CABLE TRAY FIRE IN OPEN ATMOSPHERE

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OBJECTIVES

- **Cable tray fire in compartments of nuclear facilities: An important issue for nuclear safety**
  - **Hundreds of kilometers of cables in NPP**
  - **Assess the potential fire consequences (integrity of safety electrical equipments, of glove box and waste barrels, smoke propagation, clogging of HEPA filters)**

- **PRISME-2 OCDE program led by IRSN**
  - **How the fire could ignite and spread over multiple horizontal trays fires ?**
  - **Characterization of cable tray fire both in open atmosphere and in confined compartments, concerning HRR, fire growth, soot yield, …**

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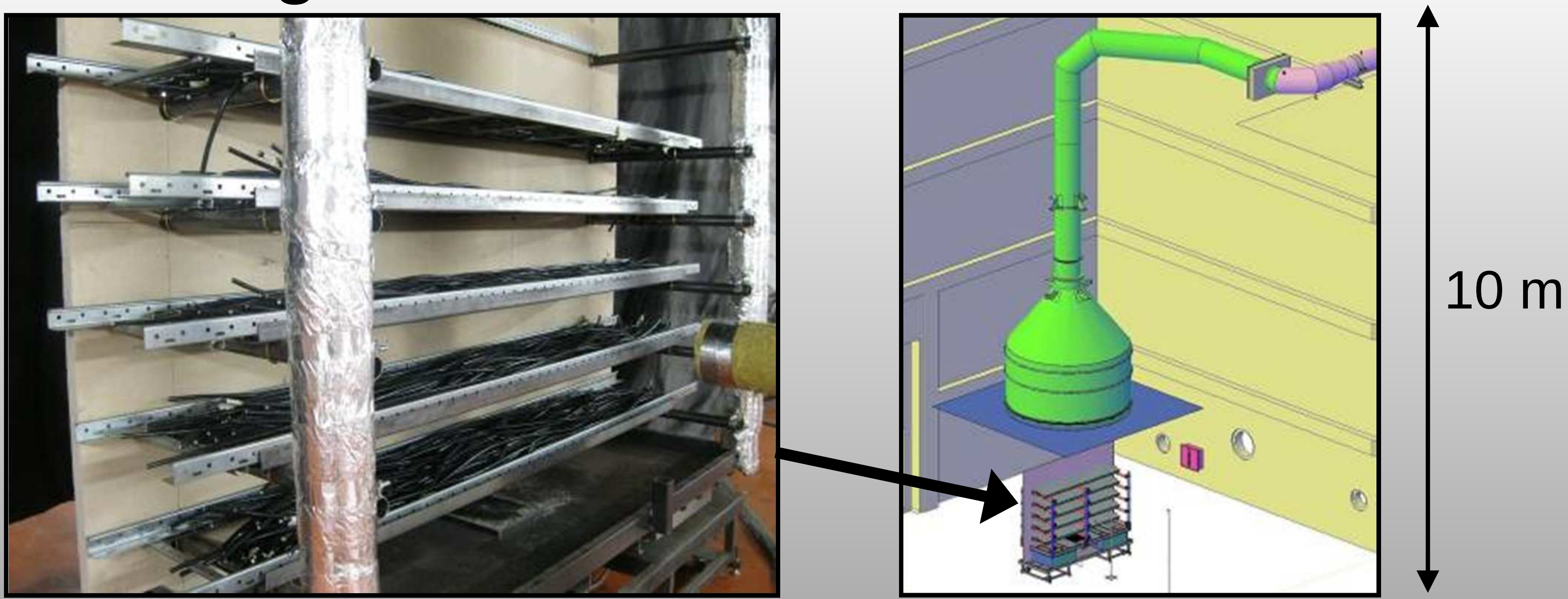
EXPERIMENTAL SET-UP: Fire source and large-scale calorimeter



- **Fire sources are composed by 5 horizontal trays located along an insulated side wall (l=2.4m, w=0.45m and s=0.3m)**
- **Cable tray fires were carried out in well-ventilated conditions, under a large-scale calorimeter**

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EXPERIMENTAL SET-UP: Cables

Cable	Technical specification
A	PVC Power cable 3x2.5 mm^2 13 mm diameter
B	PVC Control cable 8x2 mm^2 14.5 mm diameter
C	HFFR* Control cable 12x1.5 mm^2 20 mm diameter
D	HFFR Power cable 3x95 mm^2 37 mm diameter

*HFFR = Halogen-free flame retardant

A

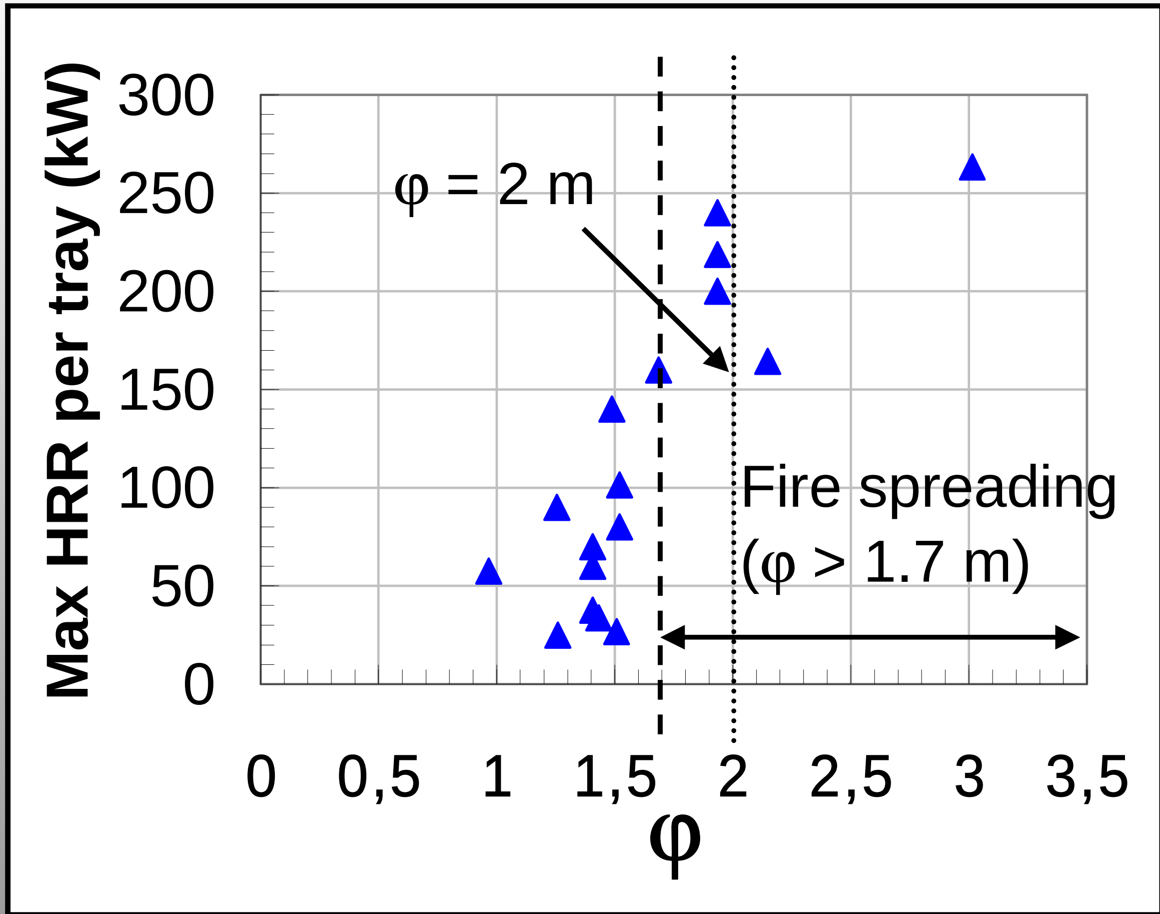
B

C

D

TRAY LOADING: Results from CHRISTIFIRE

w = 0.45 m, s = 0.3 m



$$\varphi = \frac{S_{cable,tray}}{L_{tray}} = n \cdot \pi \cdot d \ \ (m) \qquad n = \frac{2}{\pi \cdot d}$$

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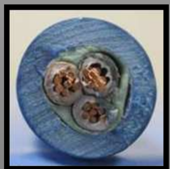
FINAL TRAY LOADING

Cable	Number of cables per tray	Maximum number of cables (EDF NPP/ NEC)
A	49 (φ = 2 m)	102/101
B	44 (φ = 2 m)	93/81
C	32 (φ = 2 m)	44/43
D1 (trays 1 and 2)	53 (φ = 2 m)	148/119
D2 (trays 3, 4 and 5)	12 (φ = 1.4 m)	12/12



D1 Cable

D2 Cable

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Loose arrangement of the cables over all trays (as in most CHRISTIFIRE tests)

D1 and D2 cables

CHRISTIFIRE

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IGNITION

- Power = 80 kW for "new" HFFR cables instead of 40 kW for "old" cables of CHRISTIFIRE
- Stop of burner when HRR > 400 kW (= time to ignition)

Cable	Time to ignition (for 80 kW)
A	1 min 20 s
B	2 min 26 s
C	12 min 24 s
D	10 min 19 s

Ignition of cable tray fires with A and B cables was five to ten times faster than the one of cable tray fires with C and D cables

FIRE SPREADING

Cable A

Movie1

Cable C

MOVIE2

Cable D

Cable B

Fire spread up to ends of all trays

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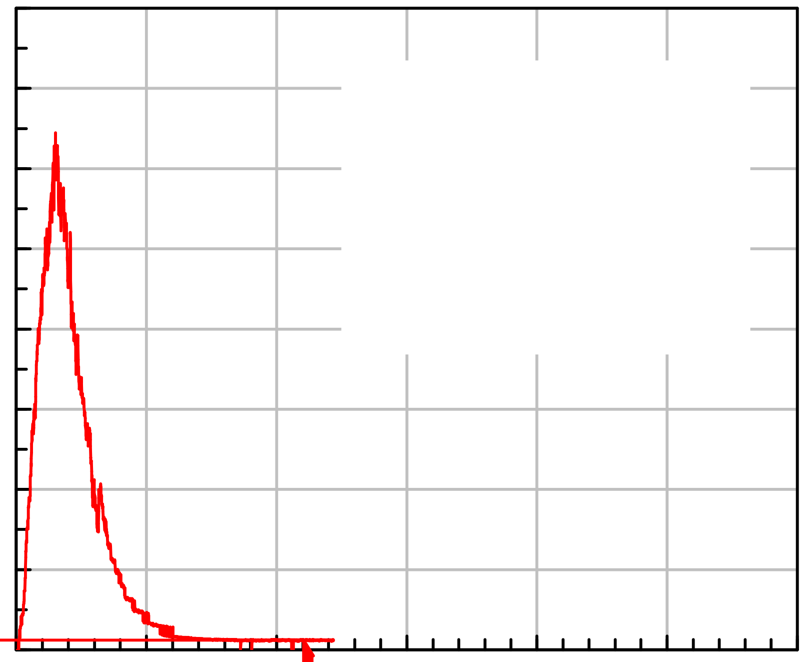
HEAT RELEASE RATE (Chemical methods)

Cable	Peak of HRR (MW)
A	3.2
B	2.7
C	2.2
D	1.0



Cable	A	B	C	D
Time to reach Pk of HRR (s)	302	385	1475	1323

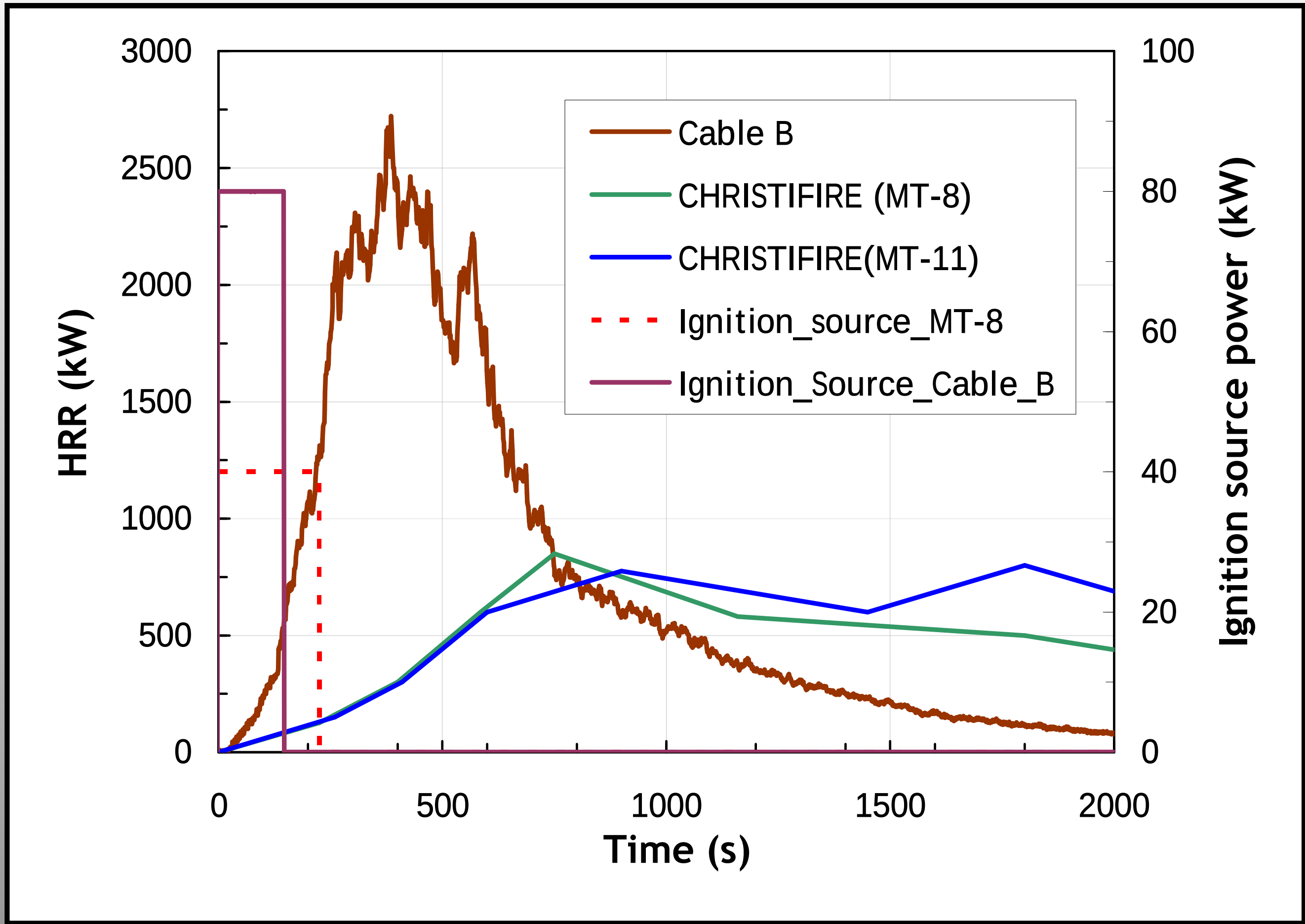
EFFECT OF THE TEST CONFIGURATION

Cable B

α = 0.028 kW/s²

Cable CHRISTIFIRE

α = 0.0019 kW/s²



Significant effect of the insulated side wall and also of the power of gas burner (80 kW instead of 40 kW)

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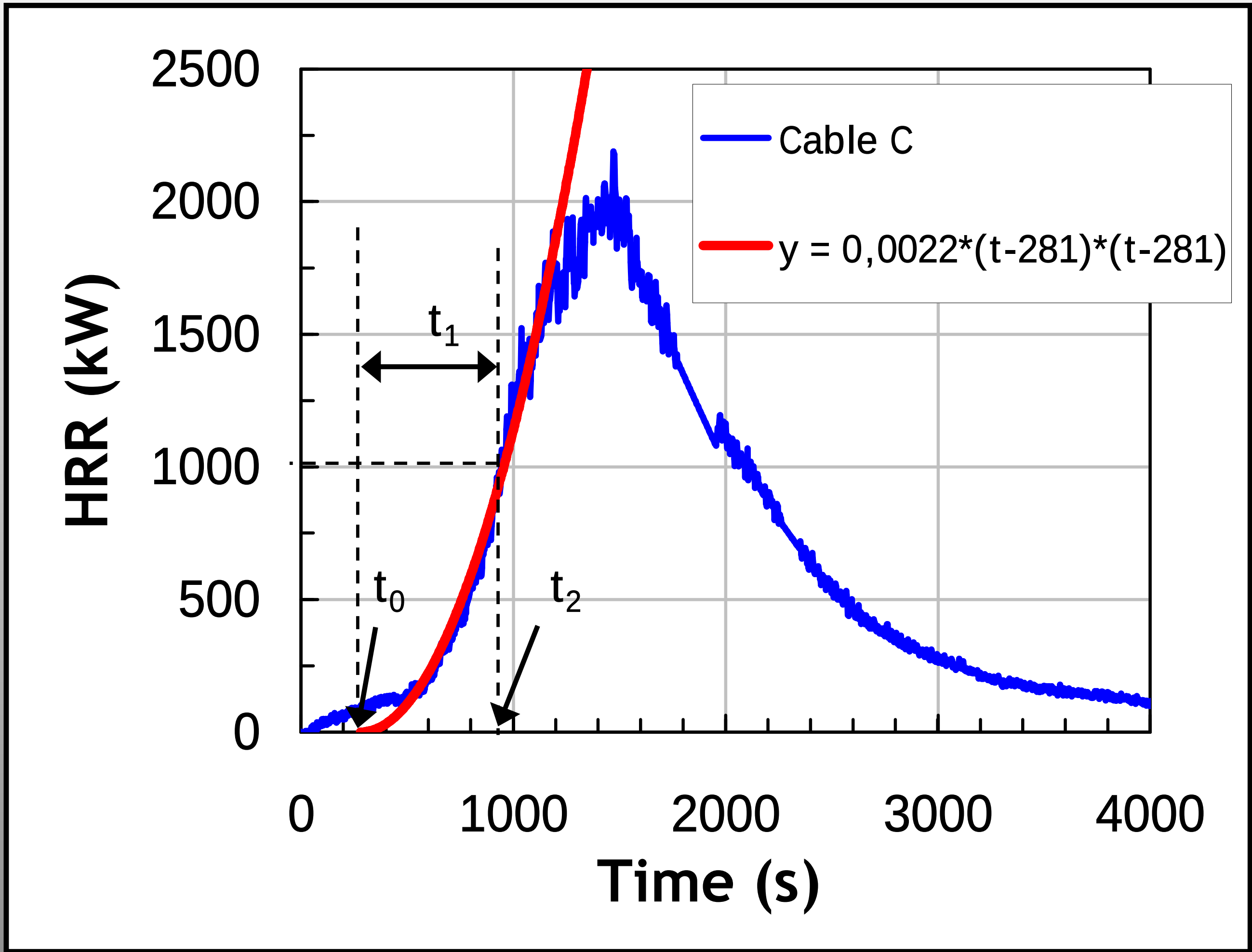
FIRE GROWTH (Quintiere and NFPA 72)



$$HRR = \left(\frac{1000}{t_1^{\,2}}\right) \cdot t^2$$

$t_1 = t_2 - t_o$

t_1: Characteristic fire growth time (s)
t_0: virtual time of origin (s)
t_2: time to reach 1000 kW since starting of fire (s)

$\alpha = 1000/t_1^2$
Fire growth rate parameter (kW/s²)

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TWO FIRE CATEGORIES

Fire classification (NFPA 72)	Characteristic fire growth time, t_1 (s)
Slow	$400\ s \leq t_1$
Medium	$150\ s \leq t_1 < 400\ s$
Fast	$t_1 < 150\ s$

Cable	A	B	C	D
Characteristic fire growth time, t_1 (s)	100	190	674	913

~ Fast growth fires with cables A and B

Slow growth fires with cables C and D

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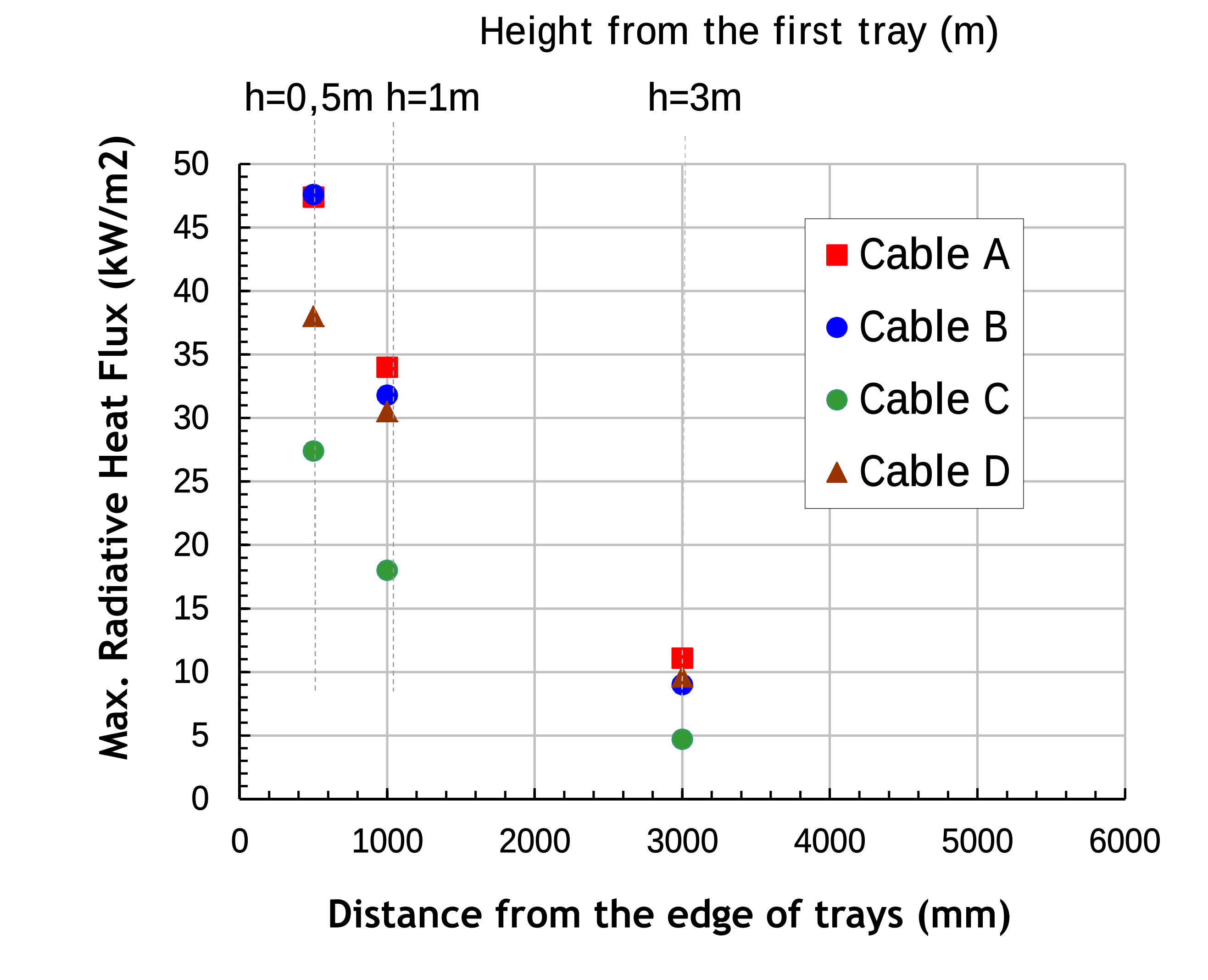
RADIATIVE HEAT FLUX

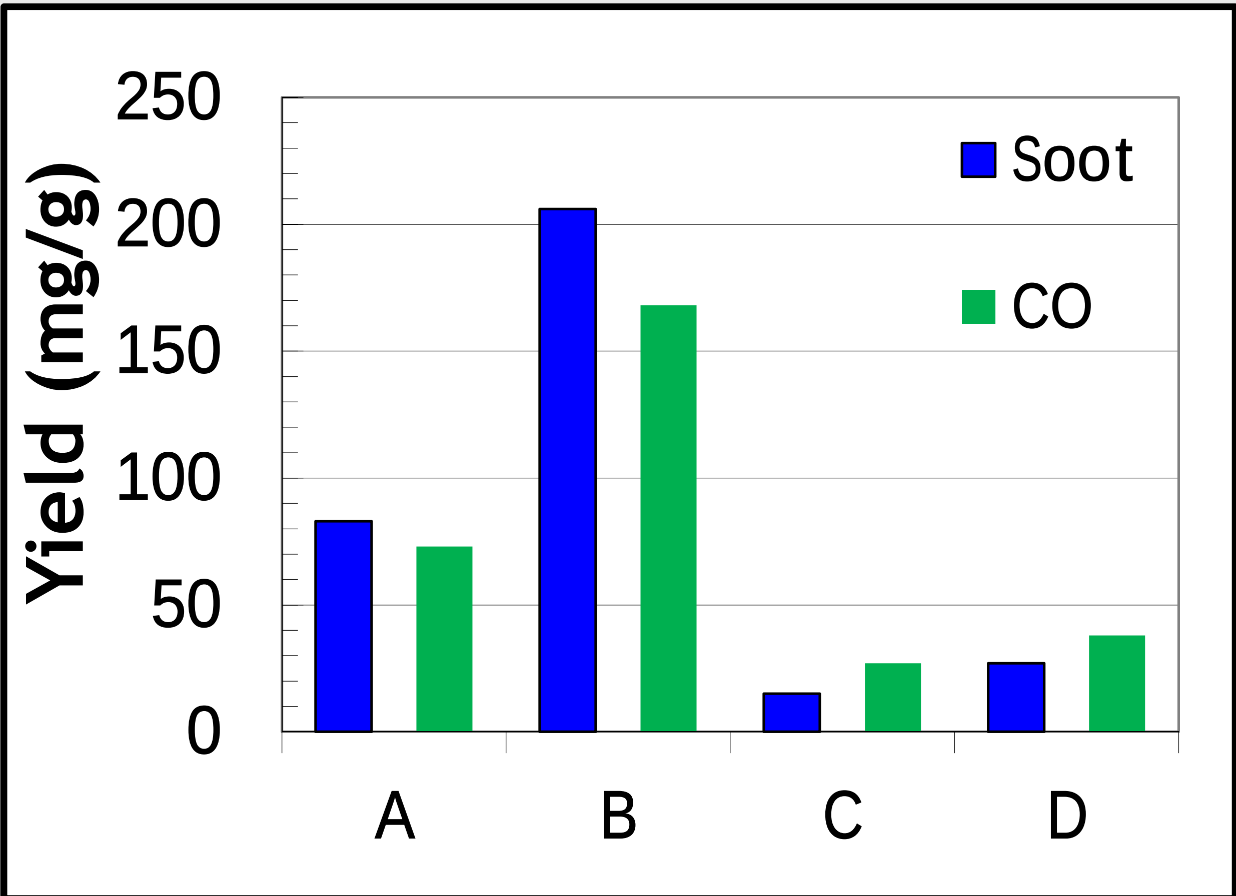


- **Maximal RHF:**
- **30 kW/m² (1 m)**
- **10 kW/m² (3 m)**

- **Time exposure to RHF higher than 5 kW/m² (3 m) is about 1000 s (Cable C)**

SMOKE RELEASE

$$Y_i = \frac{m_i}{m_{fuel\ consumed}} \quad (mg/g)$$



Higher smoke release for cable tray fires with cables A and B

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CONCLUSION

• The insulated wall and power of ignition source (80 kW) significantly increase peak of HRR and fire growth rate

• Cable tray fires with cables A and B are fast growth fires and have shorter time to ignition and higher peaks of HRR than cable tray fires with cables C and D ⇨ These results only apply for cables A,B,C and D and tray loading criteria selected for this study (i. e. same cable surface)

• Higher smoke release for Cables A and B than for cables C and D

• Another characterizations of fire sources of cable trays will be carried out in well-ventilated conditions next year

CABLE FIRE IN THE UNIT 1 OF THE REACTOR BUILDING AT BROWNS FERRY NUCLEAR PLANT (1975) - NRC

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CLASSIFICATION OF THE CABLES

Cable A	NF EN 60332-1 (C2)

Cable B	NF EN 60332-1 (C2), NF EN 60332-3-23

Cable C	NF EN 60332-1 (C2), NF EN 60332-3-22, 60332-3-23, 60332-3-24, NF EN 61034, NF EN 50267-2-2

Cable D	NF C 32-070 (C1), NF EN 60332-3-23, NF EN 61034, NF EN 50267-2-1

Vertical flame spread   Smoke   Halogen acid gas

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EFFECT OF CABLE

Fire test	Cable A	Cable B	Cable C	Cable D
Total surface of cable (m^2)	24	24	24	19.5
Total cable mass (kg)	138	169	219	375
Total non-metallic mass (kg)	88	95	159	135
Flame retardant	Chlorine	Chlorine	ATH*	ATH

*ATH = Aluminium Tri-Hydroxyde

Higher mass of cable (similar surface of cable) and use of ATH as HFFR for cables C and D (chlorine FR for cables A and B) could contribute to increase delay to ignition and characteristic fire growth time (t_1)

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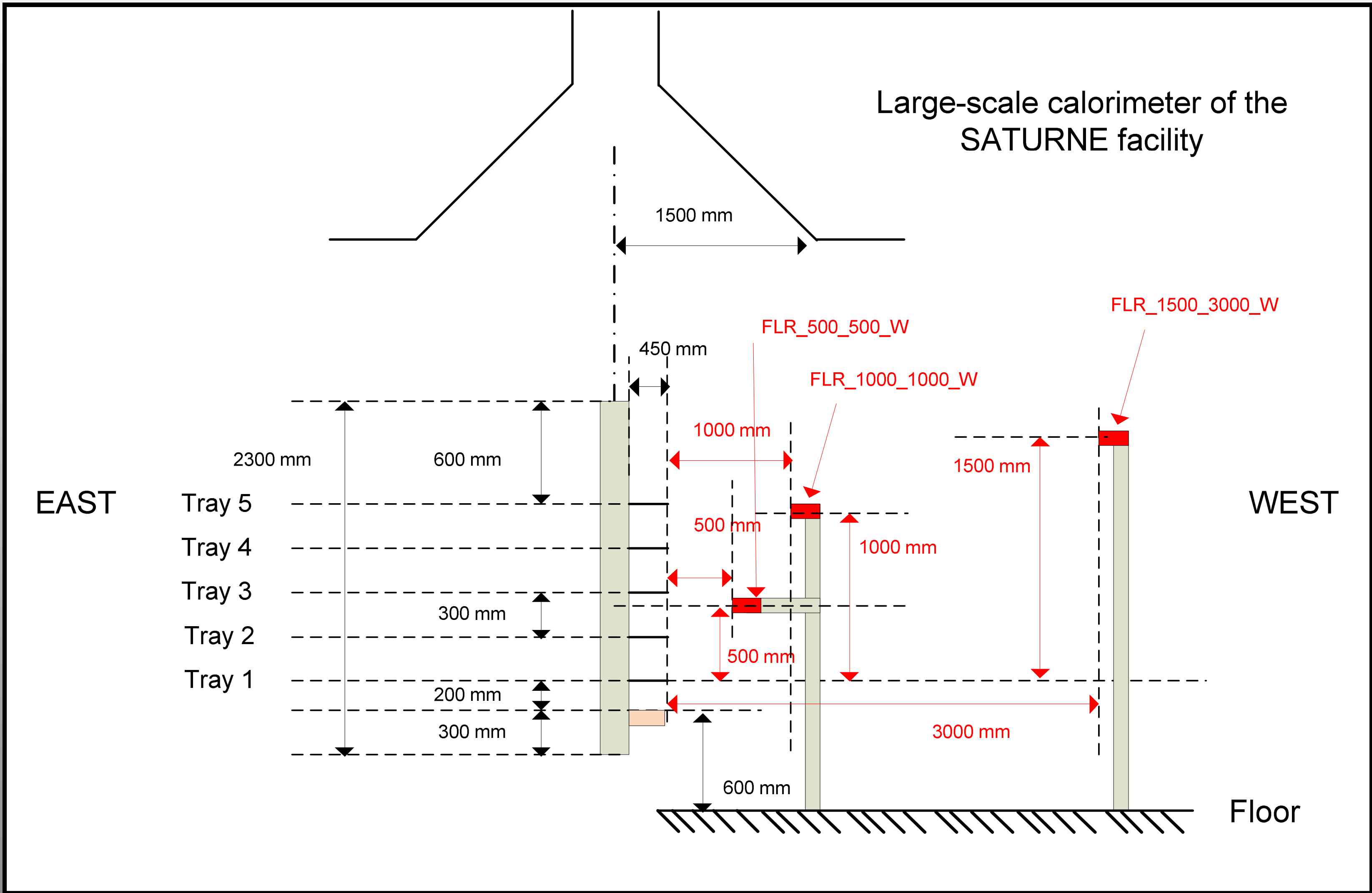
RADIATIVE HEAT FLUX



Yield of soot from ASTM E2058 fire propagation apparatus carried out in well-ventilated conditions

Material	Soot yield (mg/g)
Cable in silicone/PVC	111 and 119
PVC	172
Cable tray fire A	83
Cable tray fire B	206

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