	…
280	12519.26
290	13145.11
300	13786.06
310	14442.65
320	15115.43
330	15804.96
340	16511.80
350	17236.55
360	17979.78

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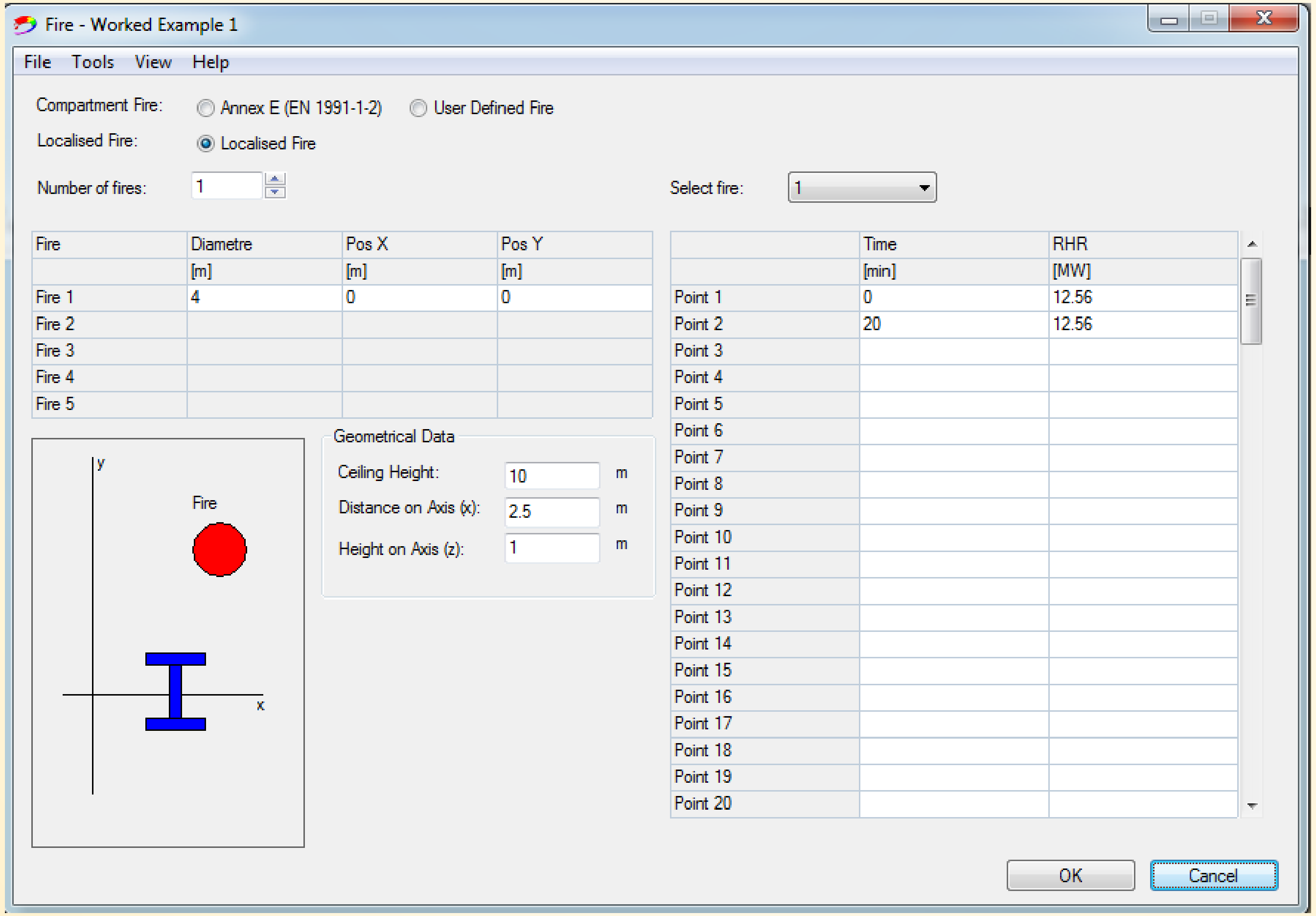

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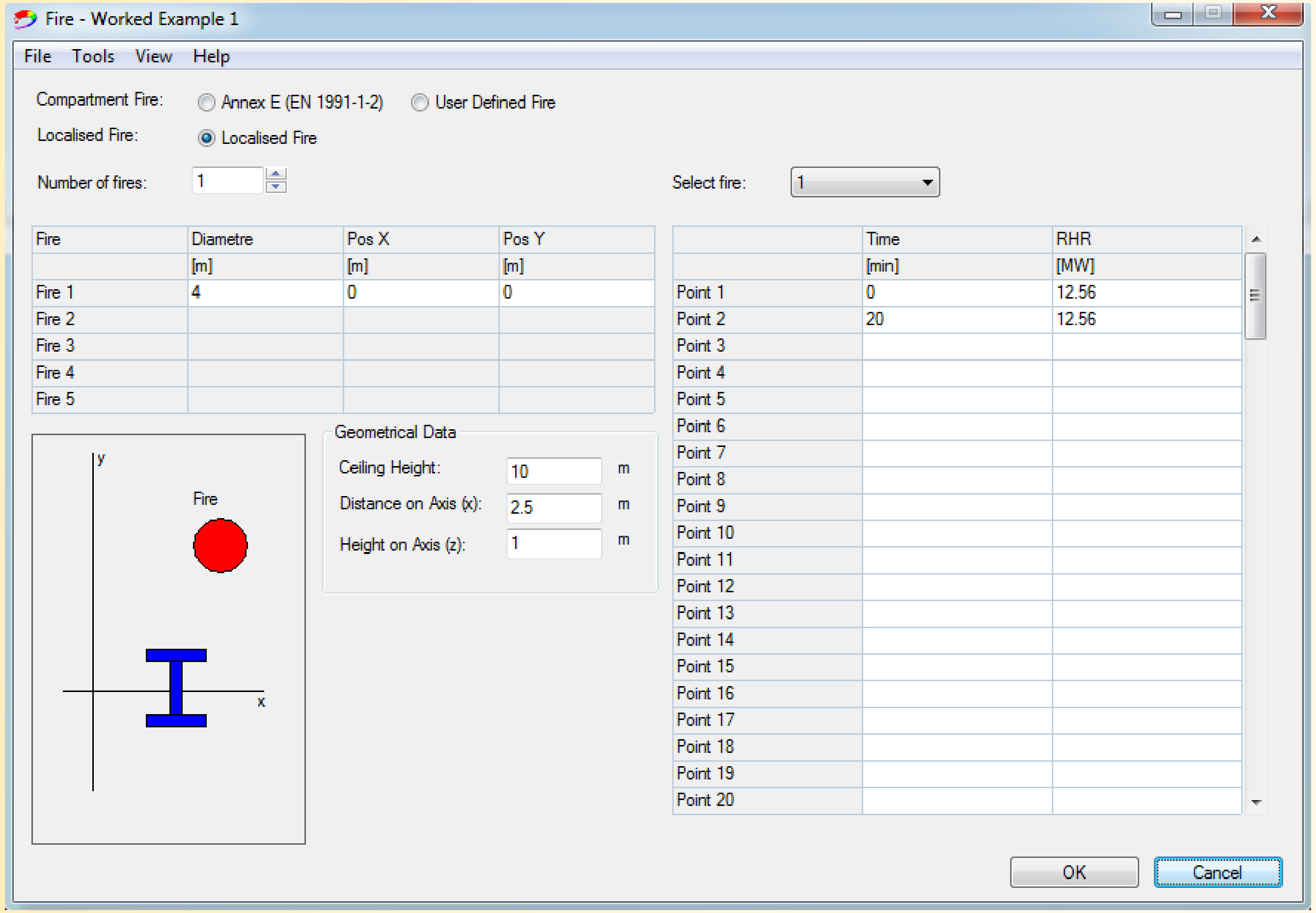

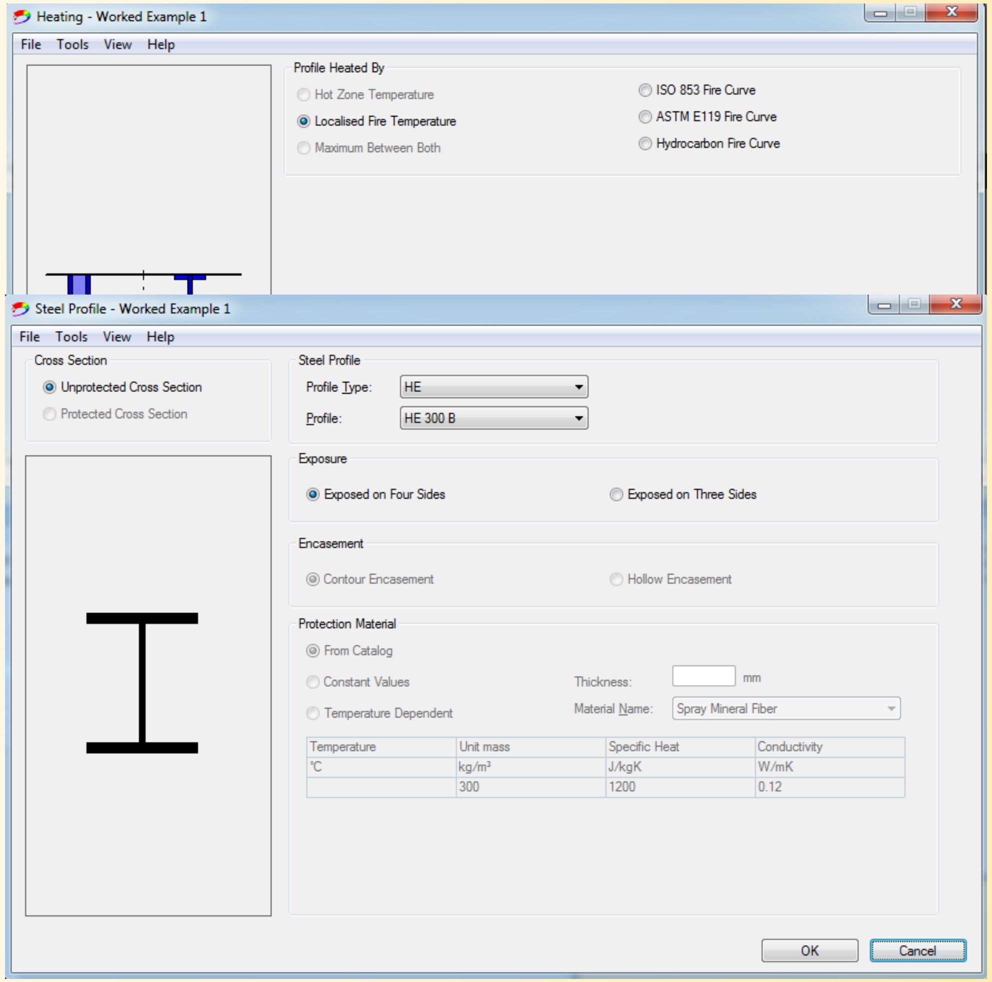

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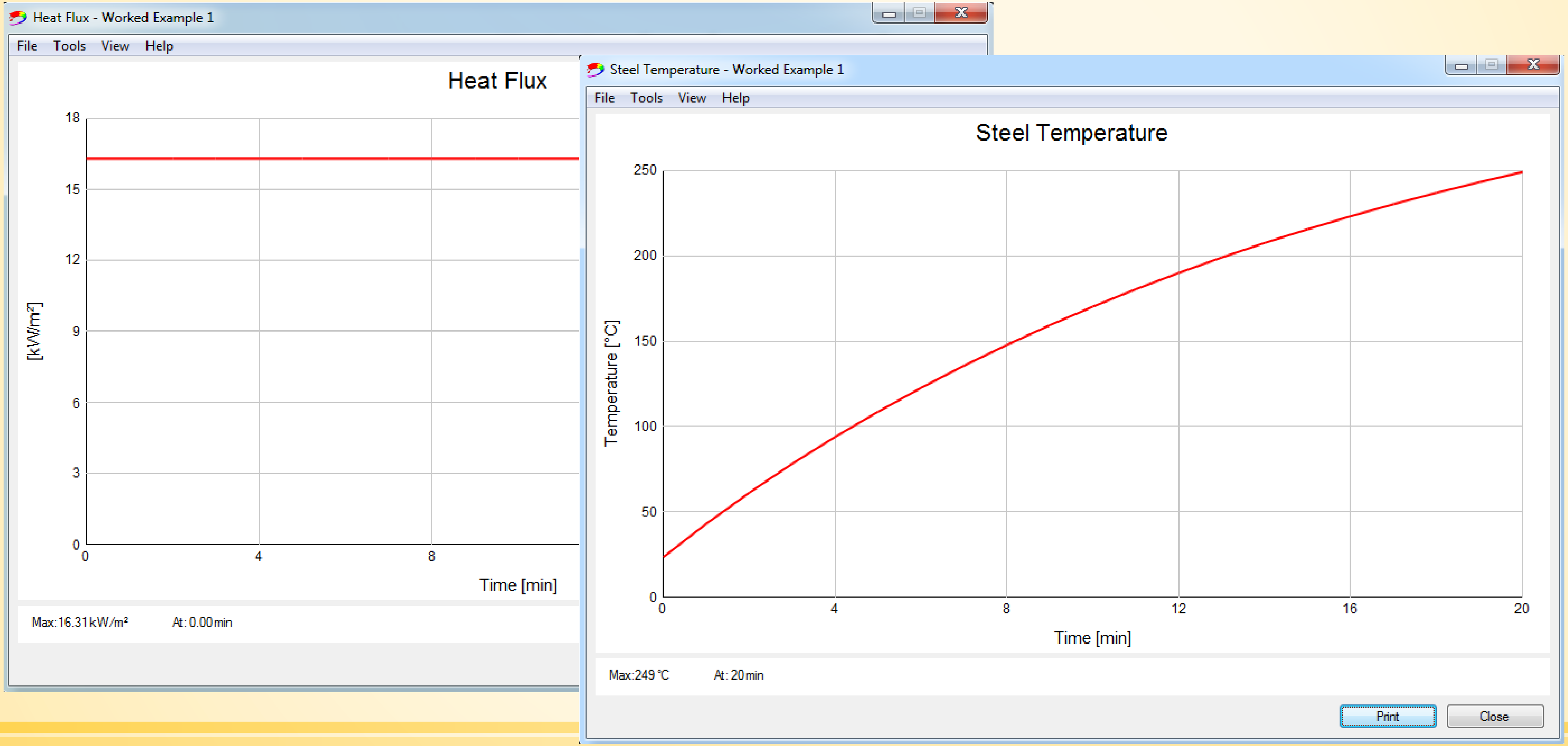
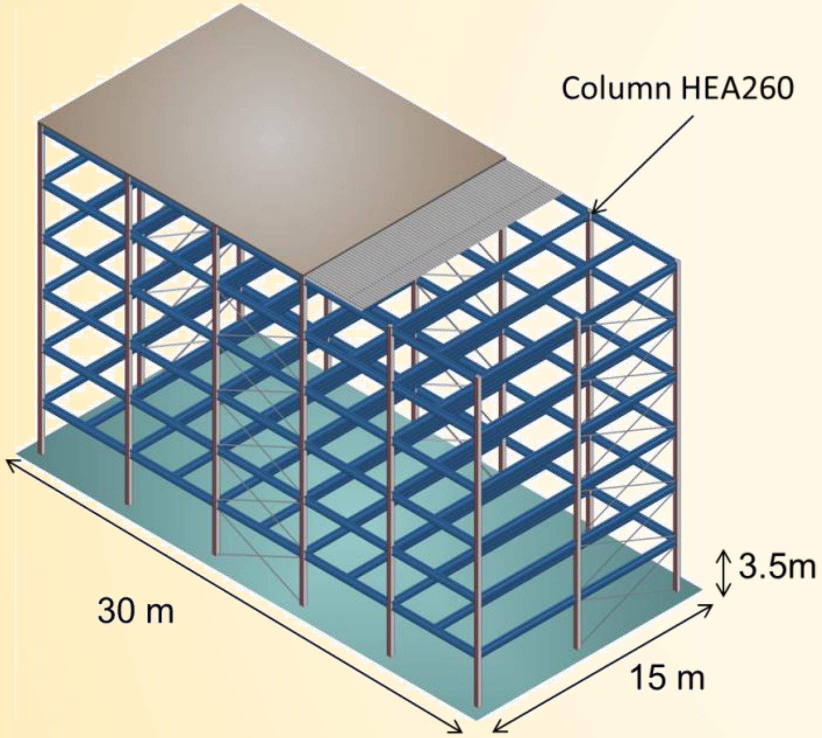


5.2. Example 2 : Column of an office building

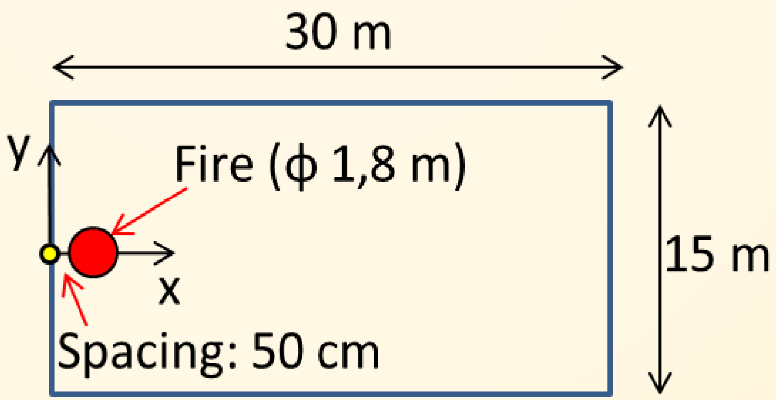


Fire source situated at a distance of 0.5 m from the column

Ceiling level : 3.5 m

Fire source : 500 kg of paper (17.5 MJ/kg) on a 2.5m² area

RHR_{max} = 1000 kW/m²



5. Worked examples

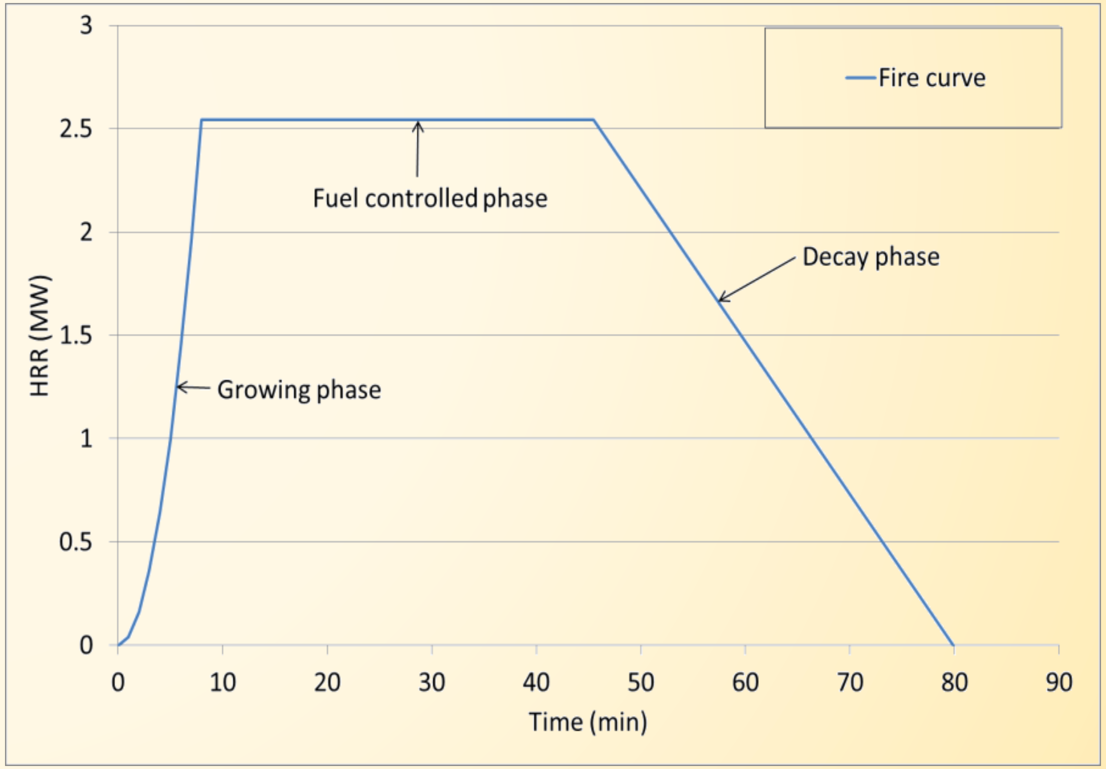
5.2. Example 2 : Column of an office building

Development of the fire according to EN 1991-1-2 Annex E

- *Growing phase : $Q(t) = 10^6 * (t/t_\alpha)^2$*
- *Speed of development : Medium*

→ RHR = 1 MW after t_α = 300 sec

- *RHR_{max} = 2.5m2 * 1000kW/m^2 = 2.5 MW*
- *Decay phase starts after 70% of the fuel has burnt*



5. Worked examples

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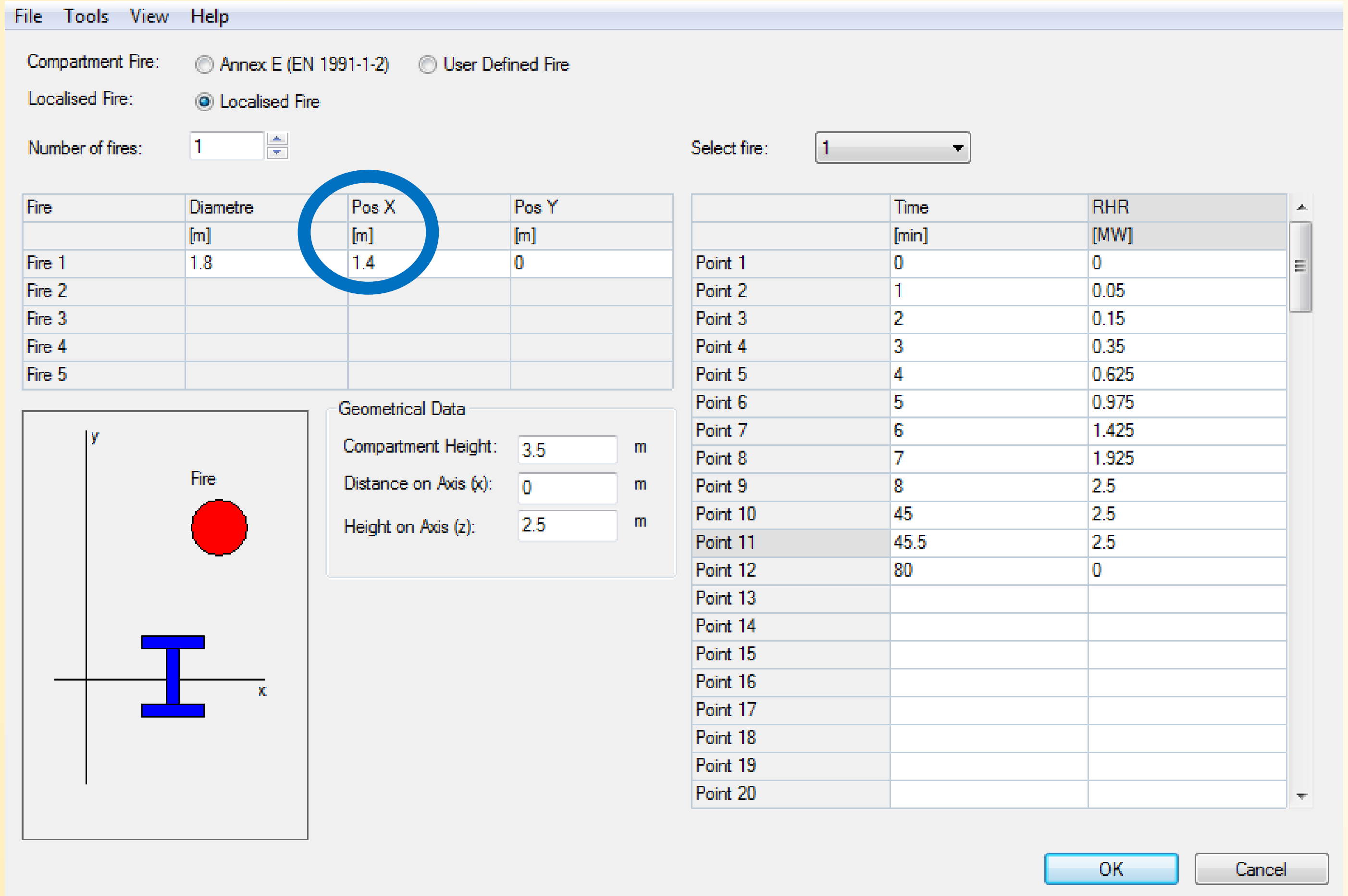
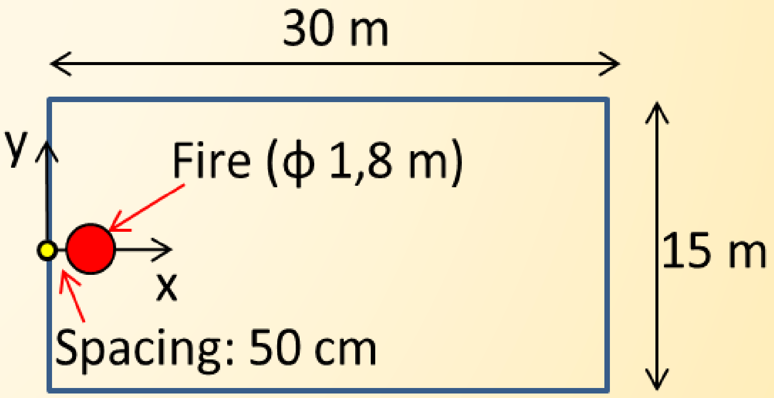


Pos x : 0.5m + 1.8m/2 = 1.4m



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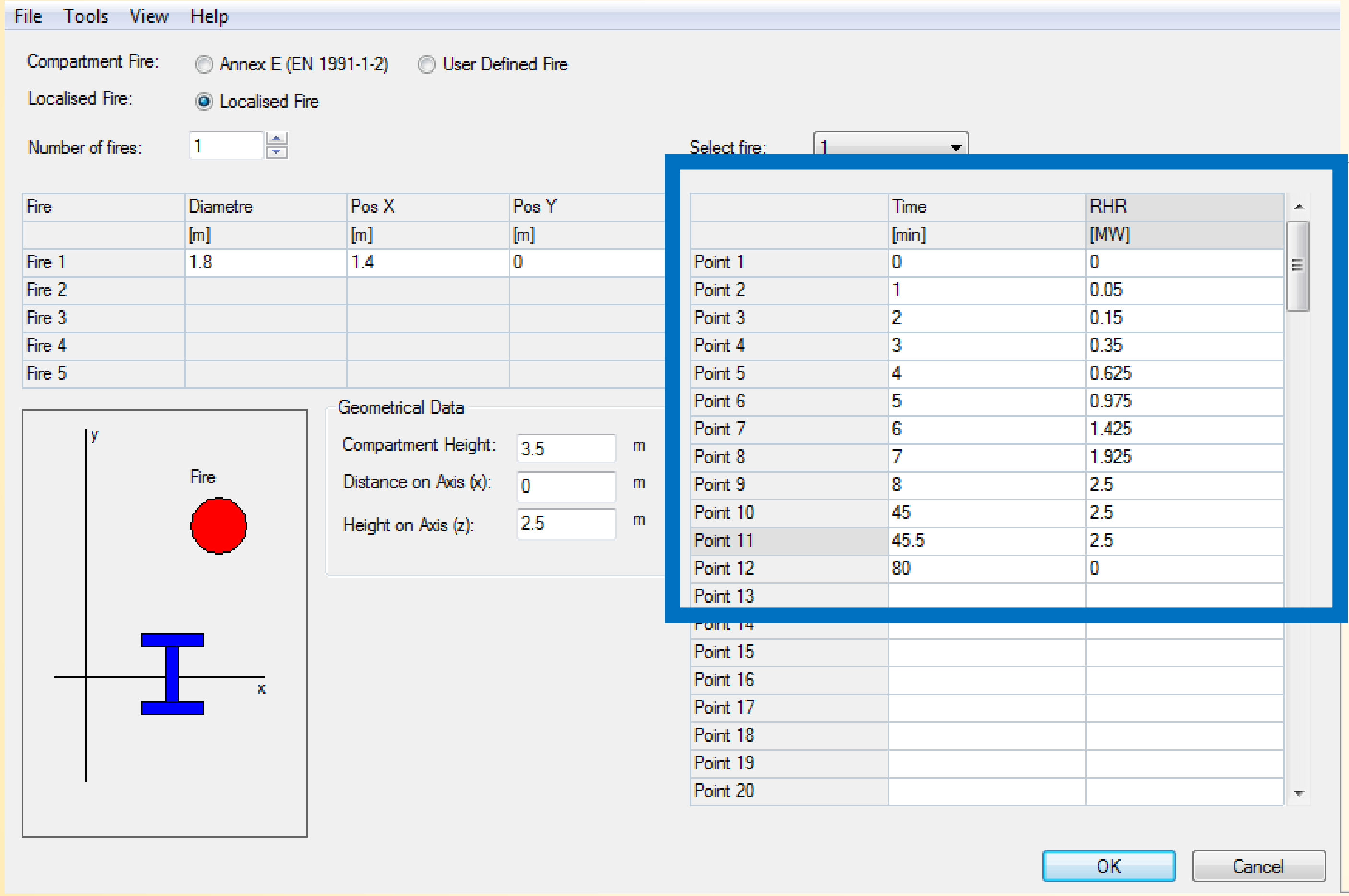

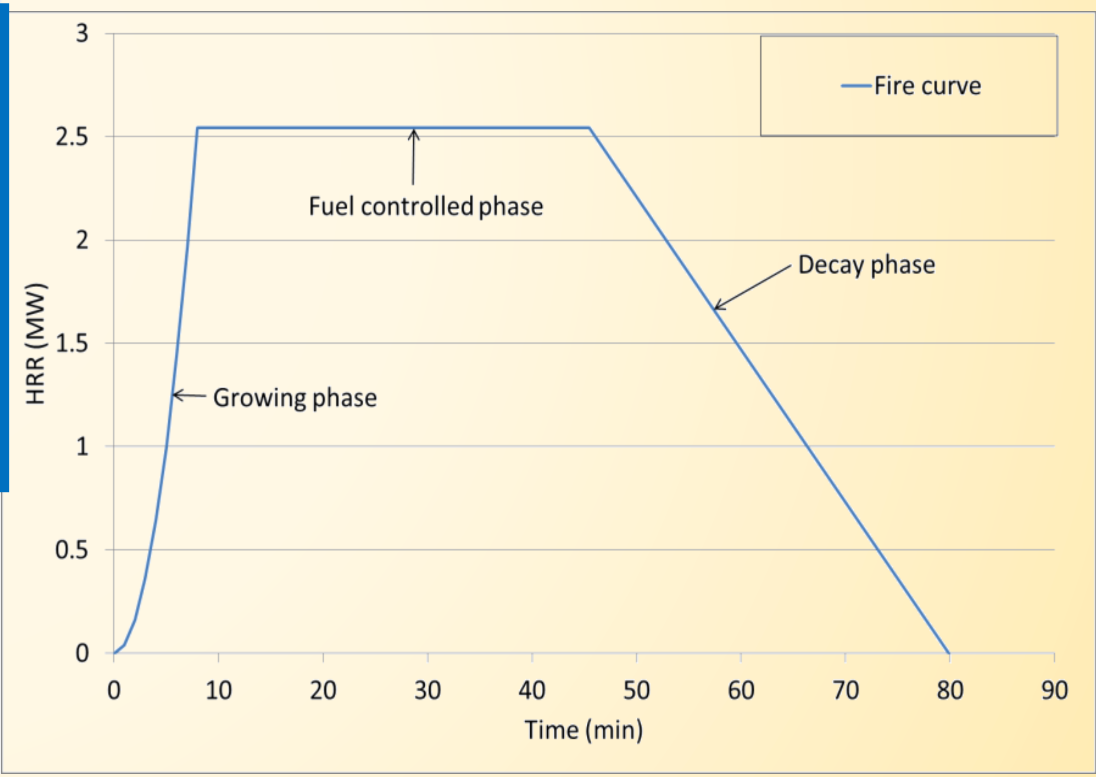

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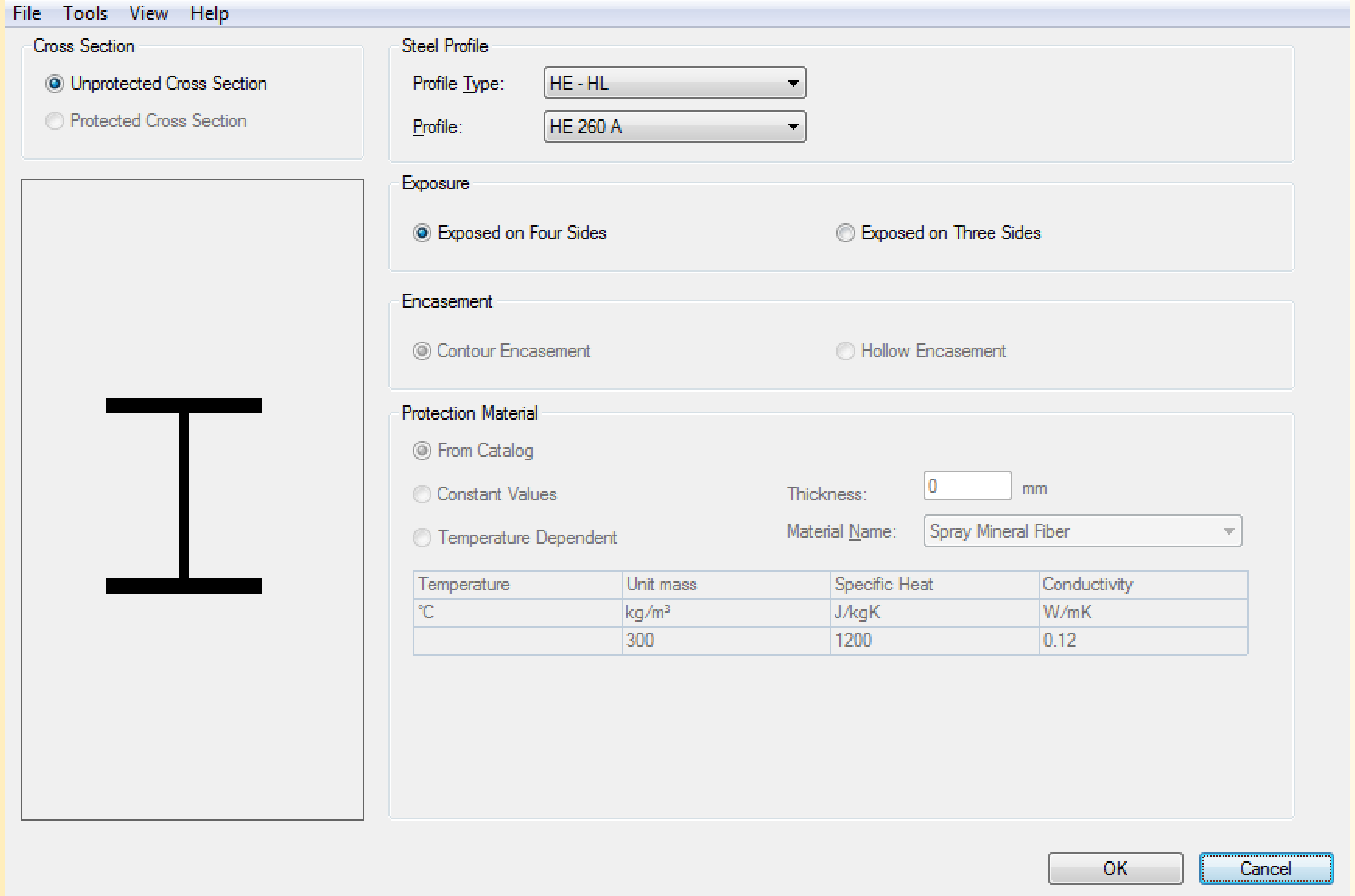

5. Worked examples

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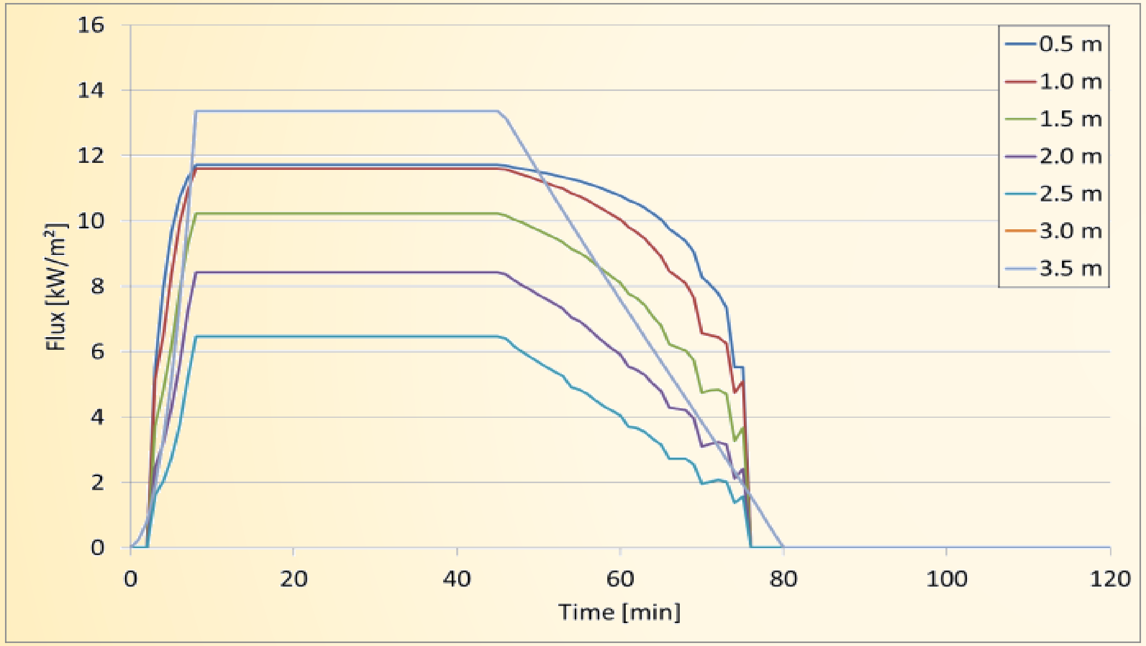
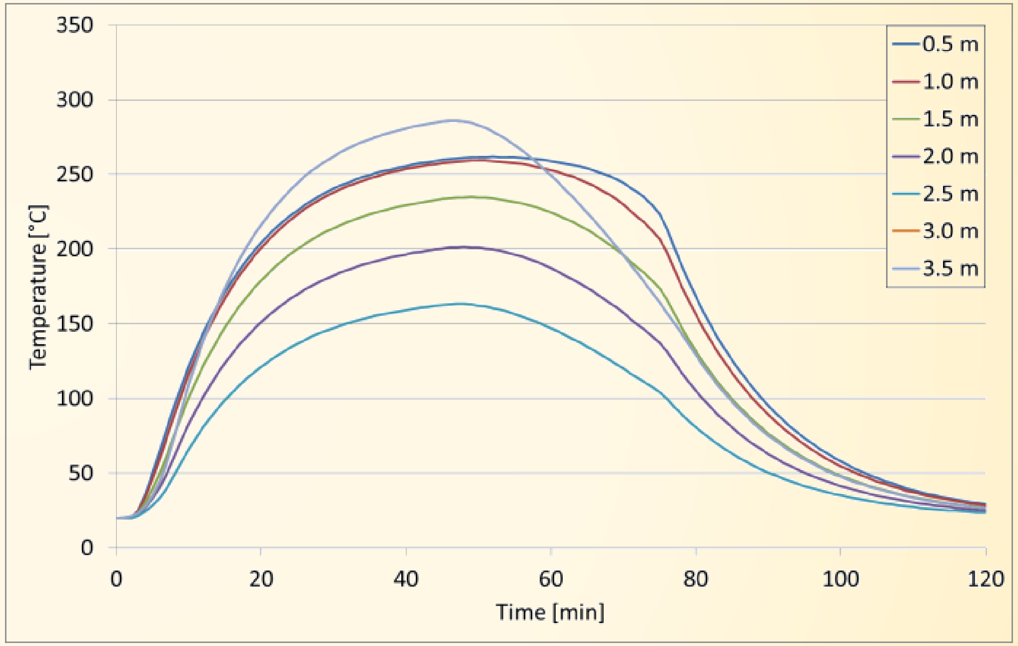
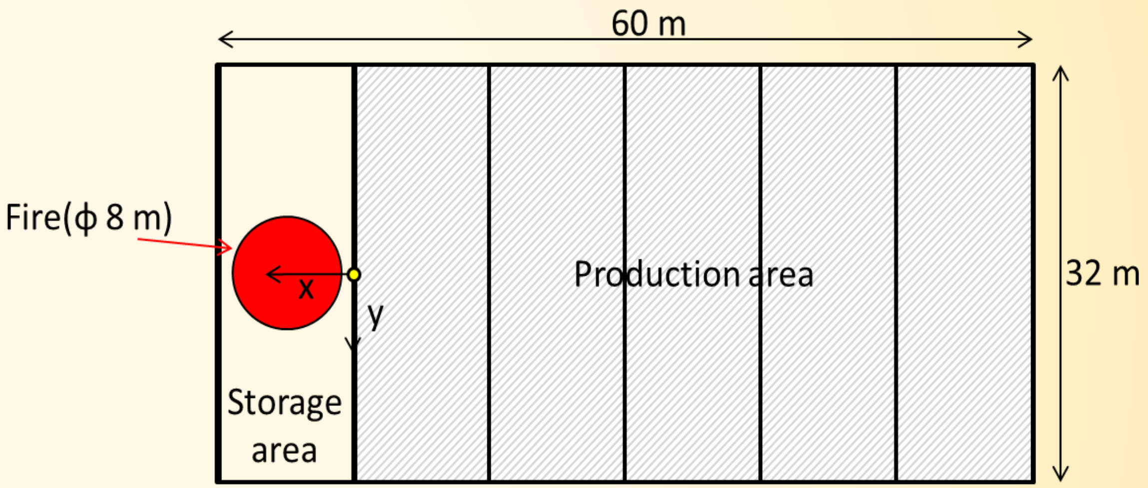




- Maximum received radiative heat flux in the hot smoke layer
- Hot smoke layer (z = 3.5m) : temperature reaches 290°C
- Outside smoke layer (z = 0.5m and z = 1m) : ~250°C

5.3. Example 3 : Truss of an industrial building

***Description of the structure* :**

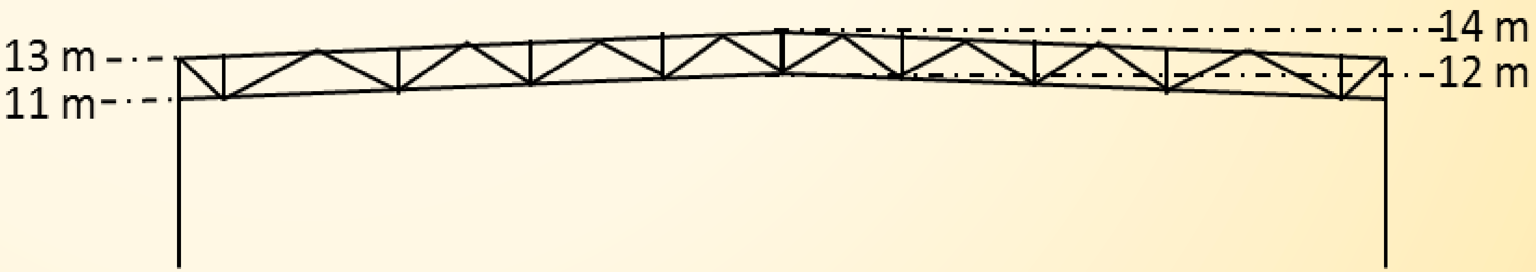


Truss flanges section : HEA 220

Truss diagonals section : 2 L60*60*6

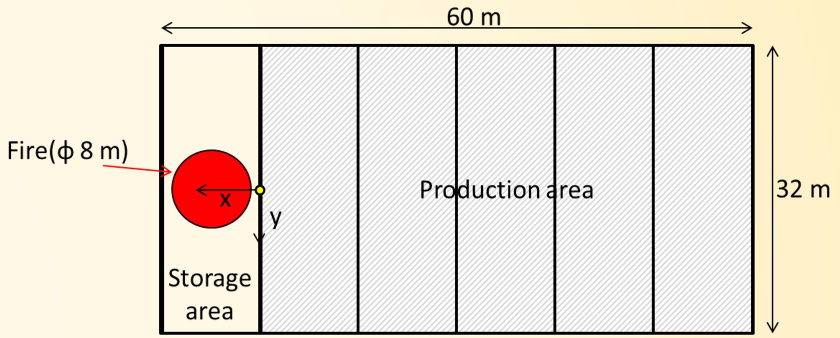
Distance between 2 steel frames : 10 m

Apex height : 14 m



5. Worked examples

5.3. Example 3 : Truss of an industrial building



Fire scenario :

Fire area : 50 m^2 (center of storage area)

→ Equivalent diameter : 8 m

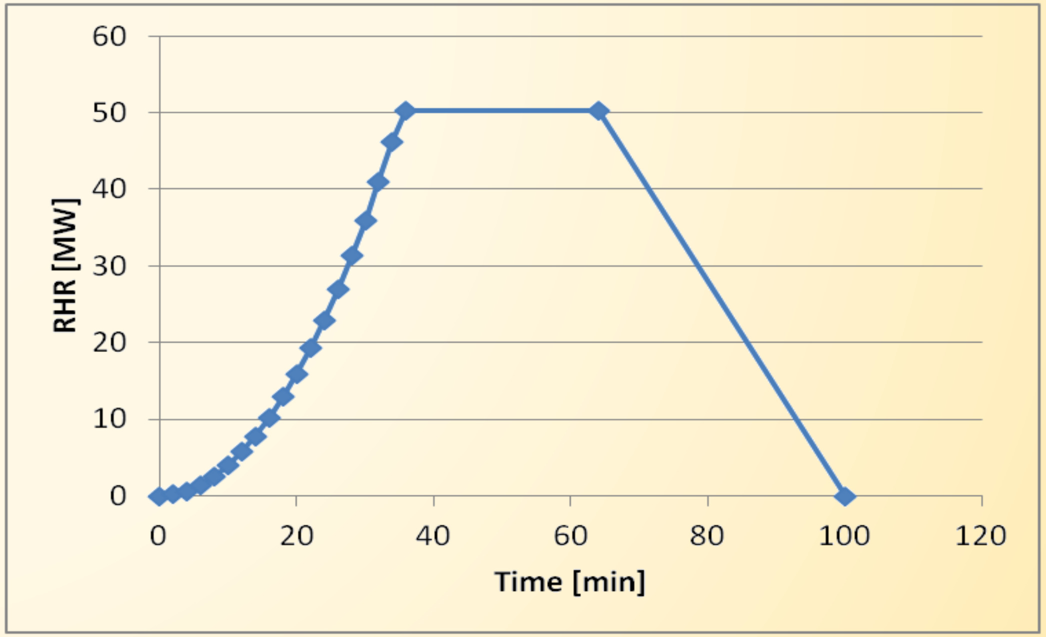
Speed of development : Medium

→ RHR = 1 MW after t_α = 300 sec

*RHR_{max} = 1000 kW/m^2*50m^2 = 50 MW*

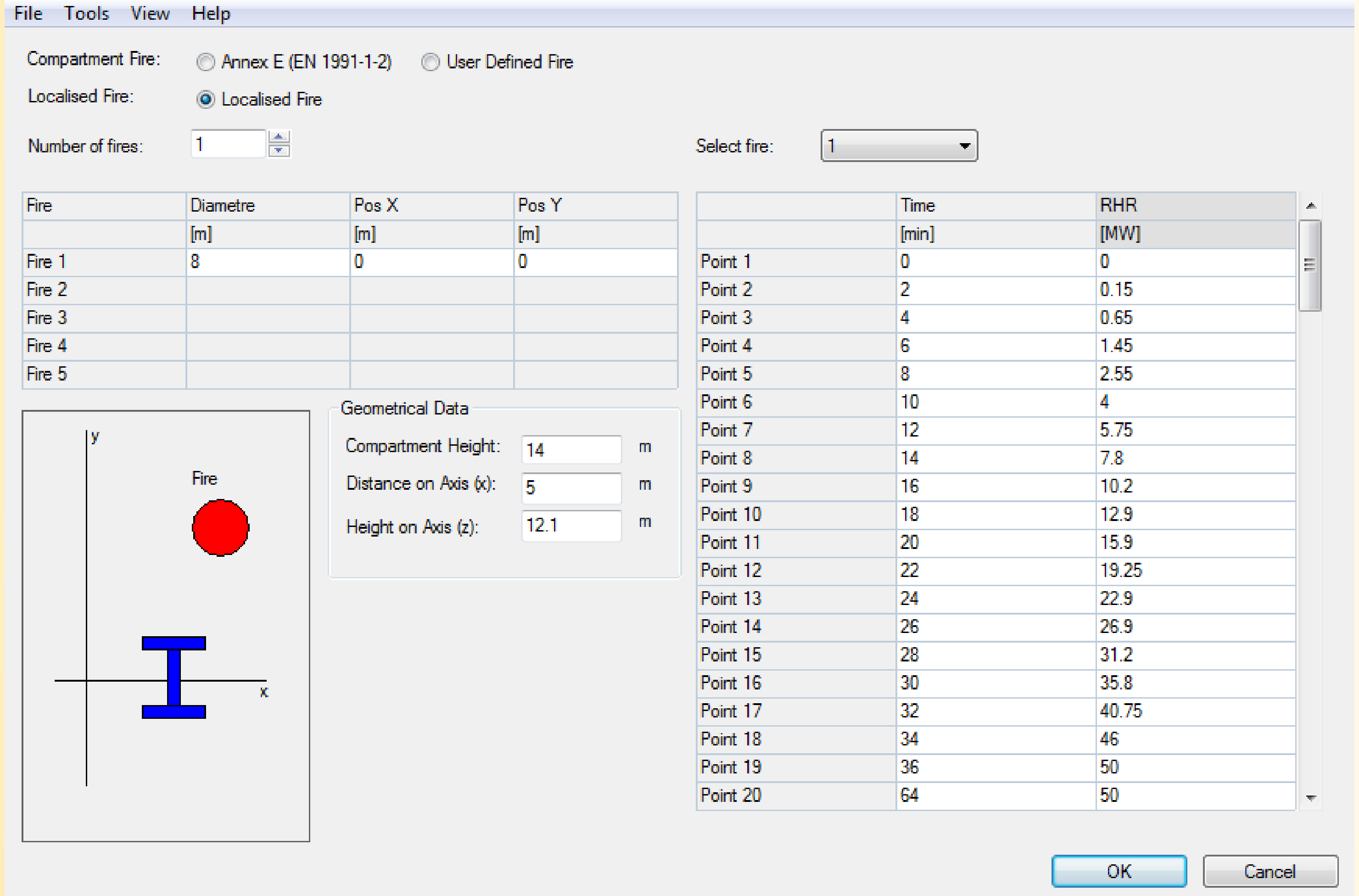
Fire Load : 10 To (cellulosic)

*→ Q = 17.5 MJ/kg*10000 kg = 175000 MJ*



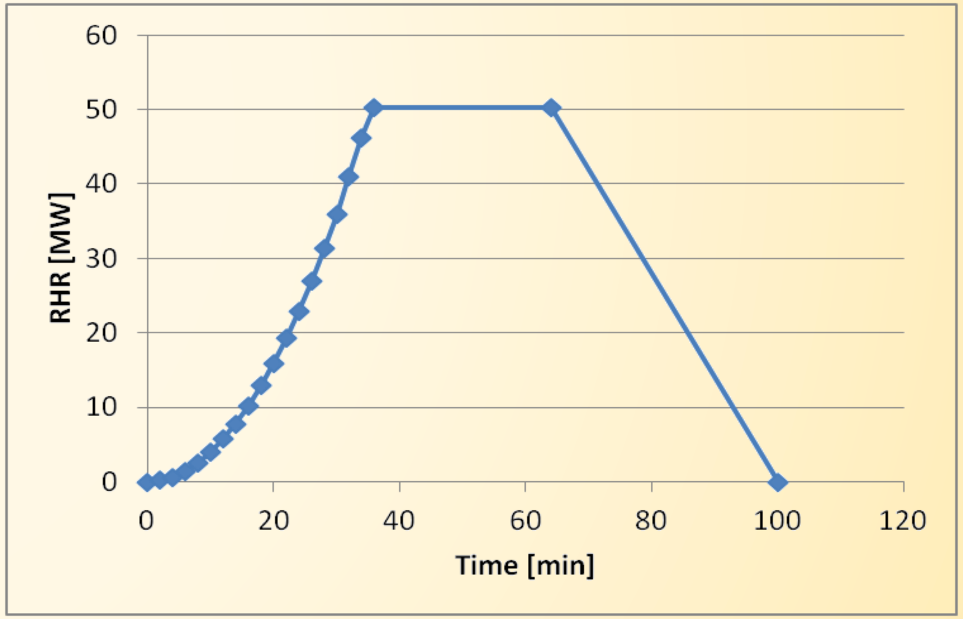
5. Worked examples

5.3. Example 3 : Truss of an industrial building

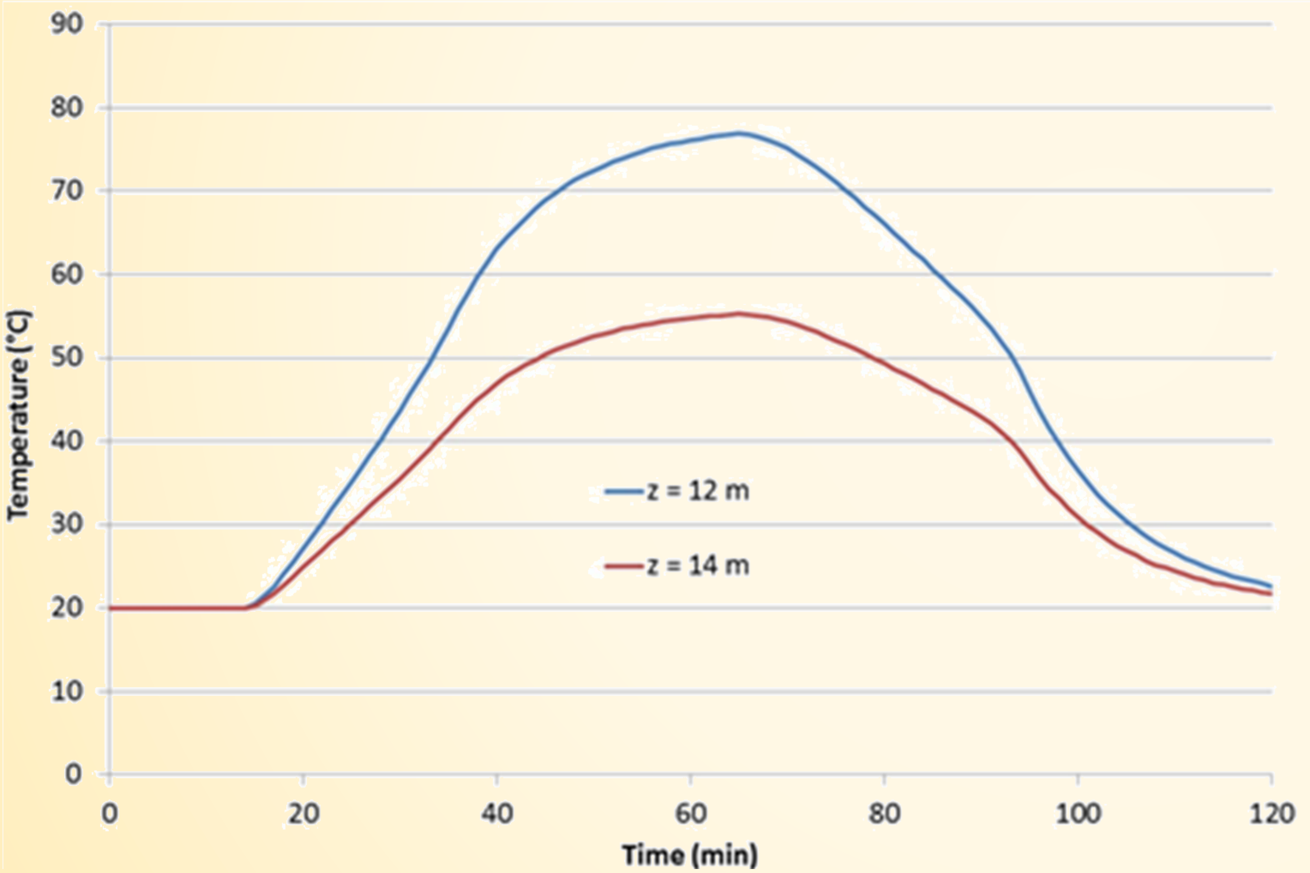


Fire	Diametre	Pos X	Pos Y
	[m]	[m]	[m]
Fire 1	8	0	0
Fire 2			
Fire 3			
Fire 4			
Fire 5			

	Time	RHR
	[min]	[MW]
Point 1	0	0
Point 2	2	0.15
Point 3	4	0.65
Point 4	6	1.45
Point 5	8	2.55
Point 6	10	4
Point 7	12	5.75
Point 8	14	7.8
Point 9	16	10.2
Point 10	18	12.9
Point 11	20	15.9
Point 12	22	19.25
Point 13	24	22.9
Point 14	26	26.9
Point 15	28	31.2
Point 16	30	35.8
Point 17	32	40.75
Point 18	34	46
Point 19	36	50
Point 20	64	50



5.3. Example 3 : Truss of an industrial building



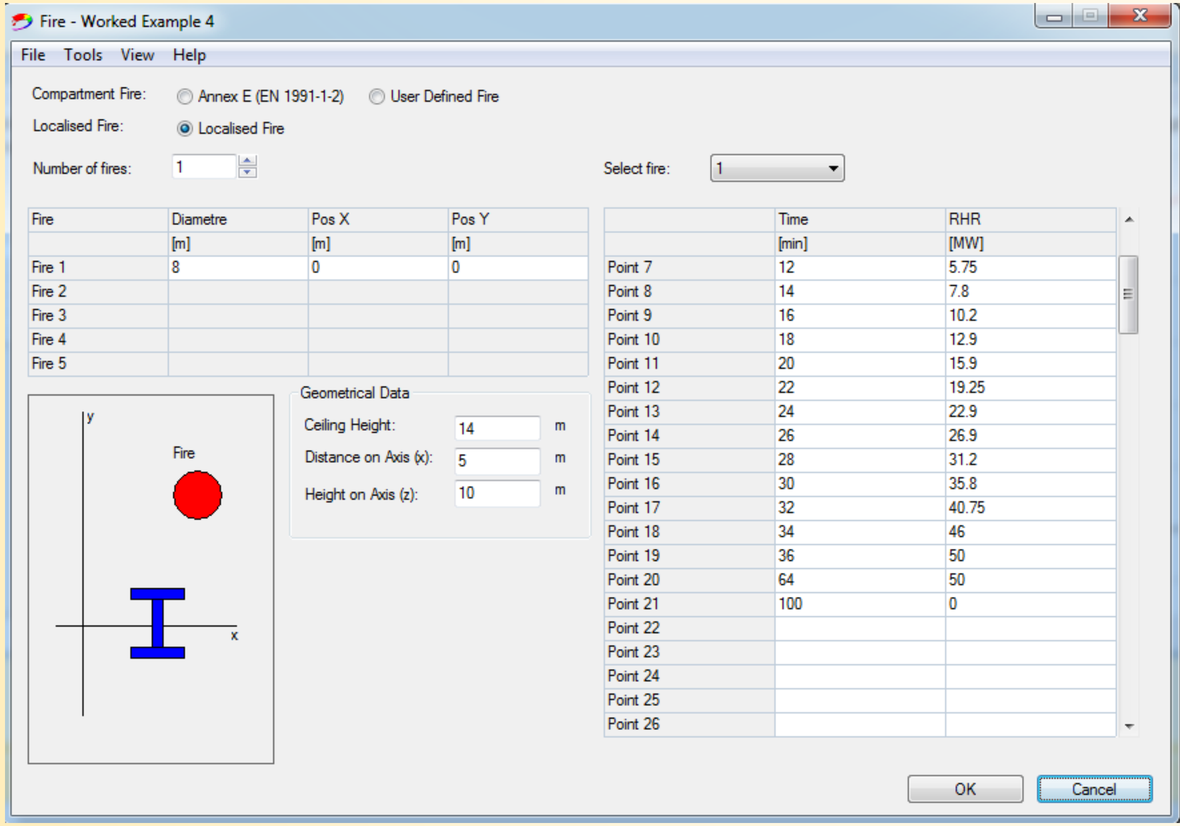
Flame height = 9.7m

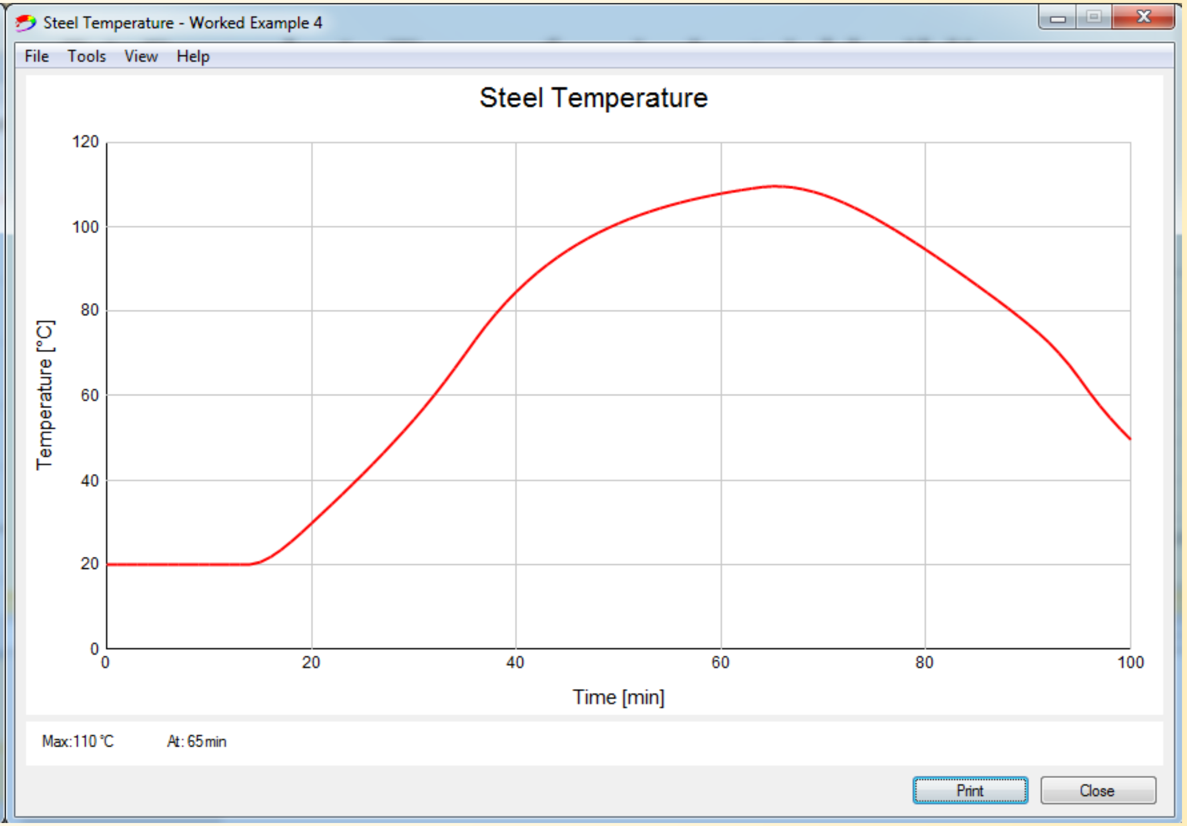
→ Truss members are situated above the solid flame

Max. temperature of trusses = 210°C

5. Worked examples

5.3. Example 3 : Truss of an industrial building

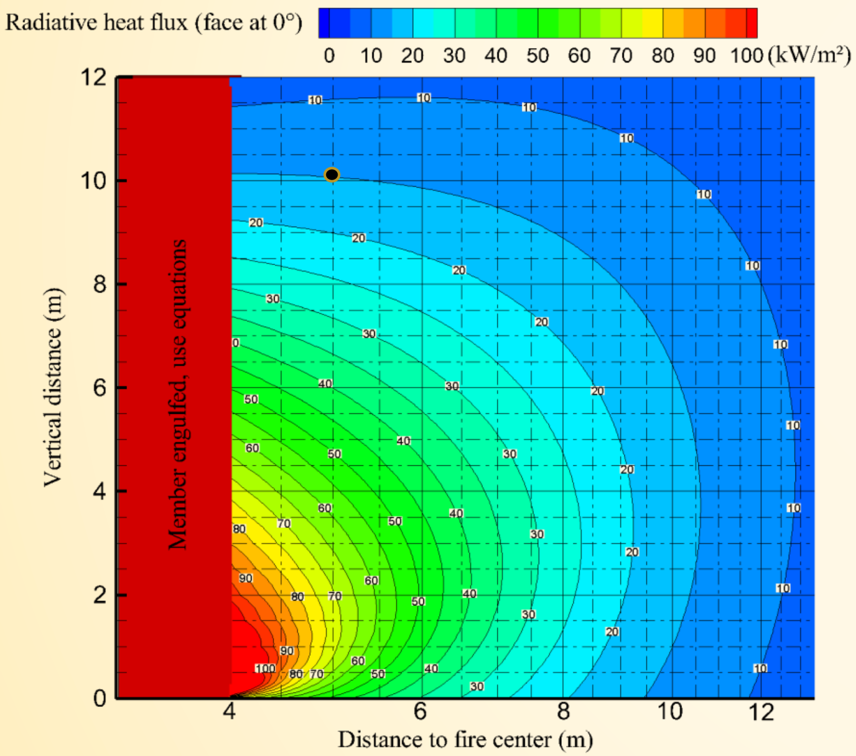




5. Worked examples

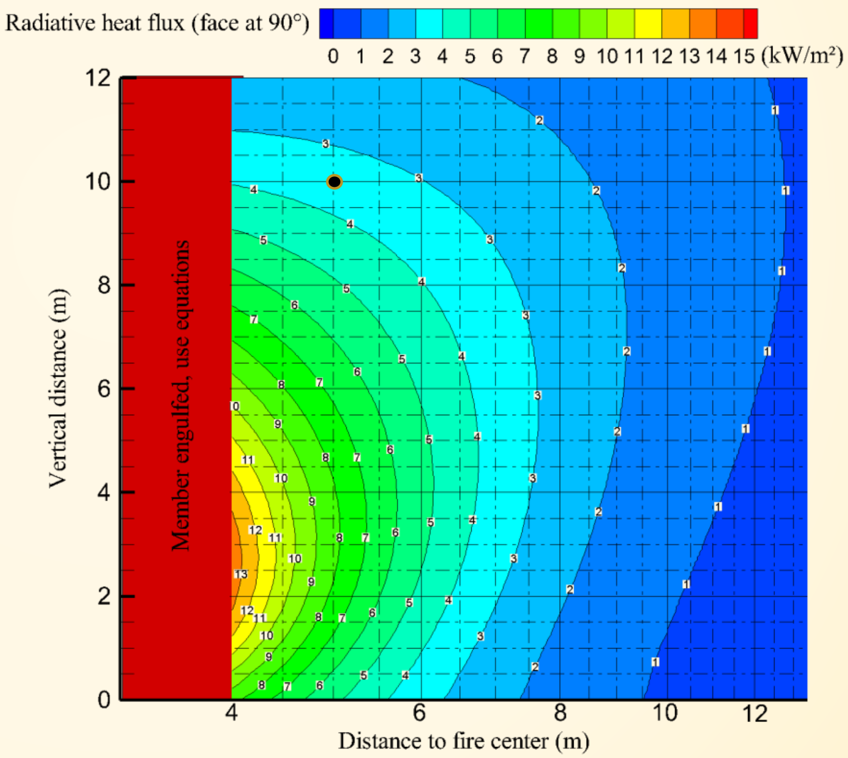
5.3. Example 3 : Truss of an industrial building

Face 1



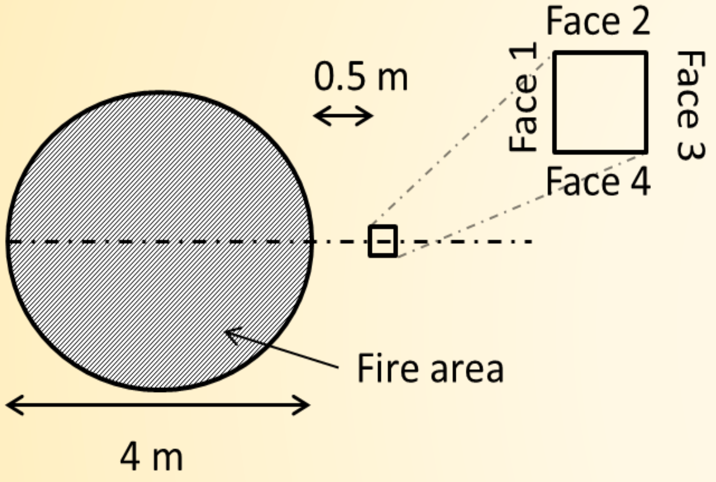
$\varepsilon * \varphi_{tot}$ = 0.7*15 kW/m^2 = 10.5 kW/m^2

Face 2



$\varepsilon * \varphi_{tot}$ = 0.7*3.5 kW/m^2 = 2.45 kW/m^2

5.3. Example 3 : Truss of an industrial building



Heat flux received by each face (assuming $\varepsilon = 0.7$)

Face 1 : 10.5 kW/m²

Face 2 : 2.45 kW/m²

Face 3 : 0.00 kW/m²

Face 4 : 2.45 kW/m²

→ Mean heat flux = 3.85 kW/m²

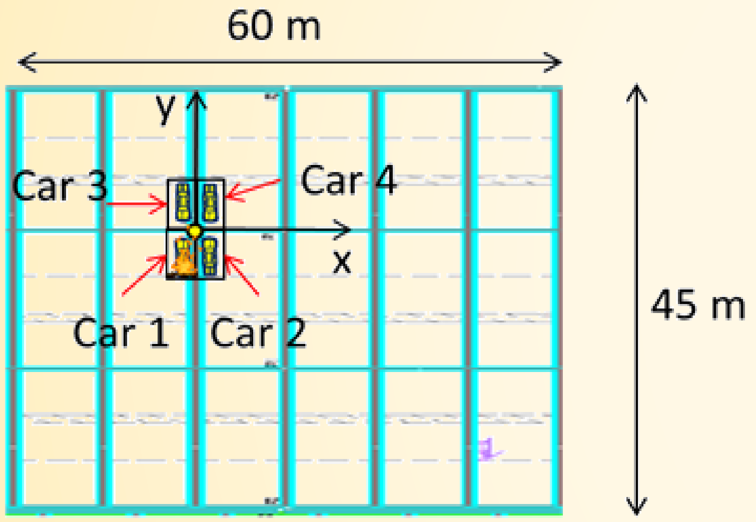
$$0 = \underbrace{h(T-20)}_{\text{Emitted convective flux}} + \underbrace{\sigma\varepsilon[(T+273)^4 - (20+273)^4]}_{\text{Emitted radiative flux}} - \underbrace{\varepsilon * \varphi_{tot}}_{\text{Received flux}}$$

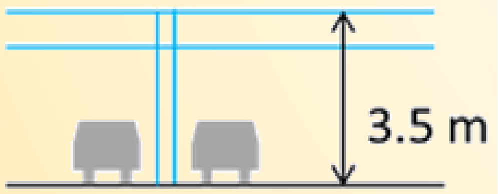
$$h = 35\, W.m^{-2}.K^{-1};\ \sigma = 5.67 * 10^{-8}\, W.m^{-2}.K^{-4}$$

T (°C)	Emitted flux W/m²
20	0
30	392.03
40	788.42
50	1189.49
60	1595.53
70	2006.84
80	2423.77
90	2846.62
100	3275.76
110	3711.52
120	4154.27
130	4604.37
140	5062.21
150	5528.18

5. Worked examples

5.3. Example 3 : Column of a car park





HEA 300 column

Ceiling level : 3.5 m

*Dimensions of the parking slot : 2.5m*5m*

→ Equivalent diameter of the fire : 4 m

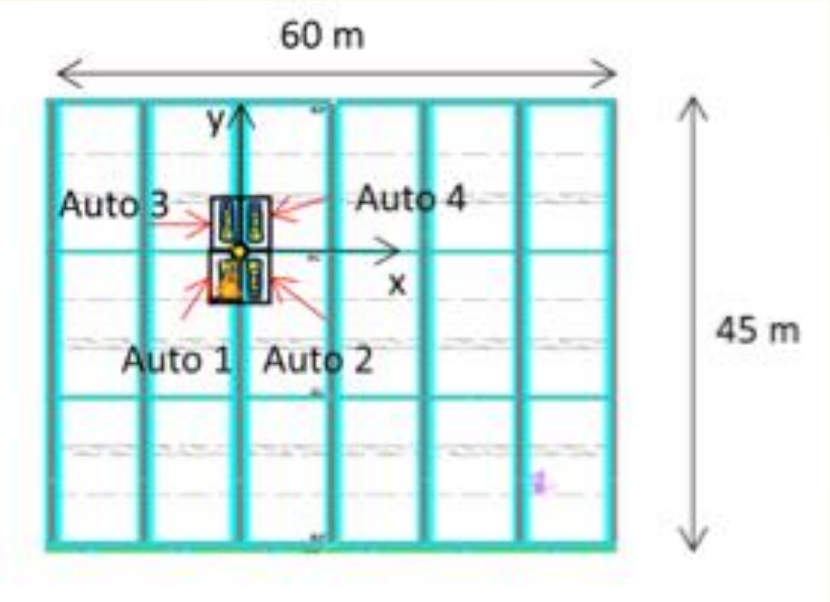
Fire scenario : 4 cars

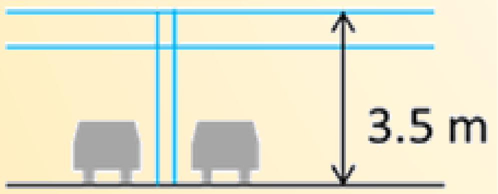
Ignition time between two consecutive cars : 12 minutes

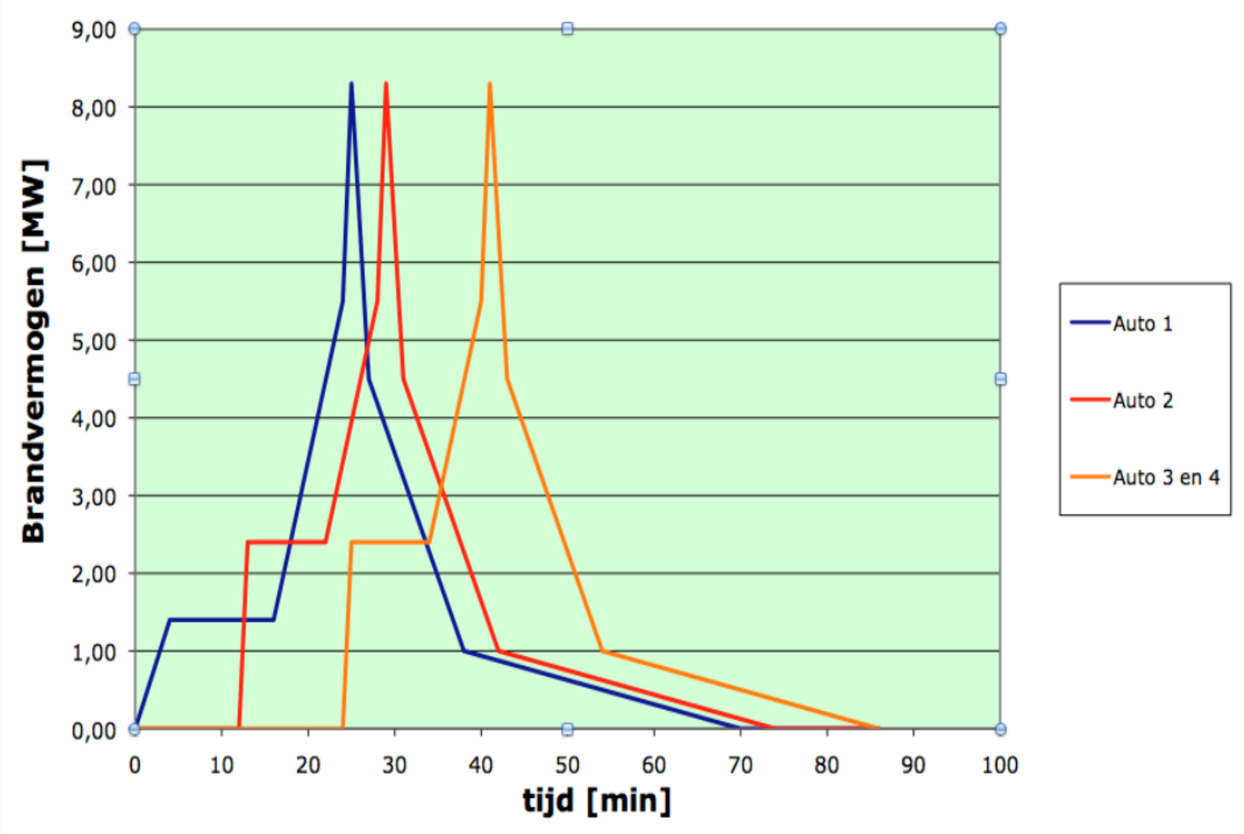
According to BmS Guideline: car 2 at 12', car 3+4 at 24'

5. Worked examples

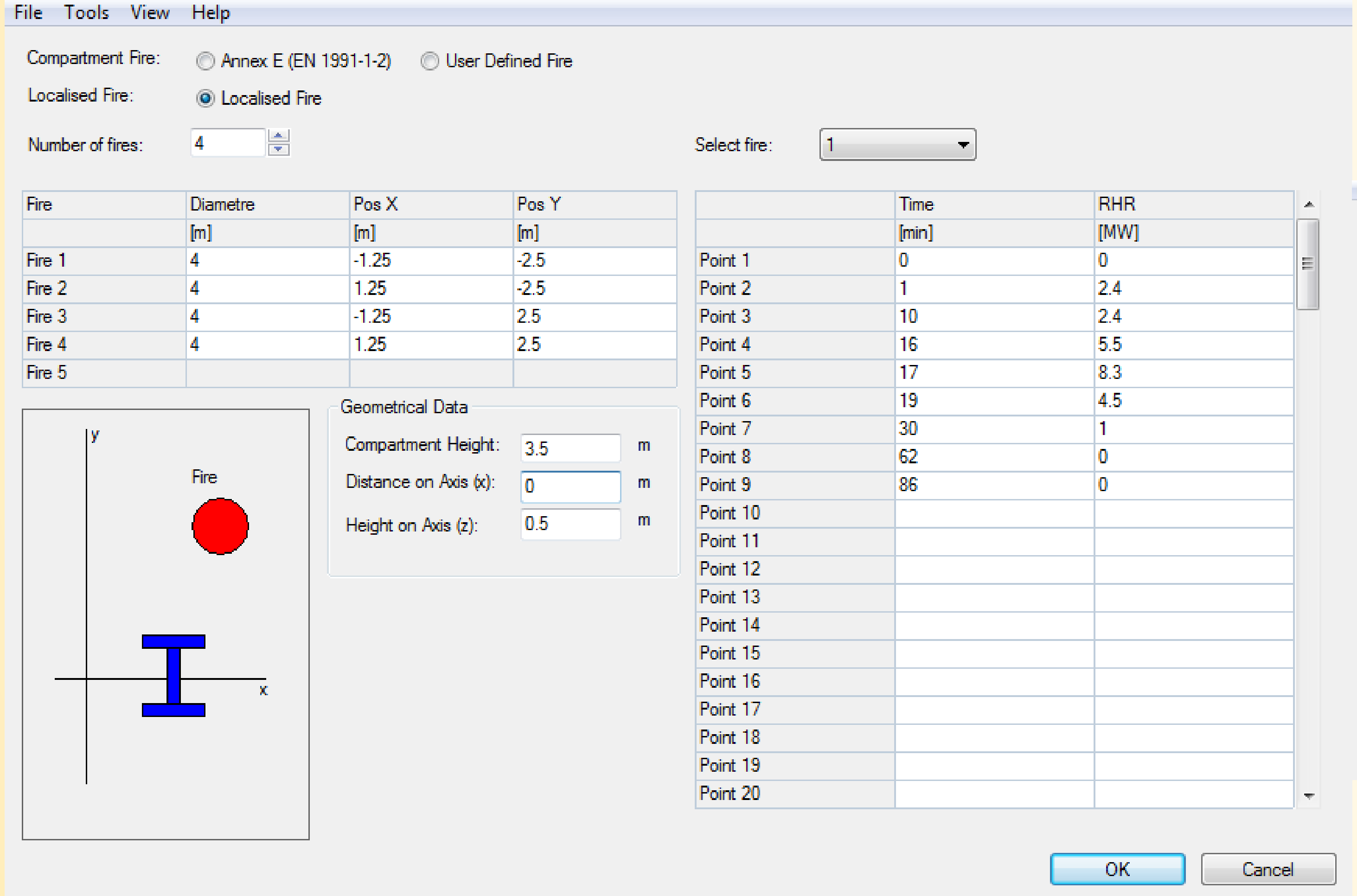
5.3. Example 3 : Column of a car park

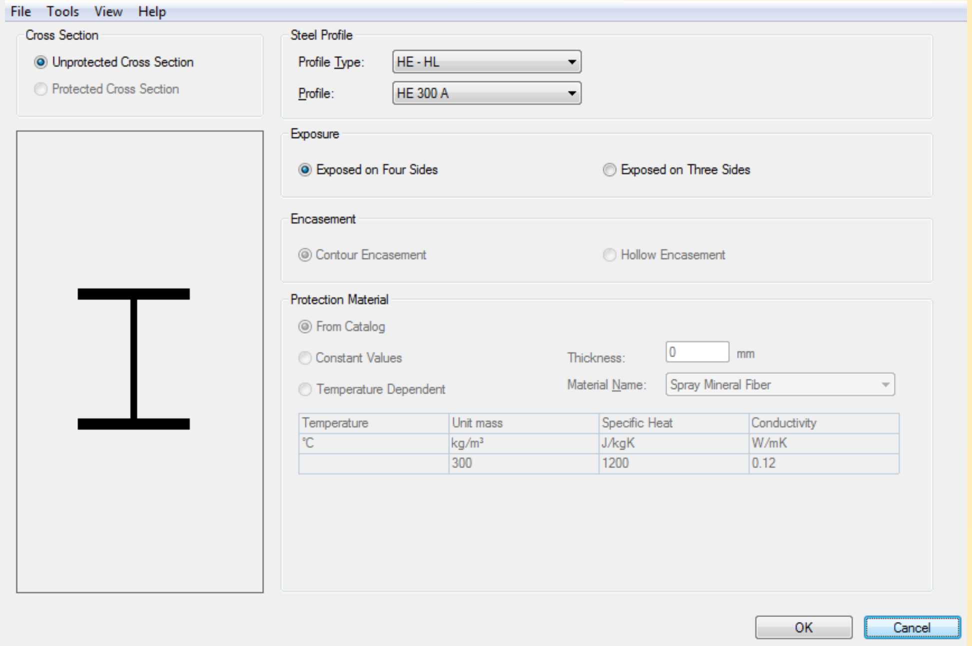






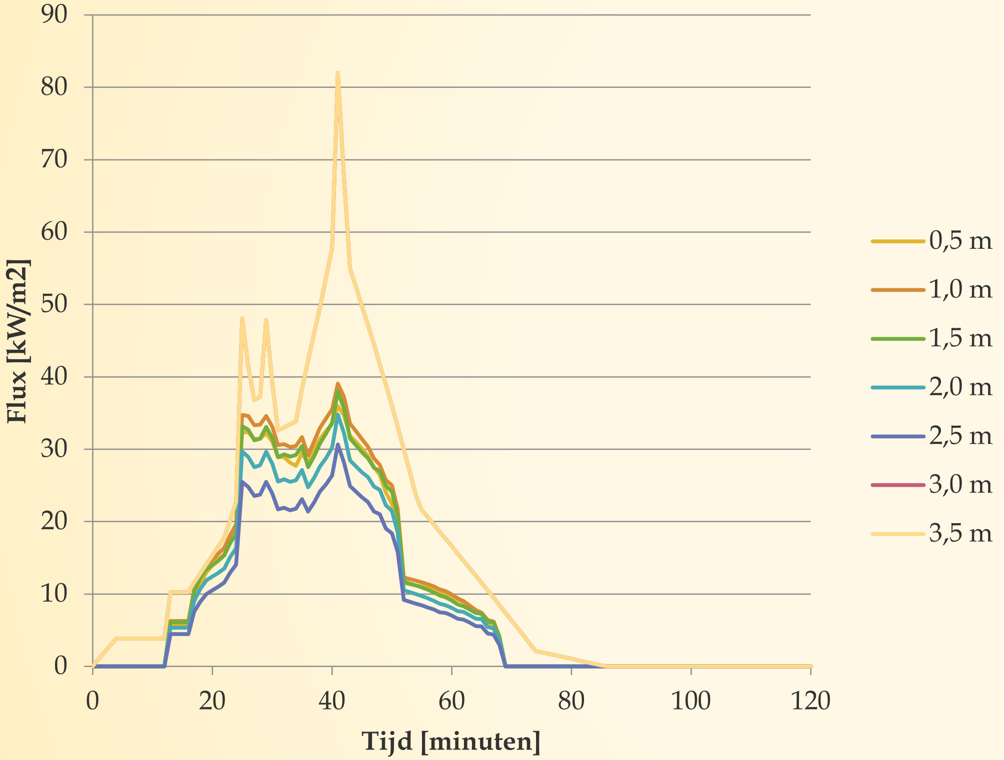
5.3. Example 3 : Column of a car park

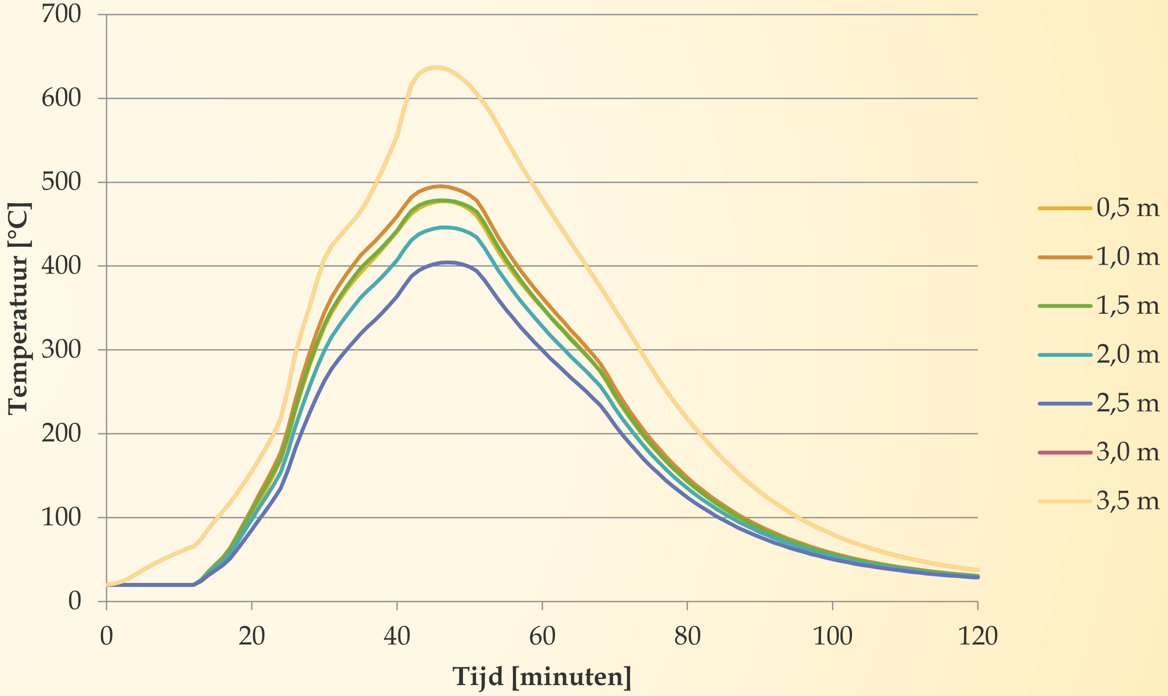




5. Worked examples

7.3. Example 3 : Column of a car park

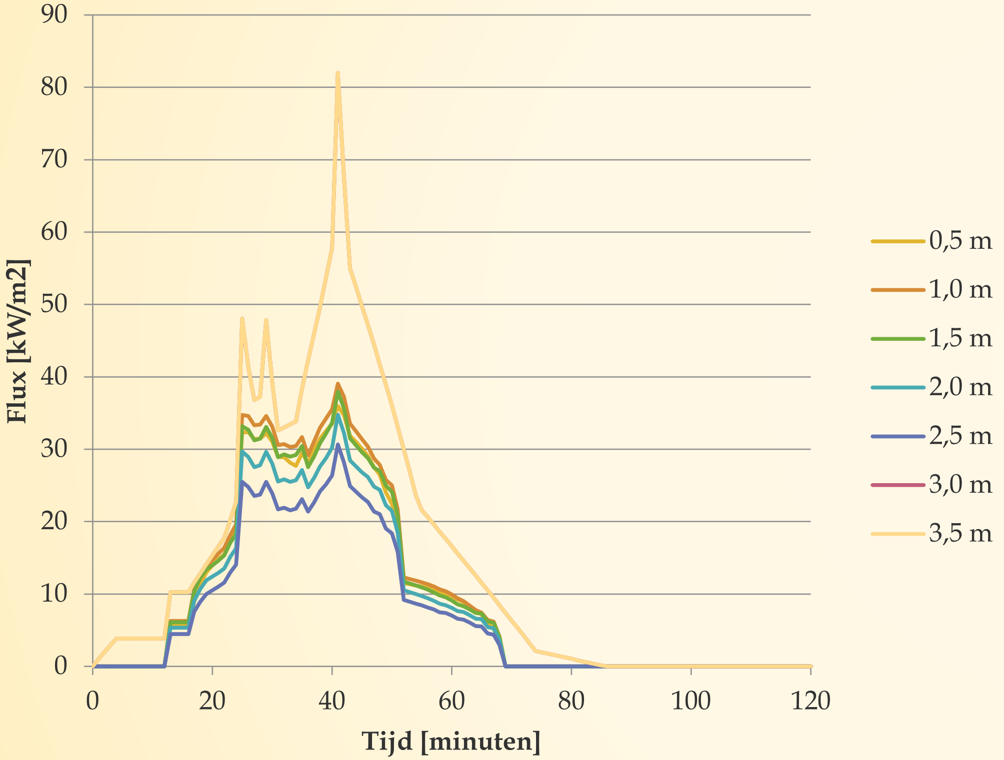


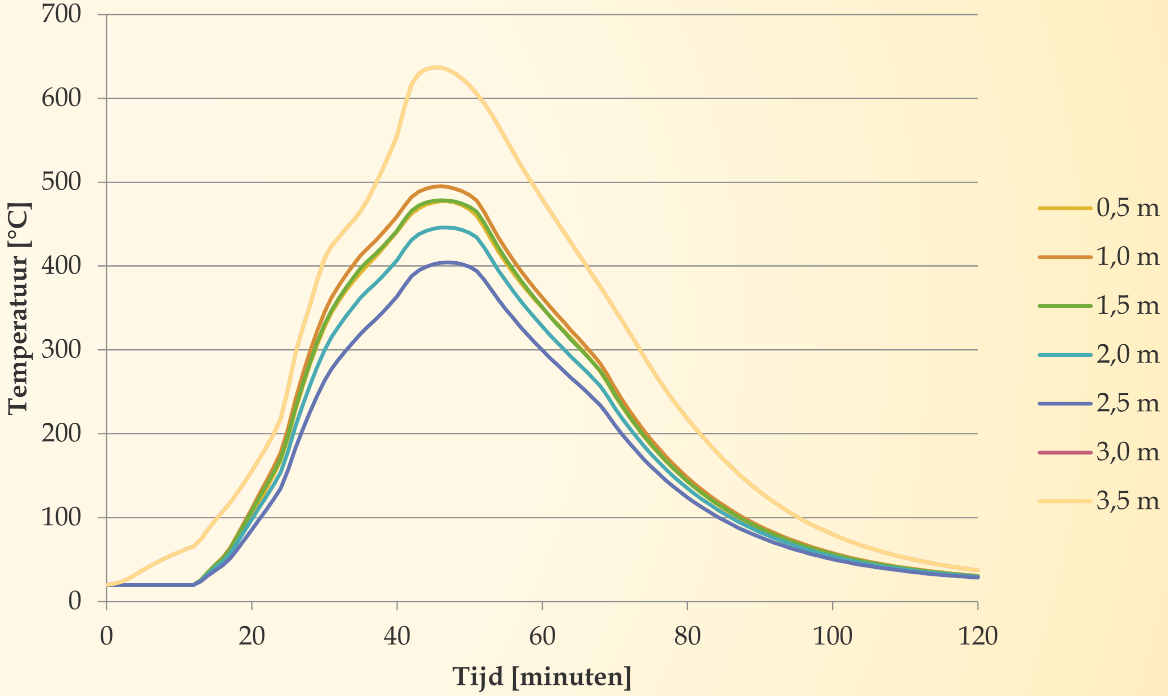


- Outside hot smoke layer (z = 1 m) : t_{max} = 495°C
- In hot smoke layer (z = 3.5 m) : t_{max} = 637°C

5. Worked examples

7.3. Example 3 : Column of a car park





- see Case D-3_NL Rev A.ozn