



LOCAFI+

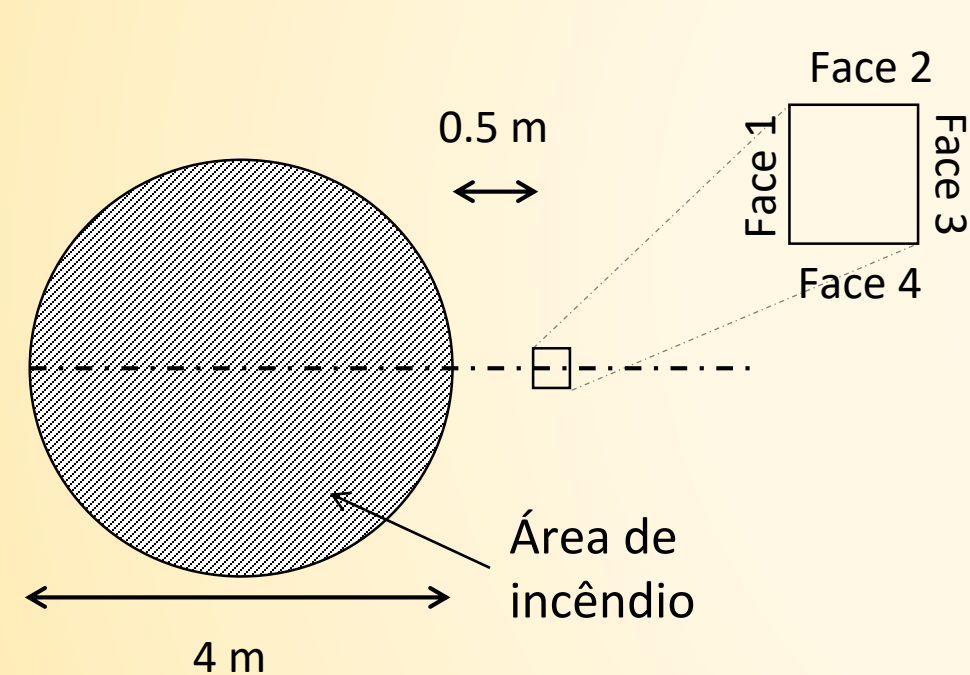
Temperature assessment of a vertical member subjected to LOCALised Fire Dissemination

Grant Agreement n° 754072

7. Exemplos de aplicação

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado



Secção da coluna: HEB 300

Diâmetro da fonte de incêndio: 4m

Distância entre o fogo e a coluna: 0.5m

Taxa de libertação de calor: 1000 kW.m⁻²

Chama cônica

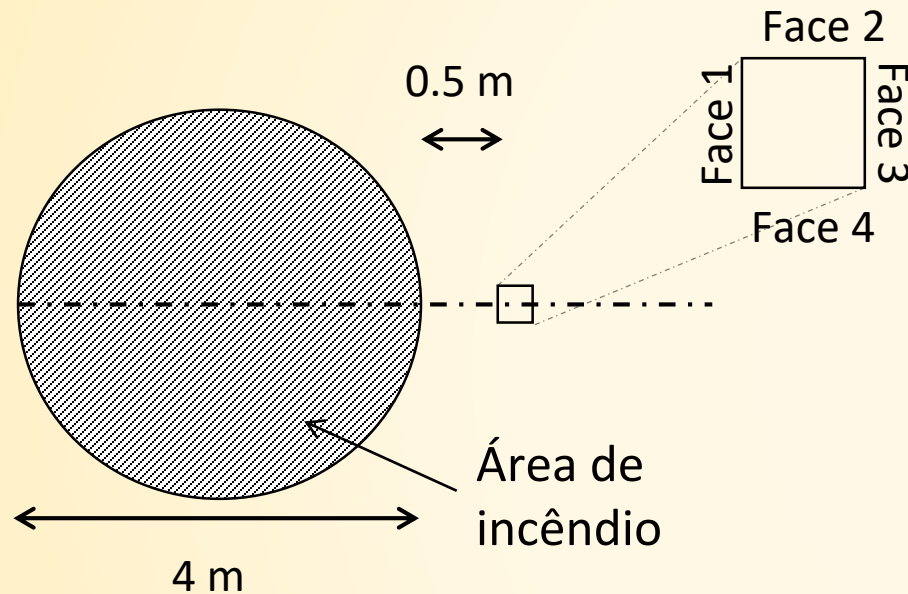
Coluna localizada no exterior do fogo e da camada de fumo

Sem teto

Cálculo realizado para $z = 1.0m$

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado



$$D = 4 \text{ m}$$

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

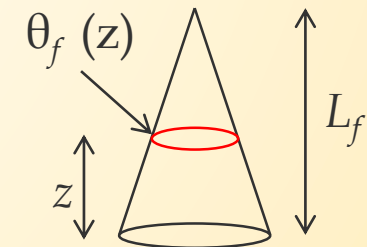
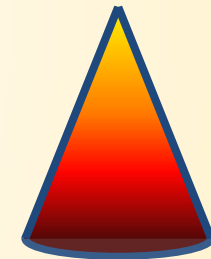
$$L_f = -1.02 D + 0.0148 Q^{0.4} = 6.15 \text{ m}$$

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

Temperatura da chama

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

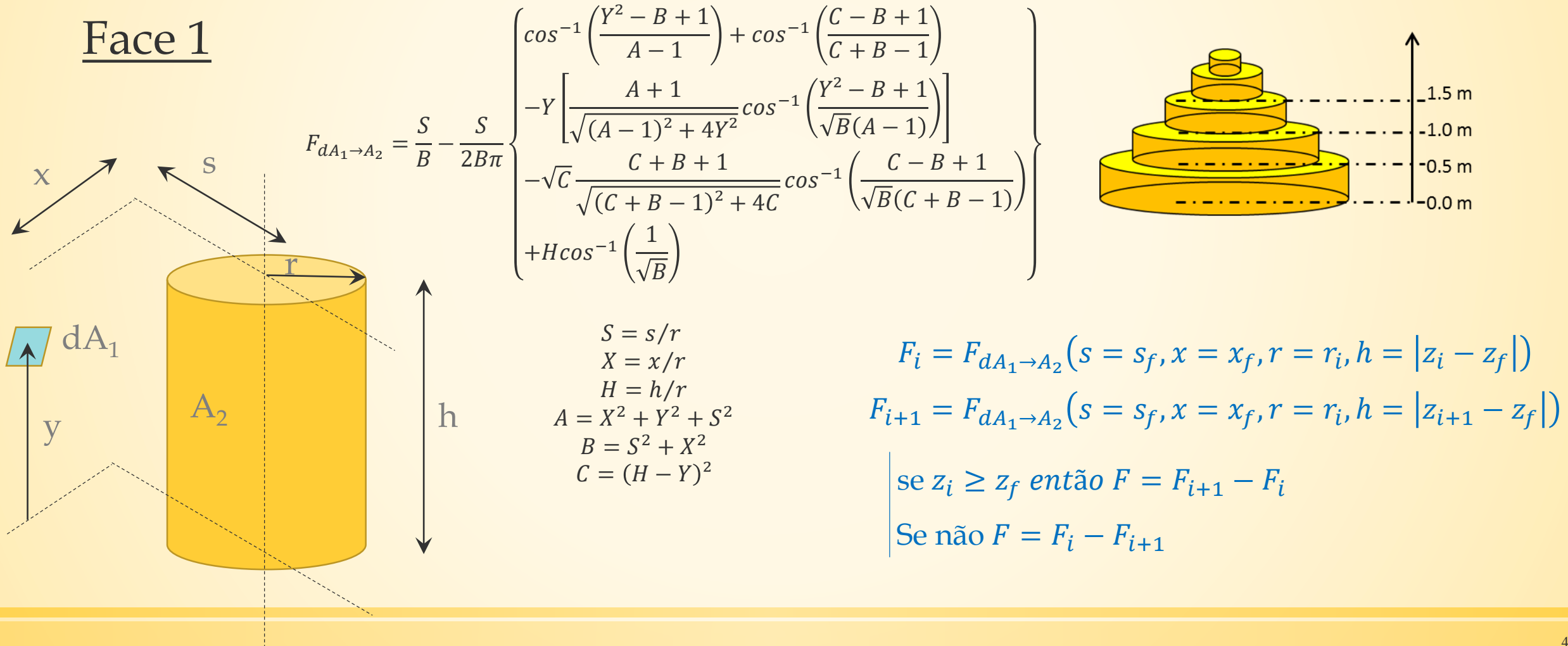
z (m)	T (°C)
0	900
0.5	900
1	900
1.5	900
2	900
2.5	900
3	900
3.5	900
4	900
4.5	827.9
5	708.4
5.5	614.8
6	540.0
6.5	479.3
7	429.1
7.5	387.2



7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

Face 1



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

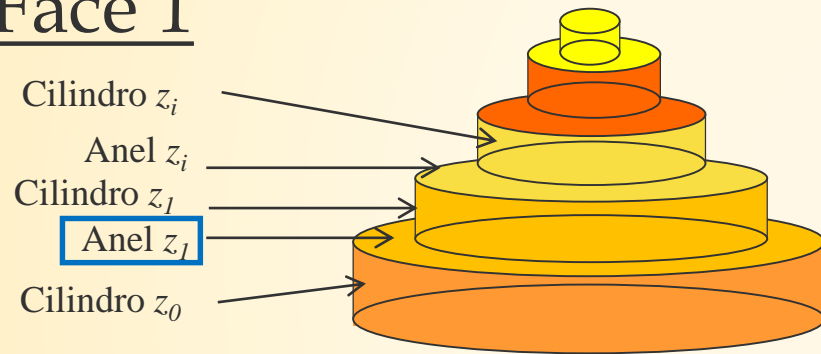
$S = s/r$
 $X = x/r$
 $H = h/r$
 $A = X^2 + Y^2 + S^2$
 $B = S^2 + X^2$
 $C = (H - Y)^2$

$F_i = F_{dA_1 \rightarrow A_2}(s = s_f, x = x_f, r = r_i, h = |z_i - z_f|)$
 $F_{i+1} = F_{dA_1 \rightarrow A_2}(s = s_f, x = x_f, r = r_i, h = |z_{i+1} - z_f|)$
 se $z_i \geq z_f$ então $F = F_{i+1} - F_i$
 Se não $F = F_i - F_{i+1}$

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

Face 1



$$z_f = 1.0m$$

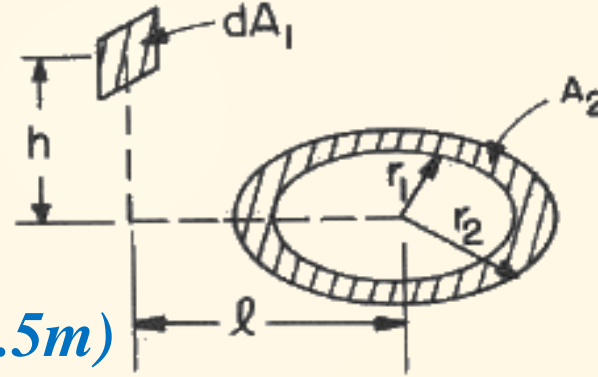
→ Apenas um anel a considerar ($z_i = 0.5m$)

Raio externo $r_2 = 2.0m$

Raio interno $r_1 = (6.15 - 0.5)/6.15 * 2.0m = 1.84m$

Simplificação: $l = 2.5m$

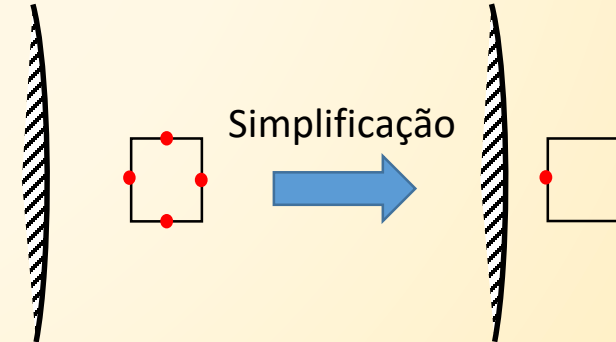
$$F_{dA_1 \rightarrow A_2} = \frac{H}{2} \left(\frac{H^2 + R_2^2 + 1}{\sqrt{(H^2 + R_2^2 + 1)^2 - 4R_2^2}} - \frac{H^2 + R_1^2 + 1}{\sqrt{(H^2 + R_1^2 + 1)^2 - 4R_1^2}} \right)$$



$$H = h/l = (1 - 0.5)/2.5 = 0.2$$

$$R_2 = r_2/l = 2/2.5 = 0.8$$

$$R_1 = r_1/l = 1.84/2.5 = 0.73$$



7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

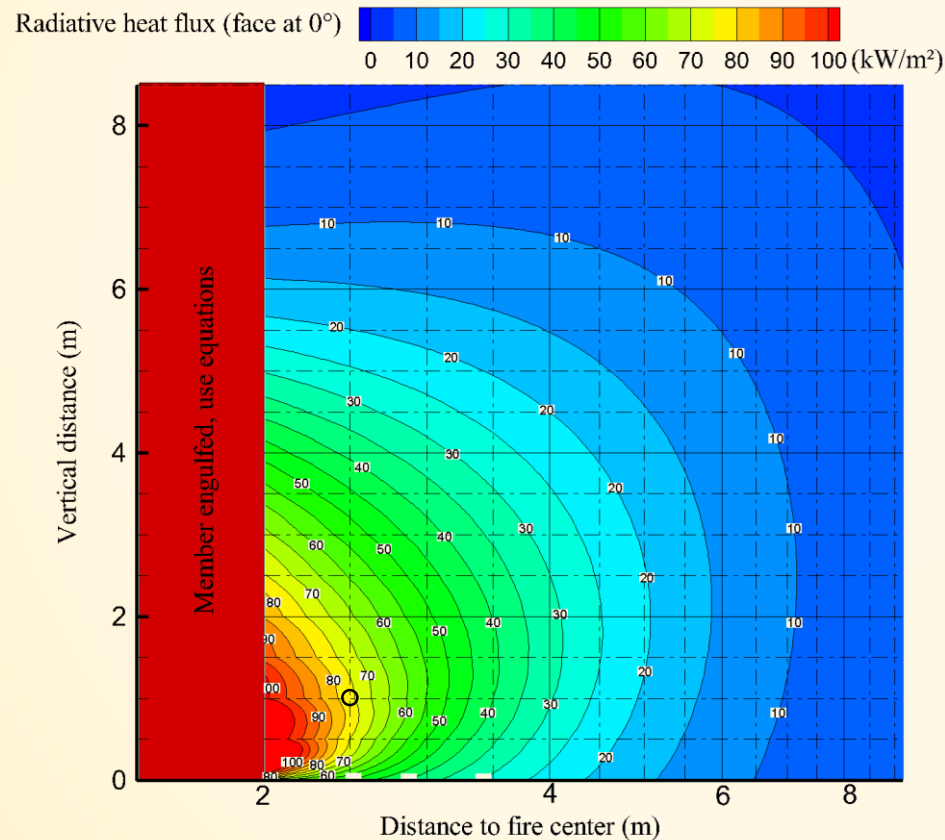
Face 1

	Input data					Constant				Section coordinate			Intermediate variables						
	HRR	Dfire	Q	Q	hf					sf	xf	zf							
	kW/m²	m	W	MW	m					m	m	m							
	1000	4	12566370.6	12.57	6.15					5.67E-08	273.15	2.5							0
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													

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

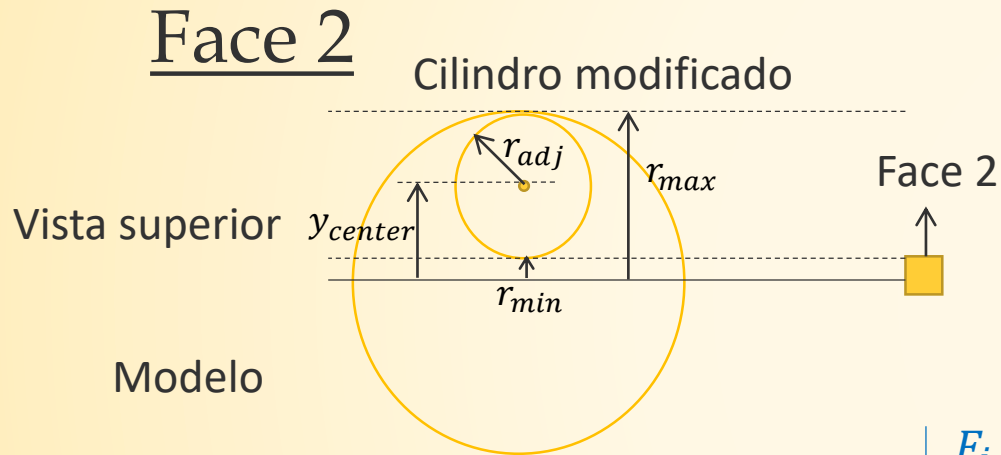
Face 1



$$\begin{aligned}\text{Fluxo absorvido} &= \varepsilon * \varphi_{tot} \\ &= 0.7 * 77 \text{ kW/m}^2 \\ &= 53.9 \text{ kW/m}^2\end{aligned}$$

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado



$$\underline{z = 0}$$

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

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

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

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

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

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

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

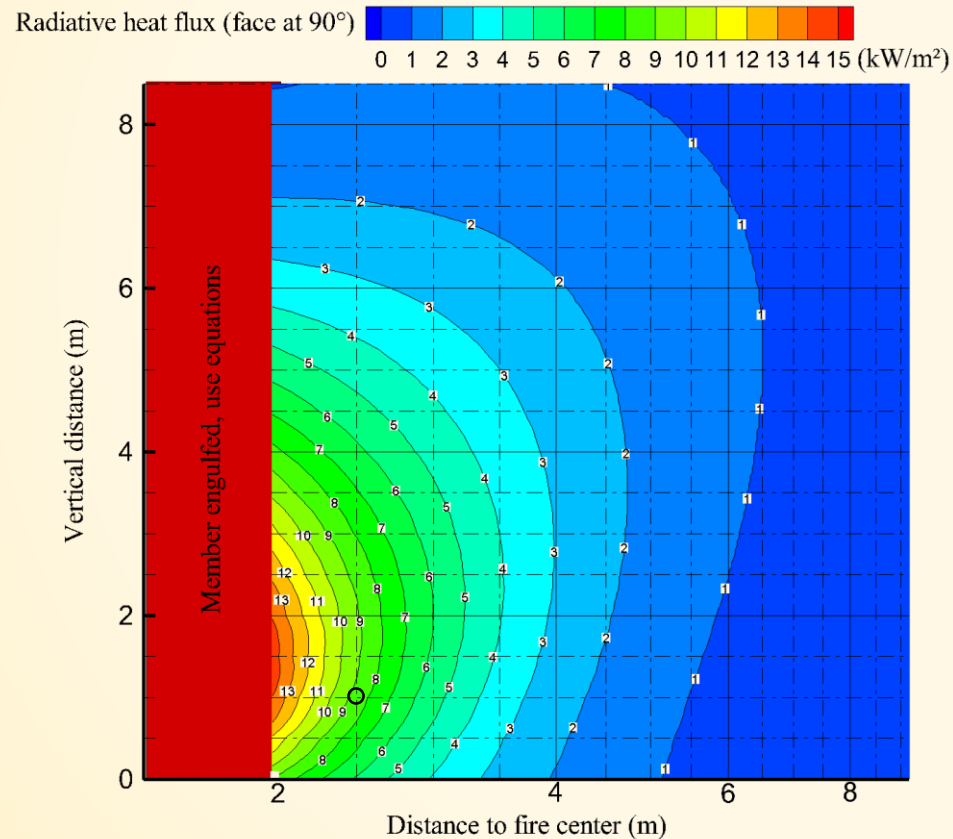
Face 2

						Ring			Input data				
zi	Tf	ri	F _{cylinder_zi}	F _{ring_zi}	Flux _{face2}	H	Ri	Ri+1	HRR	Dfire	Q	Q	hf
m	°C	m	-	-	kW/m ²	-	-	-	kW/m ²	m	W	MW	m
0	900	2.00	0.0175	0	1.88	0	0.00	0.00	1000	4	12566370.6	12.57	6.15
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/m ²							
Absorbed heat flux by face 2					6.00	kW/m ²							
Modified cylinder / ring						Cylinder							
rmin	rmax	ri_adjusted	Ycenter	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

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

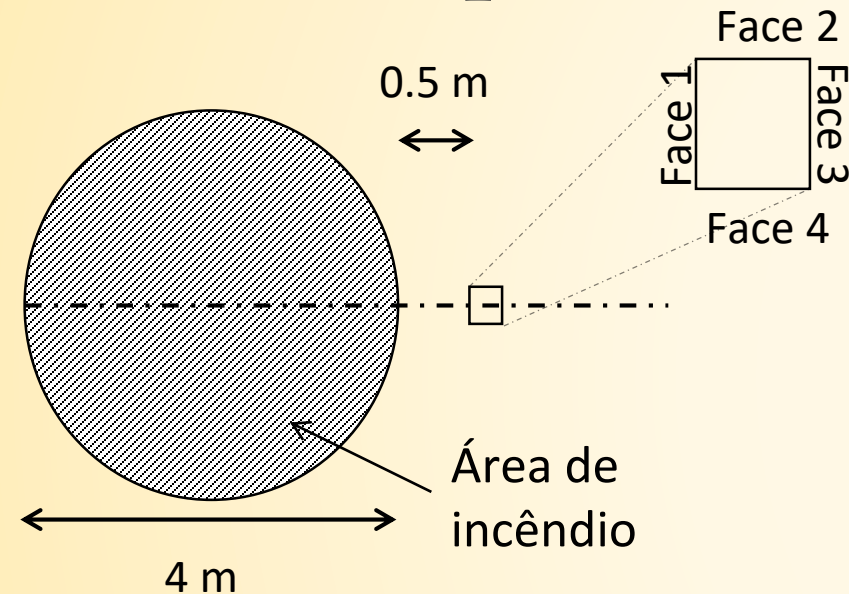
Face 2



$$\begin{aligned}\text{Fluxo absorvido} &= \varepsilon * \varphi_{tot} \\ &= 0.7 * 8.7 \text{ kW/m}^2 \\ &= 6.1 \text{ kW/m}^2\end{aligned}$$

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado



Fluxo de calor absorvido por cada face (assumindo $\varepsilon = 0.7$)

Face 1 : 53.45 kW/m²

Face 2 : 6.00 kW/m²

Face 3 : 0.00 kW/m²

Face 4 : 6.00 kW/m²

→ Fluxo de calor médio = 16.36 kW/m²

$$0 = \underbrace{h(T - 20)}_{\text{Fluxo convectivo emitido}} + \underbrace{\sigma\varepsilon[(T + 273)^4 - (20 + 273)^4]}_{\text{Fluxo por radiação emitido}} - \underbrace{\varepsilon * \varphi_{tot}}_{\text{Fluxo absorvido}}$$

Fluxo convectivo
emitido

Fluxo por
radiação emitido

Fluxo absorvido

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

θ (°C)	Fluxo emitido W/m ²
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

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

Fire - Worked Example 1

File Tools View Help

Compartment Fire: ☐ Annex E (EN 1991-1-2) ☐ User Defined Fire

Localised Fire: ☒ Localised Fire

Number of fires: 1

Select fire: 1

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

	Time [min]	RHR [MW]
Point 1	0	12.56
Point 2	20	12.56
Point 3		
Point 4		
Point 5		
Point 6		
Point 7		
Point 8		
Point 9		
Point 10		
Point 11		
Point 12		
Point 13		
Point 14		
Point 15		
Point 16		
Point 17		
Point 18		
Point 19		
Point 20		

Geometrical Data

Ceiling Height: 10 m

Distance on Axis (x): 2.5 m

Height on Axis (z): 1 m

OK Cancel

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

Fire - Worked Example 1

File Tools View Help

Compartment Fire: ☐ Annex E (EN 1991-1-2) ☐ User Defined Fire

Localised Fire: ☒ Localised Fire

Number of fires: 1

Select fire: 1

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

	Time [min]	RHR [MW]
Point 1	0	12.56
Point 2	20	12.56
Point 3		
Point 4		
Point 5		
Point 6		
Point 7		
Point 8		
Point 9		
Point 10		
Point 11		
Point 12		
Point 13		
Point 14		
Point 15		
Point 16		
Point 17		
Point 18		
Point 19		
Point 20		

Geometrical Data

Ceiling Height: 10 m

Distance on Axis (x): 2.5 m

Height on Axis (z): 1 m

OK Cancel

Heating - Worked Example 1

File Tools View Help

Profile Heated By

☐ Hot Zone Temperature ☐ ISO 853 Fire Curve

☒ Localised Fire Temperature ☐ ASTM E119 Fire Curve

☐ Maximum Between Both ☐ Hydrocarbon Fire Curve

Steel Profile - Worked Example 1

File Tools View Help

Cross Section

☒ Unprotected Cross Section ☐ Protected Cross Section

Steel Profile

Profile Type: HE

Profile: HE 300 B

Exposure

☒ Exposed on Four Sides ☐ Exposed on Three Sides

Encasement

☒ Contour Encasement ☐ Hollow Encasement

Protection Material

☒ From Catalog ☐ Constant Values ☐ Temperature Dependent

Thickness: mm

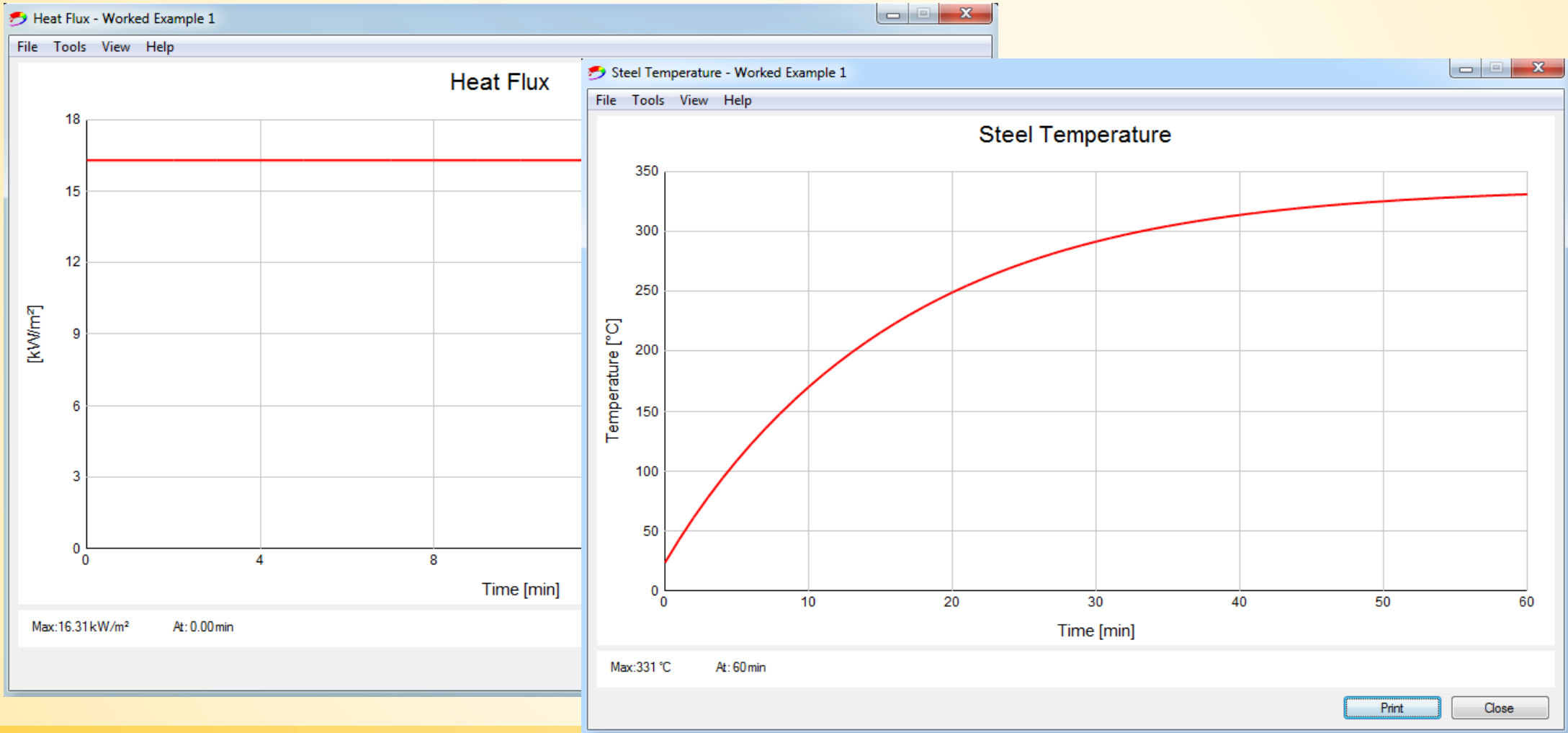
Material Name: Spray Mineral Fiber

Temperature °C	Unit mass kg/m²	Specific Heat J/kgK	Conductivity W/mK
300		1200	0.12

OK Cancel

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

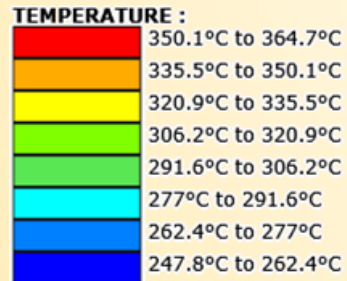
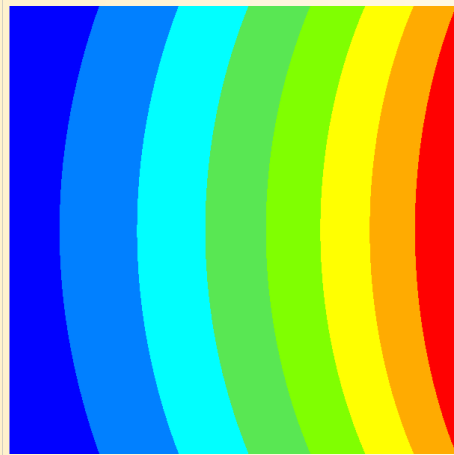


7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

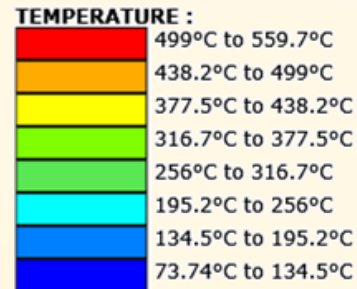
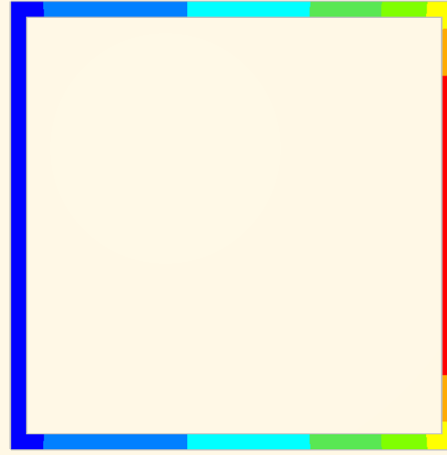
Distribuição de temperatura em equilíbrio (LOCAFI)

Quadrado 300x300



$$(T_{\max} + T_{\min})/2 = 306^{\circ}\text{C}$$

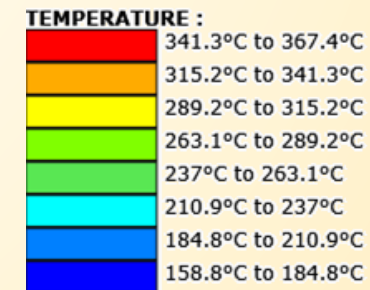
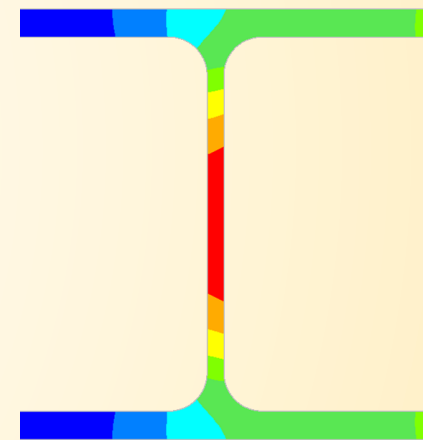
Tubular 300x300x10



$$(T_{\max} + T_{\min})/2 = 317^{\circ}\text{C}$$

Grande variação em toda a secção

HEB 300

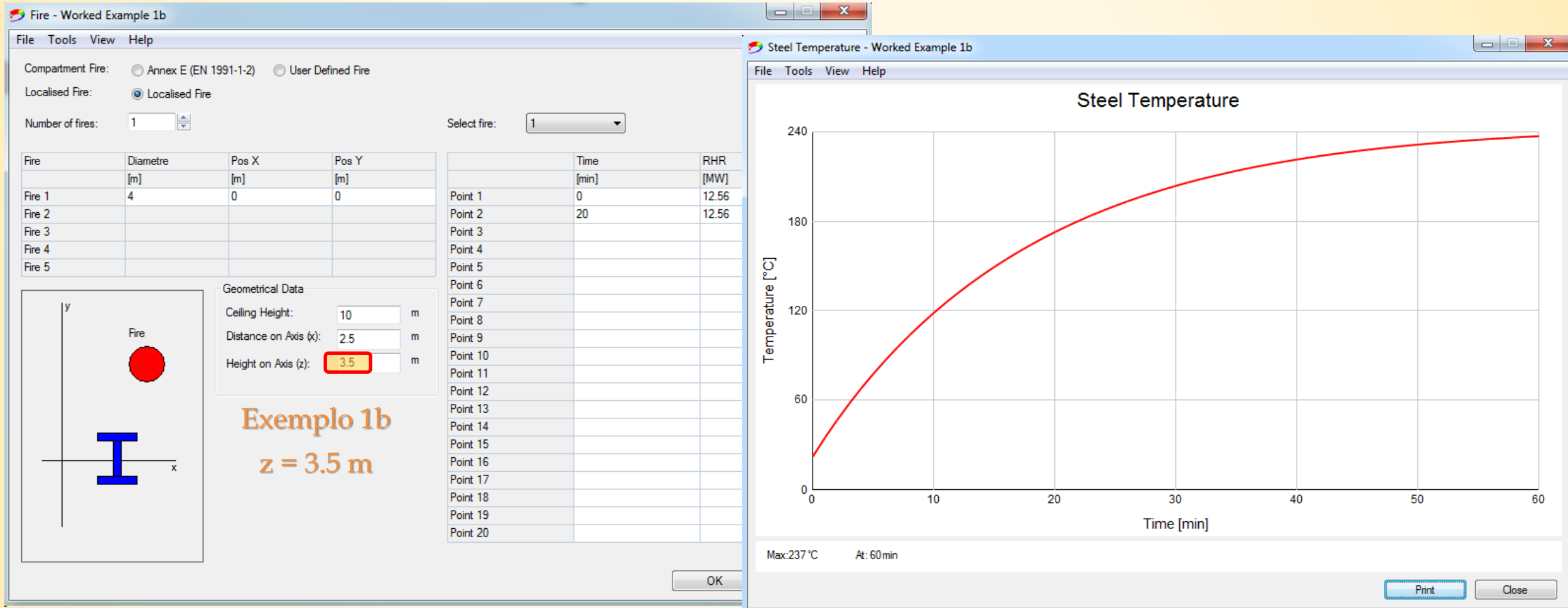


$$(T_{\max} + T_{\min})/2 = 262^{\circ}\text{C}$$

O modelo tem em consideração o efeito de sombra

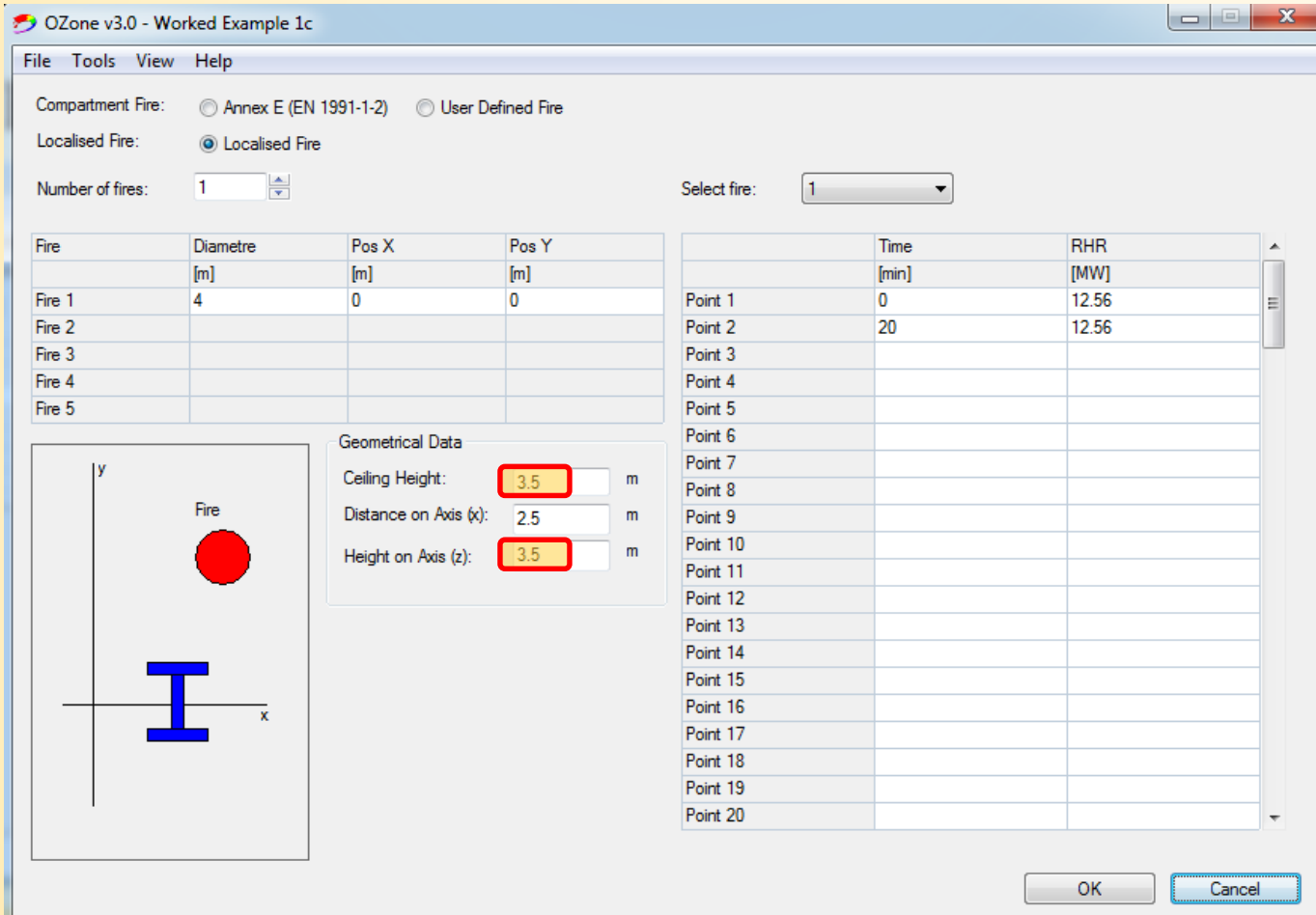
7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado



7. Exemplos

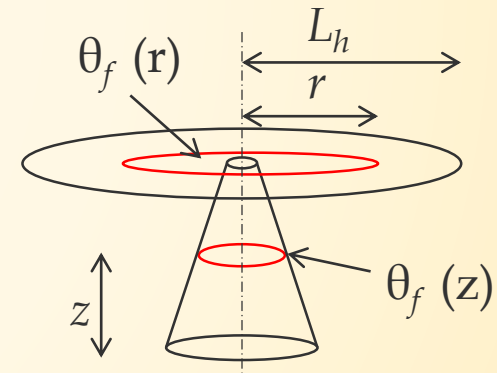
7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado



Exemplo 1c

$z = 3.5 \text{ m}$

$z_{\text{ceiling}} = 3.5 \text{ m}$



$$L_h = H(2.9Q_H^{0.33} - 1) = 4.54 \text{ m}$$

7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

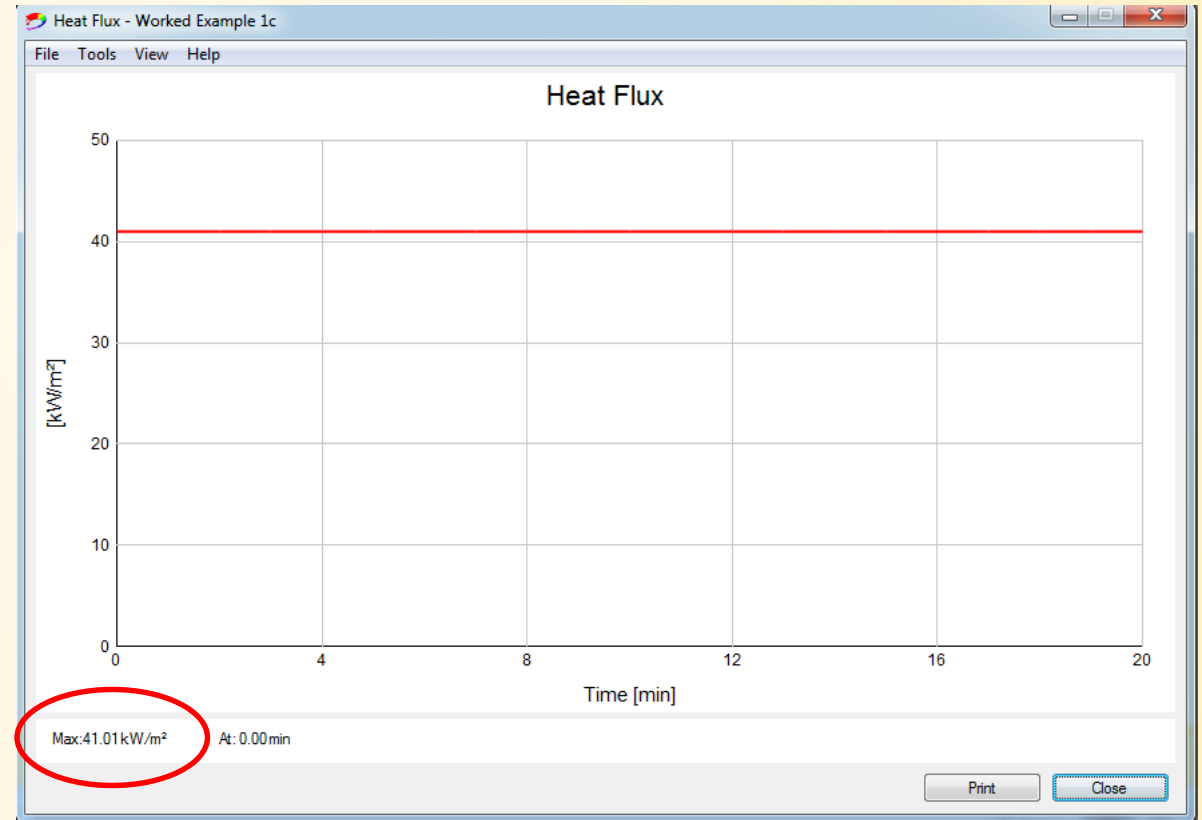
HASEMI (EN 1991-1-2 – Anexo C)

$$Q_D^* = \frac{Q}{1.11 \cdot 10^6 \cdot D^{2.5}} = 0.3536$$

$$z' = 2.4 \cdot D \cdot (Q_D^{*2/5} - Q_D^{*2/3}) = 1.535$$

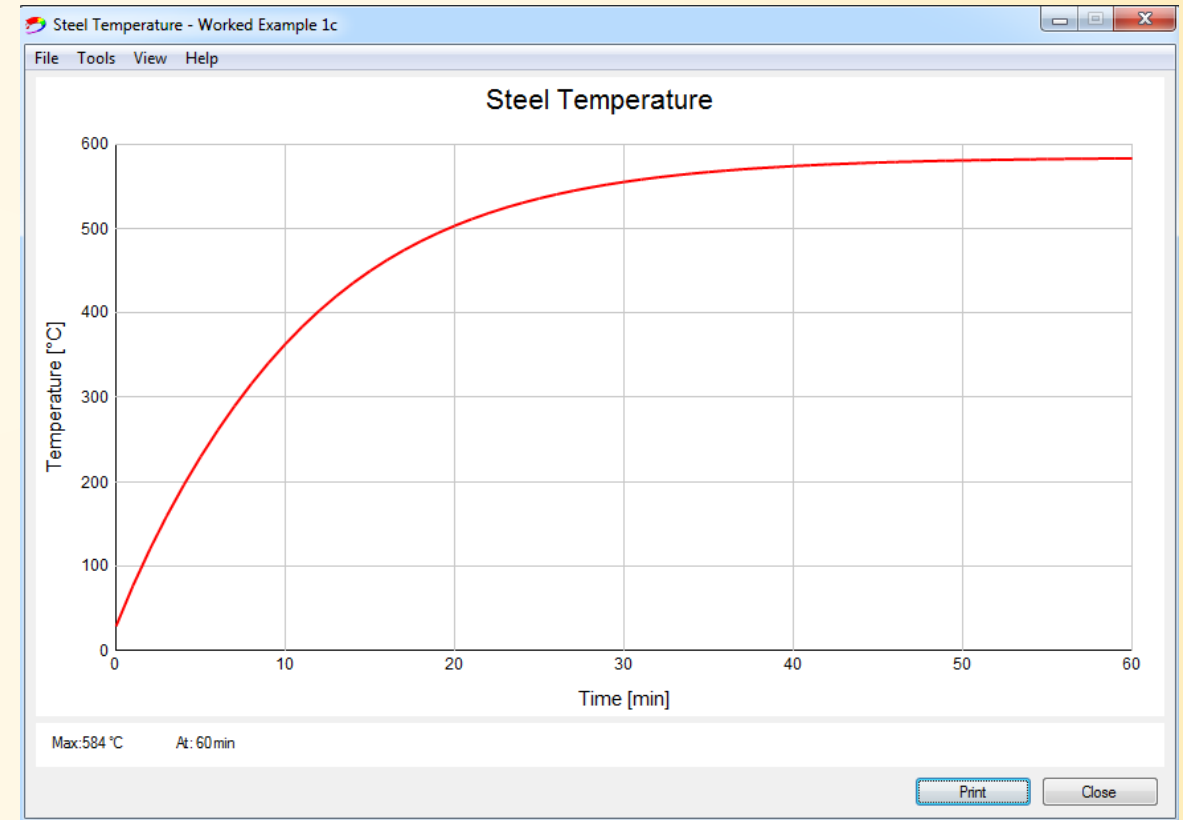
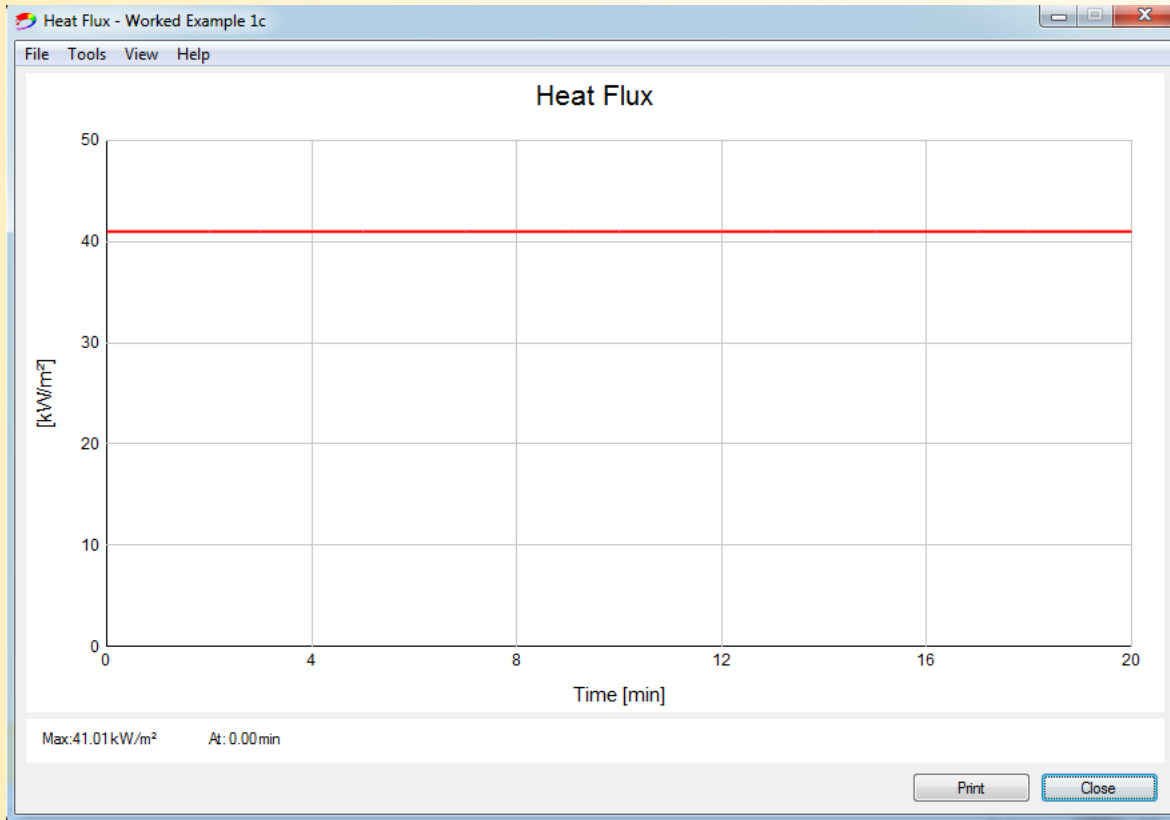
$$y = \frac{r + H + z'}{L_h + H + z'} = 0.787$$

$$0.3 < y < 1 \rightarrow \dot{h} = 136300 - 121000 y$$
$$\rightarrow \dot{h} = 41073 \text{ W/m}^2$$



7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

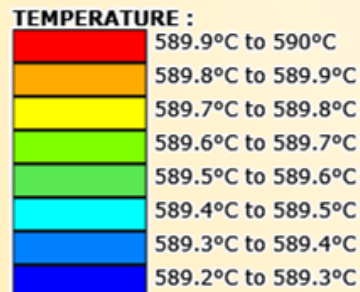
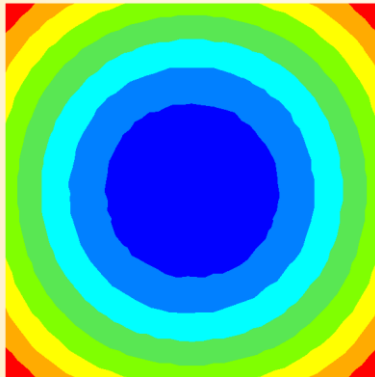


7. Exemplos

7.1. Exemplo 1: Fluxos de radiação sob incêndio localizado

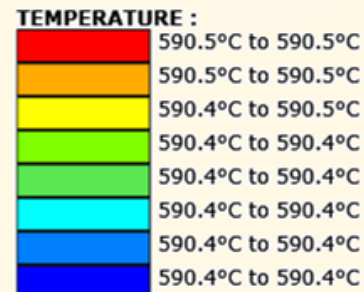
Distribuição de temperatura em equilíbrio (HASEMI)

Quadrado 300x300



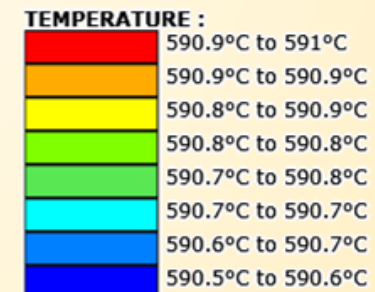
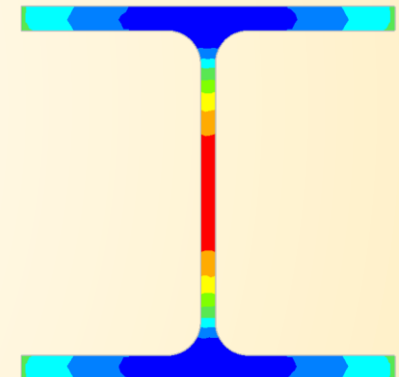
$T_{\text{média}} = 589^{\circ}\text{C}$

Tubular 300x300x10



$T_{\text{média}} = 590^{\circ}\text{C}$

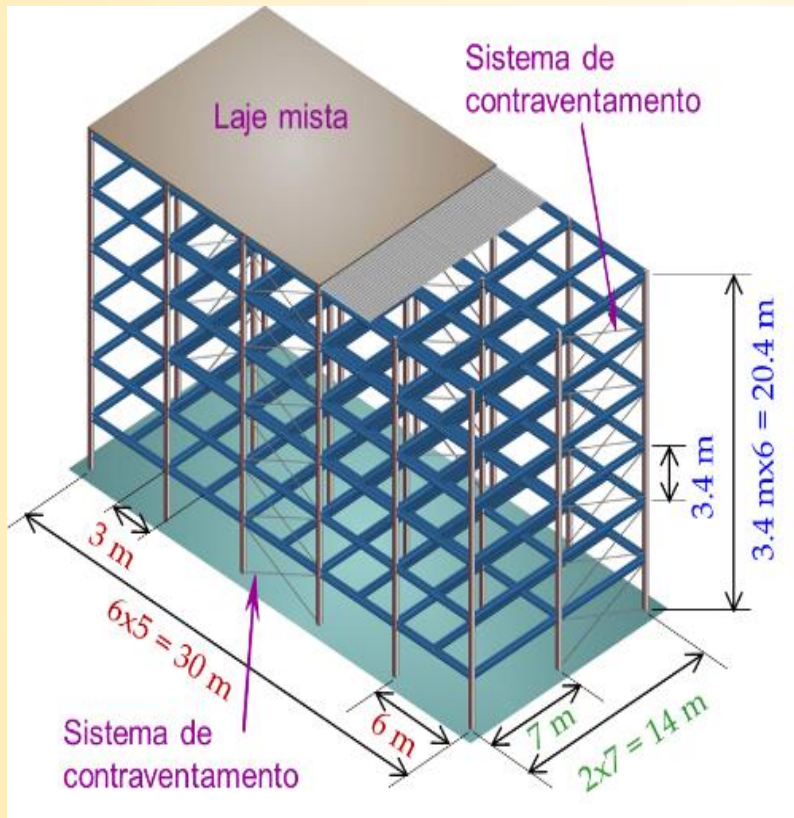
HEB 300



$T_{\text{média}} = 591^{\circ}\text{C}$

7. Exemplos

7.2. Exemplo 2: Coluna de um edifício de escritórios

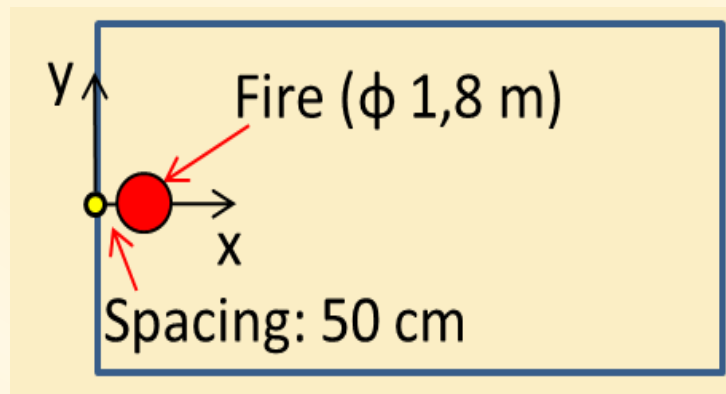


Origem do incêndio localizada a 0.5 m da coluna

Nível do teto: 3.5 m

Fonte de incêndio: 500 kg de papel (17.5 MJ/kg) numa área de 2.5m²

$RHR_{max} = 1000 \text{ kW/m}^2$

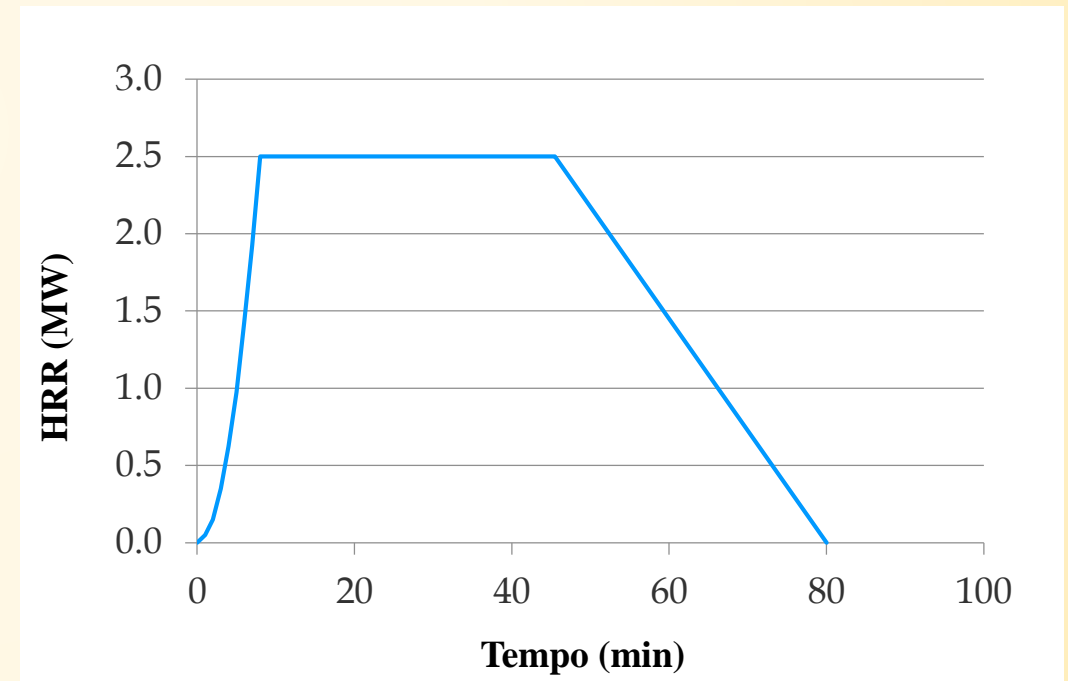


7. Exemplos

7.2. Exemplo 2: Coluna de um edifício de escritórios

Desenvolvimento do incêndio de acordo com o Anexo E da NP EN 1991-1-2:2010

- Fase de crescimento: $Q(t) = 10^6 * (t/t_\alpha)^2$
- Velocidade de desenvolvimento: Média
→ $RHR = 1 \text{ MW}$ após $t_\alpha = 300 \text{ sec}$
- $RHR_{max} = 2.5 \text{ m}^2 * 1000 \text{ kW/m}^2 = 2.5 \text{ MW}$
- A fase de arrefecimento começa após 70% do combustível ter ardido



7. Exemplos

7.2. Exemplo 2: Coluna de um edifício de escritórios

File Tools View Help

Compartment Fire: ☐ Annex E (EN 1991-1-2) ☐ User Defined Fire

Localised Fire: ☒ Localised Fire

Number of fires: 1

Select fire: 1

Fire	Diameter [m]	Pos X [m]	Pos Y [m]
Fire 1	1.8	1.4	0
Fire 2			
Fire 3			
Fire 4			
Fire 5			

Geometrical Data

Compartment Height: 3.5 m

Distance on Axis (x): 0 m

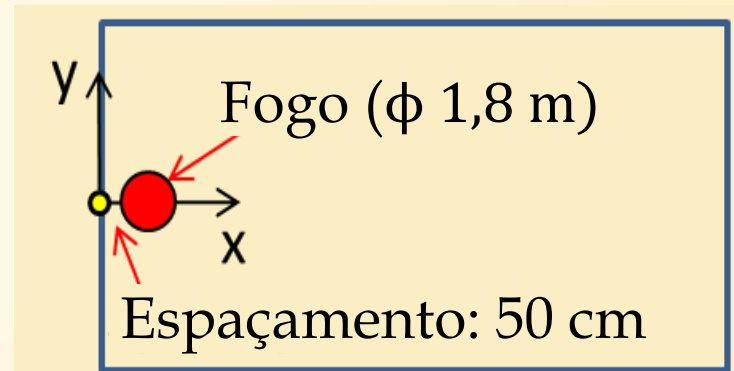
Height on Axis (z): 2.5 m

Time [min] RHR [MW]

Point 1	0	0
Point 2	1	0.05
Point 3	2	0.15
Point 4	3	0.35
Point 5	4	0.625
Point 6	5	0.975
Point 7	6	1.425
Point 8	7	1.925
Point 9	8	2.5
Point 10	45	2.5
Point 11	45.5	2.5
Point 12	80	0
Point 13		
Point 14		
Point 15		
Point 16		
Point 17		
Point 18		
Point 19		
Point 20		

OK Cancel

$$\text{Pos } x : 0.5\text{m} + 1.8\text{m}/2 = 1.4\text{m}$$



7. Exemplos

7.2. Exemplo 2: Coluna de um edifício de escritórios

File Tools View Help

Compartment Fire: ☐ Annex E (EN 1991-1-2) ☐ User Defined Fire

Localised Fire: ☒ Localised Fire

Number of fires: 1

Fire	Diameter [m]	Pos X [m]	Pos Y [m]
Fire 1	1.8	1.4	0
Fire 2			
Fire 3			
Fire 4			
Fire 5			

Select fire: 1

	Time [min]	RHR [MW]
Point 1	0	0
Point 2	1	0.05
Point 3	2	0.15
Point 4	3	0.35
Point 5	4	0.625
Point 6	5	0.975
Point 7	6	1.425
Point 8	7	1.925
Point 9	8	2.5
Point 10	45	2.5
Point 11	45.5	2.5
Point 12	80	0
Point 13		
Point 14		
Point 15		
Point 16		
Point 17		
Point 18		
Point 19		
Point 20		

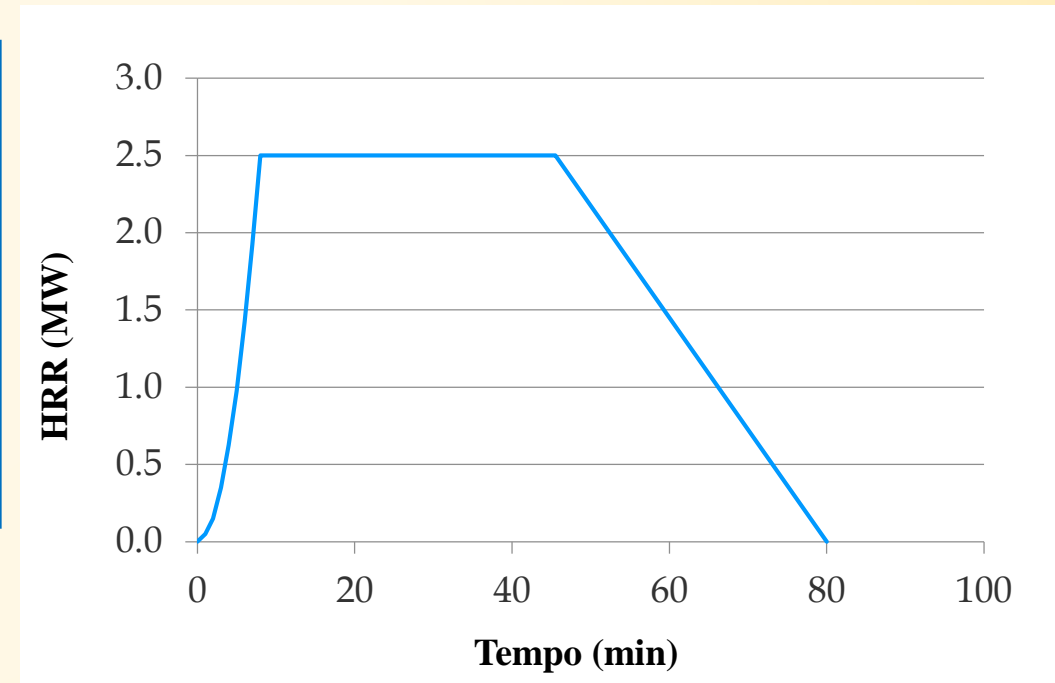
Geometrical Data

Compartment Height: 3.5 m

Distance on Axis (x): 0 m

Height on Axis (z): 2.5 m

OK Cancel



7. Exemplos

7.2. Exemplo 2: Coluna de um edifício de escritórios

File Tools View Help

Cross Section

☒ Unprotected Cross Section
☐ Protected Cross Section

Steel Profile

Profile Type:
Profile:

Exposure

☒ Exposed on Four Sides ☐ Exposed on Three Sides

Encasement

☒ Contour Encasement ☐ Hollow Encasement

Protection Material

☒ From Catalog
☐ Constant Values
☐ Temperature Dependent

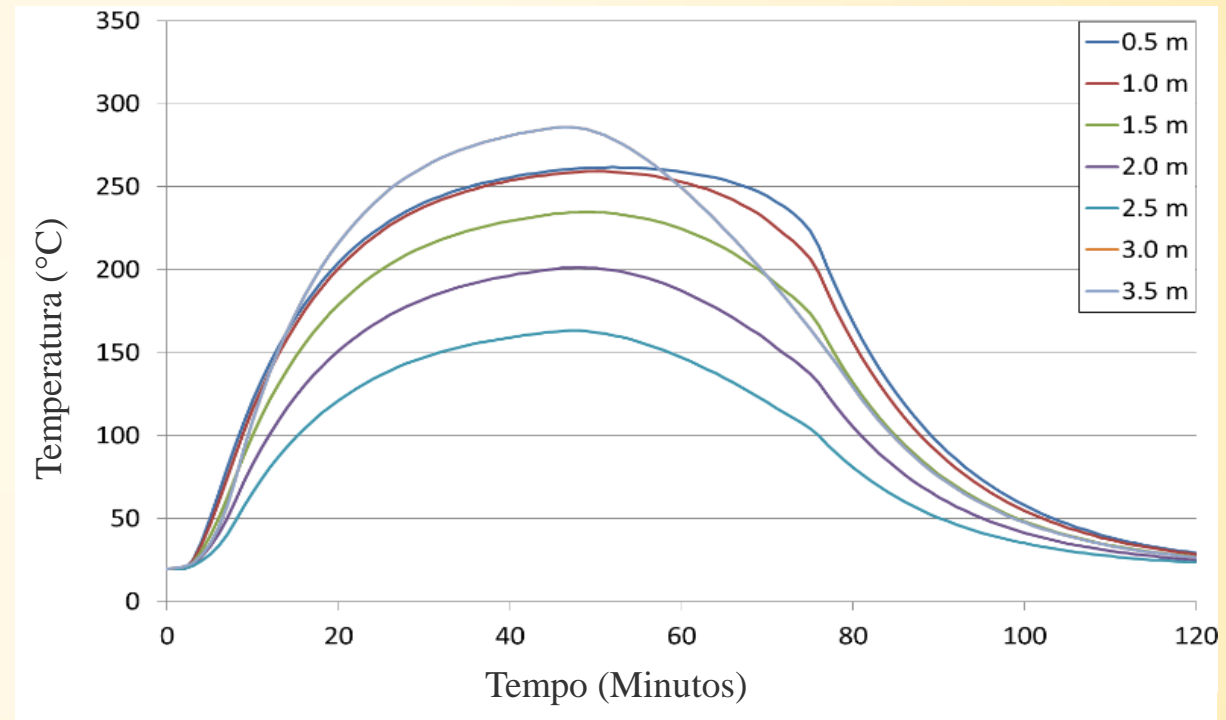
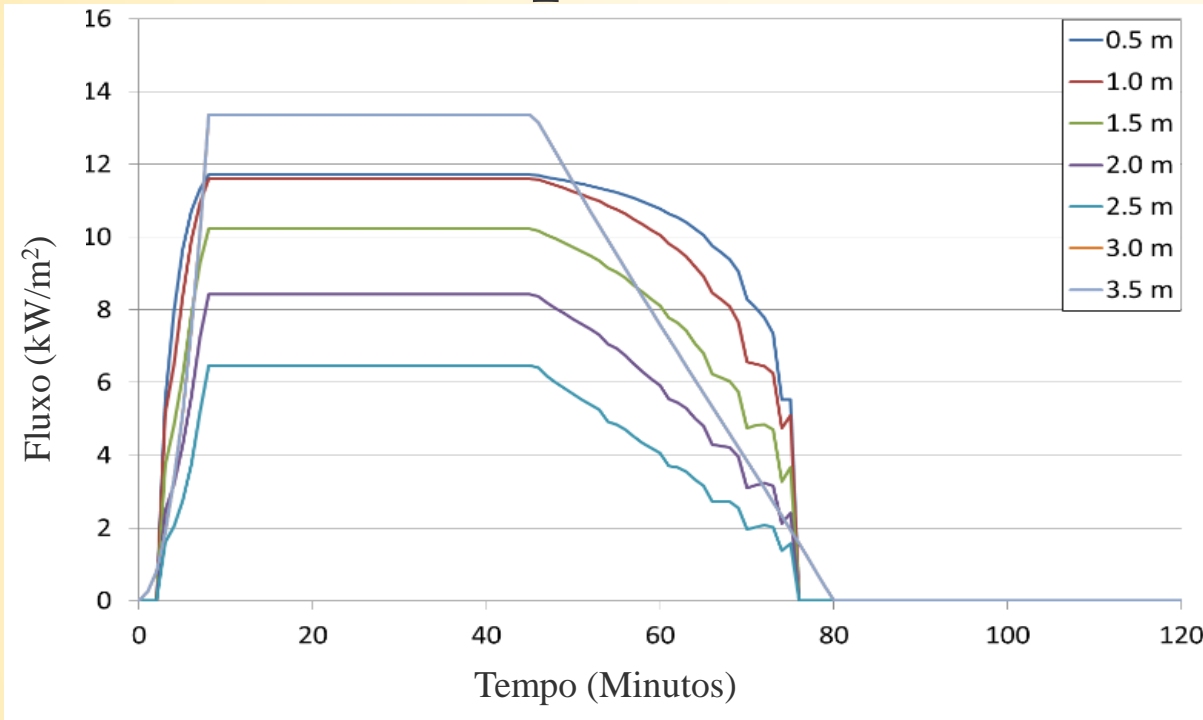
Thickness: mm
Material Name:

Temperature	Unit mass	Specific Heat	Conductivity
°C	kg/m³	J/kgK	W/mK
	300	1200	0.12

OK Cancel

7. Exemplos

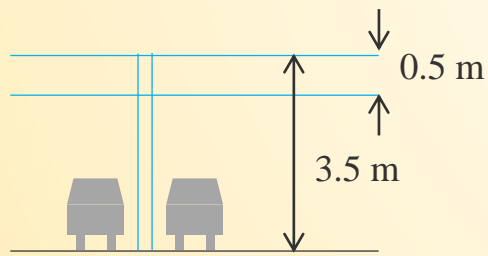
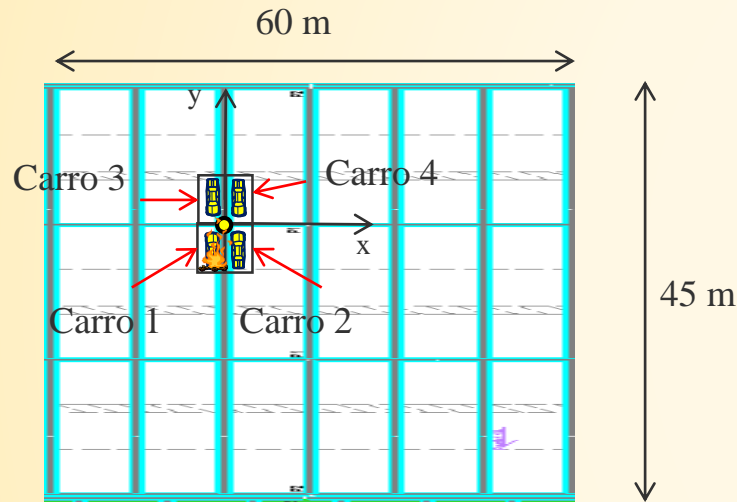
7.2. Exemplo 2: Coluna de um edifício de escritórios



- Fluxo de calor por radiação máximo absorvido na camada de fumo
- Camada de fumo ($z = 3.5\text{m}$): a temperatura atinge 290°C
- No exterior da camada de fumo ($z = 0.5\text{m}$ and $z = 1\text{m}$): $\sim 250^{\circ}\text{C}$

7. Exemplos

7.3. Exemplo 3: Coluna de um parque de estacionamento



Coluna HEA 300

Nível do teto: 3.5 m

*Dimensões do lugar de estacionamento: 2.5m*5m*

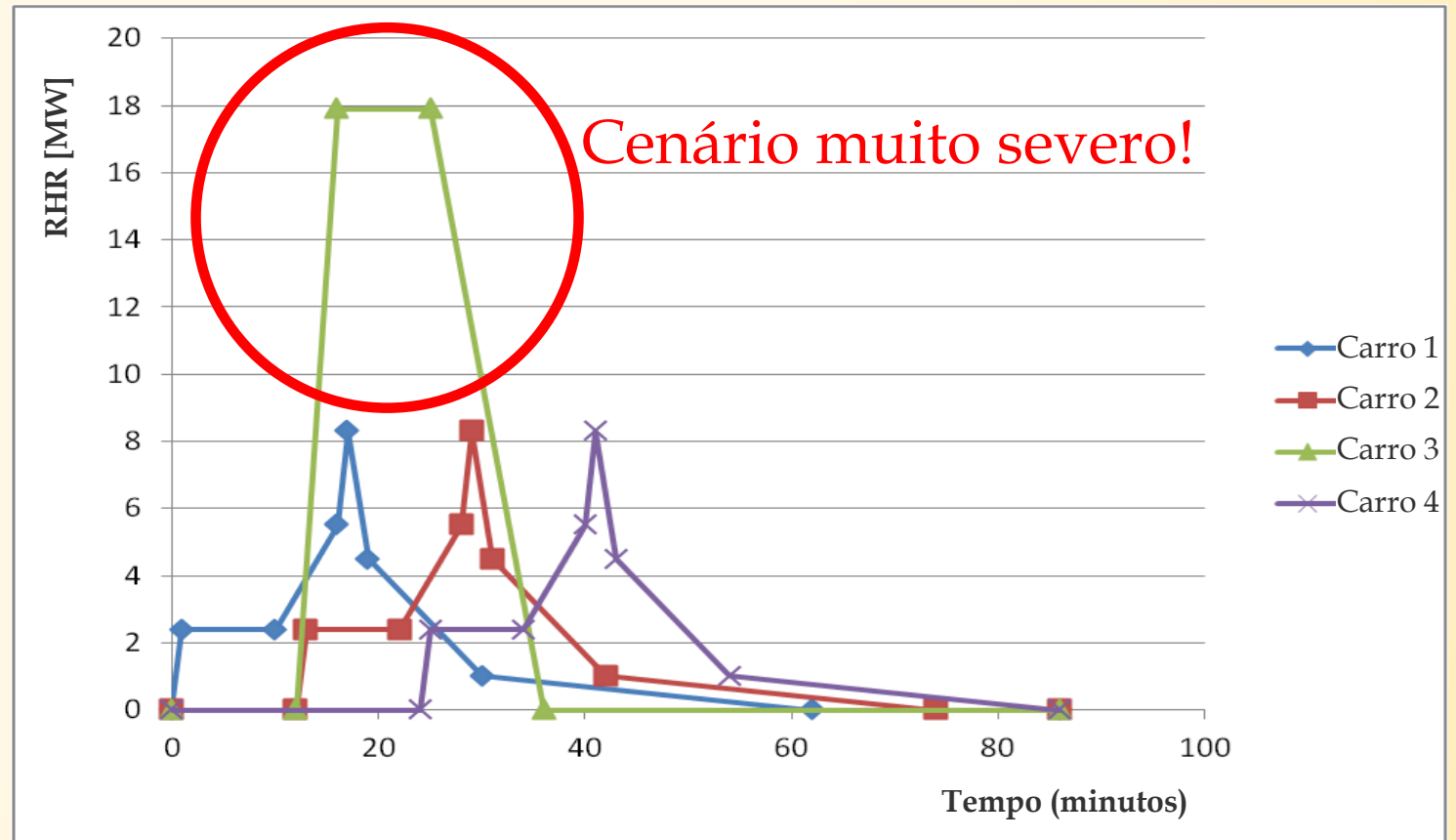
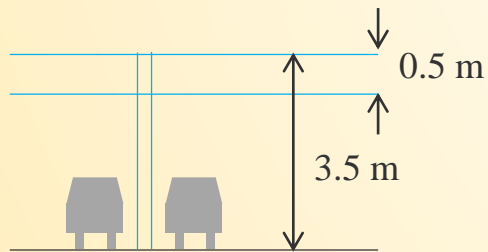
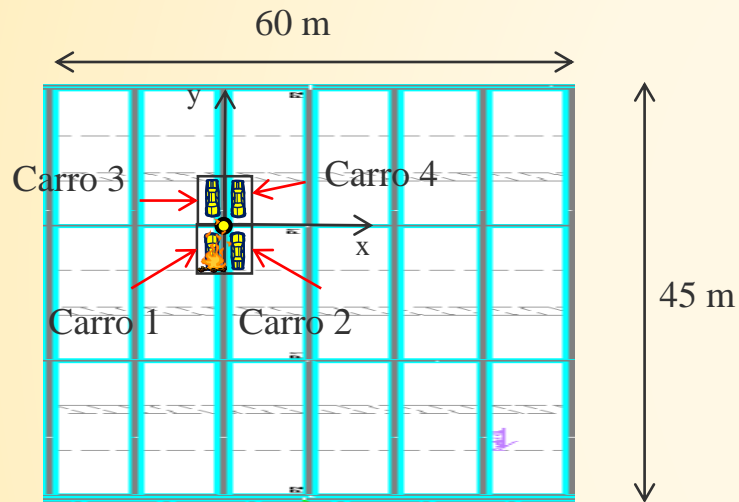
→ Diâmetro equivalente do incêndio: 4 m

Cenário de incêndio: 3 carros + 1 carrinha (análise de risco – pressuposto altamente severo)

Tempo de ignição entre dois carros consecutivos: 12 minutos

7. Exemplos

7.3. Exemplo 3: Coluna de um parque de estacionamento



7. Exemplos

7.3. Exemplo 3: Coluna de um parque de estacionamento

File Tools View Help

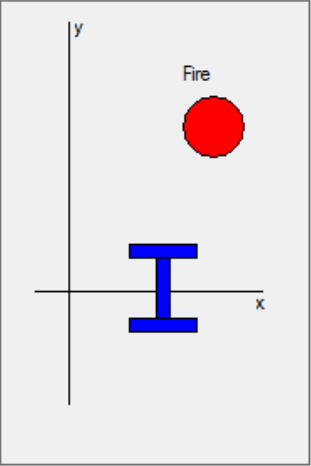
Compartment Fire: ☐ Annex E (EN 1991-1-2) ☐ User Defined Fire

Localised Fire: ☒ Localised Fire

Number of fires:

Select fire:

Fire	Diametre [m]	Pos X [m]	Pos Y [m]
Fire 1	4	-1.25	-2.5
Fire 2	4	1.25	-2.5
Fire 3	4	-1.25	2.5
Fire 4	4	1.25	2.5
Fire 5			



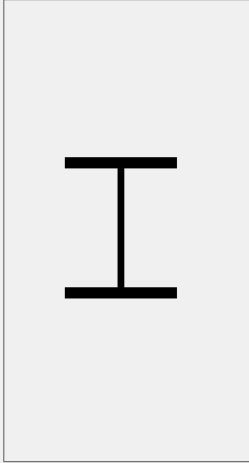
Geometrical Data
Compartment Height: m
Distance on Axis (x): m
Height on Axis (z): m

	Time [min]	RHR [MW]
Point 1	0	0
Point 2	1	2.4
Point 3	10	2.4
Point 4	16	5.5
Point 5	17	8.3
Point 6	19	4.5
Point 7	30	1
Point 8	62	0
Point 9	86	0
Point 10		
Point 11		
Point 12		
Point 13		
Point 14		
Point 15		
Point 16		
Point 17		
Point 18		
Point 19		
Point 20		

OK Cancel

File Tools View Help

Cross Section
☒ Unprotected Cross Section
☐ Protected Cross Section



Steel Profile
Profile Type:
Profile:

Exposure
☒ Exposed on Four Sides
☐ Exposed on Three Sides

Encasement
☒ Contour Encasement
☐ Hollow Encasement

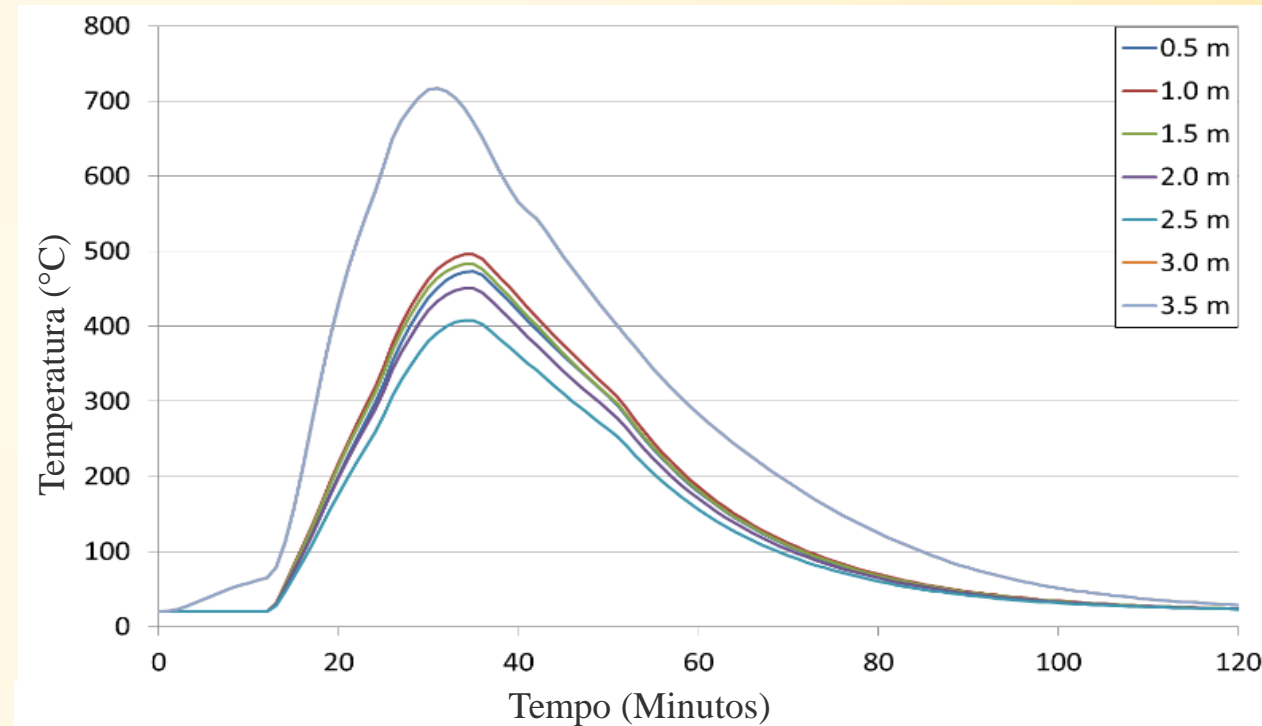
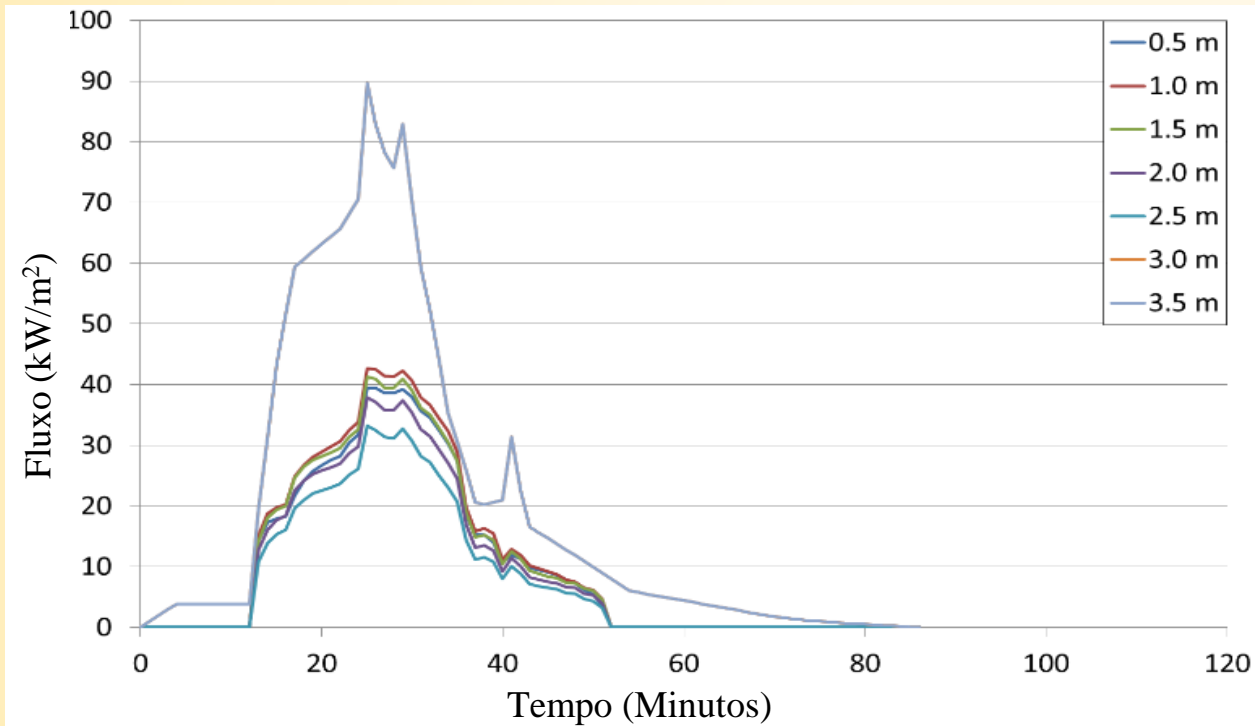
Protection Material
☒ From Catalog
☐ Constant Values
☐ Temperature Dependent
Thickness: mm
Material Name:

Temperature °C	Unit mass kg/m²	Specific Heat J/kgK	Conductivity W/mK
	300	1200	0.12

OK Cancel

7. Exemplos

7.3. Exemplo 3: Coluna de um parque de estacionamento



- Fora da camada de fumo ($z = 1 \text{ m}$): $t_{\max} = 500^{\circ}\text{C}$
- Na camada de fumo ($z = 3.5 \text{ m}$): $t_{\max} = 718^{\circ}\text{C}$

7. Exemplos

7.4. Exemplo 4: Treliça de um edifício industrial

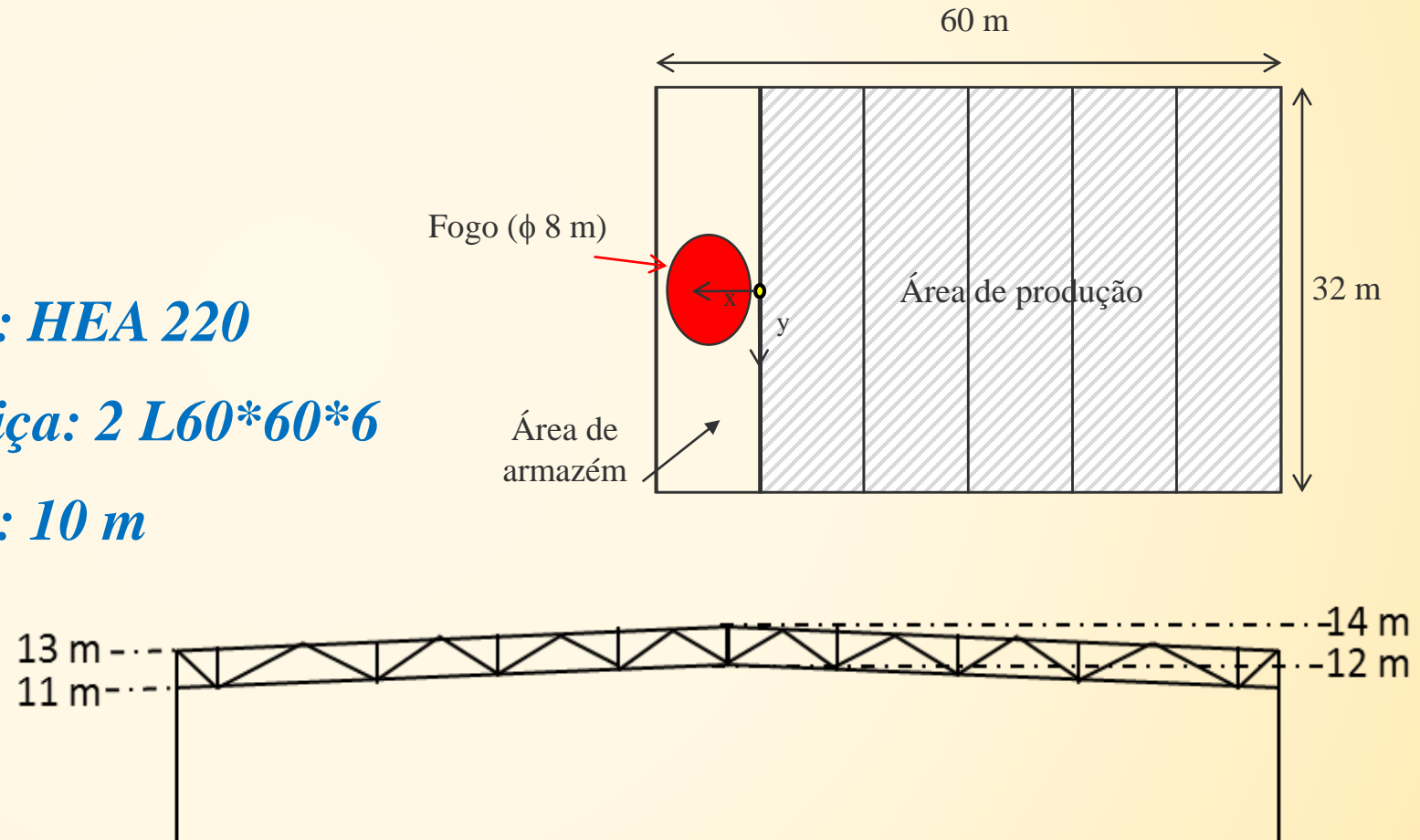
Descrição da estrutura:

Secção dos banzos da treliça: HEA 220

*Secção das diagonais da treliça: 2 L60*60*6*

Distância entre dois pórticos: 10 m

Altura do cume: 14 m



7. Exemplos

7.4. Exemplo 4: Treliça de um edifício industrial

Cenário de incêndio:

Área de incêndio: 50 m^2 (centro da área de armazenamento)

→ Diâmetro equivalente: 8 m

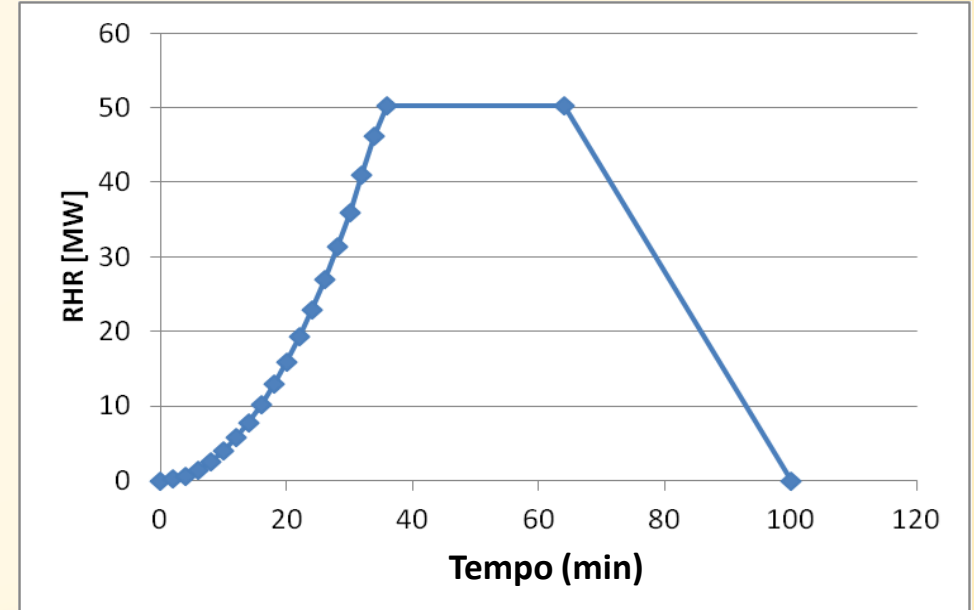
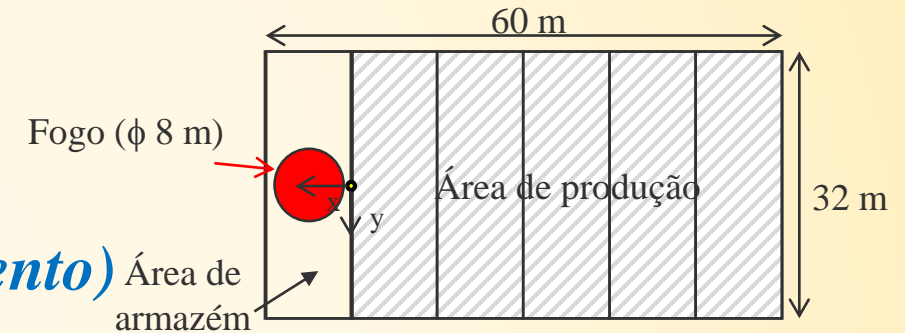
Velocidade de desenvolvimento: Média

→ $RHR = 1 \text{ MW}$ após $t_{\alpha} = 300 \text{ sec}$

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

Carga de incêndio: 10 To (celulosa)

→ $Q = 17.5 \text{ MJ/kg} * 10000 \text{ kg} = 175000 \text{ MJ}$



7. Exemplos

7.4. Exemplo 4: Treliça de um edifício industrial

File Tools View Help

Compartment Fire: ☐ Annex E (EN 1991-1-2) ☐ User Defined Fire

Localised Fire: ☒ Localised Fire

Number of fires: Select fire:

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

Geometrical Data

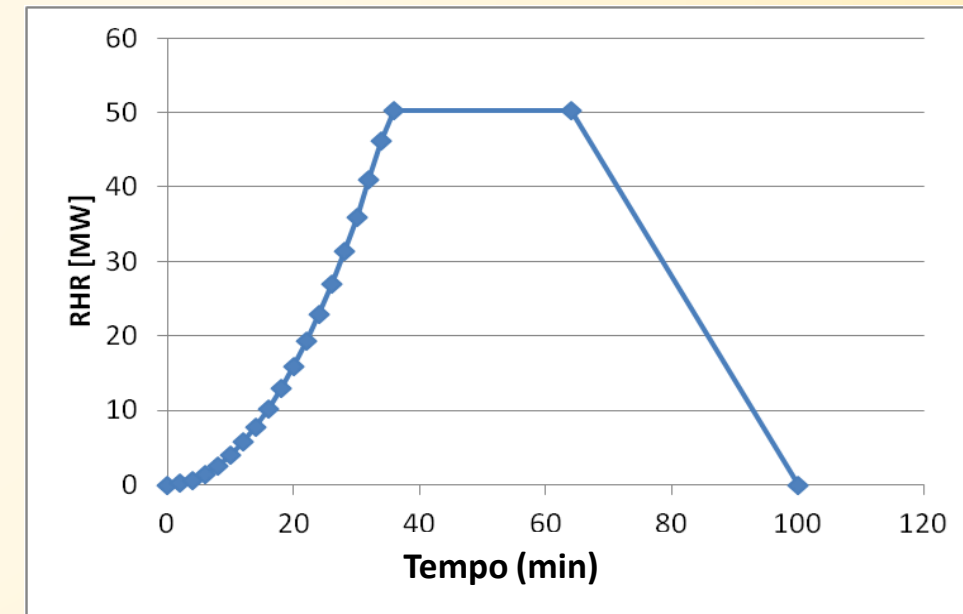
Compartment Height: m

Distance on Axis (x): m

Height on Axis (z): m

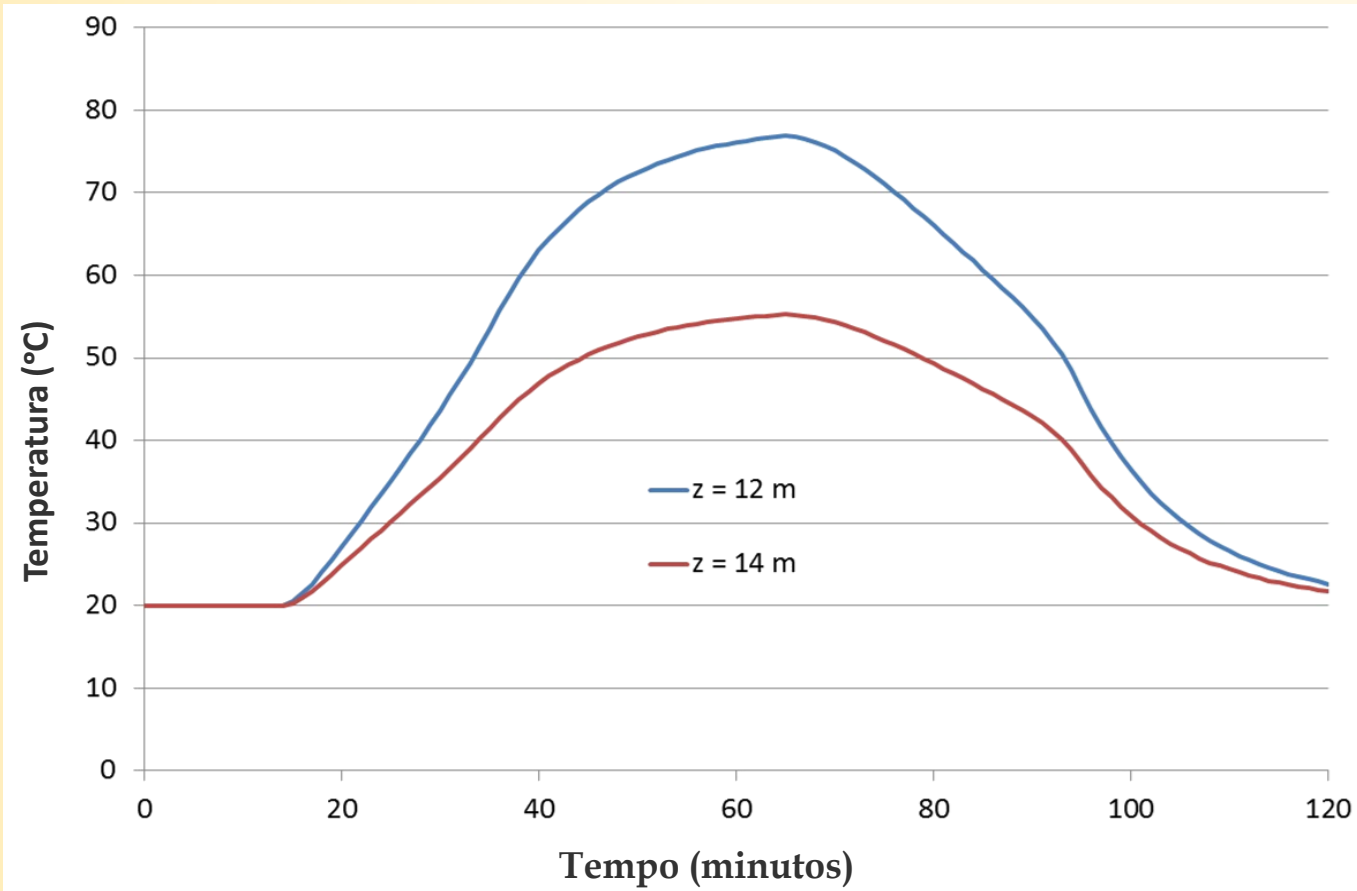
	Time [min]	RHR [MW]
Point 1	0	0
Point 2	2	0.15
Point 3	4	0.65
Point 4	6	1.45
Point 5	8	2.55
Point 6	10	4
Point 7	12	5.75
Point 8	14	7.8
Point 9	16	10.2
Point 10	18	12.9
Point 11	20	15.9
Point 12	22	19.25
Point 13	24	22.9
Point 14	26	26.9
Point 15	28	31.2
Point 16	30	35.8
Point 17	32	40.75
Point 18	34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

OK Cancel



7. Exemplos

7.4. Exemplo 4: Treliça de um edifício industrial



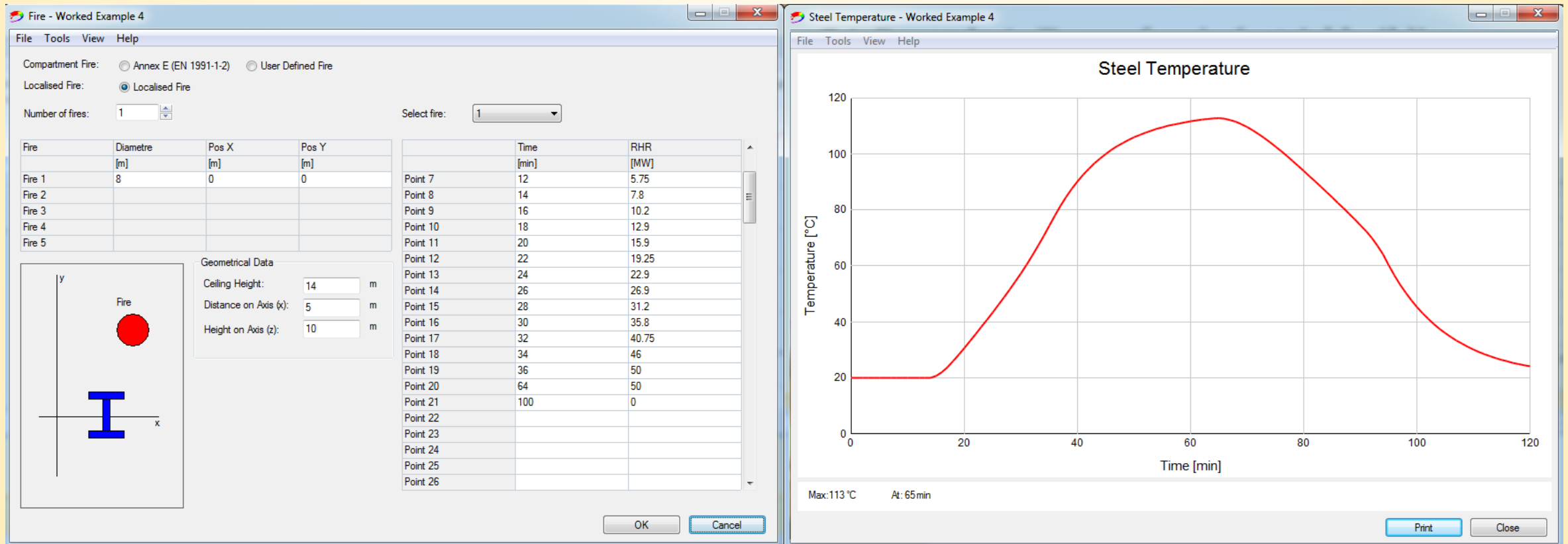
Altura da chama = 9.7m

→ Os elementos da treliça estão localizados acima da chama sólida

Temperatura máxima das treliças = 210°C

7. Exemplos

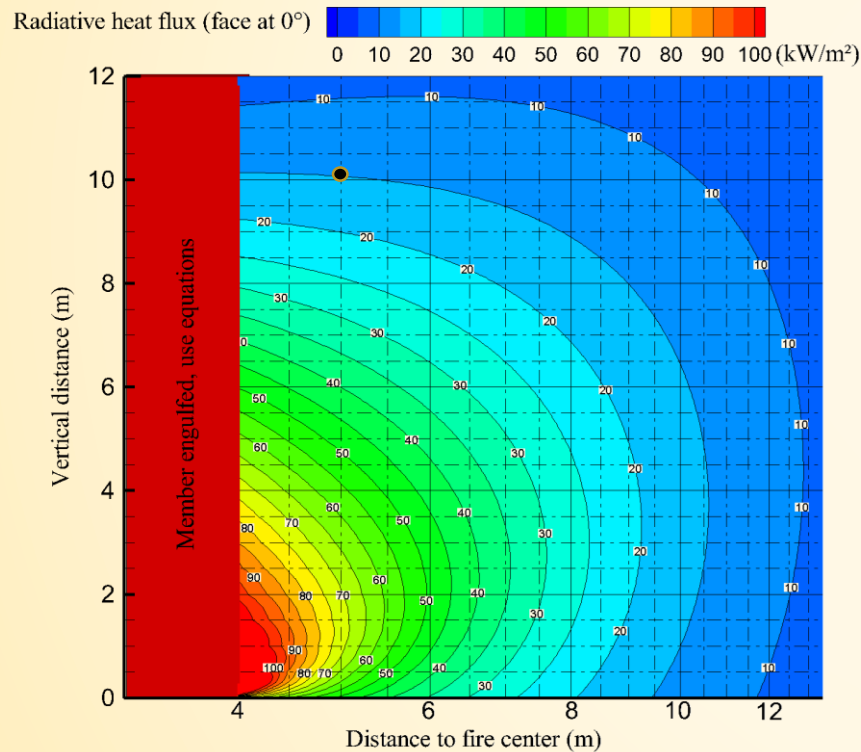
7.4. Exemplo 4: Treliça de um edifício industrial



7. Exemplos

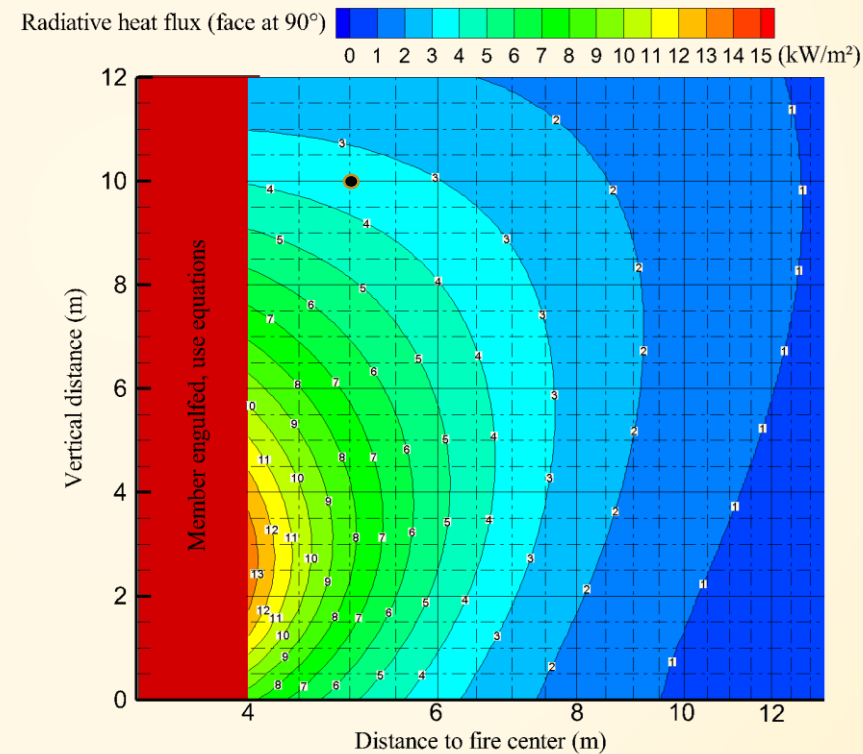
7.4. Exemplo 4: Treliza de um edifício industrial

Face 1



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

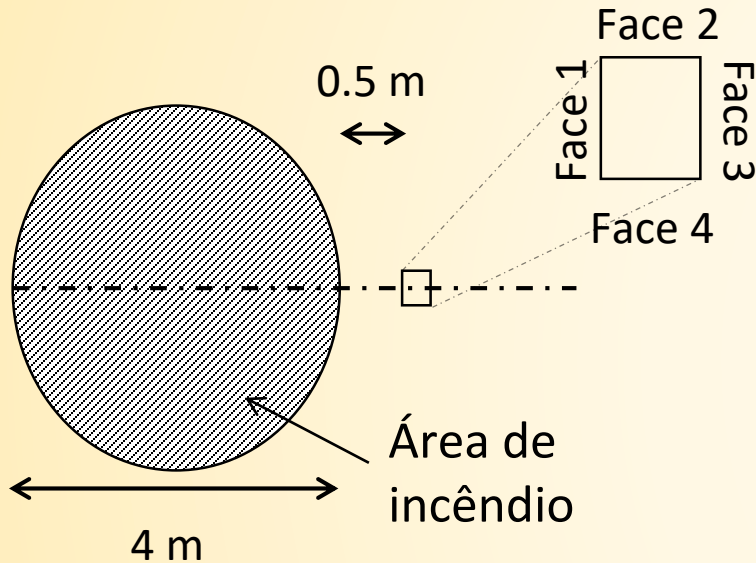
Face 2



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

7. Exemplos

7.4. Exemplo 4: Treliça de um edifício industrial



Fluxo de calor recebido por cada face (assumindo $\varepsilon = 0.7$)

Face 1 : 10.5 kW/m²

Face 2 : 2.45 kW/m²

Face 3 : 0.00 kW/m²

Face 4 : 2.45 kW/m²

→ Fluxo de calor médio = 3.85 kW/m²

$$0 = \underbrace{h(\theta - 20)}_{\text{Fluxo convectivo emitido}} + \underbrace{\sigma\varepsilon[(\theta + 273)^4 - (20 + 273)^4]}_{\text{Fluxo de radiação emitida}} - \underbrace{\varepsilon * \varphi_{tot}}_{\text{Fluxo absorvido}}$$

Fluxo convectivo
emitido

Fluxo de
radiação emitida

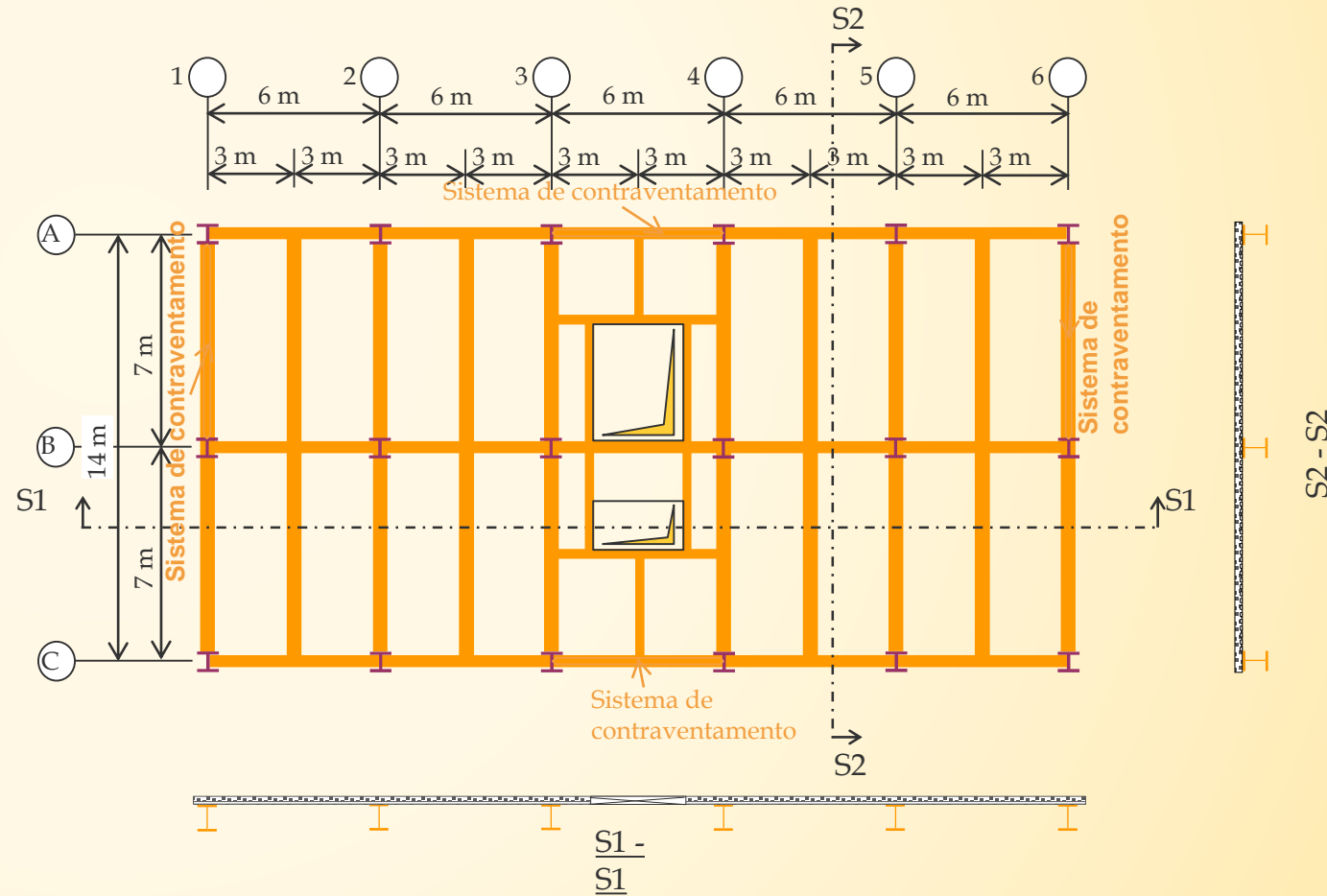
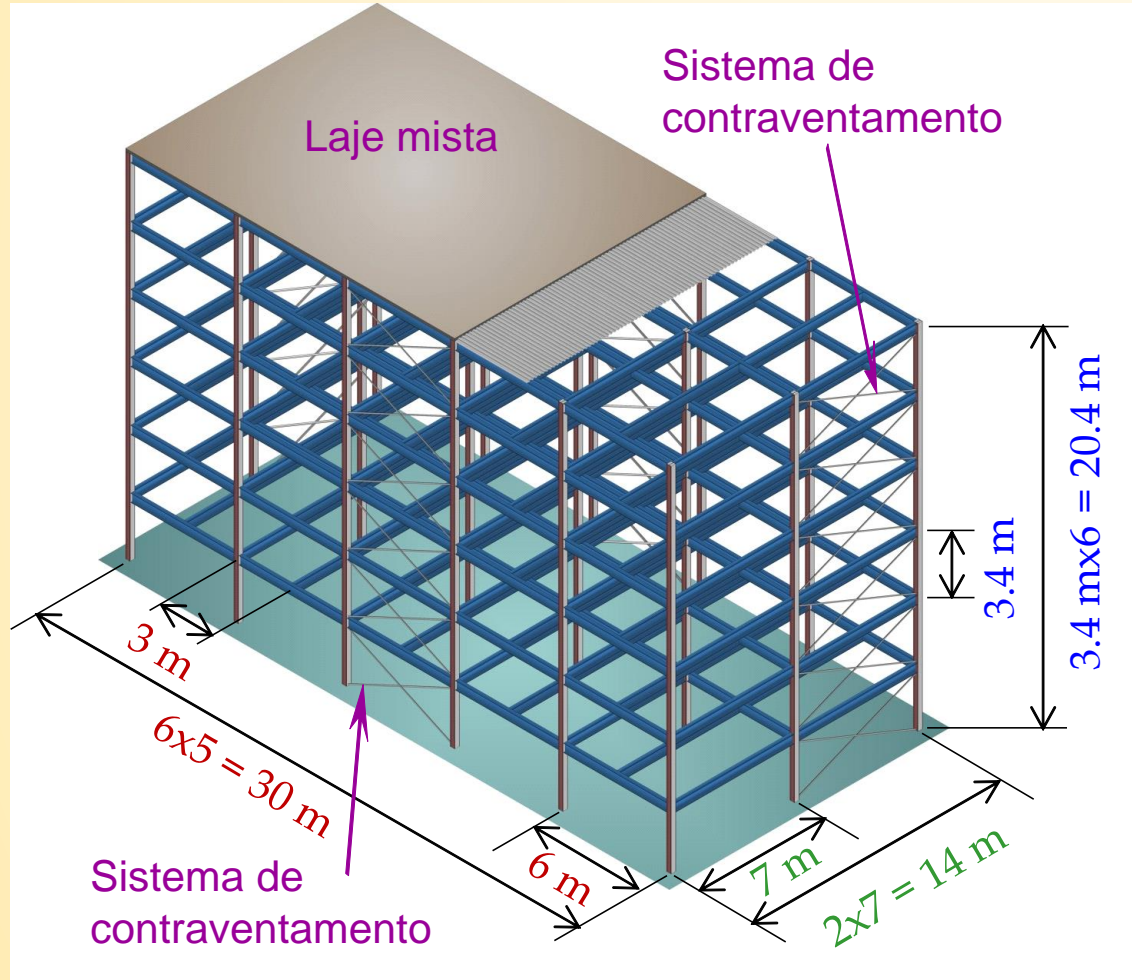
Fluxo absorvido

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

T (°C)	Fluxo emitido W/m ²
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

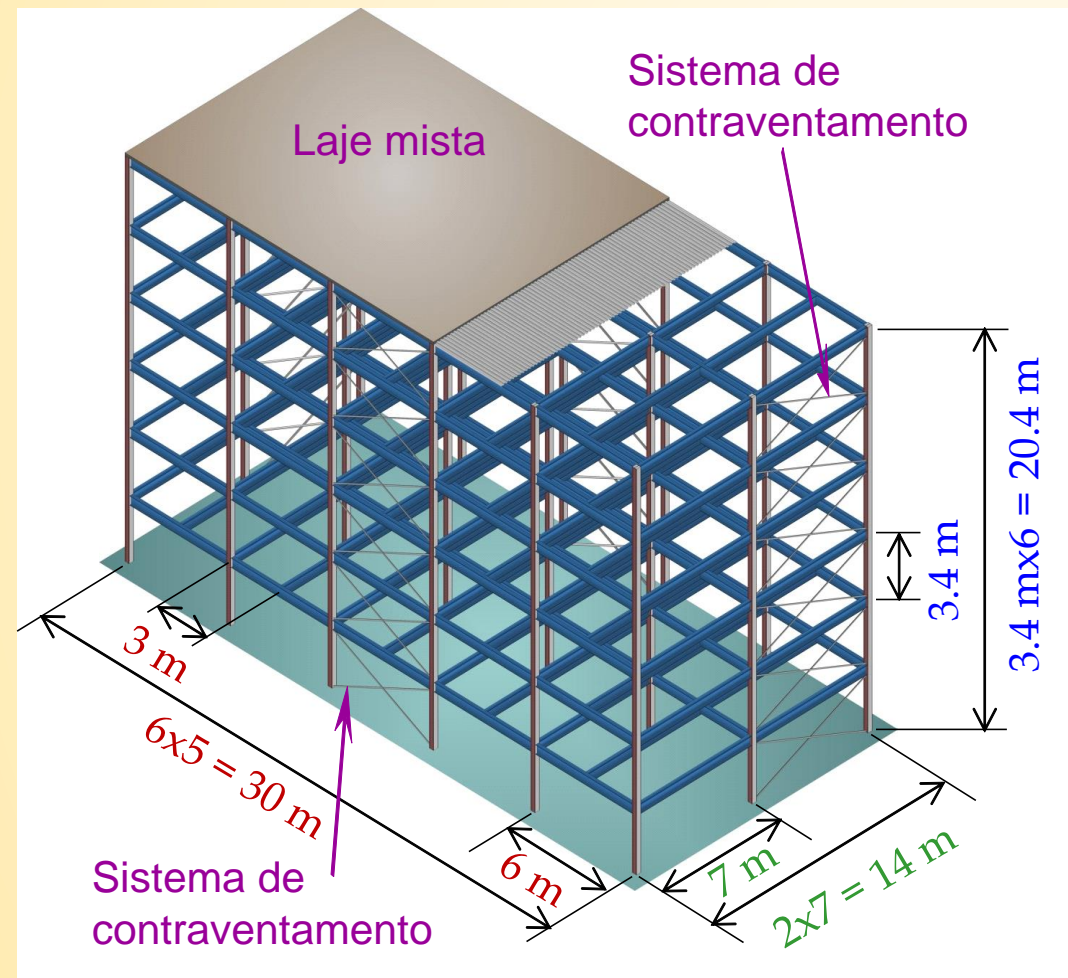
7. Exemplos

7.5. Exemplo 5: Resistência à encurvadura de uma coluna



7. Exemplos

7.5. Exemplo 5: Resistência à encurvadura de uma coluna



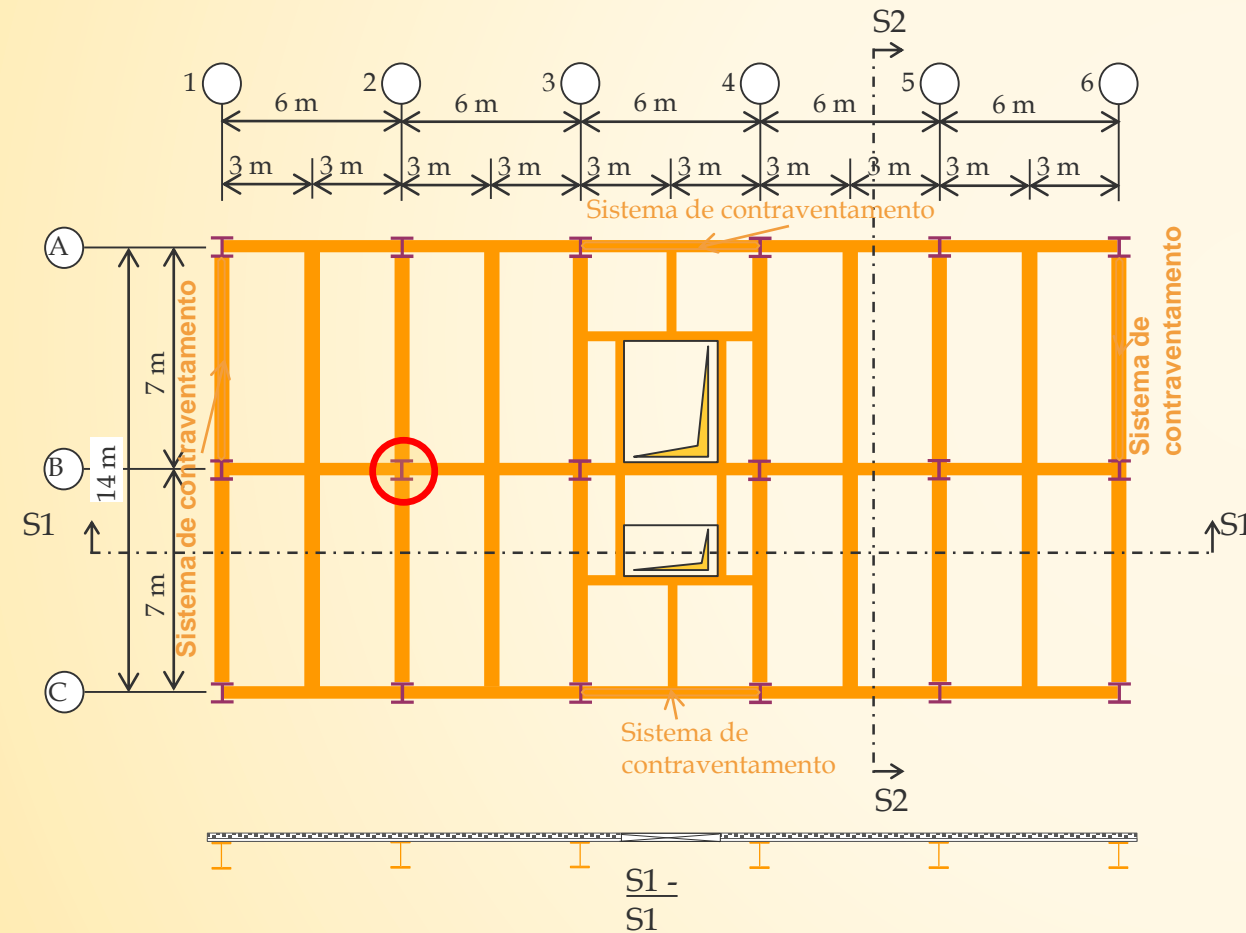
Ações (para todos os pisos)

- Peso próprio G1:
 - ✓ Peso unitário da laje mista: 2.12 kN/m^2
 - ✓ Elementos estruturais em aço: de acordo com as suas dimensões
- Carga permanente G2:
 - ✓ acabamentos, instalações, divisórias: 1.50 kN/m^2
- Carga permanente G3:
 - ✓ Carga de revestimento das fachadas: 2.00 kN/m
- Valores característicos das cargas variáveis e fatores ψ

Tipo	Q_k	ψ_1	ψ_2
Carga variável nos pisos	4.0 kN/m^2	0.7	0.6
Neve na cobertura	1.7 kN/m^2	0.2	0.0

7. Exemplos

7.5. Exemplo 5: Resistência à encurvadura de uma coluna



Elementos estruturais

- Laje mista:
 - ✓ Espessura total: 12 cm
 - ✓ Chapa de aço perfilada: COFRAPLUS60
 - ✓ Espessura chapa de aço perfilada: 0.75 mm
 - ✓ Laje continua sobre 2 vãos
- Vigas secundárias comuns:
 - ✓ IPE360 - S275
- Vigas internas principais:
 - ✓ HEA360 - S275
- Colunas para o nível do solo:
 - ✓ Colunas de bordo (nível do solo): HEA300 - S275
 - ✓ **Colunas centrais (nível do solo): HEB300 - S275**

7. Exemplos

7.5. Exemplo 5: Resistência à encurvadura de uma coluna

Passo 1: Cálculo da ação mecânica em incêndio

- Carga de cálculo em situação de incêndio

$$E_{fi,d,t} = \sum_{j \geq 1} G_{k,j} + \Psi_{2,1} Q_{k,1} + \sum_{i \geq 2} \Psi_{2,i} Q_{k,i}$$

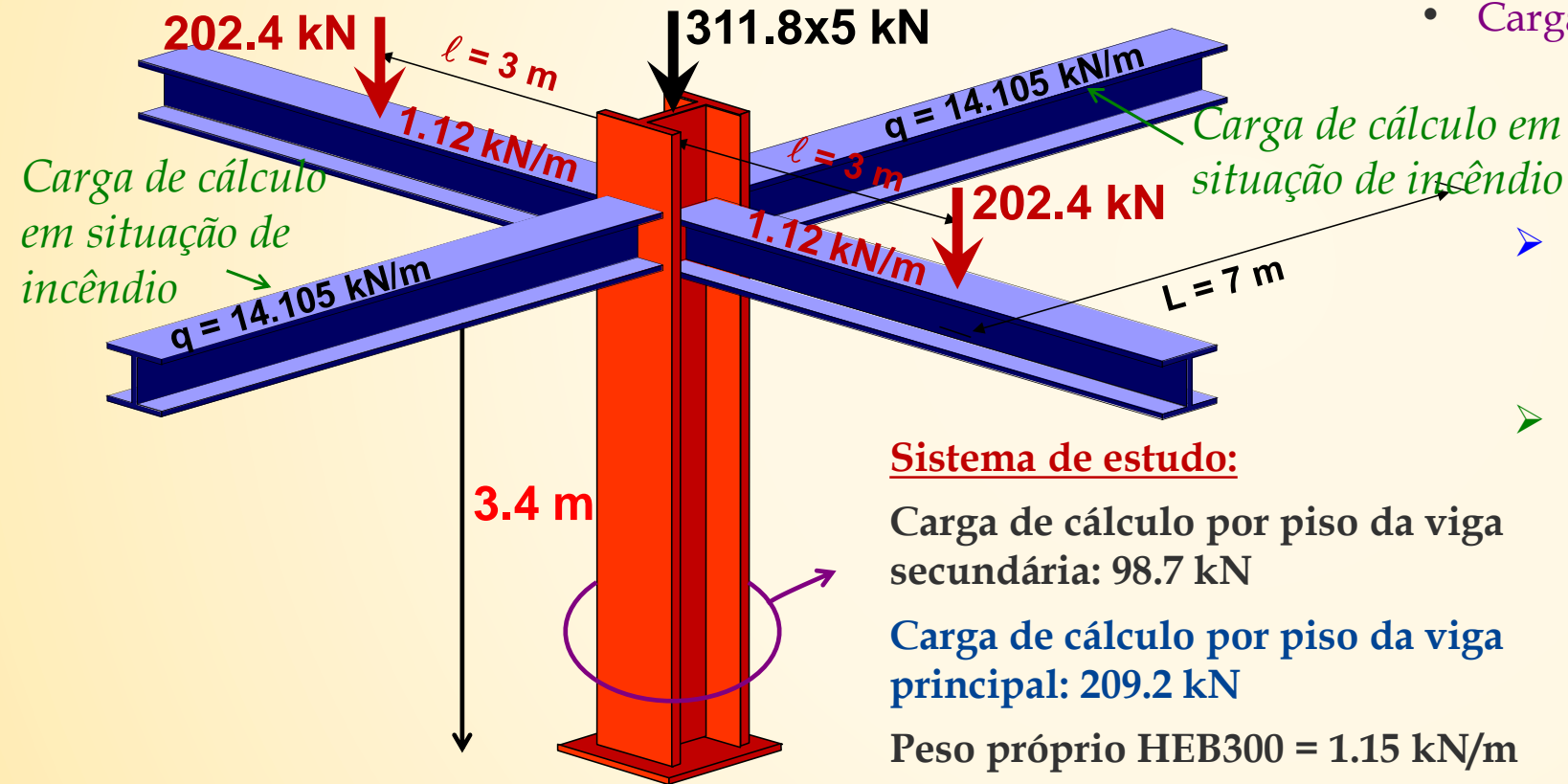
- Peso próprio da coluna

$$q_{fi,d,t} = 1.15 \text{ kN} / \text{m}$$

- Carga axial concentrada total proveniente das vigas de aço

$$\begin{aligned} P_{fi,d,t} &= \sum (G_{k,1} + \psi_{2,1} Q_{k,1}) \\ &= \underbrace{14.105 \times 7 + 202.4}_{\approx 307.9 \text{ kN}} + \underbrace{1.12 \times 6}_{\text{Viga principal}} \end{aligned}$$

Viga secundária
Viga principal



Nota: dependendo do país deve adotar-se $\psi_{1,1}$ ou $\psi_{2,1}$.

7. Exemplos

7.5. Exemplo 5: Resistência à encurvadura de uma coluna

Passo 1: Design mechanical action in fire

- Condições de carga de cálculo total em situação de incêndio

$$N_{fi,d,t} = (307.9 + 3.9) \times 6 = 1870.8 \text{ kN}$$

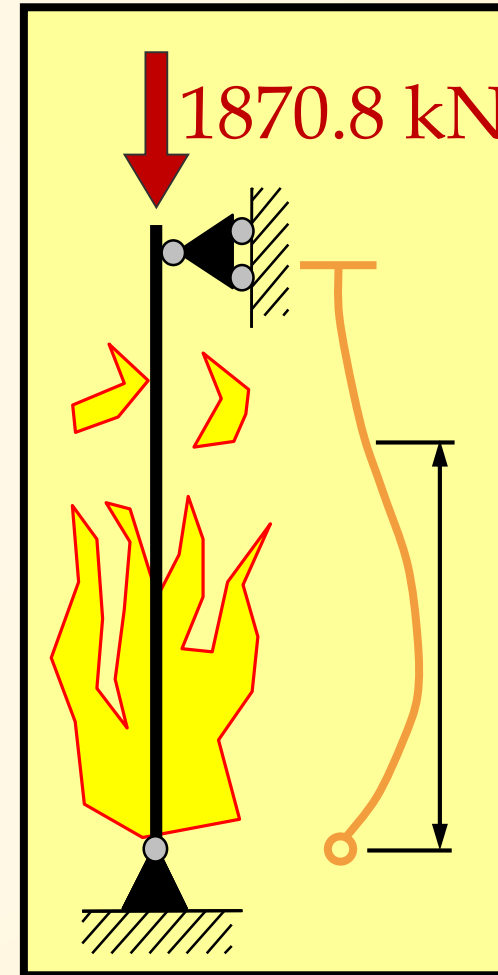
- Comprimento de encurvadura em situação de incêndio

- base da coluna fixa

$$L_{fi} = 0.7L = 0.7 \times 3.4 = 2.38 \text{ m}$$

- Carga crítica de Euler

$$N_{cr} = \frac{\pi^2 EI}{L_{cr}^2} = \frac{3.14^2 \times 210000 \times 8.563 \times 10^7}{2380^2} = 31332213 \text{ N}$$



7. Exemplos

7.5. Exemplo 5: Resistência à encurvadura de uma coluna

Passo 2: Classificar o elemento

- Elemento em flexão

Relação 4.2 do Eurocódigo 3 parte 1-2

$$\varepsilon = 0.85 \sqrt{235/f_y} = 0.786$$

\searrow S275

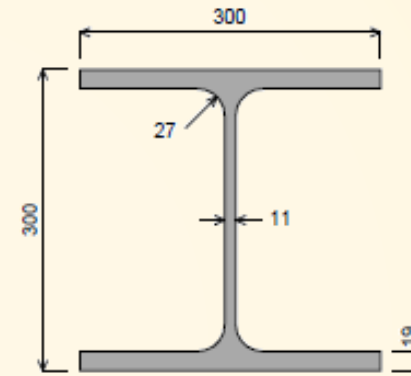
Tabela 5.2 do Eurocódigo 3 parte 1-1

$$c/t_w \leq 33\varepsilon \rightarrow \text{Classe da alma 1}$$

$$\searrow = 18.9 \quad \rightarrow = 25.9$$

$$c/t_f \leq 9\varepsilon \rightarrow \text{Classe do banzo 1}$$

$$\searrow = 6.2 \quad \rightarrow = 7.07$$



HEB300



Secção de classe 1

7. Exemplos

7.5. Exemplo 5: Resistência à encurvadura de uma coluna

Passo 3: Resistência de cálculo no instante 0 (temperatura ambiente)

Resistência de cálculo no instante 0 (temperatura ambiente) de acordo com o Eurocódigo 3 parte 1-2

- Esbelteza normalizada à temperatura normal

$$\bar{\lambda} = \sqrt{\frac{N_{Rk}}{N_{cr}}} = \sqrt{\frac{Af_y}{N_{cr}}} = \sqrt{\frac{14910 \times 275}{31332213}} = 0.362$$

- Esbelteza a elevada temperatura

$$\bar{\lambda}_{\theta} = \bar{\lambda} \sqrt{\frac{k_{y,\theta}}{k_{E,\theta}}} = 0.361 \sqrt{\frac{1.0}{0.825}} = 0.399$$

- Coeficiente de redução

$$\chi_{fi} = \frac{1}{\varphi_{\theta} + \sqrt{\varphi_{\theta}^2 - \bar{\lambda}_{\theta}^2}} = \frac{1}{0.699 + \sqrt{0.699^2 - 0.398^2}} = 0.786$$

- Resistência axial plástica

$$N_{b,fi,t,Rd} = \chi_{fi} A k_{y,\theta} \frac{f_y}{\gamma_{M,fi}} = 0.786 \times \frac{14910}{1000} \times 1.0 \times \frac{275}{1.0} = 3223 \text{ kN}$$

HEB300	
A (cm ²)	149.08
I _z (mm ⁴)	8.56

7. Exemplos

7.5. Exemplo 5: Resistência à encurvadura de uma coluna

Passo 4: Grau de utilização para dados tabelados

$$\mu_0 = \frac{N_{fi,d,t}}{N_{pl,fi,0}} = 0.452$$

Passo 5: Temperatura crítica

Interpolação linear de dados tabelados $\bar{\lambda}_{fi,0} = 0.362$

$\bar{\lambda}_{fi,0}$	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
μ_0											
...
0.40	629	603	578	544	499						
0.42	621	595	569	535	477						
0.44	613	588	561	525	455						
0.46	604	581	553	516	433						
0.48	597	573	545	506	411						
0.50	590	566	536	494	367						
0.52	584	559	528	477							

