IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

Electrical failure during NPP cable fires

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International Experts' Meeting on Strengthening Research and Development Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant

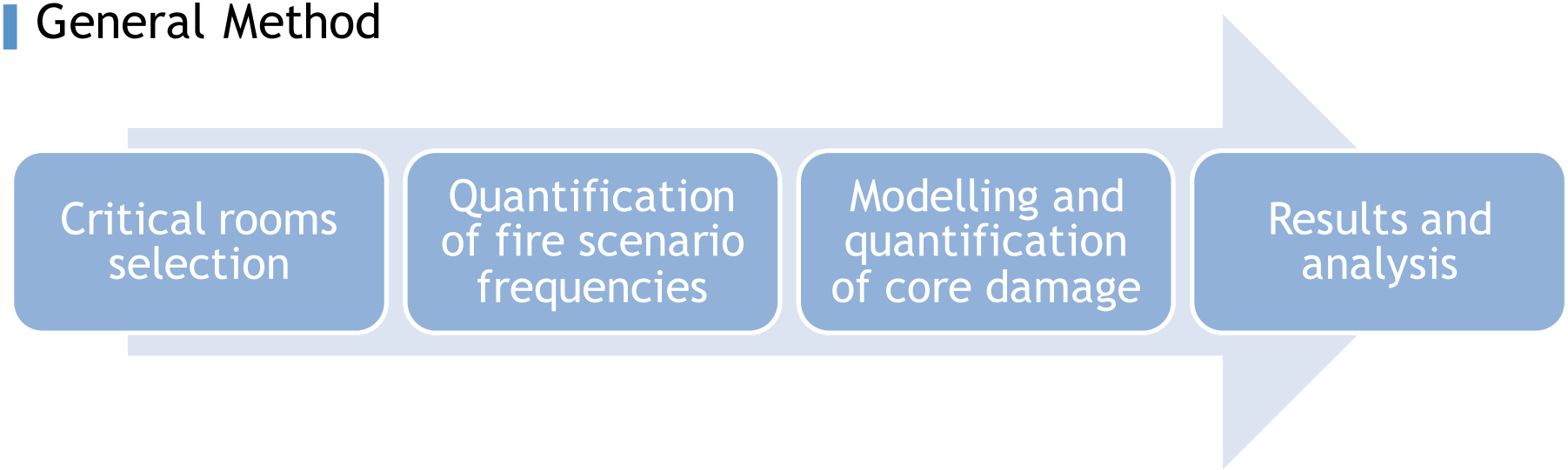
Contents

Safety needs: Fire PSA

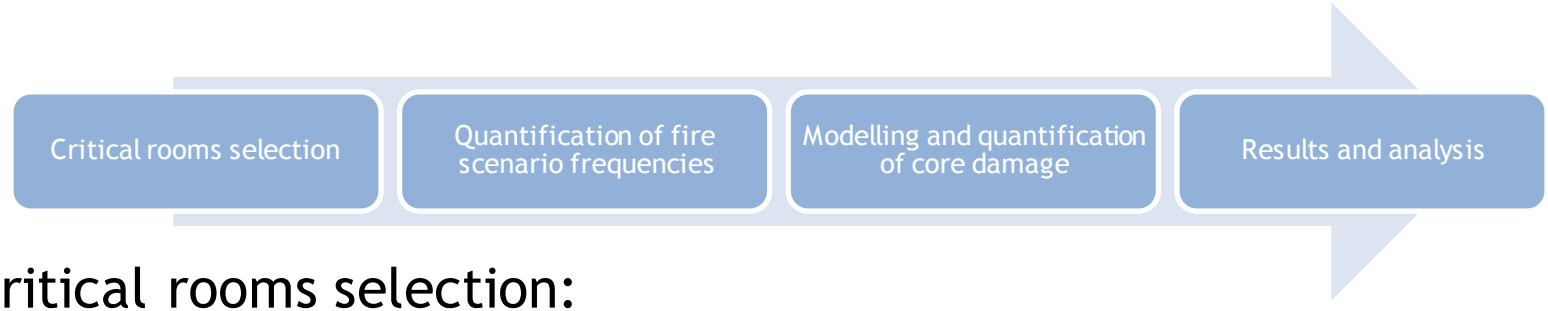
Main objectives of IRSN Fire PSA

- Analyze the main factor contributing to the core damage frequency
- Assess the design and the operating measures implemented by the utility
- Perform an independent assessment of utility Fire PSA and evaluate the employed methodology

General Method



Safety needs: Fire PSA



Critical rooms selection:

- Based on the most critical safety equipment during fire scenarios in terms of fire-related risks

Modelling and quantification of core damage

- Fire simulations that use
  - Fire source data
    - The fire source characteristics (HRR, fire growth, combustion products…) based on open and confined fire tests representative of fire scenarios in NPPs
  - Failure criteria of electrical safety equipment
    - The malfunction criteria of electrical safety equipment due to smoke and heat stresses generated by the compartment fire

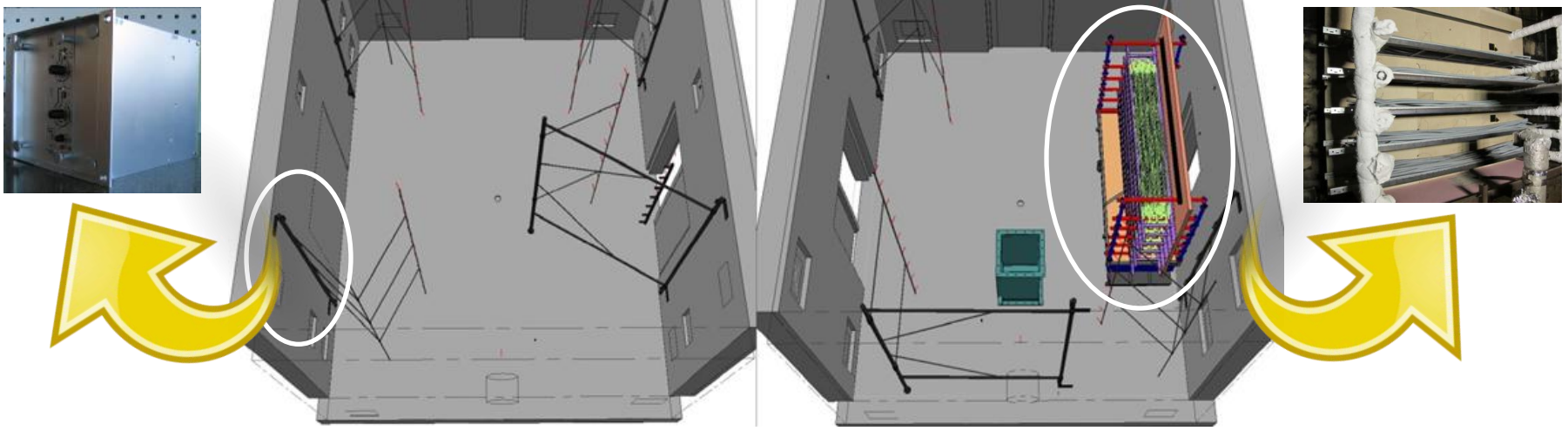
Safety needs: Fire PSA

Fire scenario

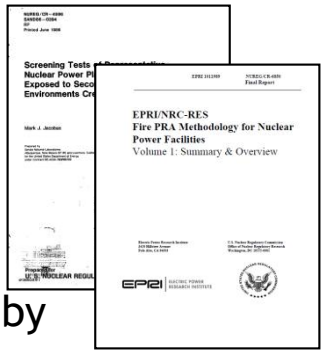
- What are the consequences of a cable trays fire on an electronic equipment?
- What are the malfunction criteria of an electrical/electronic equipment?

Adjacent room
Target: electronic or electrical equipment

Fire room
Fire source: horizontal cable trays

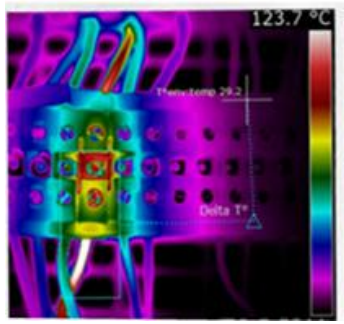


Damage criteria of electrical equipment



- Literature review:
  - NUREG-CR/6850: a thermal damage target of 65°C is recommended
  - NUREG/CR-4596: thermal stress of relay in an environmental chamber by step increases of temperature. Thermal failures were observed from 150°C up to 350°C.

- Objectives of IRSN experimental studies:
  - Getting further information about malfunction of electrical equipment of interest due to a fire
  - Investigating the malfunction of electrical equipment due the effect of hot smoke from real fire source



Damage criteria of electrical equipment

Experimental studies

Thermal stress tests

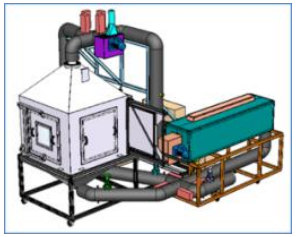
- Stress inducing malfunction: temperature
  - For example, 170°C for an electronic card

Real fire tests

- Stress inducing malfunction: combined effect of both soot concentration and ambient temperature

New device

- Need to build an experimental device able to investigate the combined effect of ambient temperature and soot concentration



IRSN approach

Need:

- To determine experimentally the malfunction criteria of electronic or electrical safety equipment in fire conditions

Objectives of IRSN DELTA Program

- To develop an experimental protocol to study the combined effect of soot concentration and ambient temperature

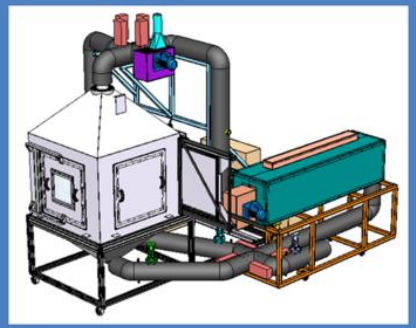
Real fire tests

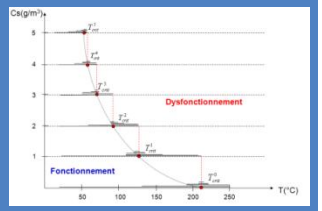
Behavior of electronic equipment submitted to fire conditions

Comparison of malfunction criteria

Analytical tests

Determine malfunction criteria

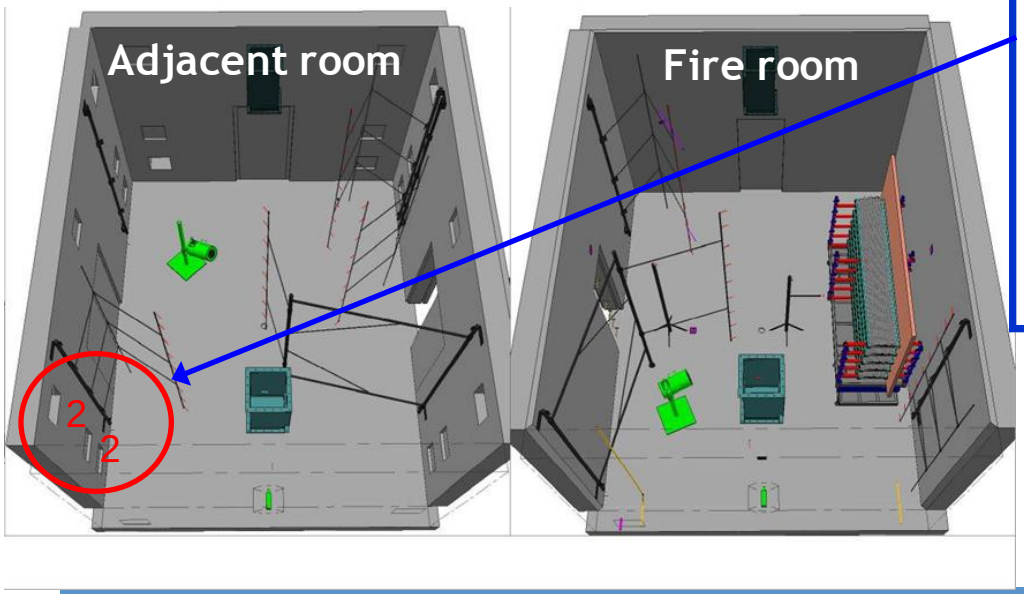


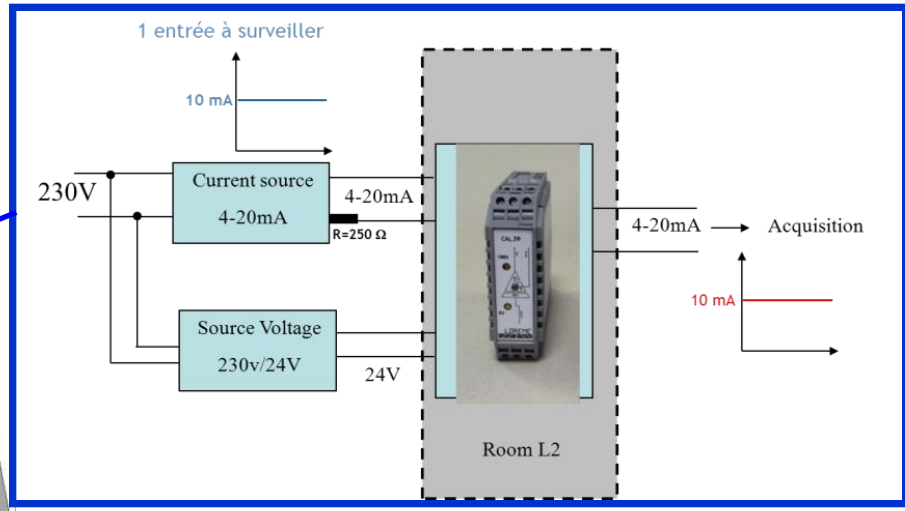


Experimental protocol to determine malfunction criteria of safety equipment

Real Fire tests

- Fire Scenarios providing fire conditions (temperature and smoke) close to analogic converter
  - Fire source: cable trays or electrical cabinets and cable trays
  - Equipment of interest: Analogic converter
  - Location: Adjacent room, lower and upper zones (red line)

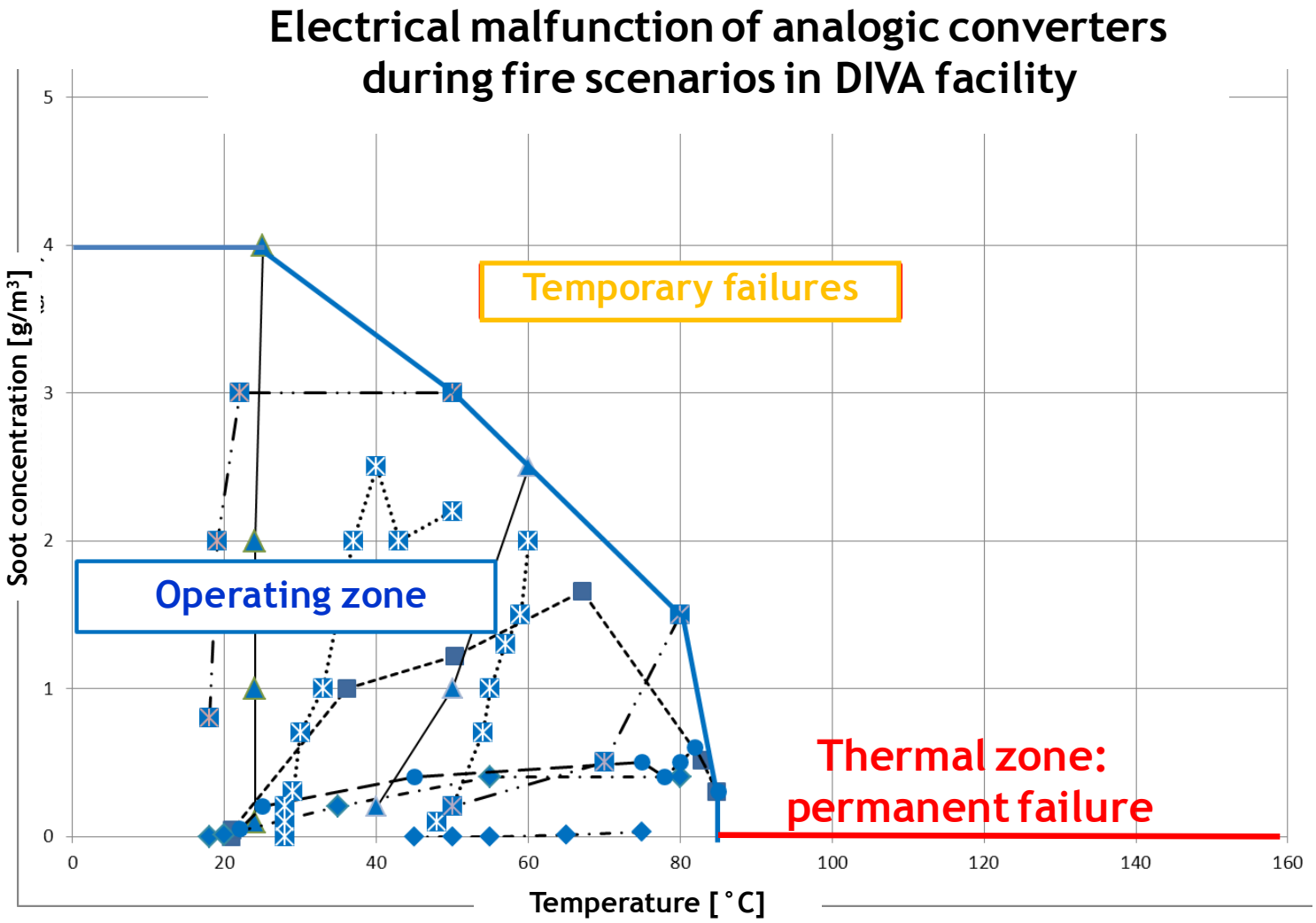




Analogic converter

Real Fire tests

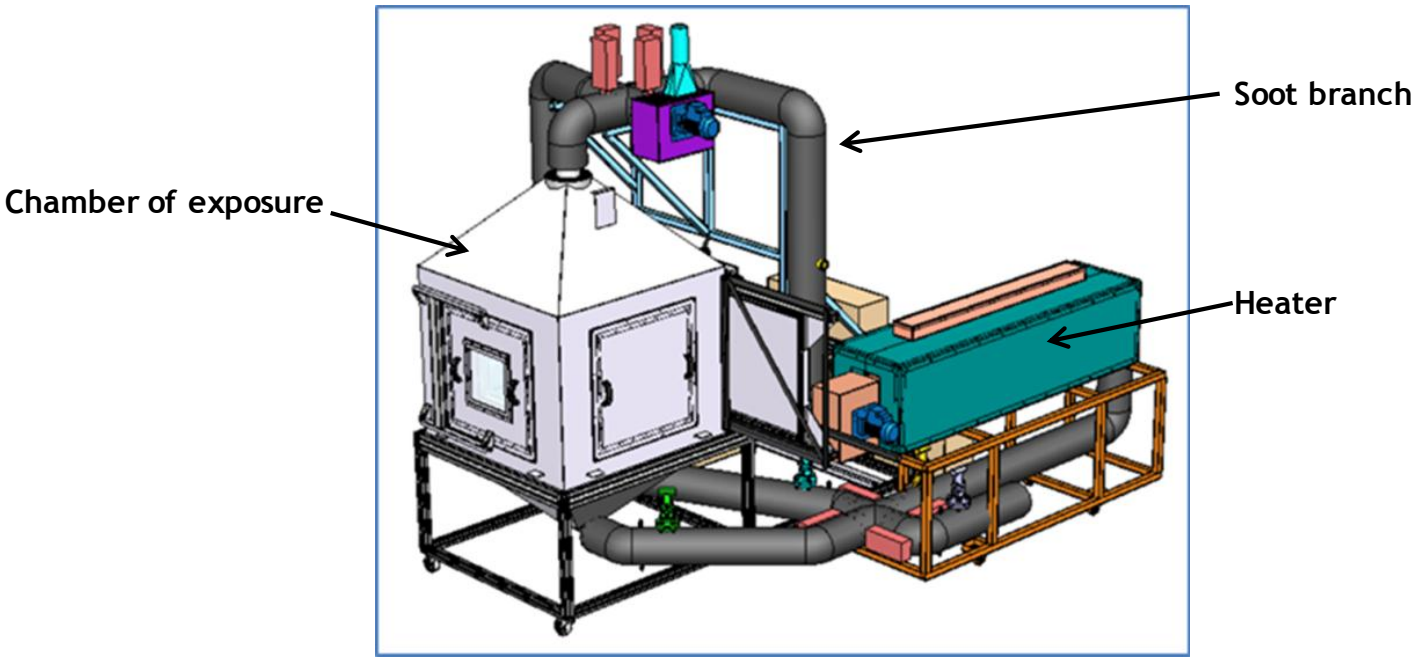
- Some results



Analytical tests

New Experimental Apparatus

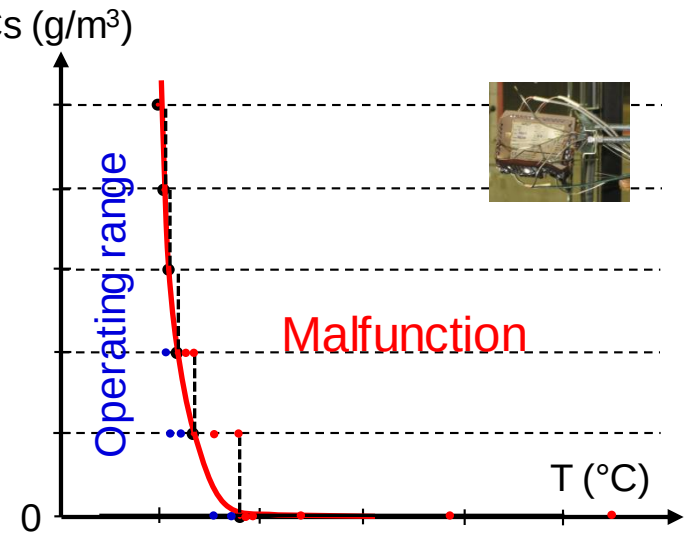
- Objectives: Design and built a new experimental apparatus able to investigate the combined effect of ambient temperature and soot concentration
- Experimental device: Furnace (DANAIDES) able to monitor both thermal stress (up to 250°C) and soot concentration (up to 5 g/m^3)



Analytical tests

Experimental Program (DELTA) in progress

- Objectives: Develop an experimental protocol to characterize the malfunction of electrical components due to both thermal stress (T) and soot concentration (Cs). Two challenges:
  - Use of a soot surrogate: carbon powder
  - Limited number of tests for determining the operating range of equipment in case of fire
- Expected results: Malfunction curve (T, Cs) for an electrical component
- First encouraging results



Conclusion

Support studies of Fire-PSA:

- Need to assess the malfunction of electrical equipment important for safety (i.e. fire-related risks to reach the core melting): damage criteria of electrical equipment considered

Main outcomes of real fire tests

- Electrical malfunction of analogic converters in real fire conditions depends on both soot concentration and ambient temperature: Malfunction = f(T,Cs)

DELTA Program (in progress at IRSN)

- This program proposes to define an experimental procedure to characterize properly malfunction of electrical components by means of a dedicated furnace (named DANAIDES)
- After this step, the expected outcomes will be to determine the malfunction of electrical equipment in case of fire by means of a quasi-standards experimental method

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Thank you for your attention

Enhancing nuclear safety