SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Development of an in-pile HLM materials test loop for BR2

Helimert 2009

Jan Heyse, Ben Caers, Marc Dierckx, Rafaël Fernandez, Joël Janssens, Paul Schuurmans
SCK•CEN, ANS-RTR/RTD/DEO, Mol, Belgium

Sergei Dementjev, Werner Wagner
PSI, Villingen, Switzerland

Guy Laffont
CEA, Cadarache, France

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Summary

- Introduction and objective
- Boundary conditions
- In-pile Loop design
- Mock-up Loop design and experiments
- Conclusion

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Introduction

- HLM as coolant/spallation target in GEN IV/ADS (e.g. MYRRHA/XT-ADS)
  - ➔ New technologies, materials, instrumentation, …
- Conditions: combination of radiation, corrosion/erosion, embrittlement, mechanical/thermal stress
- Few experiments combining relevant HLM and radioactive conditions (LISOR, STIP, ASTIR, …)

➔*Need for a high temperature lead alloy loop for use in a existing MTR reactor*

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

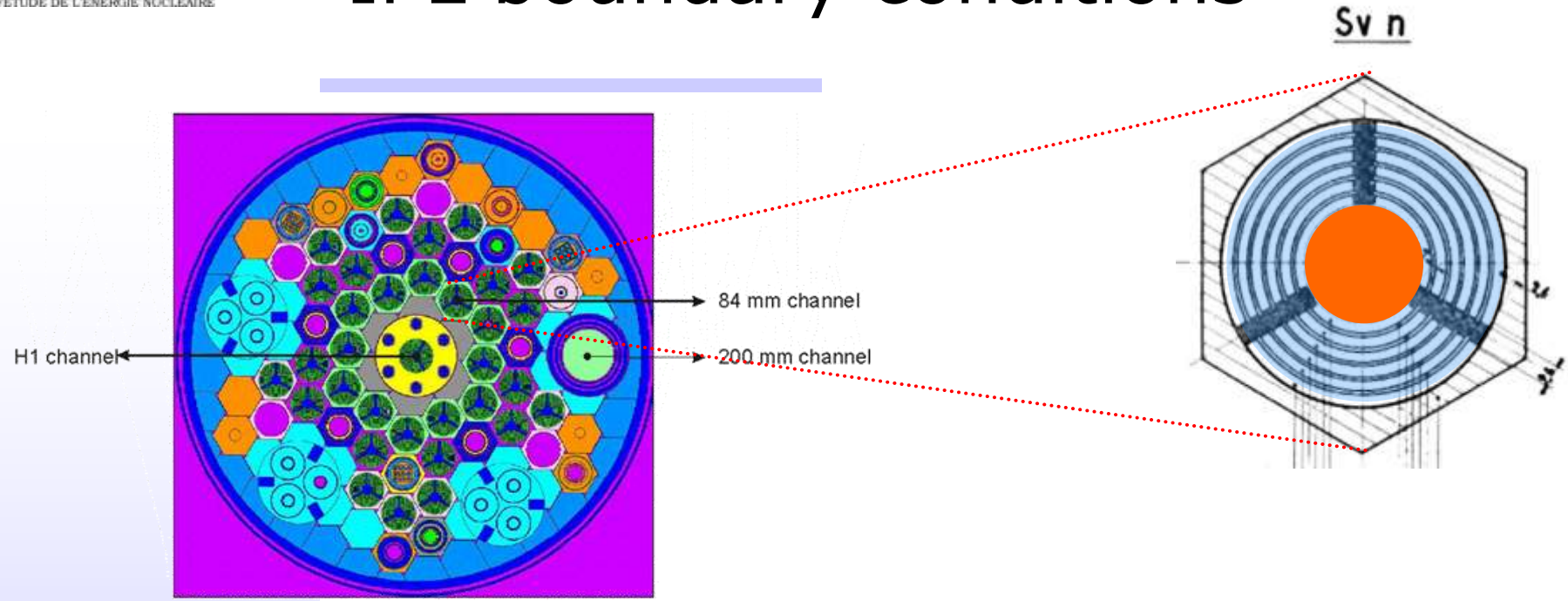
Objective

- Investigation of
  - Reactor materials
  - HLM conditioning and chemistry control
  - Reactor components and instrumentation
- Under relevant conditions:
  - HLM flowing at $\leq$ 2 m/s
  - Radiation
  - Temperature
  - Mechanical stress

International framework

- Follow-up of ASTIR irradiation programs (IP-EUROTRANS/DEMETRA)
- MTR-I3 (WP3.2)
  - *Design* of a high-temperature lead alloy **in-pile loop** (IPL) for BR2
- VELLA (JRA4.2)
  - *Validation* of the design and *operation* of this HLM loop in an **out-of-pile mock-up**
  - Proof of reliability, stability, safe operation
  - Licensing procedure

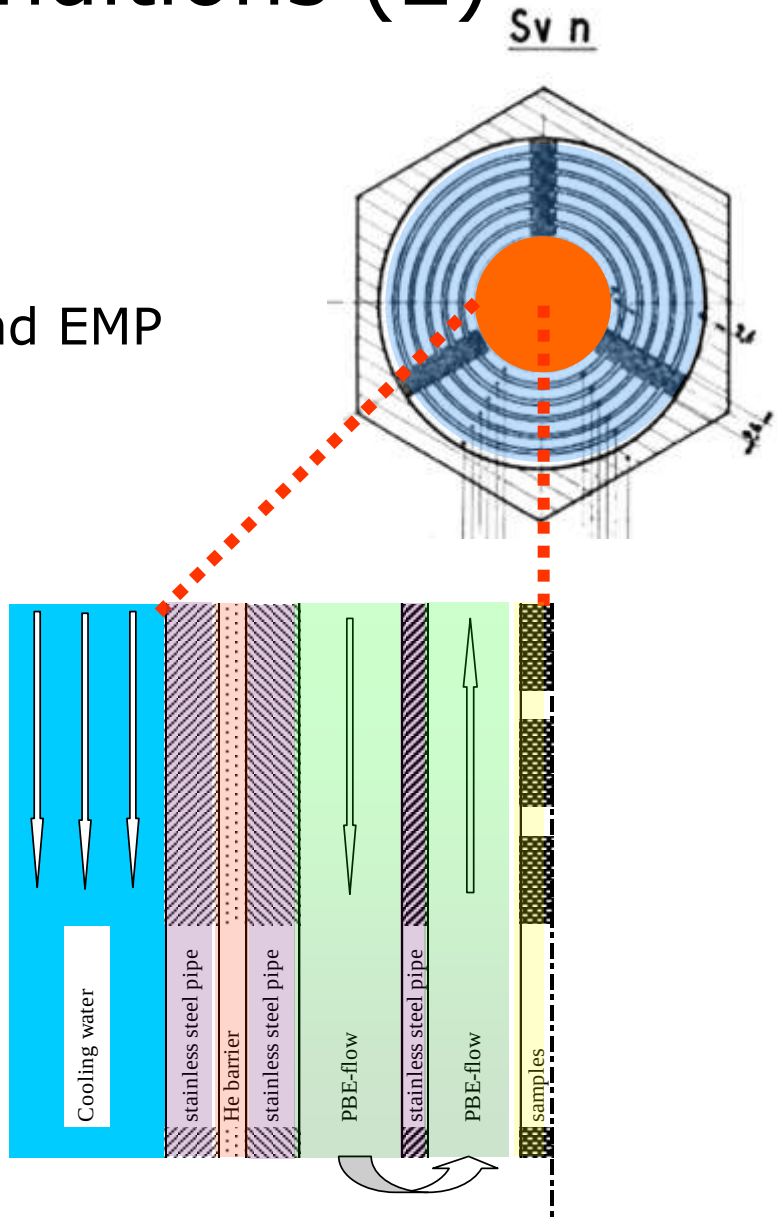
IPL boundary conditions



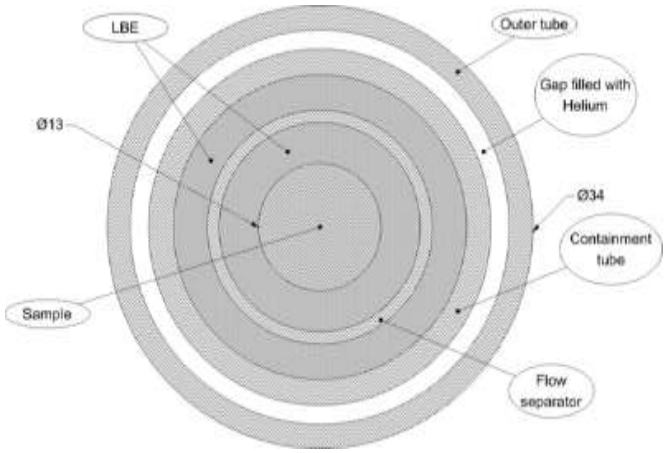
- General loop layout:
  - Critical components have to fit within spatial limitations of **BR2 irradiation channel**
    - 5 plate fuel element
    - outer diameter of 34 mm
    - About 90% of 6 plate fuel element flux (cfr. SPEED ASTIR)

IPL boundary conditions (2)

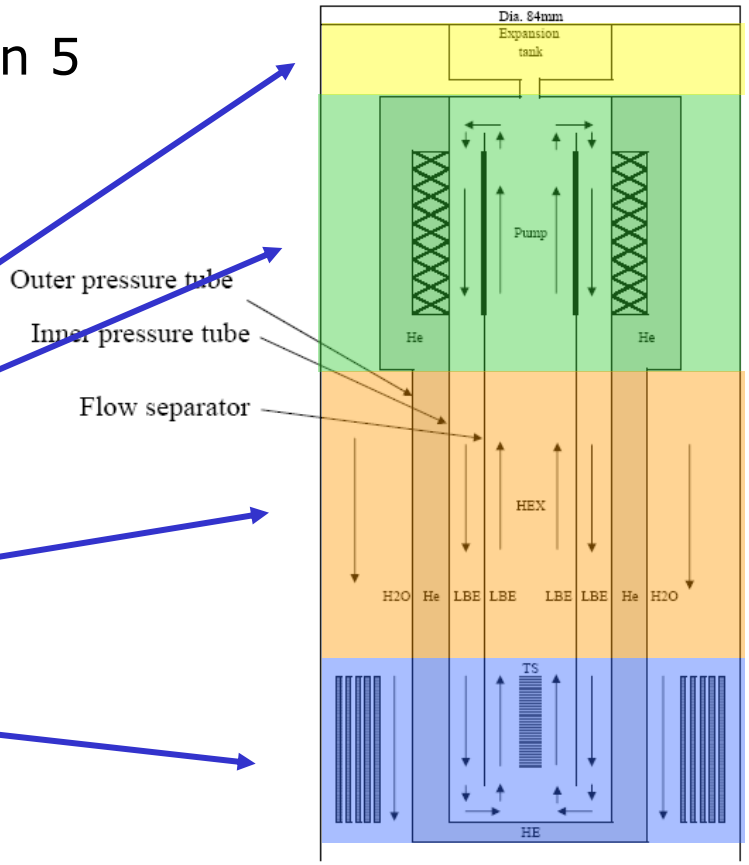
- Temperature range:
  - Cooling by BR2 water/HEX
  - Heating by gamma radiation and EMP
- Structural materials:
  - Corrosion and radiation resistant
  - Minimal activation
- Pump:
  - Sufficient flow and ΔP
- Dismantling:
  - Hot cell dimensions (<6m)
- Safety issues:
  - Double wall filled with He gas



IPL design

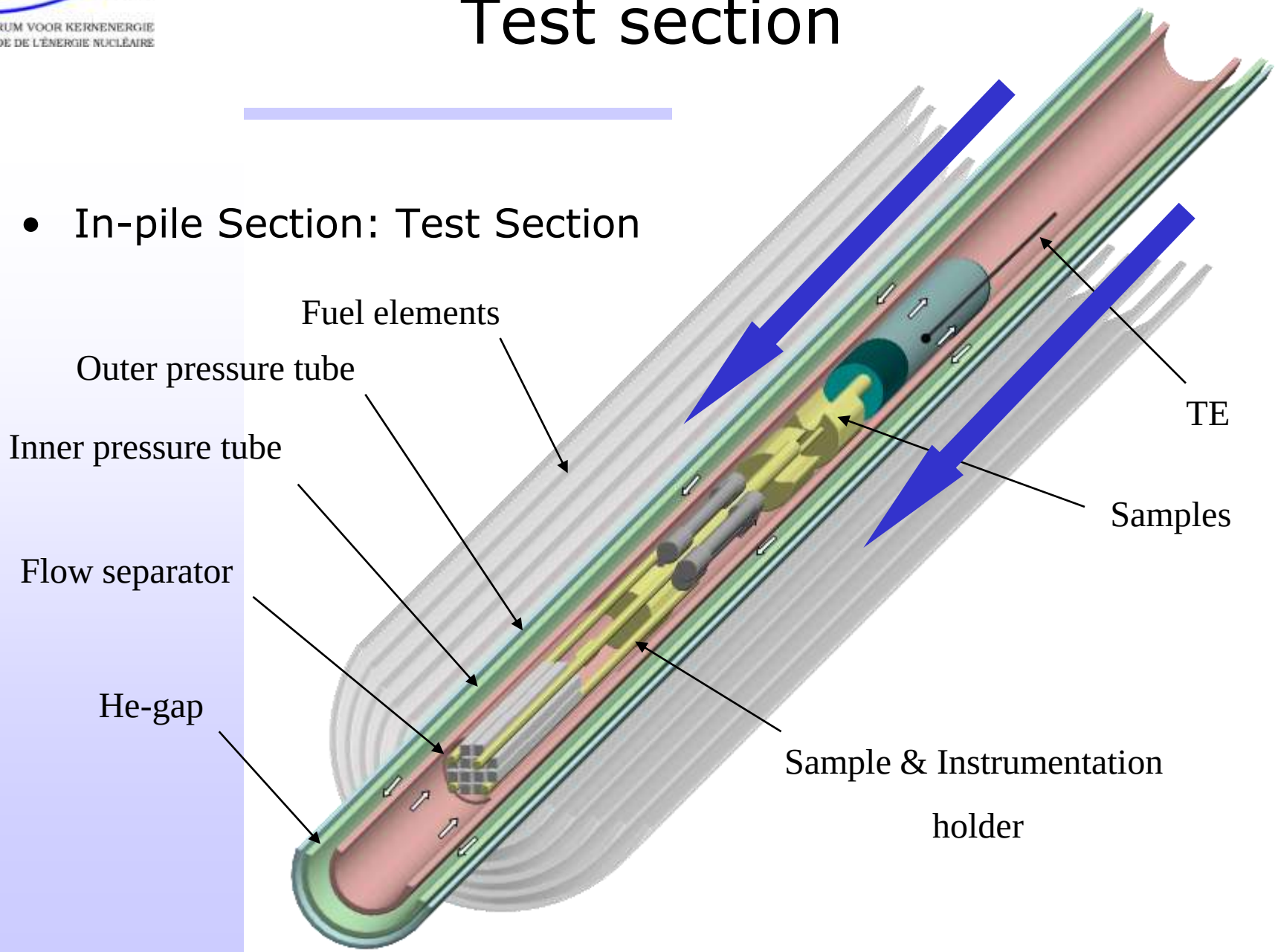


- Conceptual design:
  - 3 concentric channels within 5 plate fuel element:
    - ♣ LBE out/up + samples
    - ♣ LBE in/down
    - ♣ He gap
  - 4 main sections:
    - ♣ Expansion
    - ♣ MHD
    - ♣ HEX
    - ♣ Test section



Test section

- In-pile Section: Test Section

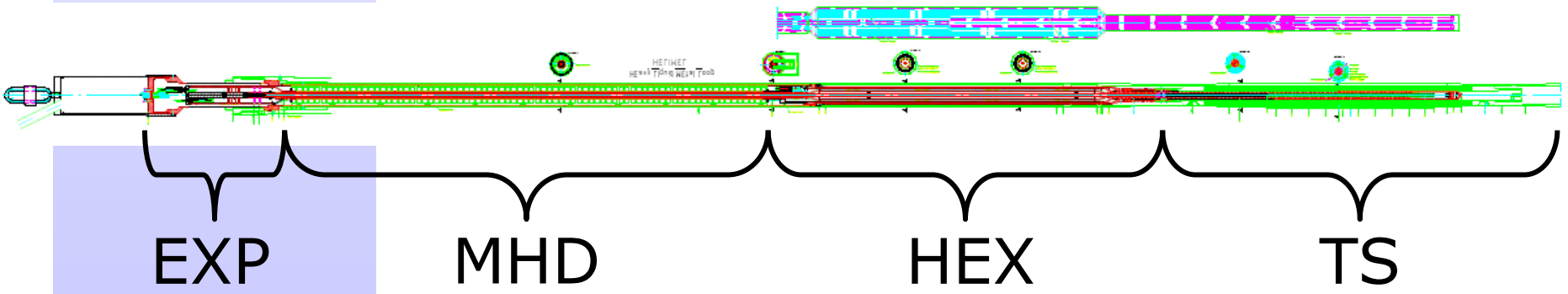


Process conditions

- General Process conditions BR2:
  - Temperature of the cooling water : 50 °C
  - Velocity of the cooling water : 10 m/s
  - Pressure of cooling water : 10 bar
  - Velocity of the LBE : 2 m/s at samples
  - Sample temperatures : 300-550°C (to choose)
  - LBE temperature : minimal 180°C
  - Double barrier required : He-gap
  - Heat source: nuclear heating of metal parts (construction steel + LBE flow)
  - He-pressure: variable

Status of the IPL design

- Conceptual design: finished
- Calculations: thermal model, strength analysis and hydraulic analysis finished
- Engineering design: to be completed
- Technical drawings: // engineering
- Conceptual design MHD pump: finished
- Safety stydies & system analysis: ongoing



SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Mock-up loop

- Check critical components of IPL
  - Test section (TS)
  - Gas pressure control
  - HEX
  - Instrumentation
- Match IPL components in material, layout and size
  - In accordance with spatial and material constraints imposed by BR2
  - Validation of thermal hydraulic behavior
- Check safe operation
  - Operational safety (pressure, temperature, …)

Strategy for mock-up: Modification of IPL design

- First fase (by Sep 2009)
  - "Stripped" IPL (2 concentric channels, no He gap)
    - ♣ Isothermal configuration
    - ♣ Measurement of pressure losses
    - ♣ General operation of the loop in steady state and transient conditions
    - ♣ Testing of critical components (e.g. LBE compatibility of feed throughs)
  - Cooling properties of He gap
    - ♣ separate experimental study of heat transfer across the He gap at relevant temperatures
- Second fase (after Sep 2009)
  - Full blown experiment, including external cooling with representative water flow

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Mock-up instrumentation

- Copy of IPL instrumentation
- Extra
  - First fase
    - ♣Pressure losses in different sections
    - ♣Oxygen probe and control
    - ♣Flowmeter
  - Second fase
    - ♣Water temperature

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Conclusion

- Design of in-pile materials test loop to investigate combined exposure of materials to HLM and radiation finished by September 2009
- Out-of-pile mock-up will be constructed and operated to test critical components and safe operation of IPL by September 2009

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Contributors

- SCK-CEN – ANS institute
  - Reactor Technology Design group (RTD)
    - ♣ Rafaël Fernandez, Joël Janssens
  - Reactor Technology Research group (RTR)
    - ♣ Ben Caers, Marc Dierckx, Jan Heyse, Paul Schuurmans
  - Design and Engineering Office (DEO)
    - ♣ Frans Schellens, Erwin Vandenbussche, Bart Van Helden
- PSI
  - Sergei Dementjev, Werner Wagner
- CEA Cadarache
  - Guy Laffont