IRSN
INSTITUT
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OECD

GDR Feux

(18ème Rencontre au Pôle Universitaire de Niort)

OECD PRISME 2 Fire Research Project (2011-2016)

Current Status and Perspectives

Audouin L., Pretrel H., Zavaletta P.

1 – PRISME Project 2006-2011

Project framework and achievements

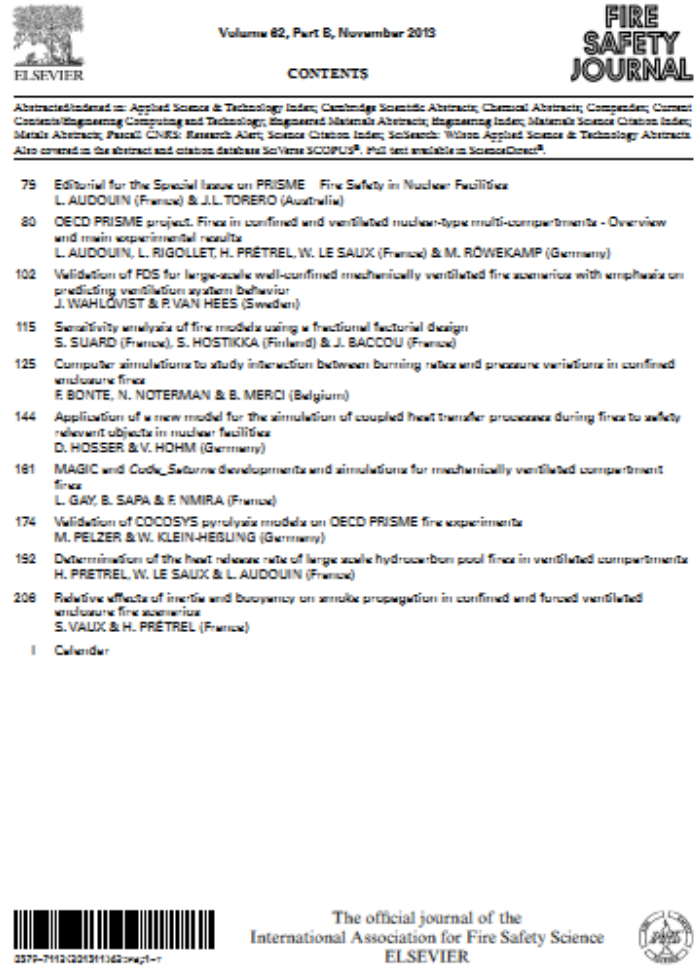
(1) Project framework: For more than five years (2006-2011), the PRISME research program were conducted in an international framework (Coordinator: OECD/NEA/CSNI ; Operating agent: IRSN) including 20 partners from 12 countries: Belgium (TRACTEBEL-Suez, BEL_V), Canada (AECL), Finland (STUK, VTT), France (IRSN, EdF, DGA), Germany (GRS, iBMB, BfS), Japan (JNES), Korea (KINS), Spain (CSN), Sweden (Vattenfall Ringhals, Univ. Lund), UK (HSE), The Netherlands (VROM-KFD, NRG), and USA (NRC).

(2) Project achievements: This program investigated mainly smoke and heat propagation mechanisms in multi-compartment fire scenarios and assessed the consequences of fire on targets of interest (thermal stress on electrical cables and their potential malfunction). Cable fires, cabinet fires and water sprinkler system were also addressed in the last campaign.

(3) Completions: Large-scale fire tests on 4 campaigns, ~50 reports, ~35 papers (conf./jour.) including a Special Issue in Fire Saf. Jou.

1 – PRISME Project 2006-2011

Special Issue in Fire Safety Journal (released in November 2013)



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Special Issue
Special Issue on PRISME – Fire Safety in Nuclear Facilities

Guest Editors
Laurent Audouin and José L. Torero

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1 – PRISME Project to PRISME 2 Project

PRISME 2 Project: Why and What ?

(1) Why?: On the basis of PRISME project's conclusions and from the contribution of PRISME partners giving their needs and priorities for some remaining issues in nuclear fire safety, most of the PRISME partners have impulsed the definition of a new nuclear fire safety project, namely PRISME 2.

(2) What?: Three topics identified by partners (=> Objectives):

1. Smoke and hot gas propagation through a horizontal opening between two superposed compartments;
2. Fire spreading on real fire sources such as cable trays and electrical cabinets (cables -> cables, cabinet -> cables);
3. Investigation of the performance of various extinguishing systems (fire extinction, cooling).

2 – OECD PRISME 2 Project: Content

PRISME 2 Project: Framework and partners

(1) Project framework: For five years (2011-2016), PRISME 2 fire research program will be conducted in an international framework (Coordinator: OECD/NEA/CSNI ; Operating agent: IRSN)

(2) 16 partners from 9 countries:

- Belgium (TRACTEBEL-Suez, BEL_V),
- Canada (CNSC),
- Finland (VTT),
- France (IRSN, EdF, DGA),
- Germany (GRS, iBMB, BfS),
- Japan (JNES, CRIEPI),
- Spain (CSN),
- Sweden (SSM, Univ. Lund),
- UK (HSE).

2 – OECD PRISME 2 Project: Content

PRISME 2 Project: Technical framework

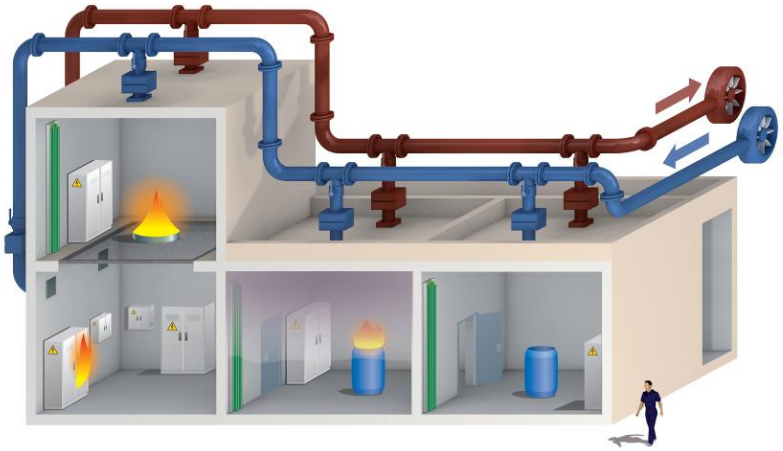
In order to achieve the previous objectives, the experimental programme is divided into four campaigns of fire tests for 20 large-scale tests:

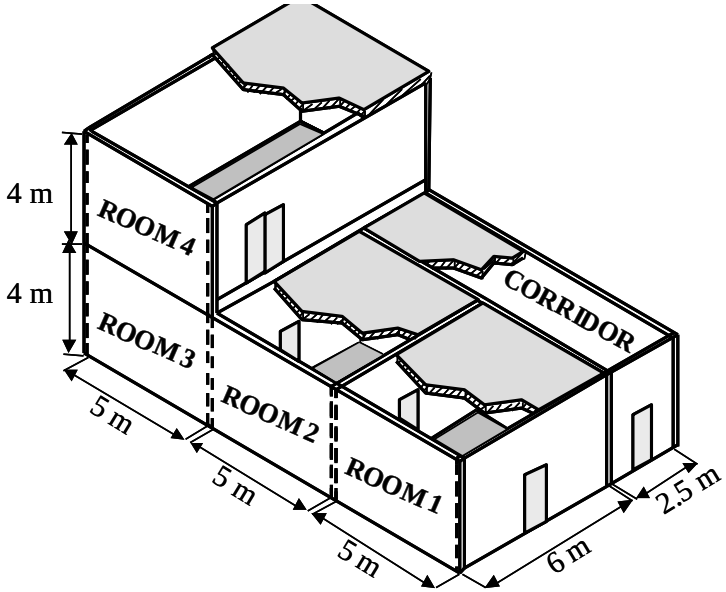
- Three campaigns for fire scenarios of interest (vertical propagation of smoke/hot gases through a hopper, cable fires and water systems);
- One fourth open campaign, the fire scenarios will be defined after discussions with partners based on experimental outcomes from previous tests and on numerical simulations.

Each campaign includes a set of three to six large-scale fire tests in DIVA facility. Each set of experiments leads to an in-depth analysis (physical/chemical phenomena, data processing, uncertainties…). Additionally, extra support tests (e.g., fire characterization of material properties in open atmosphere…) are performed all along the experimental programme. Deliverables are database and reports.

3 - Experimental Facilities &Instrumentation

Description of DIVA facility





(1) 5 compartments: Rooms 1 to 3 (120 m^3), room 4 (180 m^3) and corridor (160 m^3).

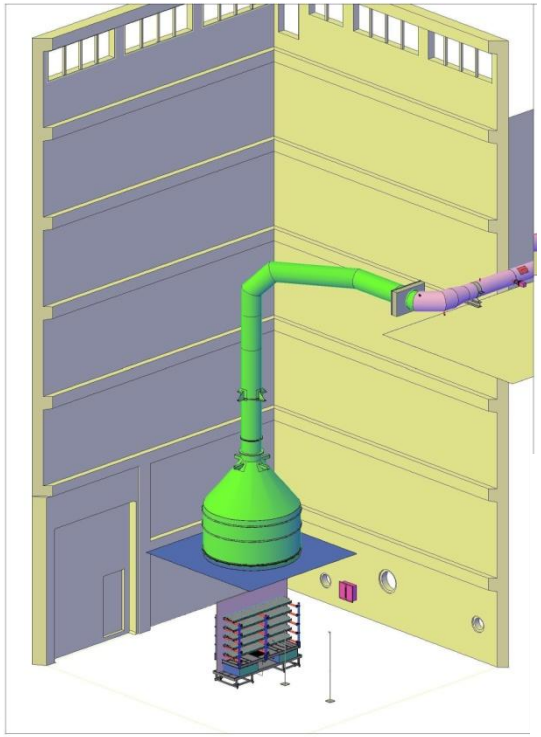
(2) Experimental configurations: Each room is connected with a mechanical ventilation system by means of inlet and outlet ducts. Each room can be connected with its adjacent rooms through doorway and/or simple openings. Dampers can be set up in ventilation system and water system is also available for studying fire extinguishing and/or cooling by water.

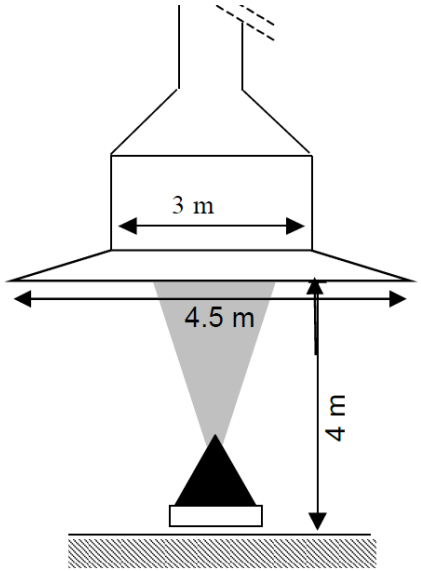
(3) Instrumentation: up to 800 possible measurement channels (control/measure) on the data acquisition system.

(4) Measurements: Fuel mass, gas and wall temperatures, gas concentrations (CO, CO2, O2 and HCT), soot concentrations, heat fluxes, pressures, flow rates in all compartments (inlet/exhaust ducts, doorways) and in ventilation network, video.

3 - Experimental Facilities & Instrumentation

Description of large-scale calorimeter (SATURNE Hood)





(1) Hood: 4.5 m (square sides).

(2) Height from floor: the height between the floor and the bottom rim of the hood is about 4 m.

(3) Ventilation system: The smoke exhaust system (fan, ducts, HEPA filters, dampers, chimney) is designed to exhaust flow rate ranging from 1,000 to 25,000m^3/h.

(4) This calorimeter is designed for studying fire source up to nearly 3.0 MW.

(5) Measurements: Fuel mass, pressure, gas flow rates, temperatures, gas concentrations (O_2, CO, CO_2 and HCT) and soot concentration, heat fluxes, and video.

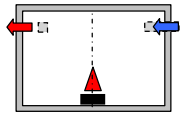
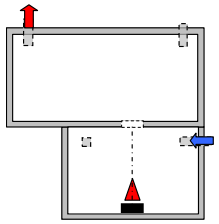
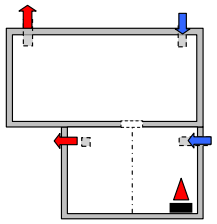
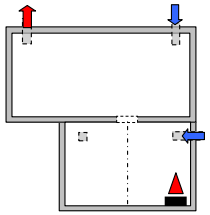
4 - Experimental Campaigns in PRS2 Project

Campaign 1: Vertical Smoke propagation (or VSP fire tests)

(1) Objectives

This campaign is devoted to investigate the vertical smoke propagation (four tests) through a horizontal opening (or hopper) for mechanically ventilated fire room scenarios.

(2) Fire test matrix

	PRS2_VSP_1	PRS2_VSP_2	PRS2_VSP_3	PRS2_VSP_4
Ventilation adj room fire Room	- IN/OUT	OUT/- -/IN	OUT/IN OUT/IN	OUT/IN -/IN
Fire location	Centre	Centre	Off centre	Off centre
Objective	•Heptane MLR in vitiated environnment	• Axial momentum due to fire • ΔP high • ΔT free	• Radial momentum due to ceiling jet • ΔP low • ΔT free	•Radial momentum due to ceiling jet • ΔP medium • ΔT free
Configuration				

(1) Pool Fire: 0.3m² (VSP_1) and 0.4m² (other tests).

(2) Fuel: Heptane

(3) Ventilation:

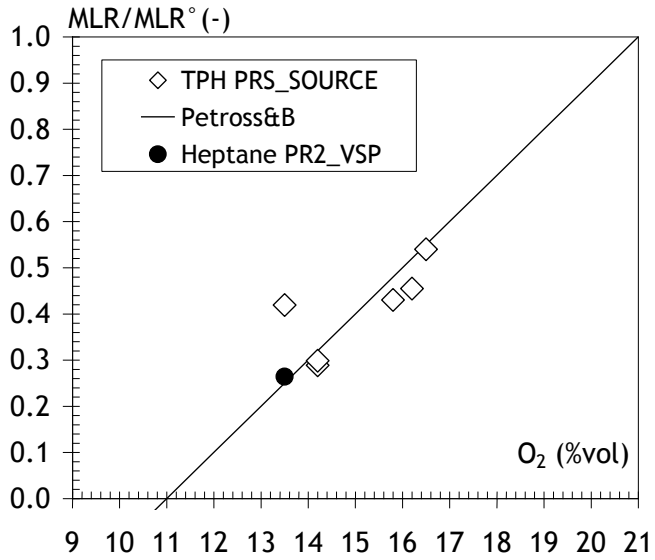
- 2000m³/h (VSP_1, 17RR)
- 2340m³/h (VSP_2, 8RR)
- 960m³/h (L) / 1360m³/h (U) (VSP_3, 8RR/room)
- 960m³/h (L) / 1360m³/h (U) (VSP_4, 8RR/room)

4 - Experimental Campaigns in PRS2 Project

Campaign 1 (VSP fire tests): First Outcomes

(1) Heptane under vitiated conditions

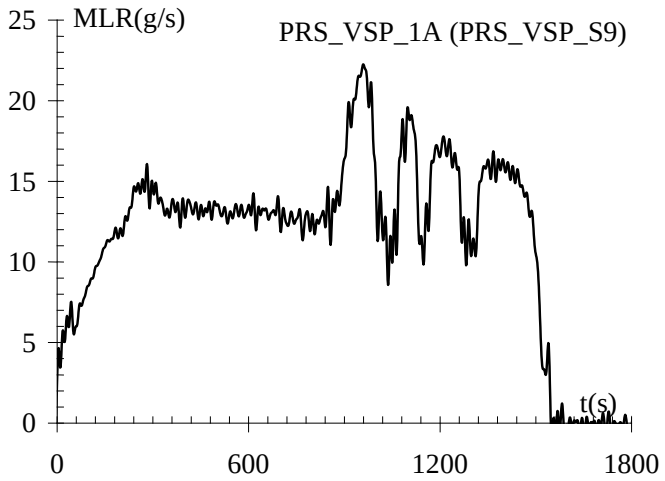
Heptane fuel showed a behavior for the mass loss rate (MLR) in accordance with Peatross and Beyler correlation (i.e. decrease of MLR with decrease of oxygen concentration near the fire source)



(2) Oscillating behaviour of fire

Both steady and unsteady regimes were observed for the heptane MLR (and consequently heat release rate) showing even an outbreak of mass loss rate oscillation during the fire tests

(video: 0'30" -> 3'00" -> 4'00")

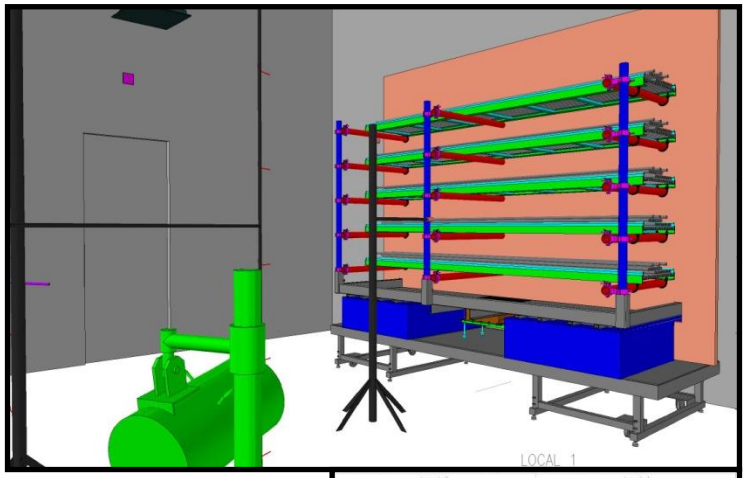


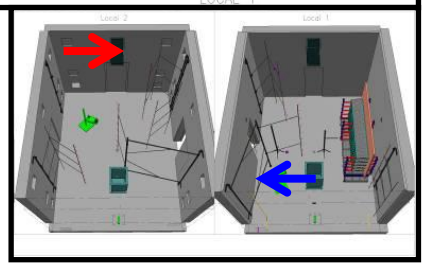
4 - Experimental Campaigns in PRS2 Project

Campaign 2: Cable Fire Spreading (or CFS fire tests)

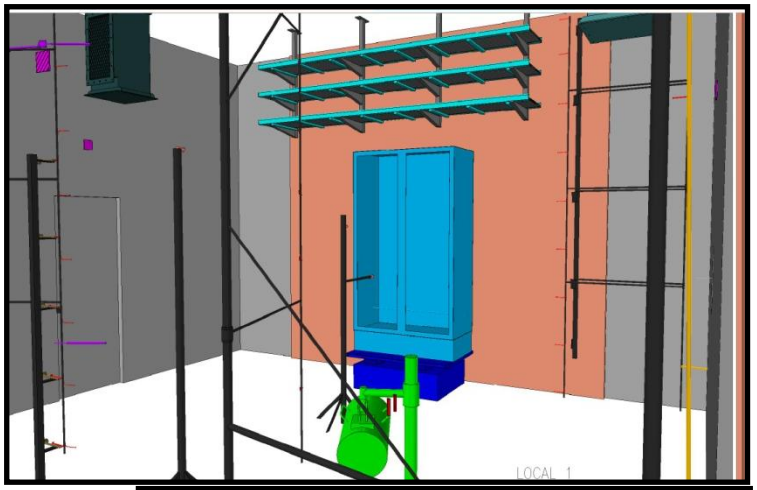
(1) Objectives

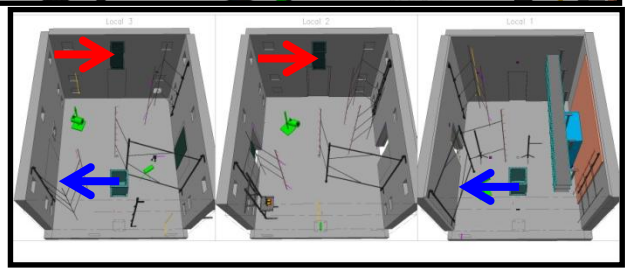
This test series studies fire spreading on five superposed cable trays (CFS_1 to 4)) and the fire propagation from cabinet fire to three overhead cable trays (CFS_5 to 7). One test (CFS_7) investigates additionally the closure of fire dampers to assess the effect of pressure due to highly-confined condition in such fire scenario. A last objective is to assess the malfunction of electrical/electronic components of interest for partners in real fire conditions (i.e.both smoke and thermal stress effects).





CFS_1 to 4





CFS_5 to 7

4 - Experimental Campaigns in PRS2 Project

Campaign 2: Cable Fire Spreading (or CFS fire tests)

(2) Support test: Fire scenario

(1) Length of trays: 2.4 m

(2) Width of trays: 0.45 m

(3) Spacing between trays: 0.3 m

(4) Cable arrangement: Loosely

(4) Ignition: Propane square burner (0.4x 0.4m²) of about 80 kW.

CFSS Fire Test	Cable	Outer diameter [mm]	Number of Cables per Tray	Tray Loading Parameter [% of NEC_{max}]*
CFSS-1	HP	13	49	48
CFSS-2	NHC	20	32	74
CFSS-3	Trays 1 and 2 : NHPS	12	53	44 for trays 1 and 2
	Trays 3, 4 and 5 : NHPL	37	12	96 for trays 3, 4 and 5
CFSS-4	HC	14.5	44	54

Tray loading for cables (similar CHRISTIFIRE fire tests except wall)

(1) HP: Power cables with halogen in fire retardant.

(2) HC: Control cables with halogen in fire retardant

(3) NHC: Control cables without halogen in fire retardant

(4) NHPS and NHPL: Power cables without halogen in fire retardant

4 - Experimental Campaigns in PRS2 Project

Campaign 2: Cable Fire Spreading (or CFS fire tests)

(4) Support test: First outcomes

- **Fire spread up to ends of all trays for the four CFSS trays fires**

CFSS-1

CFSS-2

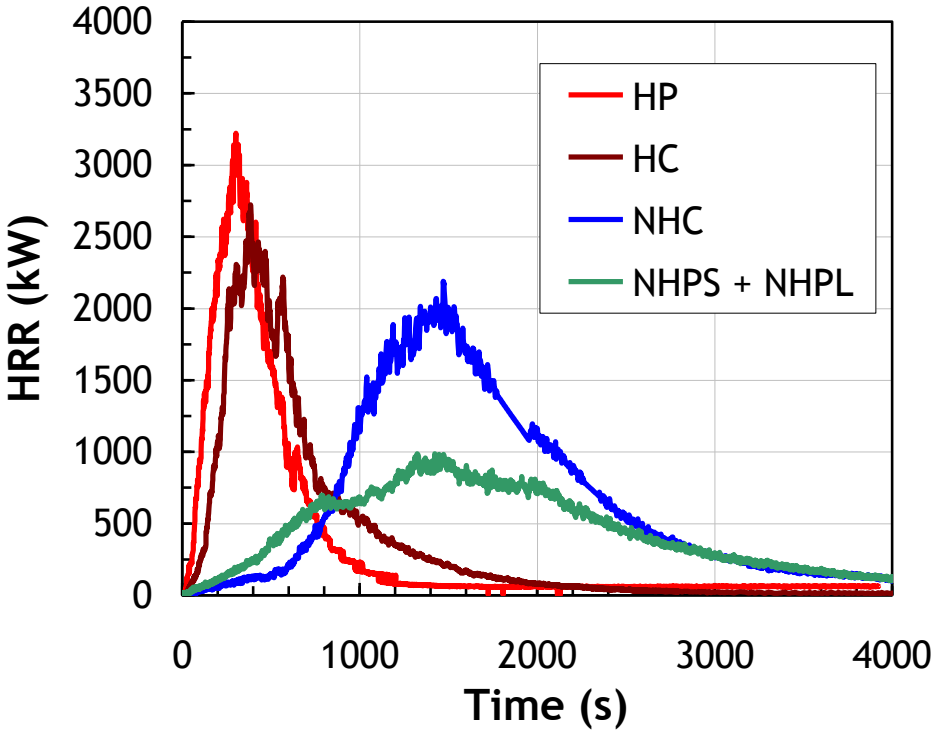
CFSS-3

CFSS-4

4 - Experimental Campaigns in PRS2 Project

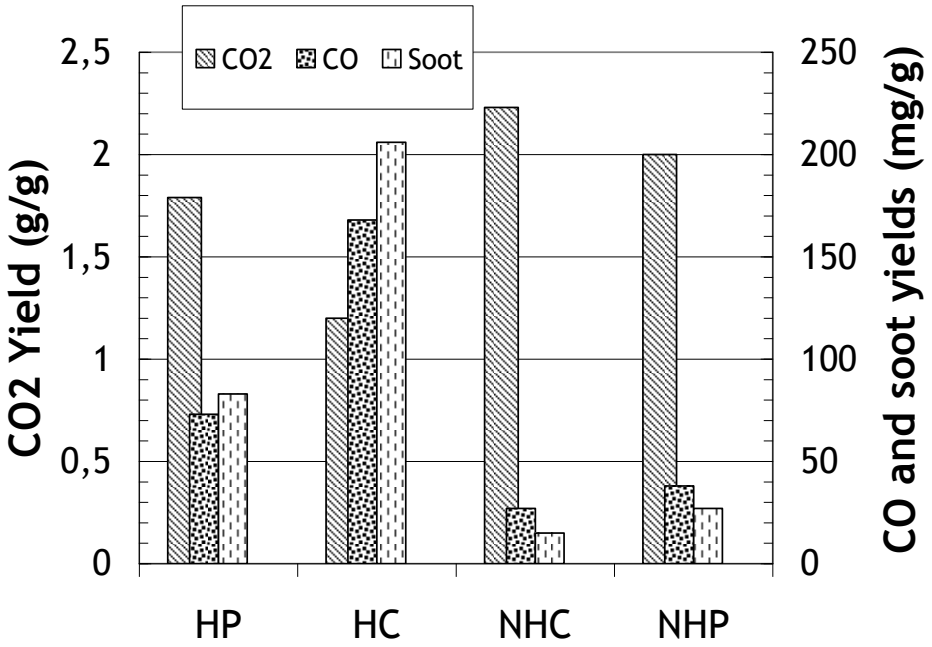
Campaign 2: Cable Fire Spreading (or CFS fire tests)

(4) Support test: First outcomes



Heat release rate

Combustion products



4 - Experimental Campaigns in PRS2 Project

Campaign 3: Fire Extinguishing System (or FES fire tests)

(1) Objectives

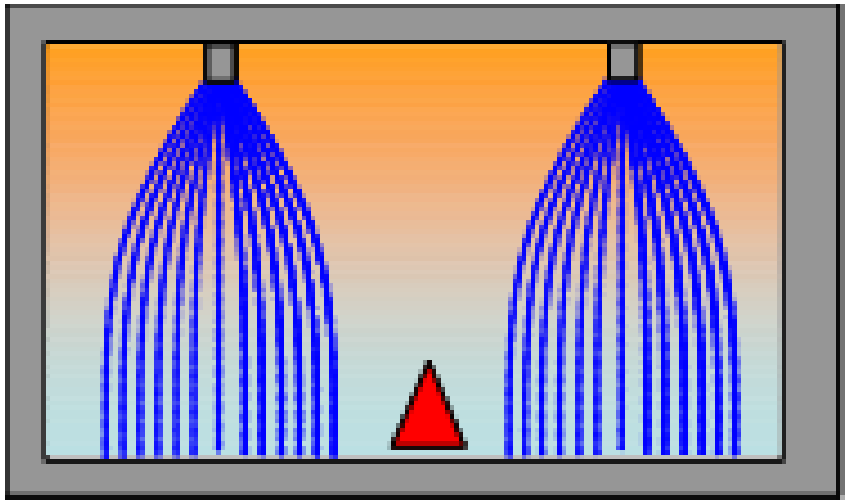
The objective of this third campaign is to assess the performance of water systems (FES) based on water sprinkler/deluge system. Indeed, this topic is of great interest because water systems are often used to extinguish fire or decrease the thermal effects in switchgear rooms and cable rooms in nuclear power plants

(2) Fire test matrix

(1) Parameters: size of droplets and water flow rate.

(2) Status: 4 fire tests will be carried out from Nov. 2014 to Feb. 2015.

Fire scenario (single room)



4 - Experimental Campaigns in PRS2 Project

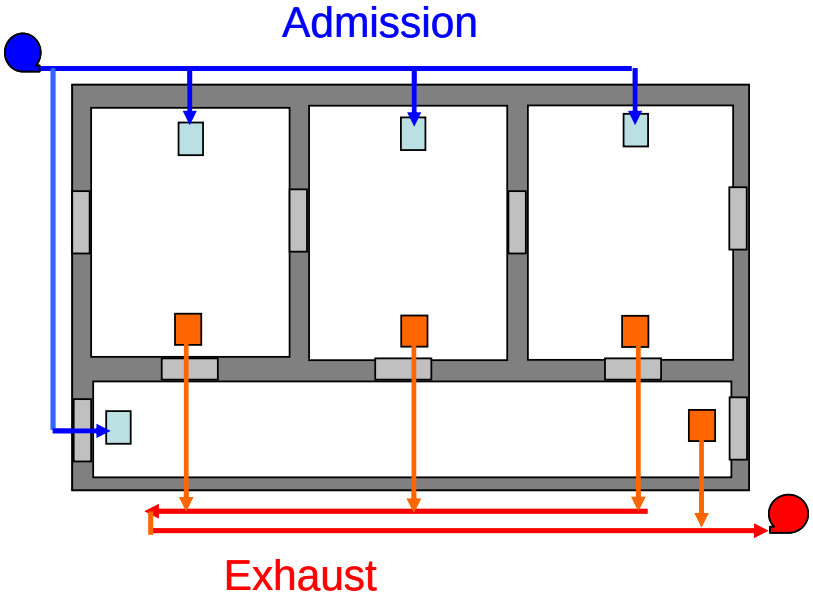
Campaign 4: Provisional Fire Tests

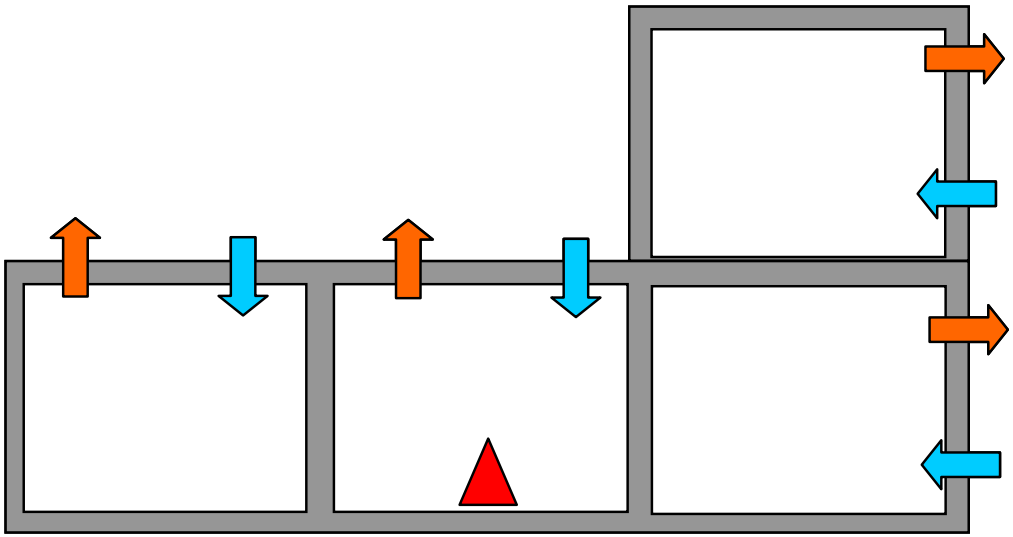
(1) Objectives

The last campaign is not yet fixed and thus the technical objectives are kept open. The final definition will be fixed with partners on the basis of the results of the previous campaigns, the evolution of fire safety priorities, the interest in carrying out some fire tests for repeatability and the special wishes from the project partners.

(2) Fire test matrix

Any kind of fire scenarios (5 fire tests foreseen) is possible in DIVA facility (except for safety issues)





5 – Ongoing and Future Works

Conclusion

(1) Work already done and in progress

- The first VSP campaign (4 fire tests, data analysis) was fully done including the fire characterization of heptane fuel under large-scale calorimeter.
- The second CFS campaign (7 fire tests) is on-going on the year 2013 and the last test is today (Jan 2014). Moreover, fire properties of five cable trays under SATURNE calorimeter has already been done in 2012.

(2) Future work

- The third FES campaign (4 fire tests) is nearly fully designed with partners. The fire tests in DIVA and SATURNE facilities are planned in 2014/2015.
- The last campaign (5 fire tests) will be discussed with PRISME partners in order to define the fire scenarios of interest following partners' wishes based on previous fire tests and their special requests (safety research priorities, repeatability…). These fire tests are foreseen from 2015.

The End…

Thank you for your attention