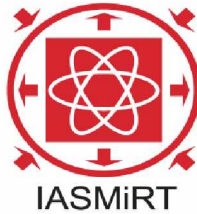


IRSN

INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety



Benchmark Activity of the OECD/NEA PRISME 3 and FIRE Projects

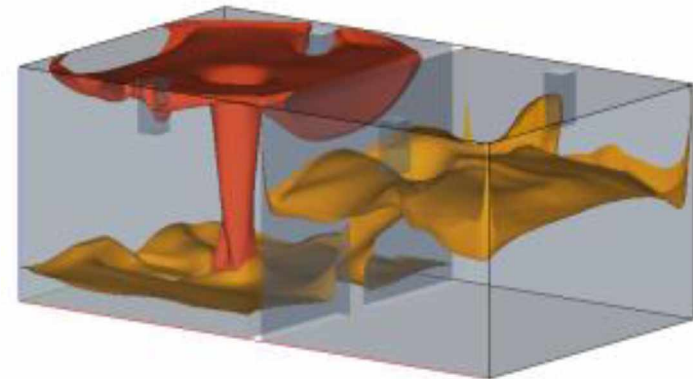
S. BASCOU

S. SUARD

L. AUDOUIN

*16th International Post-Conference
Seminar on
“FIRE SAFETY IN NUCLEAR POWER
PLANTS AND INSTALLATIONS”*

27 - 29 October 2019, Ottawa, Canada

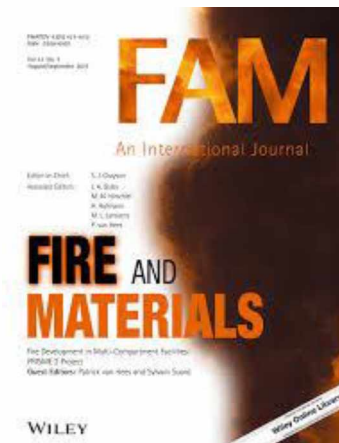


Context - OECD/NEA PRISME Programs

PRISME, 2006 - 2010

PRISME 2, 2011 - 2016

PRISME 3, 2017 - 2021



Context - Main issues of PRISME 3

- **Complex fire scenarios addressing safety concerns**
- **Enhancing knowledge for real and complex fuel fires in confined and ventilated environments**
- **Analytical fire tests for validation of full-scale numerical simulations**

Context - General organization

- **2 meetings per year**

- **2 working days for each meeting**

- **Program Review Group**

- **Analytical Working Group**

Introduction

Background

- Request from the OECD/NEA FIRE Database Project and recommendation from the 10th PRISME 2 Program Review Group in 2016

Define a Benchmark Exercise on a realistic cable fire scenario

- Using guidance of the FIRE Database project
- Experimental results of cable fires from PRISME 2 & 3 Projects
- Blind and open simulations

Introduction

PRISME cable fire experiments have significantly increased the knowledge on cable fire behavior and investigated various types of cables implemented in nuclear power plants

➔ *Simulate a real cable fire scenario in order to assess and compare the capabilities of different types of fire simulation codes to model such complex and realistic events*

Real fire event selected from the FIRE Database: heater bay of a NPP involving two electrical cable trays loaded with PVC insulated cables

Benchmark methodology (1 / 3)

- **Assessing the quality of numerical results simulating such an event is highly challenging as inputs and outputs are weakly under control**
- **A three-step methodology has been proposed**
 - **Step#1: calibration phase on a cable fire experiment**
 - Calibrate the fire modelling of each participant using a cable fire experiment from PRISME 2 (CFS-2)
 - Open calculation, experimental data available, assessment of numerical versus experimental results i.e. error estimation, assessment of the relative behavior of numerical results i.e. behavior estimation

Benchmark methodology (2/3)

- Step#2 : blind simulation phase of a cable fire experiment
 - Simulate a cable fire scenario from PRISME 3 (CFP) in blind conditions
 - Blind calculation, experimental results available after completion of the test, error and behavior estimations

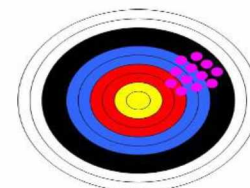
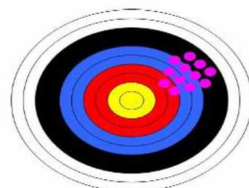
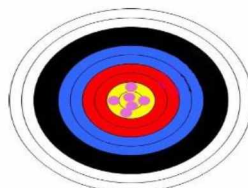
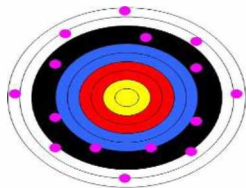
- Step#3 : blind simulation phase of the fire event
 - Simulate a real cable tray fire event from the OECD/NEA FIRE Database
 - Blind calculation, few fire data available, no assessment of numerical versus event results, but behavior estimation is still possible

Benchmark methodology (3/3)

- Methodology based on the fact that a similar behavior is expected between step#2 and step#3 making it possible to extrapolate the error estimation

Extrapolate the error estimation

Comparison	Step#1 - Open PRISME-2	Step#2 - Blind PRISME-3	Step#3 - Blind Fire event
Code / Exp	OK	OK	NO
Code / Code	OK	OK	OK



Error estimations

■ Error estimation

- Aims to compare quantitatively the difference between a simulation result (the output) and an experimental result (or a mean simulation)

■ Output quantities

- HRR, MLR, gas and wall temperatures, gas concentrations, relative pressure, ventilation mass flowrates

■ Metric operators

- Normalized relative difference (local error) for single point comparison
- Normalized Euclidean distance between two vectors (global error) for time-dependent values

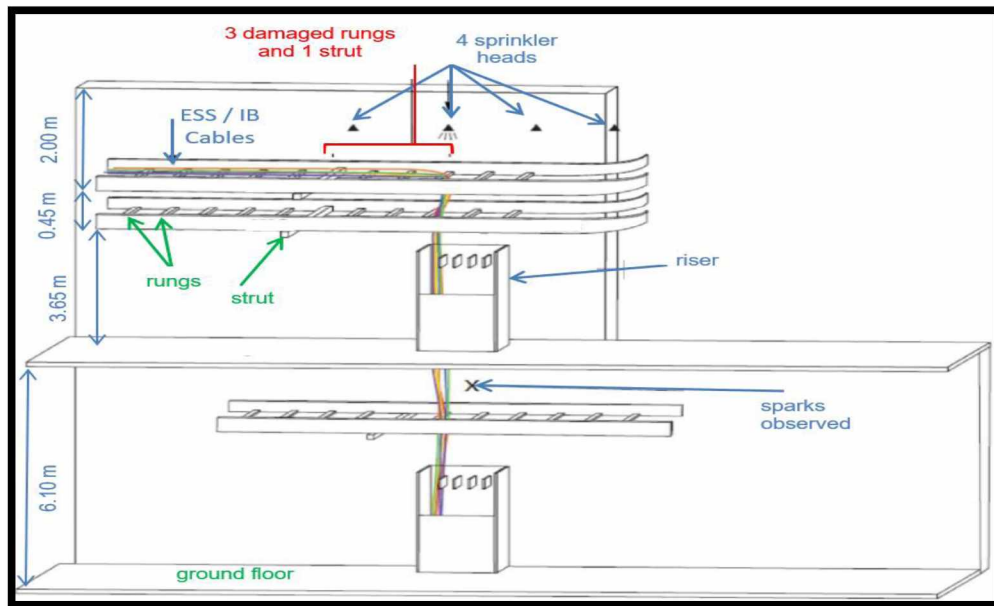
Fire event from the OECD/NEA FIRE Database

- **Fire Database: up to 500 fire events recorded up to the end of 2017**
- **Selection criteria from the PRISME 2 PRG members**
 - Cable fire scenario with flames and smoke
 - Quite recent event
 - A fire duration between 15 min and 60 min
- **Gathering data from licensees**
- **Selection of the event at the first Benchmark meeting held in Aix-en-Provence, France, in November 2018**

Fire event from the OECD/NEA FIRE Database

Event interpretation

- Occurred in a heater bay of a turbine building of a NPP
- The fire involved two 90 cm wide horizontal cable trays loaded with PVC insulated cables
- The fire started by the self-ignition of power cables due to an arc fault
- Identified cause: inconsistent routing with the current standard for minimum static bend radius

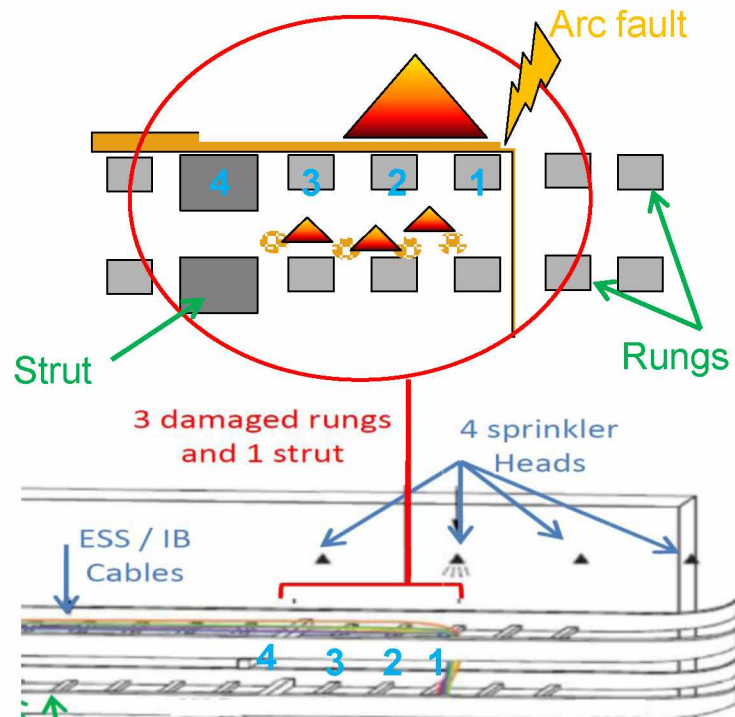


Front view scheme of the heater bay and cable routing

Fire event from the OECD/NEA FIRE Database

Ignition phase

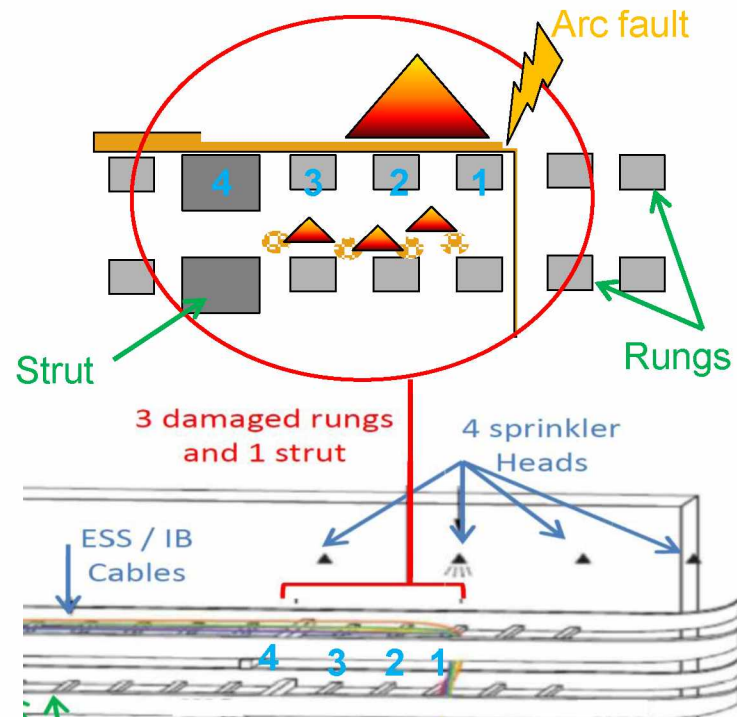
- ✦ The arc fault from one of the 6 cables to the rung at the exit point damaged the insulation of nearby cables, and heated the rung, leading to the severing of 5 of the 6 cables
- ✦ When severed, 2 cables arc faulted together / 61 cm of copper consumed in 1 min
- ✦ The fire on the bottom tray was initiated by debris falling from the fire on the top tray



Fire event from the OECD/NEA FIRE Database

Extinguishing phase

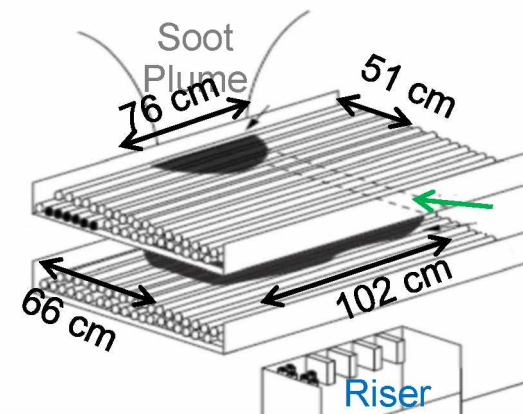
- Heat generated by the fire caused smoke flow from one of the four sprinkler nozzles located in the vicinity
- Fire duration between ignition and successful extinguishing by sprinkler system was estimated to be approximately 20 min



Fire event from the OECD/NEA FIRE Database

Damages to cables, trays and surrounding

- # First inspection: localized fire damage
 - Semi-circle 76 x 51 cm for the top tray
 - Semi-circle 102 x 66 cm for the bottom tray
- # Presence of Char
 - Entire depth of cables (15 cm) for the top tray
 - On the top 10 cm for the bottom tray
- # Cable damage included cables severed, cable jacket/insulation damage, cable jacket/insulation completely removed and sections of cable missing



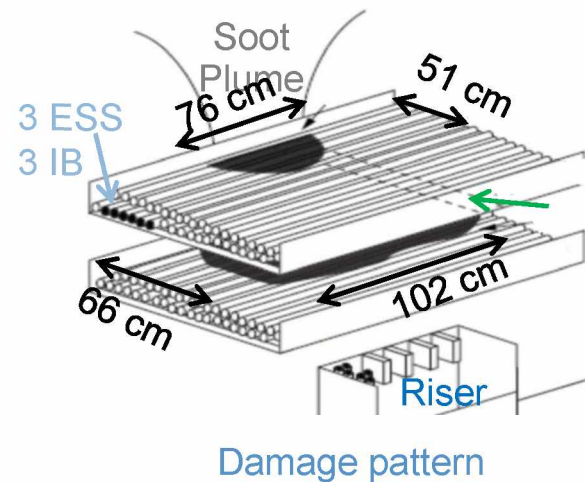
Damage pattern

The most extensive charring and damage was on the cables located on the bottom

Fire event from the OECD/NEA FIRE Database

Damages to cables, trays and surrounding

- ✘ Molten drop of cuprous oxide were present in large quantities on the cables of the bottom tray
- ✘ Severe degradation was observed on a strut with the top completely molten
- ✘ Three rungs had sections completely melted
- ✘ Signs of minor concrete spalling were observed on the concrete overhang located above the affected cable trays

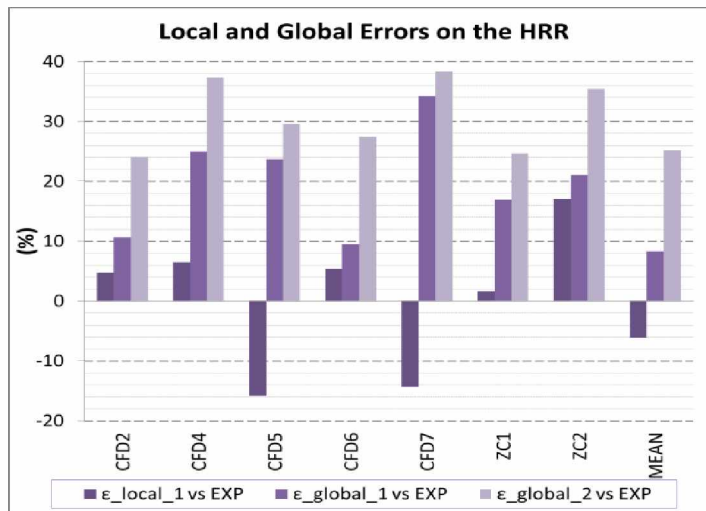


Current status and progress of the benchmark

Step#1 predictive simulations of the CFS-2 experiment

7 simulations performed with 5 fire models

- # CRIEPI: BRI2002
- # GRS: COCOSYS
- # IBMB: FDS
- # IRSN: ISIS & SYLVIA
- # NRC: FDS
- # VTT: FDS



PRISME 2 – CFS set-up

Conclusion and discussion

- A 3-step methodology proposed to assess the capability of different fire models to simulate a real fire scenario
- Metrics operators used for differences assessment
- Extrapolation of error estimation on the real fire event scenario from previous step
- Results for step#1: Predictive simulations of the CFS-2 experiment
- Next step, step#2: blind simulation PRISME 3 experiment

Thanks you for your attention

Authors are grateful for the financial and technical support by the member countries participating to the joint OECD PRISME 2, PRISME 3 and FIRE Projects from Belgium, Canada, Czech Republic, Finland, France, Germany, Japan, Korea, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom, and the United States of America.