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Ignition of electrical components contained in a closed enclosure adjacent to a controlled fire source

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1. INTRODUCTION



Row of adjacent cabinets in a NPP

About 400 fire events occurred in OECD nuclear power plants (NPPs) between 1975 and 2010 (OECD FIRE database [1])

About 50 fire events involved electrical cabinets [1] which are commonly arranged in rows of adjacent cabinets in NPPs

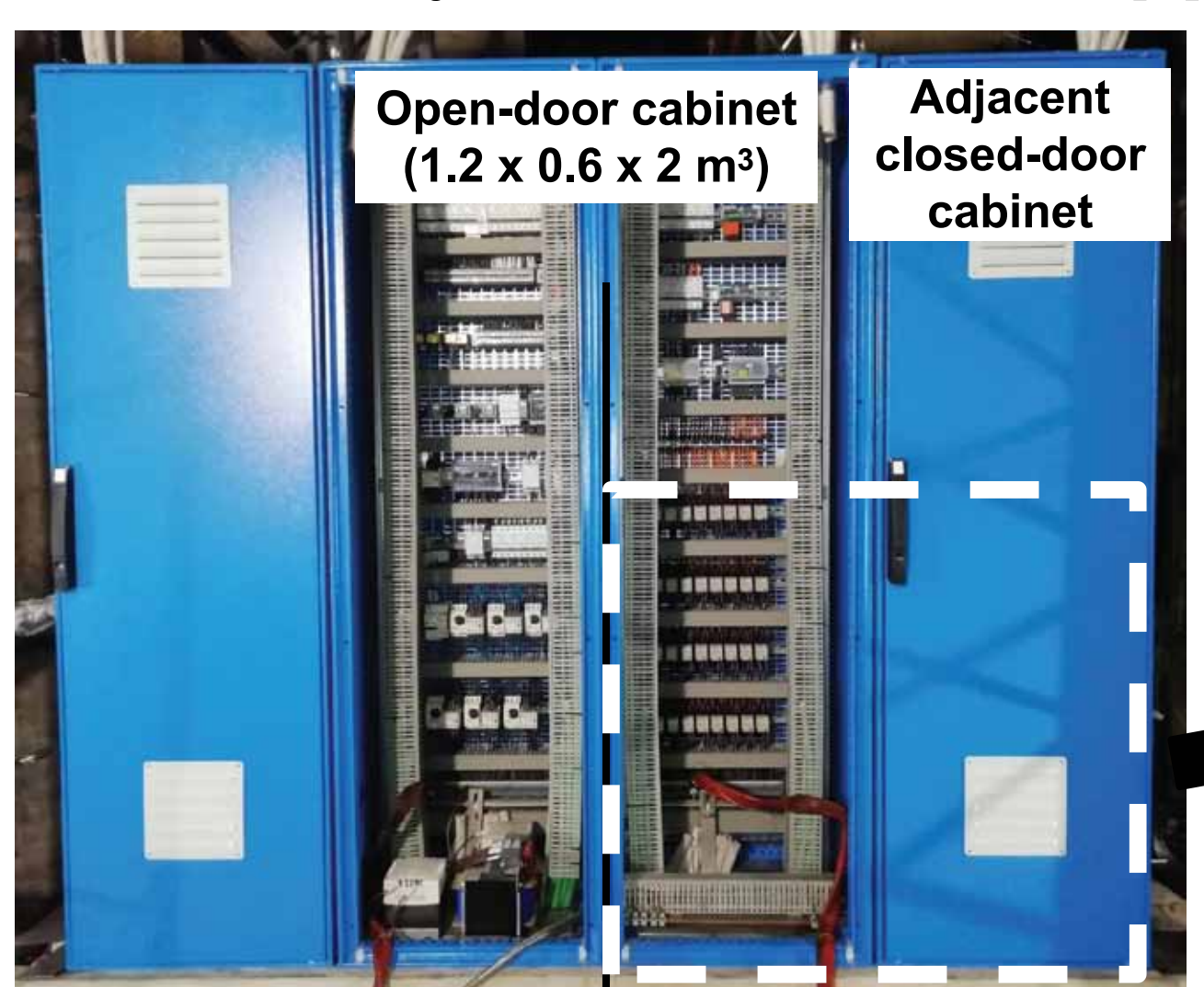
→ The ability of a cabinet fire to spread to adjacent cabinets is a major concern for fire safety in NPPs

- How can ignition occur in the adjacent cabinets?
- What is the impact on ignition of the electrical component type contained in the cabinet?
- What are the effects on ignition of the air gap (between the cabinets) and the cabinet ventilation mode ?

2. EXPERIMENTAL SET-UP

Design study

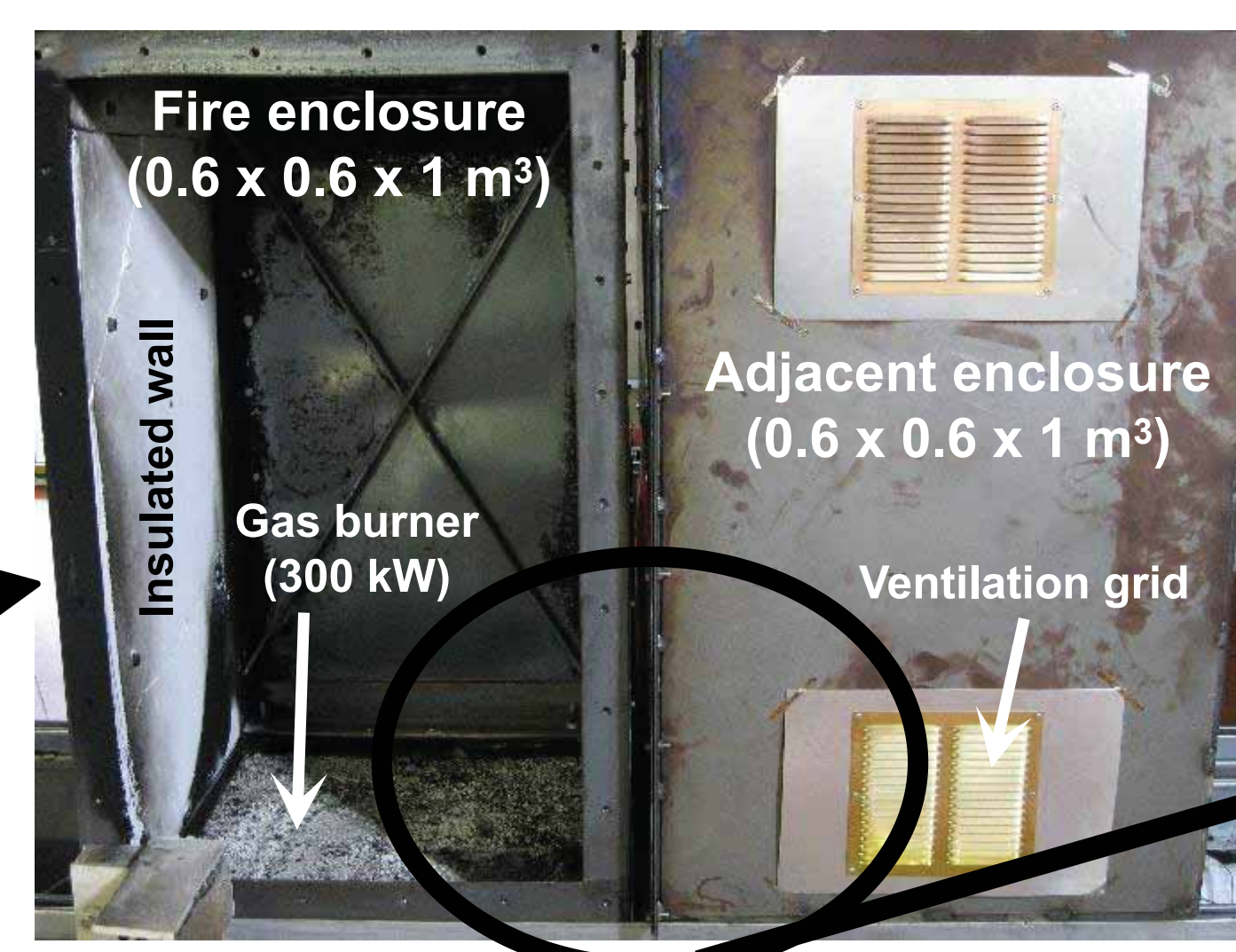
Real-scale adjacent cabinets studied [2]



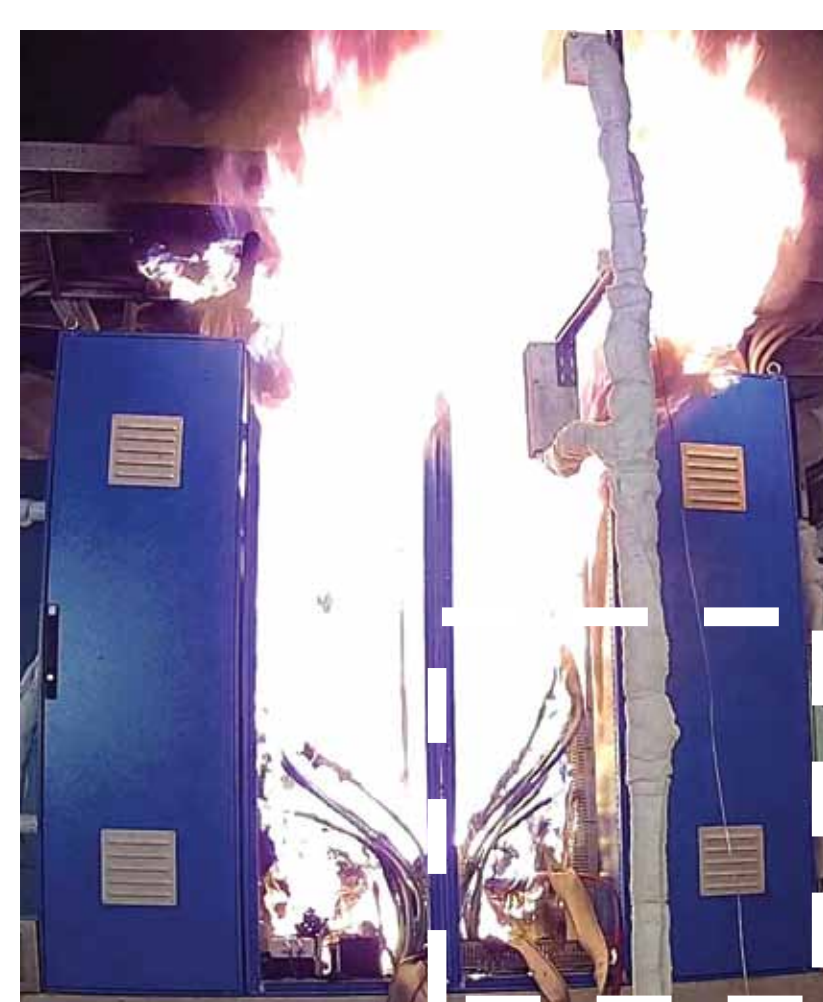
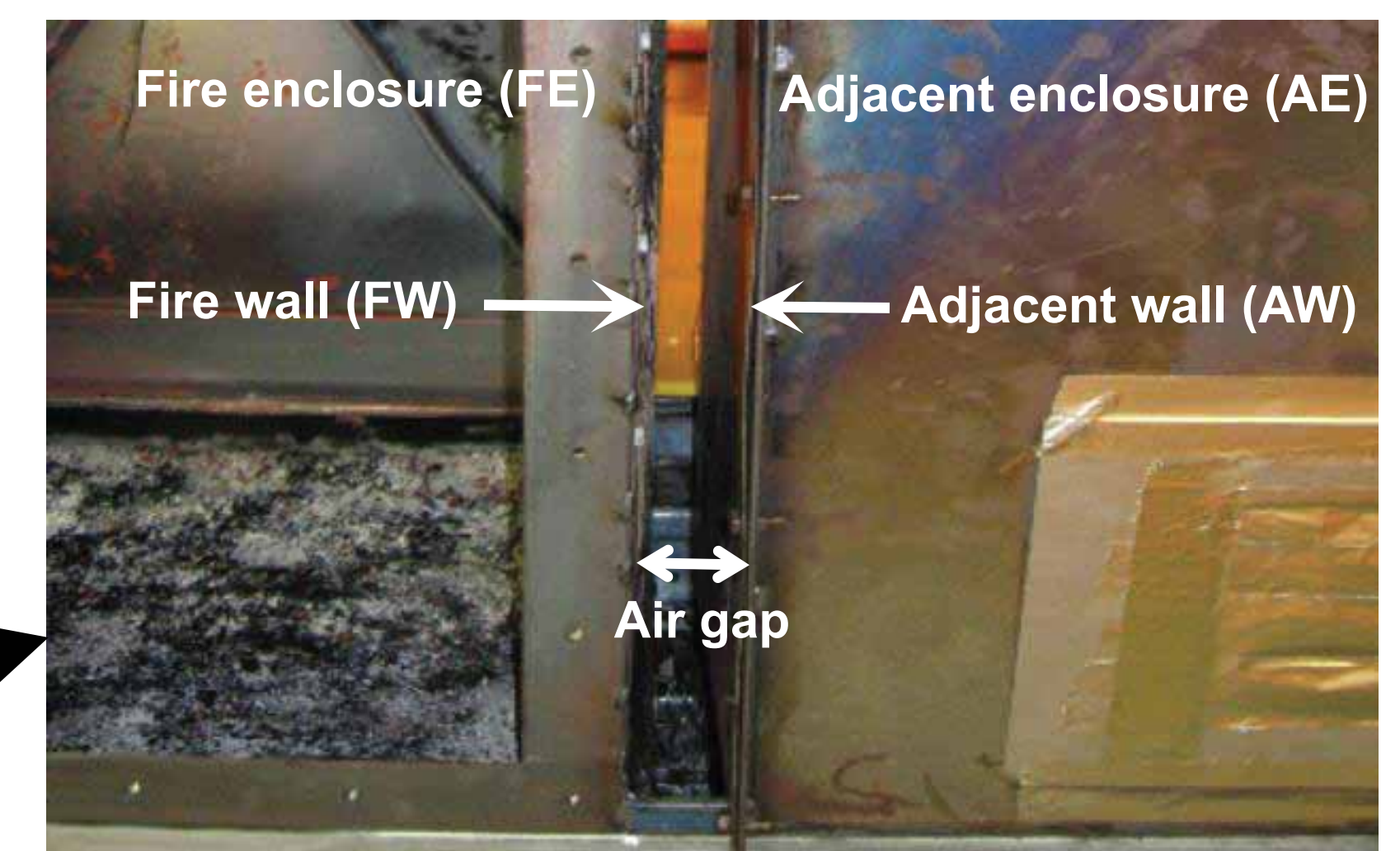
Symmetry plane

One-quarter scale reduction:
 ○ Half-part of real-scale adjacent cabinets was first considered
 ○ Then, a height reduction of a factor 2 was applied

Reduced-scale test device

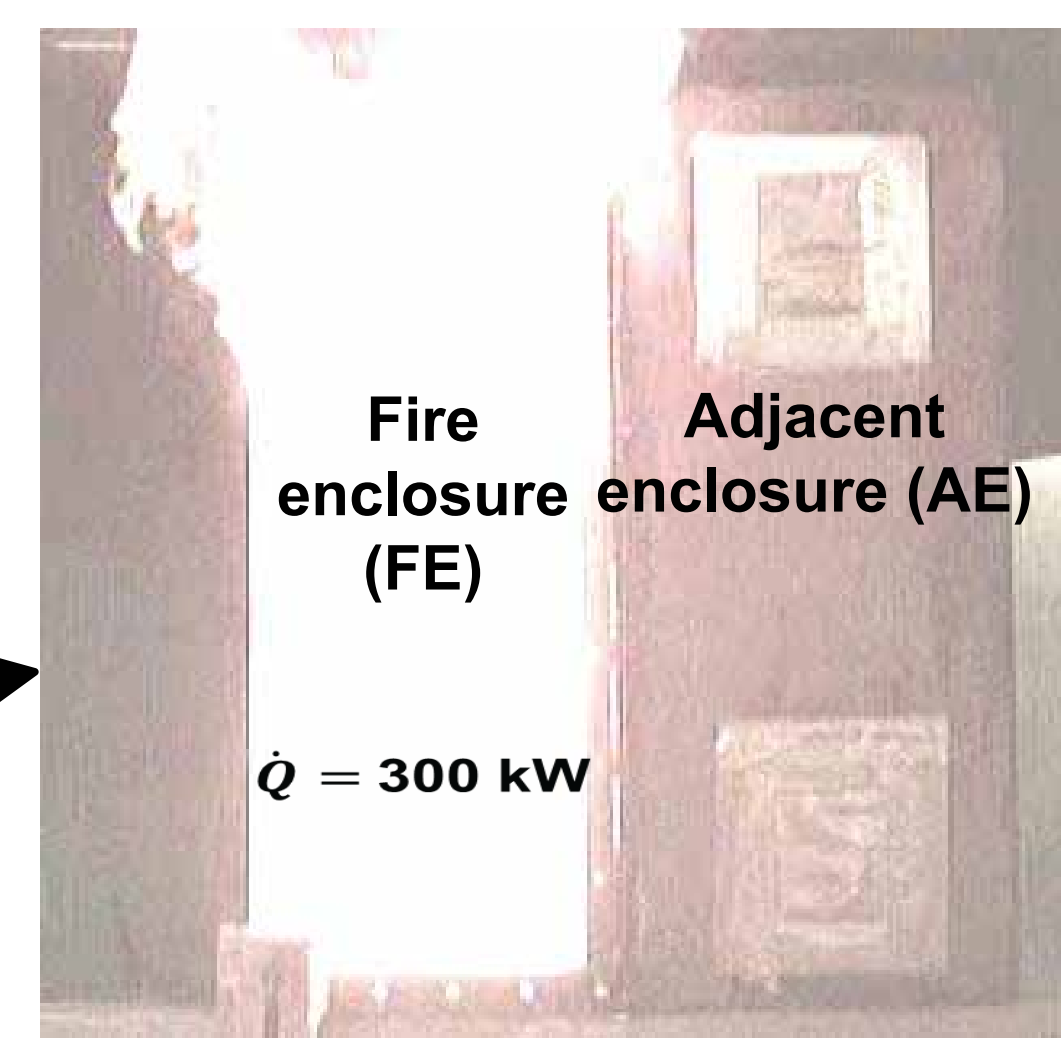


Air gap between the cabinets



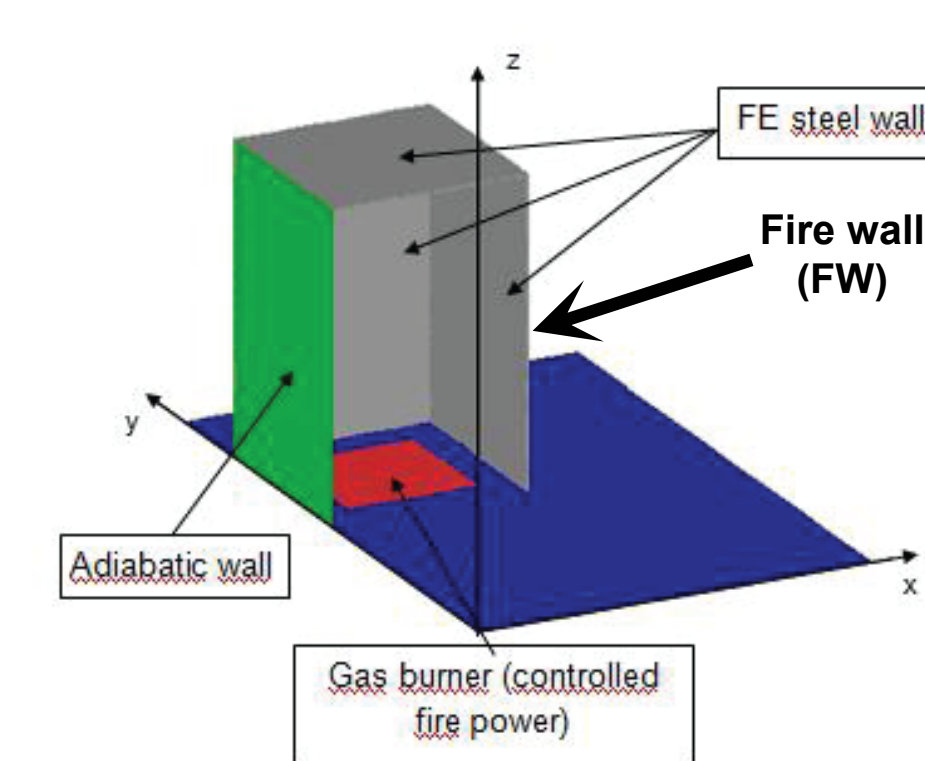
Cabinet fire [2]

One-quarter reduction of the maximal fire power (1200 kW) of the real-scale cabinet fire [2] → Fire power of 300 kW for the gas burner of the reduced-scale device

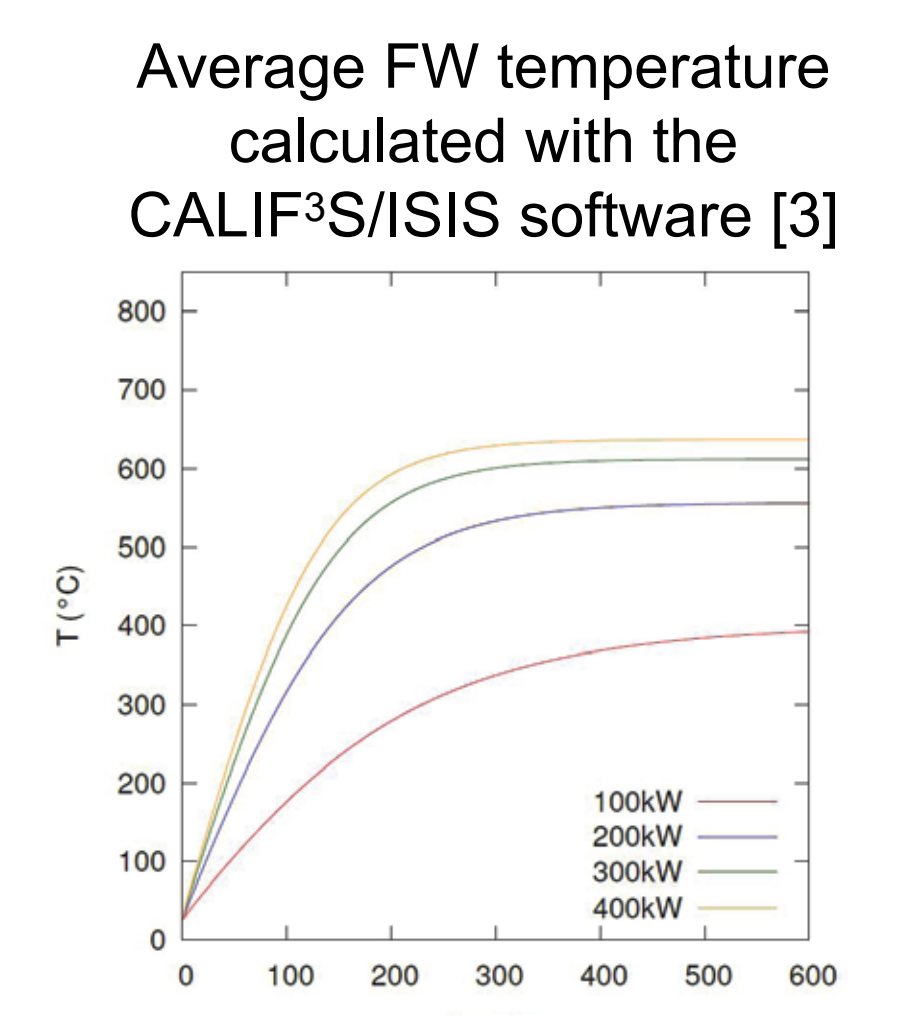


The reduced-scale device during a test

Fire enclosure modelling with the CALIF3S/ISIS software [3]

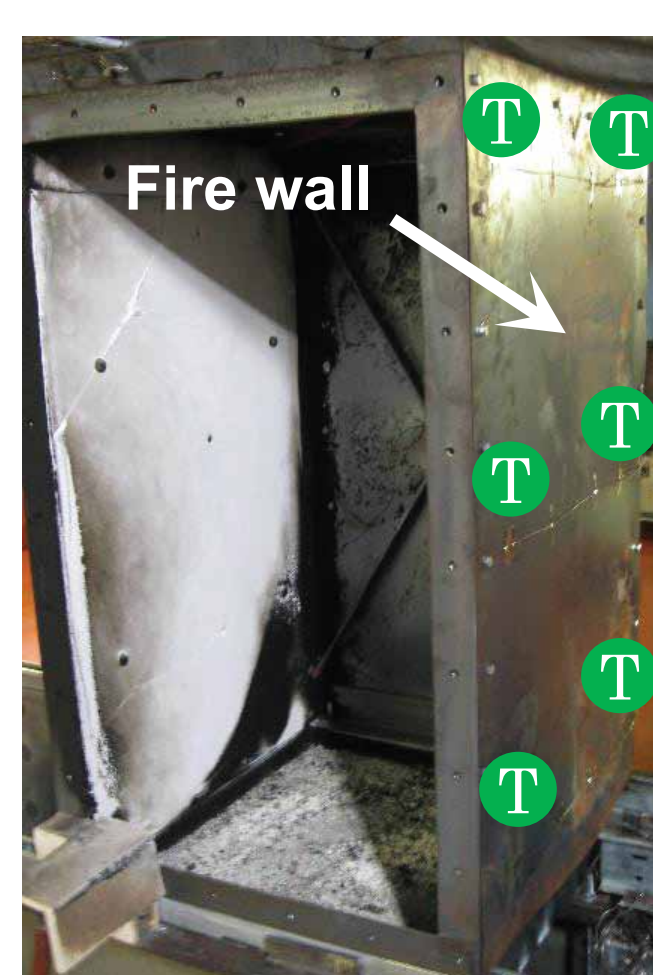


Numerical simulations with the CALIF3S/ISIS fire field model confirm that the reduced-scale fire enclosure design with a fire power of 300 kW allows to reach fire wall temperature $\geq 600^\circ\text{C}$ (as measured for real cabinet fire [2])

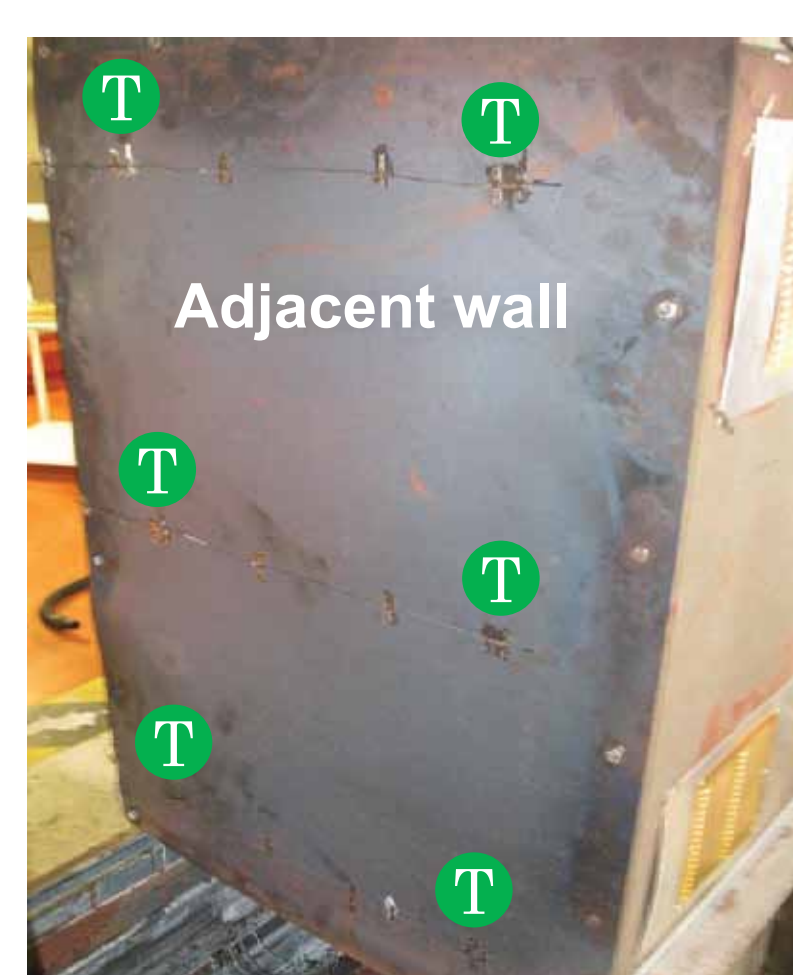


Instrumentation

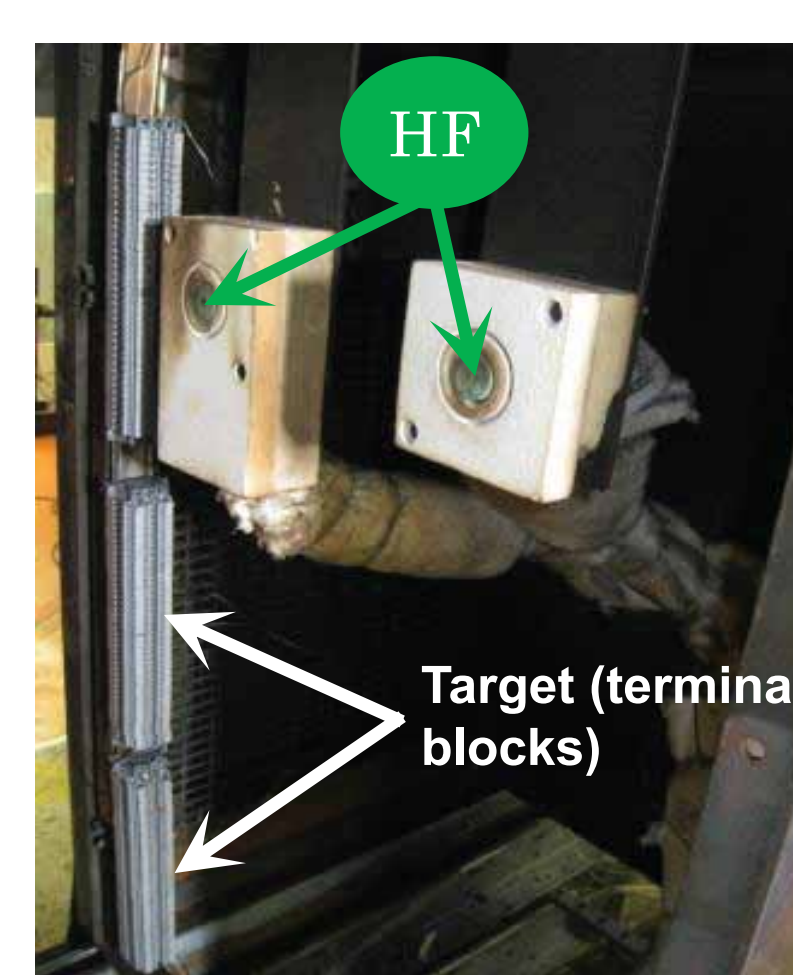
Measurement	Sensor
Surface temperature of the fire and adjacent walls	Six 0.5 mm type K Thermocouples brazed on each wall
Heat flux in the adjacent enclosure	Two Heat Flux sensors (Gardon type) close to the adjacent wall



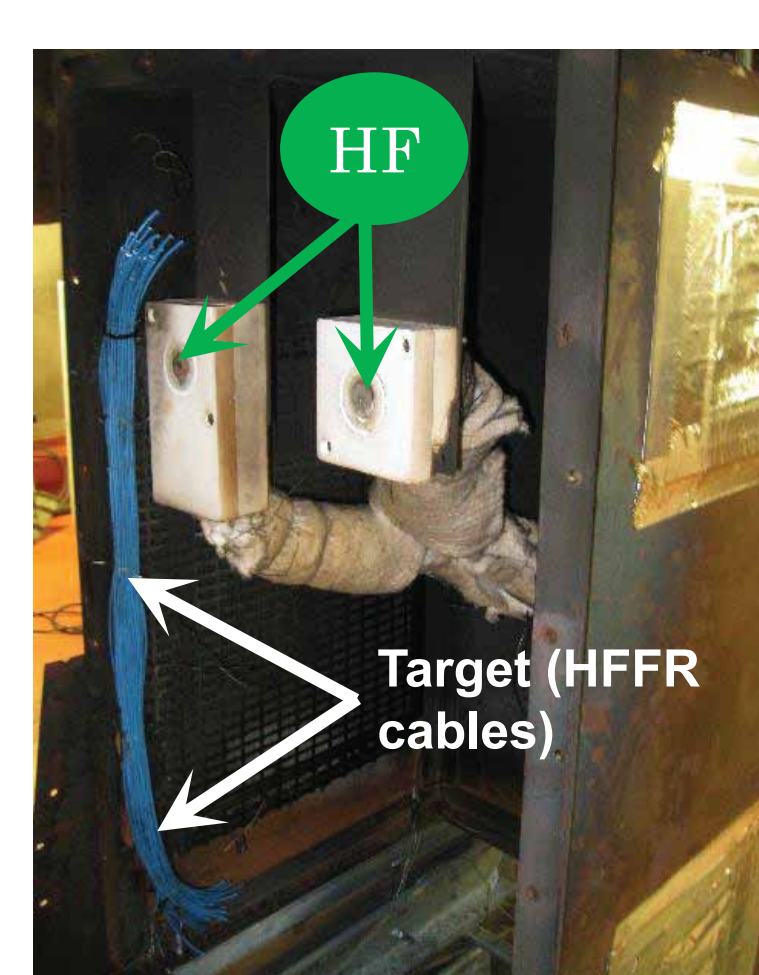
Fire enclosure



Adjacent enclosure



Inside the adjacent enclosure (wall removed)

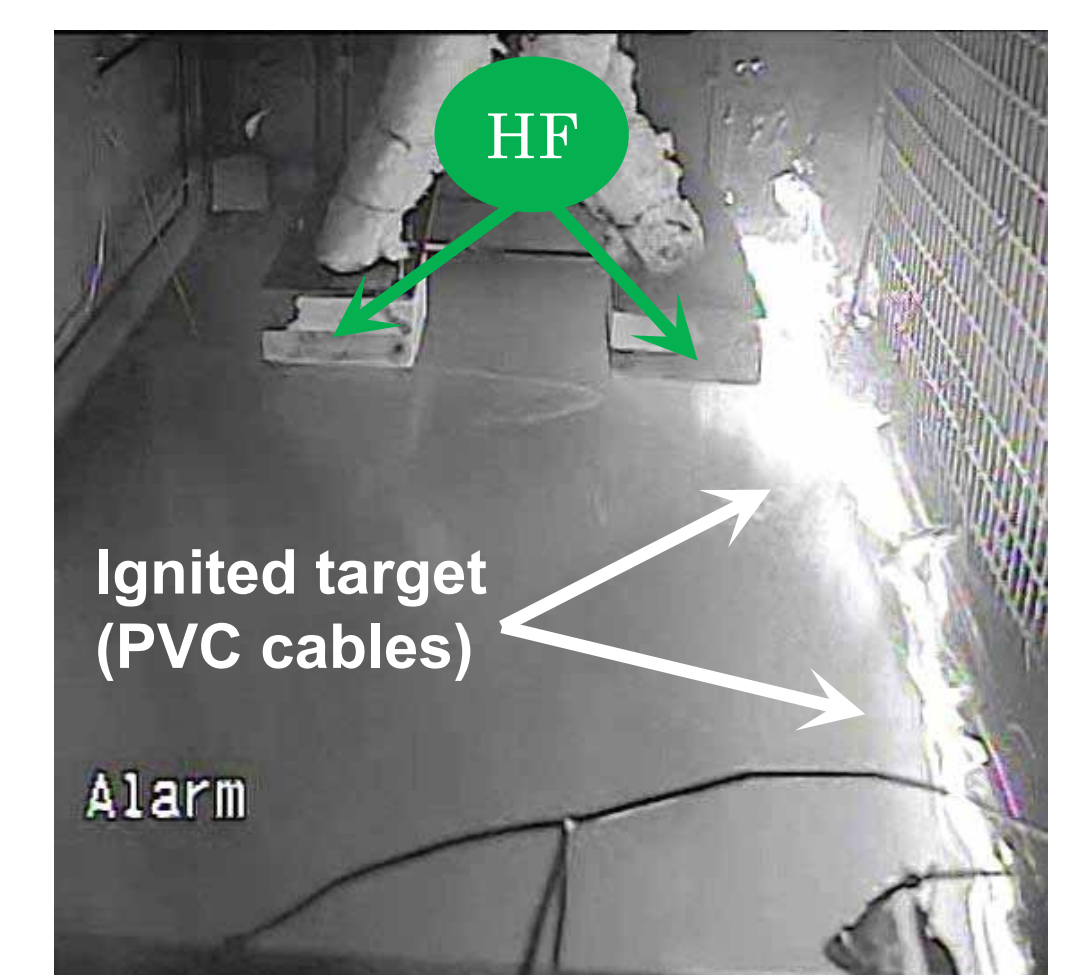


Target (HFFR cables)

Fire test matrix

Test ID	Target type	Air gap (cm)	Ventilation mode
T1	PVC cable	1	Without
T2	PVC cable	3	Without
T3	PVC cable	3	Without
T4	PVC cable	3	Natural
T5	PVC cable	1	Mechanical
T6	HFFR cable	1	Without
T7	HFFR cable	1	Without
T8	HFFR cable	1	Without
T9	TB	1	Without
T10	TB	3	Without
T11	TB	5	Without

PVC, poly(vinyl chloride); HFFR, halogen-free flame retardant; TB, terminal block



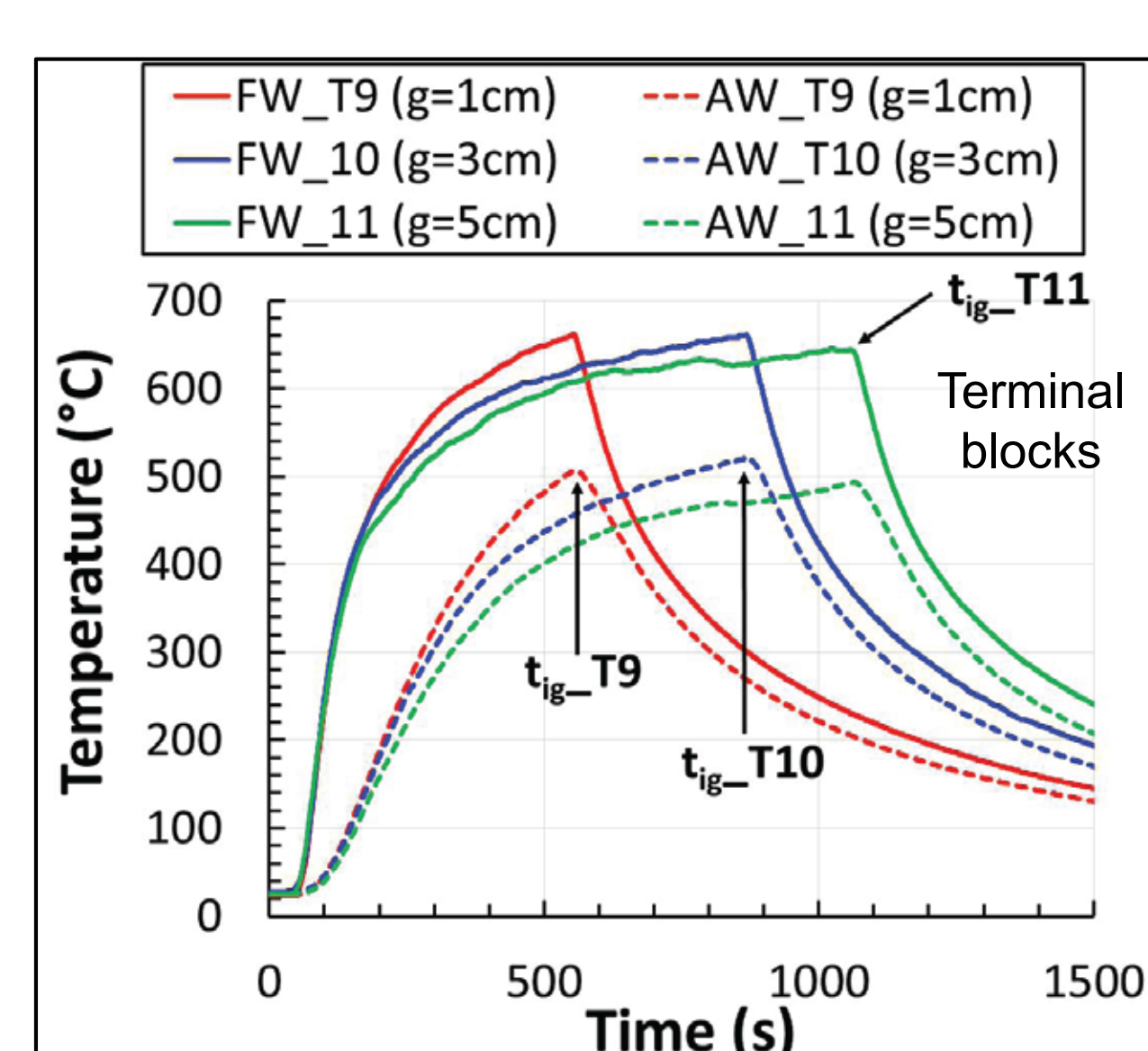
Inside the adjacent enclosure during a test

3. RESULTS

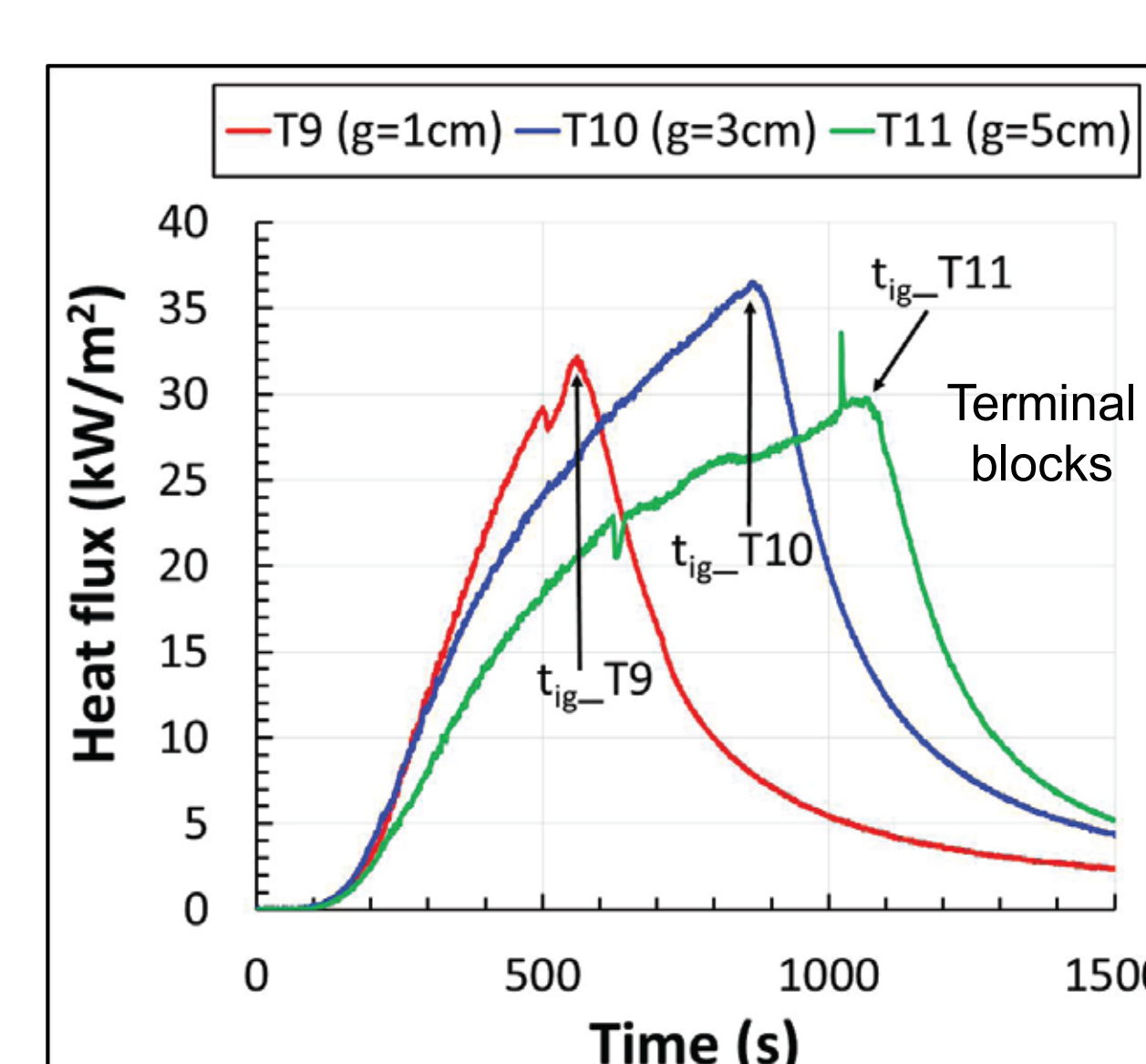
Critical ignition temperature ($T_{c,ig}$) and incident heat flux at ignition (\dot{q}_{ig})

Target type	PVC cables	HFFR cables	Terminal blocks
$T_{c,ig}$ ($^\circ\text{C}$)	527 ± 6	582 ± 28	499 ± 19
\dot{q}_{ig} (kW/m^2)	35.5 ± 1	45 ± 6	31 ± 4

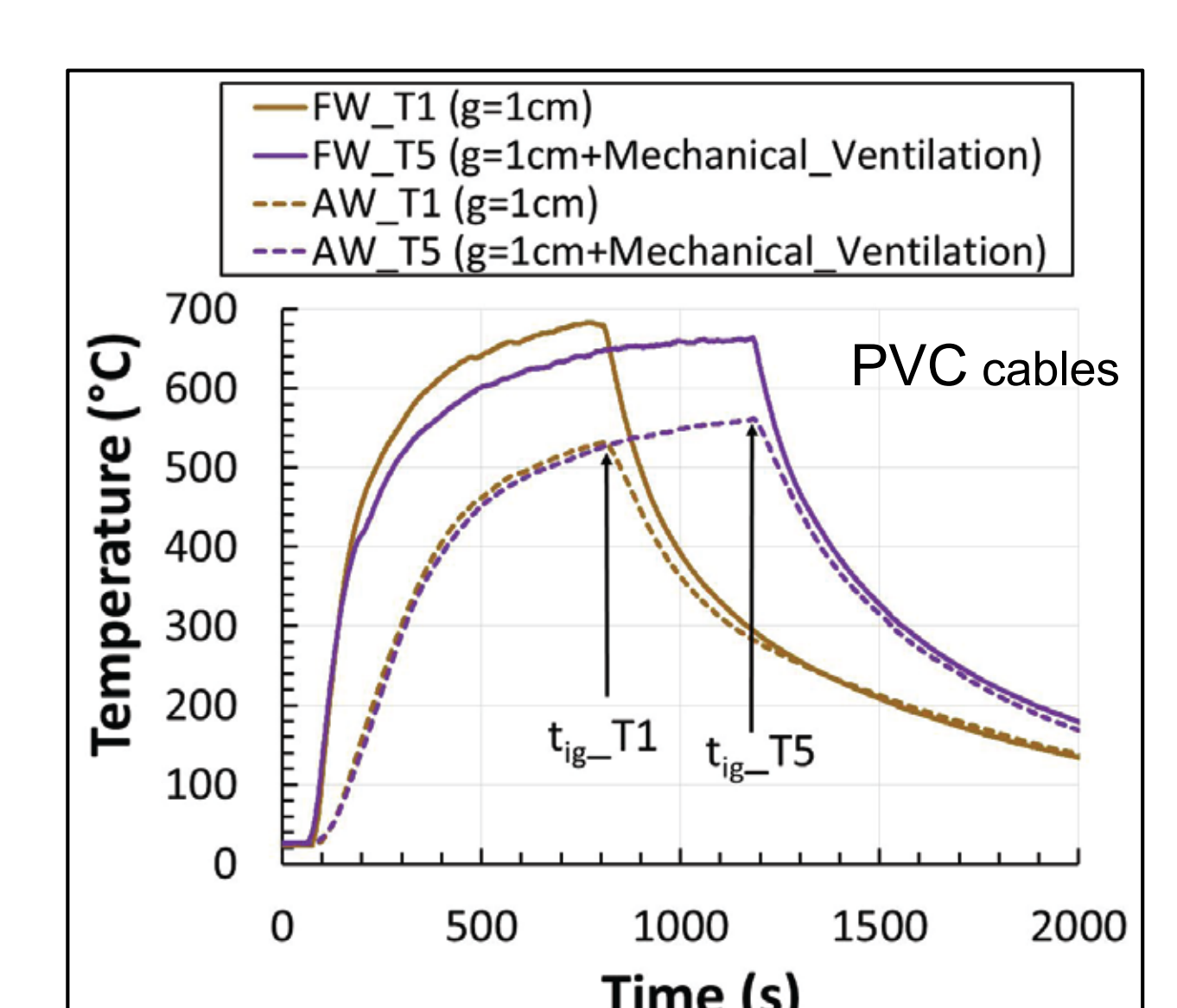
Av. temperatures of the FW and AW



Heat flux in the AE close to the target



Av. temperatures of the FW and AW



- 1 Spontaneous ignition of the targets when $T \geq T_{c,ig}$ (or $\dot{q} \geq \dot{q}_{ig}$)
- 2 Increase of the air gap leads to raise the time to ignition (t_{ig})

- 3 Mechanical ventilation of the AE increases t_{ig} (while natural ventilation shows small impact)

4. REFERENCES

[1] Organisation for Economic Co-operation and Development (OECD), Nuclear Energy Agency (NEA), July 2011, "OECD FIRE Database" (OECD FIRE DB 2010:1)

[2] Zavaleta P, Suard S, Audouin L. Fire spread from an open-doors electrical cabinet to neighboring targets in a confined and mechanically ventilated facility. Fire and Materials. 2018; 1 – 20. <https://doi.org/10.1002/fam.2685>

[3] CALIF3S/ISIS software, Collaborative website : <https://gforge.irsn.fr/gf/project/isis/>