NEA NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK:

Success Stories and Opportunities for Future Developments

9-13 January 2023

NEA NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK:

Success Stories and Opportunities for Future Developments

9-13 January 2023

Welcome

Day 2 – Tuesday 10 January

NEA NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK:
Success Stories and Opportunities for Future Developments

9-13 January 2023

Questions: Questions, feedback and suggestions

Event public page: Nuclear Energy Agency (NEA) - NEA Nuclear Safety Research Joint Projects Week: Success Stories and Opportunities for Future Developments (oecd-nea.org)

Form: Questions, feedback and suggestions link available in the registration confirmation email

NEA NUCLEAR ENERGY AGENCY

ABOUT US TOPICS NEWS AND RESOURCES LEARNING AND TOOLS

Webinar (Online Event)

To address the challenges announced, please write here your questions to the speakers and we will do our best to include as many of them as possible in the discussions.

Please enter your questions in the dedicated spaces below for each session.

Session 1: Nuclear Safety Research Joint Projects: Benefits and Challenges for the Future

Questions for session 1

Session 2: Joint Projects for Safety in Design, Learnings and Perspectives

Questions for session 2

Session 3: Joint Projects for Safety in Operation, Learnings and Perspectives

Questions for session 3

Session 4: Joint Projects for Safety in Accidental Situations, Learnings and Perspectives

Questions for session 4

Session 5: Future Needs for International Co-operation in Nuclear Safety Research

Questions for session 5

Please suggest specific topics you consider to be priorities for future joint safety research projects.

Topics for future safery research joint projects

If you already know the NEA joint projects framework, please suggest specific items for future revisions.

If you are not familiar with the NEA joint projects framework, please share with us what you consider to be key elements to incorporate in the framework of future NEA joint safety research projects.

If you already know the NEA joint projects framework, could you please tell us what suggestions you have for future revisions, and in case you are not familiar with the NEA joint projects framework, please share with us potential mechanisms and frameworks that could be used in the future to address nuclear safety research. *

Professional information

First Name *

LAST NAME *

ORGANISATION *

COUNTRY *

Professional e-mail address *

Thank you very much for your most kind contribution to the successful outcome of this event.

SUBMIT CANCEL

Session 2

Joint Projects for Safety in Design, Learnings and Perspectives

SESSION MODERATOR

Dr Jinzhao ZHANG

Technical Director, Business Area Global Nuclear, Tractebel (ENGIE), Belgium

Dr Jinzhao ZHANG, is a Technical Director, Business Area Global Nuclear, at Tractebel (ENGIE). He is in charge of nuclear fuel design, safety analysis and licensing. He has 40 years' experience of R&D, engineering and consulting in nuclear reactor thermal hydraulics, fuel thermal mechanics, multi-physics modelling, uncertainty and sensitivity analysis, safety analysis and licensing. He is an active member of the NEA Working Group on Analysis and Management of Accidents (WGAMA), Working Group on Fuel Safety (WGFS) and Expert Group on Reactor Fuel Performance (EGRFP); the IAEA Technical Working Group on Fuel Performance and Technology (TWGFPT) and the Pressurized Water Reactors Owners Group (PWROG) Analysis Sub-Committee (ASC). He has contributed to writing or updating safety guides, technical guidance and technical reports for the IAEA and the NEA in his domain of expertise. Currently, Dr Zhang is Chair of the Management Board of the NEA Rod Bundle Heat Transfer (RBHT) Project, and task leader of the NEA WGAMA/WGFS activity to write a Status Report on Good Practices for Analyses of Design Extension Condition without Significant Fuel Degradation (DEC-A) for Operating Nuclear Power Plants. He is also the co-chair of the IAEA Coordinated Research Project on Testing and Simulation for Advanced Technology and Accident Tolerant Fuels (ATF-TS).

Session 2

Joint Projects for Safety in Design, Learnings and Perspectives

► Examples of Nuclear Fuel Safety Projects

QUENCH-ATF

Dr-Ing Th. Walter TROMM

Head of the Nuclear Waste Management, Safety and Radiation Research Programme (NUSAFE), Karlsruhe Institute of Technology (KIT), Germany

Dr Th. Walter TROMM is Head of the Programme Nuclear Waste Management, Safety and Radiation Research (NUSAFE) at Karlsruhe Institute of Technology (KIT). In 2014, he was appointed to the executive committee of KIT's Division 3, Mechanical and Electrical Engineering. In 2019 he was appointed as acting head of the Institute of Nuclear and Energy Technology and in 2022 he was appointed scientific spokesperson of the KIT Energy Center. He is active in various national and international committees, at the NEA where he is the German representative at the Nuclear Science Committee and Data Bank Management Board for the Development, Application and Validation of Nuclear Data and Codes, and at the IAEA where he serves in the Technical Working Group on Advanced Technologies in Light Water Reactors. Furthermore, he is member of the German Alliance of Competence in Nuclear Technology and within the VDI, the Association of German engineers, he is Chairman of the Power Plant Technology Committee and a member of the Energy and Environment Division.

Karlsruhe Institute of Technology

OECD-NEA Joint Undertaking QUENCH-ATF

Juri Stuckert, Martin Steinbrück, Th. Walter Tromm (KIT)

NEA Nuclear Safety Research Joint Projects Week, 9-13 Jan 2023

Institute for Applied Materials IAM-AWP and Program Nuclear Waste Management, Safety and Radiation Research (NUSAFE)

QUENCH-ATF Joint Undertaking

➡ Worldwide first large-scale bundle experiments with Accident-Tolerant Fuel (ATF) cladding materials under DBA and severe accident conditions

Fact sheet

- Duration: Oct. 2021 – Oct. 2025
- Budget: 1.6 Mio €
- 20 participants from 9 countries

Accident tolerant fuel (ATF) cladding requirements

- Excellent high-temperature properties
  - Oxidation resistance to steam
    - Reduced hydrogen production and chemical energy release
  - High mechanical strength to maintain fuel rod integrity and core coolability
  - **Extended coping time for operator to restore cooling system**
- Compatibility with current fuel and reactor designs
- Meet regulatory and operational requirements
  - Equal or better operational behavior
    - Corrosion resistance and hydrogen uptake
    - Irradiation resistance
  - Licensing
  - Availability and economics

Most promising ATF cladding concepts

- Cr-coated Zr alloys

  Still Zr-based near-term solution
  Improvement of oxidation, hydrogen uptake, mechanical properties up to 1300°C
  Cr-Zr eutectic at 1332°C

- FeCrAl alloys

  Cheap and easy to produce

  DBA LOCA degradation and HT oxidation significantly reduced

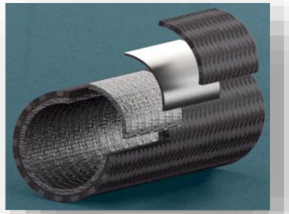
  Neutronic penalty, relatively low melting temperature, tritium permeability

- SiC_f-SiC ceramic matrix composites

  First of a kind ceramic composite fuel cladding

  Very good neutronic behavior and oxidation resistance up to >1700°C

  In-pile hydrothermal corrosion and leak tightness



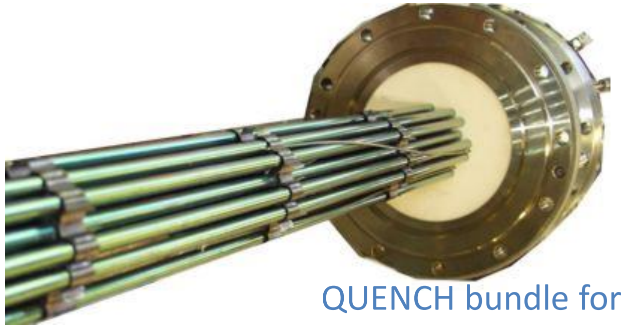
Images from Framatome, ORNL and Westinghouse

KIT-QUENCH activities and expertise on ATF cladding

- Participation in international programs
  - OECD-NEA (EGATFL, TOPATF)
  - IAEA CRP on Accident Tolerant Fuel Concepts for Light Water Reactors (ACTOF)
  - EC project IL TROVATORE
  - Westinghouse CARAT
- Large-scale bundle tests in the QUENCH facility
- High-temperature oxidation of ATF cladding materials
  - Coated Zr alloys (Cr, MAX phases)
  - Fe-based alloys
  - SiC_f-SiC CMC

SiC_f-SiC cladding after 64 h at 1600°C in steam

Inductively heated single-rod test



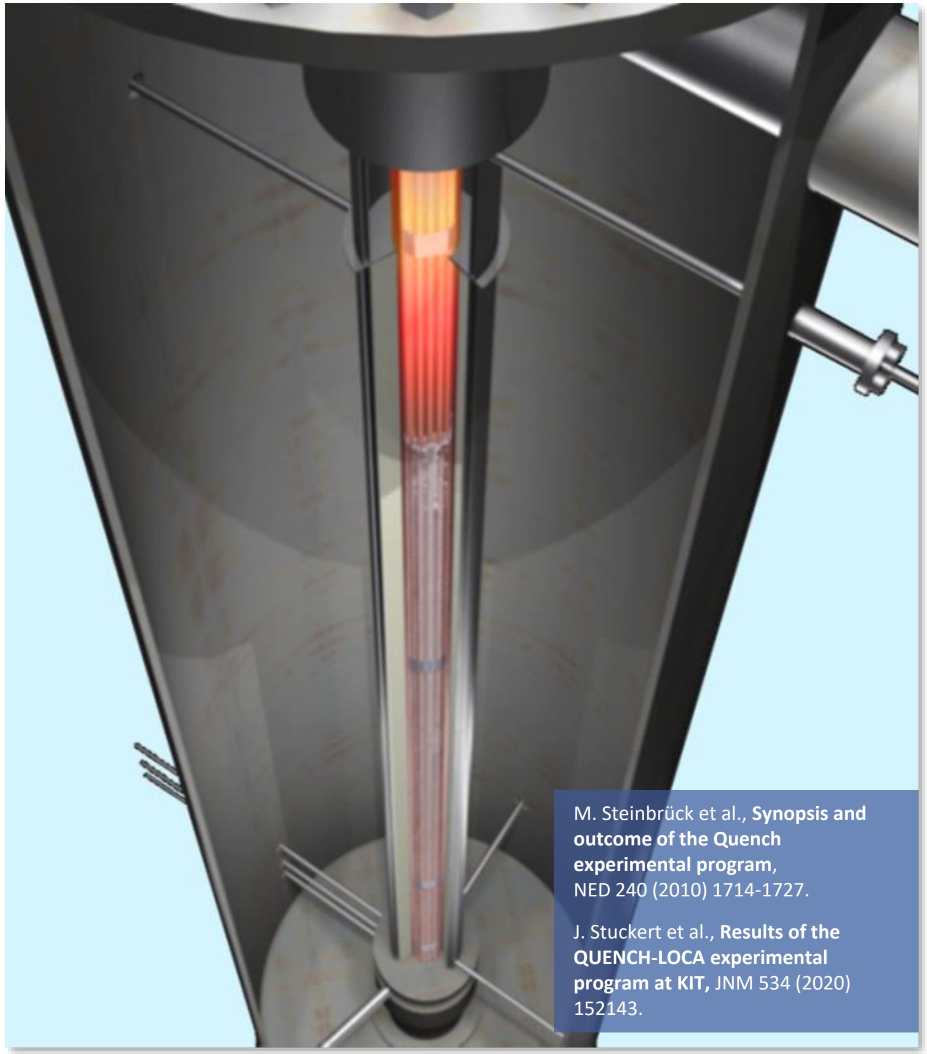
QUENCH bundle for large-scale tests

QUENCH-ATF Joint Undertaking

- Three bundle experiments with ATF cladding in the QUENCH facility
  - Focus on Cr-coated Zr alloys
  - Option for SiC cladding in second phase of project
  - Tubes provided by Westinghouse (US) (and others?)
  - Design basis and beyond design basis accident conditions
- Supporting separate-effects tests
  - at KIT
  - Complementary tests at IRSN (France)
- Code support for test preparation and code benchmark exercises, coordinated by GRS

QUENCH Facility

- Unique out-of-pile bundle facility to investigate reflood of an overheated reactor core
- So far, 21 experiments on SA performed (1996-today)
- 7 DBA LOCA experiments with separately pressurized fuel rods
- QUENCH-19: First bundle test with ATF cladding material (FeCrAl)



M. Steinbrück et al., **Synopsis and outcome of the Quench experimental program**, NED 240 (2010) 1714-1727.

J. Stuckert et al., **Results of the QUENCH-LOCA experimental program at KIT**, JNM 534 (2020) 152143.

Test matrix

QUENCH-ATF #1 (July 2022)

- **Cr coated Zr** (provided by Westinghouse)
- Bundle with 24 heated rods, 12.6mm pitch
- **Extended LOCA** conditions: similar conditions as QUENCH-L3HT (LOCA 3 High Temperature) with optimized ZIRLO™, which will allow for comparison

QUENCH-ATF #2 (2023)

- **Cr coated Zr**
- **Severe accident conditions**

  (above Zr-Cr eutectic)
- ATCR under discussion

QUENCH-ATF #3 (2024)

- Cr coated Zr or SiC
- GO/NOGO on SiC in 2023
- Scenario depending on material and results of previous tests

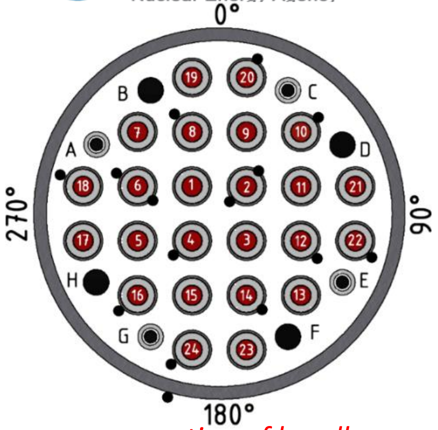
Participants from 9 countries

- **Czech Republic**
  - ÚJV Řež
- **France**
  - CEA
  - EDF
  - Framatome
  - IRSN
- **Germany**
  - GRS
  - KIT (Operating Agent)
- **Japan**
  - CRIEPI
  - JAEA
- **Russian Federation (suspended)**
  - Bochvar Institute
  - Kurchatov Institute
  - TVEL
- **Sweden**
  - SSM
- **Switzerland**
  - PSI
  - ENSI
- **United Kingdom**
  - NNL
- **United States**
  - EPRI
  - GA
  - USNRC
  - Westinghouse*

** under discussion*

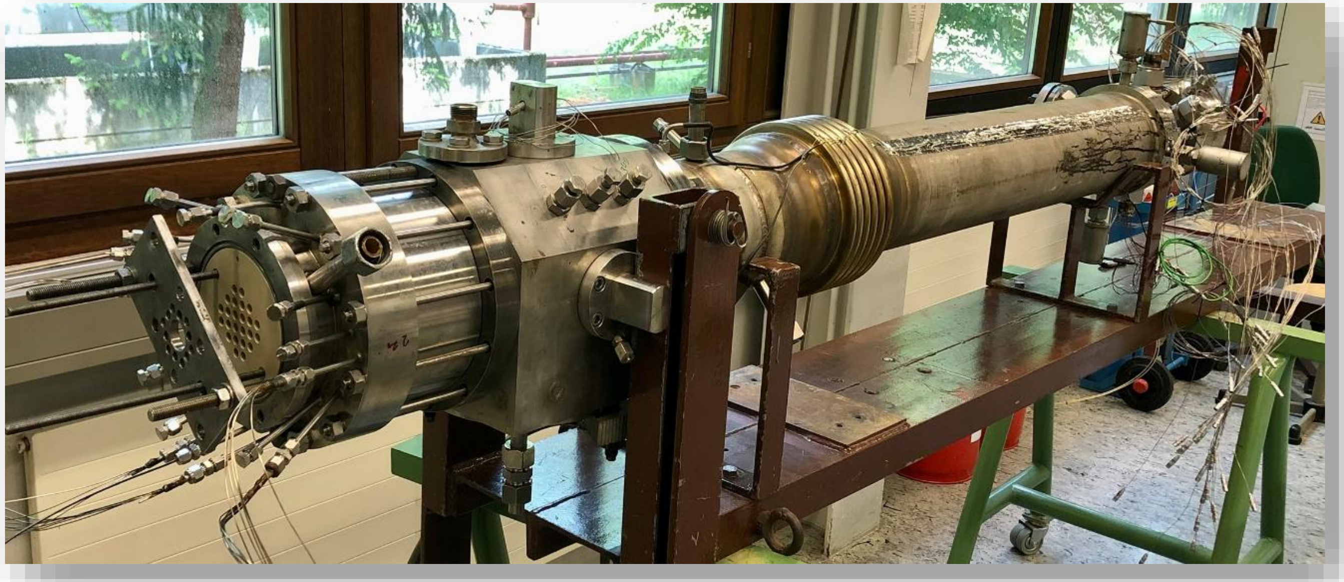
QUENCH-ATF #1 experiment

test bundle



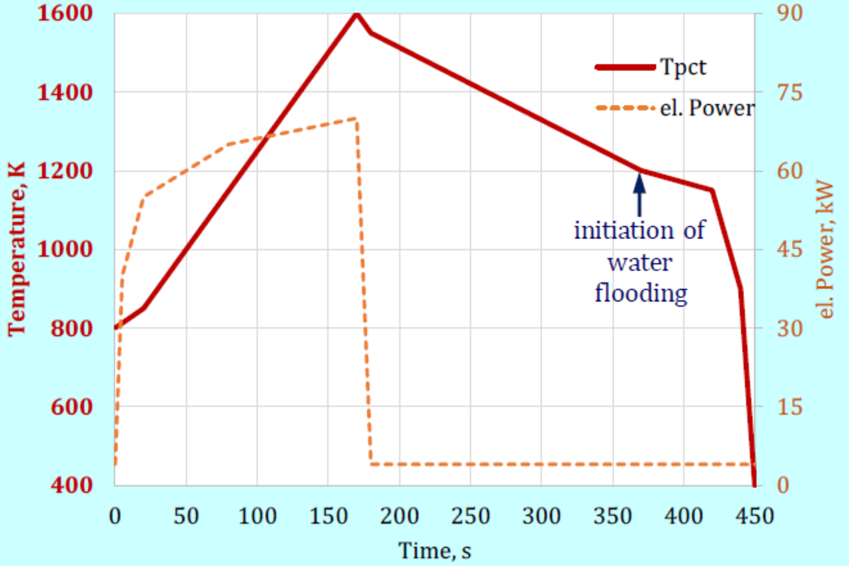
cross-section of bundle instrumented with thermocouples

- Improved handling of Cr coated cladding tubes during bundle assembly



QUENCH-ATF #1 scenario

- Extended LOCA conditions
  - Heating-up rate during the heating in superheated steam 5 K/s
  - Peak cladding temperature at the end of the heat-up stage 1600 K
  - Duration of cool down stage 200s
  - Final quenching by water



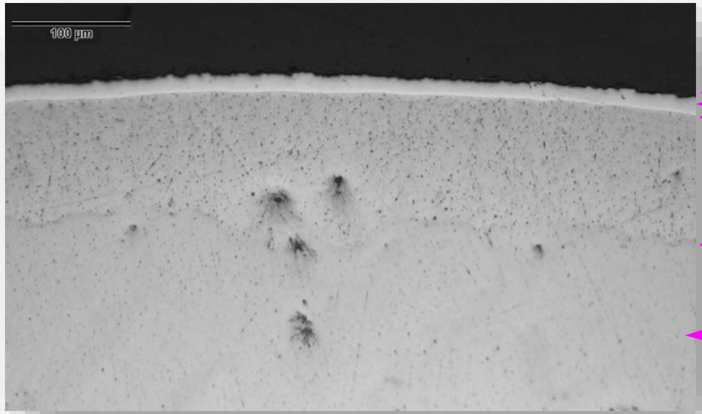
QUENCH-L3HT scenario

➡ Should demonstrate enhanced performance at high temperature during a LOCA transient

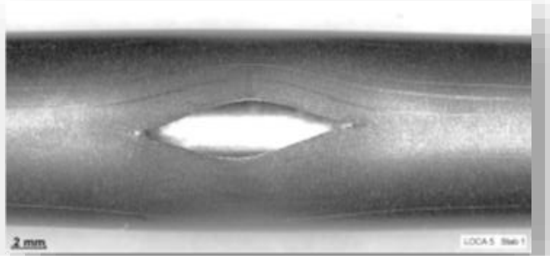
QUENCH-ATF #1 post-test examinations (KIT/IRSN)

Laser scanner profilometry (pre-/post-test)

Neutron radiography and tomography



tube cross-section



Burst opening parameters

QUENCH-ATF #1 benchmark exercise

Blind post-test benchmark

- Coordinated by Th. Hollands, GRS (DE)
- Simulation of bundle temperatures and mechanical cladding behaviour (strain of ballooning region and burst parameters)
- Strong impact of QUENCH tests on codes V&V
- Many organisations are currently working on leveraging their code to address ATF claddings incl. Cr coated Zr – therefore the timing is optimal
- 6 organisations volunteered to participate:
  - GRS/RUB PSS with AC2/ATHLET-CD
  - KIT with ASTEC
  - USNRC/SNL with MELCOR
  - EPRI with MAAP
  - UJV Rez with MELCOR (and TRANSURANUS?)
- Launched shortly after test performance, finished 12/2022
- After finalisation of blind phase, experimental data were delivered and open benchmark analysis started

KIT activities and collaborations of relevance for QUENCH-ATF

- CSARP (Cooperative Severe Accident Research Program of the US Nuclear Regulatory Commission)
- EC Research Program IL TROVATORE (Innovative cladding materials for advanced accident-tolerant energy systems)
- IAEA Coordinated Research Project on Testing and Simulation of Advanced Technology Fuels (ATF-TS)
- OECD-NEA activities (e.g. TOPATF, EGATFL, EGIFE)
- OECD-NEA project TCOFF (Thermodynamic Characterization of Fuel Debris and Fission Products Based on Scenario Analysis of Severe Accident Progression at Fukushima-Daiichi Nuclear Power Station)

Example:
IAEA Coordinated Research Project (CRP): “Testing and Simulation for Advanced Technology and Accident Tolerant Fuels (ATF-TS)”

- Start Date: 6 April 2020 Expected End Date: 1 August 2024
- Participants: 29 organizations from 22 countries

Objectives:
- To perform experimental tests including single rod and bundle tests on ATFs' performance under normal, Design Basis Accident (DBA) and Design Extension (DE) conditions
- To benchmark fuel codes against new test data either obtained during the CRP or from existing data relevant to advanced fuel and cladding concepts
- To develop LOCA evaluation methodology for ATF performance with a view for NPP applications

Outputs:
- ATF performance dataset and bundle tests for normal operating conditions, DBAs and DECs
- Experimentally validated fuel codes and modelling methods for ATF
- A demonstration case for the application of the new ATF materials and validated fuel models for assessing fuel performance and quantifying fuel margins for LOCA

Concluding remarks for the QUENCH-ATF project

- QUENCH-ATF project will provide valuable data on bundle behavior of ATF claddings through a series of three tests
- Making the most of the unique QUENCH facility
- Test #1 on Cr coated Zr in LOCA conditions successfully conducted in July 2022
- Second test with more severe conditions under preparation

Cooperation within QUENCH-ATF beneficial for many partners, e.g.:

- QUENCH test and post-test examination by operating agent KIT,
  - cooperation with PSI, CEA and ILL/Grenoble for neutron-tomography
- Complementary post-test examination kindly provided by IRSN
- Analytical support and benchmark exercise kindly coordinated by GRS

Possible Outlook for a future continuation QUENCH-ATF project?

- Continuation of the project with more detailed investigation on Design Basis Conditions and Design Extension Conditions for ATF Cladding Materials.
- Maintaining and further developing facilities and competences in the field of material investigations
- Attracting young scientists worldwide
- E.g. 2 facilities at KIT available for these investigations:
  - COSMOS-H for DBC up to critical heat flux
  - QUENCH for Severe Accident Conditions

General Outlook and Closing Remarks

- Various new cladding materials under development and investigation
- Needs for experimentally accompanied material research for design basis conditions and design extension conditions
- Infrastructures and experimental facilities have to be maintained for out-of-pile tests and in-pile tests
- Engagement of industry as the main driver for innovation needed
- But as well strong involvement of regulators and TSOs mandatory
- Collaboration of research centers and universities for:
  scientific expertise, experimental facilities, code development
  - Education and training of next generation of young scientists
  - Maintaining and further development of research facilities
- OECD / NEA is a strong support for the cooperation

CABRI CIP

Dr Vincent BUSSER

CABRI CIP Project Manager, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France

Dr Vincent BUSSER obtained his PhD in Mechanics and Materials in France, in which he focused on the studies of the damage of the zirconia layer formed at the outer surface of a fuel rod submitted to a mechanical loading, for instance during a control rod ejection transient. After completing his PhD, he worked at the IRSN on the modelling of fuel and cladding behaviour including base irradiation, transportation and storage conditions with the FUEL+ platform numerical codes. He recently returned to the accidental condition domain, serving as the CABRI International Programme (CIP) project manager at IRSN. IRSN is the operating agent of this programme, involving 15 partners from 12 countries under the aegis of the NEA.

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

NEA
Nuclear Energy Agency

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

OVERVIEW OF THE OECD/NEA CIP PROJECT

Vincent BUSSER, François BARRE

NEA
NUCLEAR ENERGY AGENCY

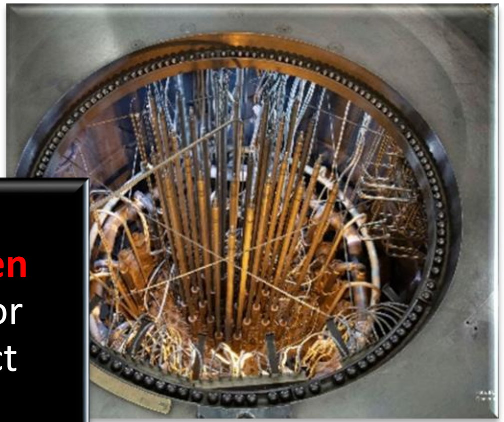
NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK
Success Stories and Opportunities for Future Developments
9-13 January 2023

IRSN/FRM-296 ind. 06

GENERAL DESCRIPTION OF THE CIP PROJECT

SEVERAL JOINT PROJECTS IN FUEL SAFETY

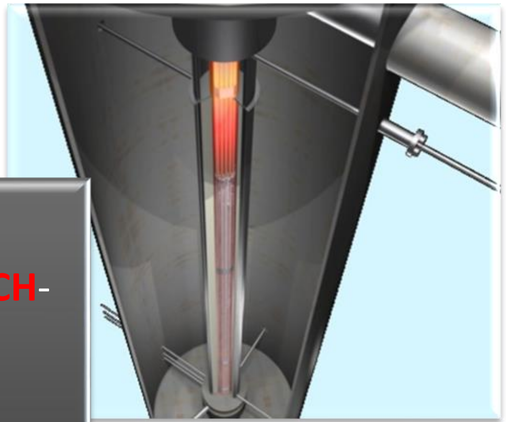
https://www.oecd-nea.org/jcms/pl_25445/studsvik-cladding-integrity-project-scip



Halden Reactor Project

https://www.oecd-nea.org/jcms/pl_24970/halden-reactor-project-fuels-and-material

Studsvik Cladding Integrity Project **SCIP**

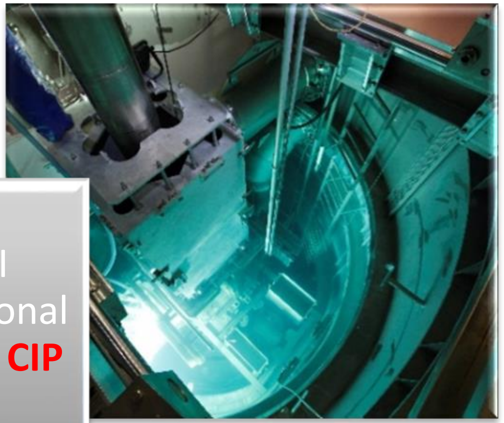


- **QUENCH**-ATF

https://www.oecd-nea.org/jcms/pl_36597/quench-atf-project

- Second Framework for Irradiation Experiments **FIDES II**

https://www.oecd-nea.org/jcms/pl_70867/second-framework-for-irradiation-experiments-fides-ii



CABRI International Program **CIP**

https://www.oecd-nea.org/jcms/pl_24821/cabri-international-project-cip

GENERAL DESCRIPTION OF THE CIP PROJECT

REP-NA PROGRAM… CIP

CIP : First tests in the sodium loop on fuel

1963

CABRI first neutron early 64

Sodium loop implementation
New core (UO2 rods)

1977

Tests dedicated to research reactors

1993

REP-Na1 1993
(…)
REP-Na12 2000

2001

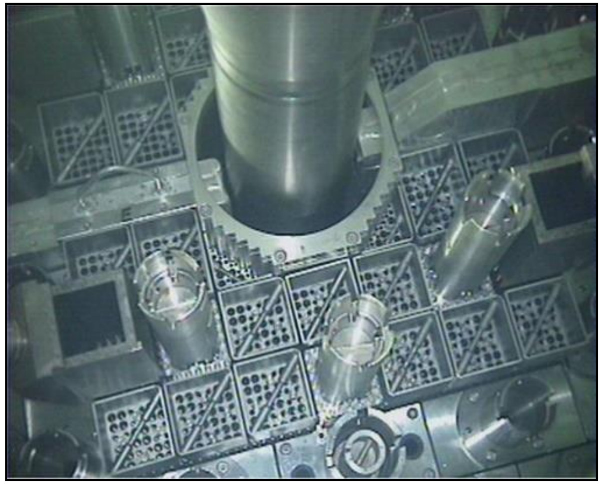
CIP0-1 2001
CIP0-2 2002

2003

CABRI refurbishment and PWL implementation

CIP partners sign the umbrella agreement on 4 February

International consensus on the need for tests in PWR representative conditions -> Pressurized Water Loop



GENERAL DESCRIPTION OF THE CIP PROJECT

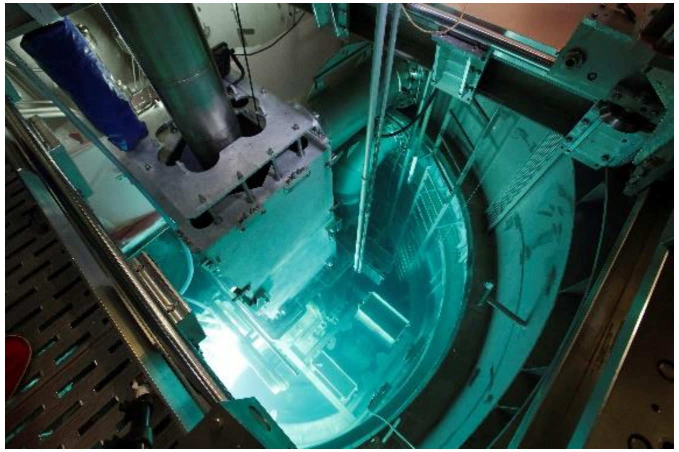
[IDENTITY CARD

CABRI is owned and operated by cea

- A decree gives priority to IRSN in order to use the reactor for its research programs on fuel safety
- Refurbishment and operation of the reactor are 100 % sponsored by IRSN, CEA remaining the owner

1st phase: CABRI REP-Na program

- Sodium loop, 12 tests
- PCMI phase, rod failure threshold and mechanism, fuel ejection
- 1992-2002 with EDF cooperation + US-NRC support



CABRI perfectly mimics Pressurized Water Reactor conditions

The reactor design allows performing rapid power transients

2nd phase: CABRI International Program CIP

- 2 in sodium (CIP0-1/CIP0-2) + 10 in water
- **Operating Agent**: IRSN
- **Partners**: 12 foreign countries,
  16 partners representing:
  - Operators (EPRI, EDF)
  - Safety authorities (CSN, NRI, HSE, …)
  - TSO (IRSN, NRC, GRS, …)
- **Budget**: Initial cost of EUR 74 million

- **Main Objectives**:
  - To carry out integral tests performed on irradiated material
  - To improve the knowledge for these phenomena during RIA transient:
    - boiling crisis (post-DNB) phenomena,
    - post-failure (Fuel-Coolant Interaction FCI) events,
    - microstructure influence,
    - advanced cladding.

MAIN OUTCOMES AND BENEFITS

[CIP TEST → AMBITIOUS AND COMPLEX

- Pool Type Reactor
- Core Size: 65x65x80cm
- Pulse: 10-80ms
- Core Fuel Rods : 1488 UO_2 & Stainless Steel Cladding
- Pressurized water circulation : P = 155 bar, T = 280°C, v = 4m/s

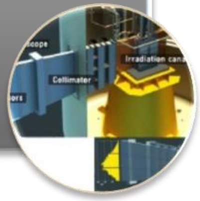
Reactor

- Unique design and fabrication of the test device
- Embedding of the instrumentation

Test device

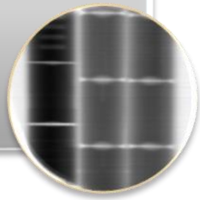
- Hodoscope system

Observation of fuel in real time



- Non Destructive Examinations
  - X-Ray radiography
  - X-Ray transmission tomography
  - Gamma-scanning

Post-test examination



→ DEVELOPMENT OF A UNIQUE FACILITY WITH ADVANCED EXPERIMENTAL TOOLS

→ TECHNOLOGICAL CHALLENGE

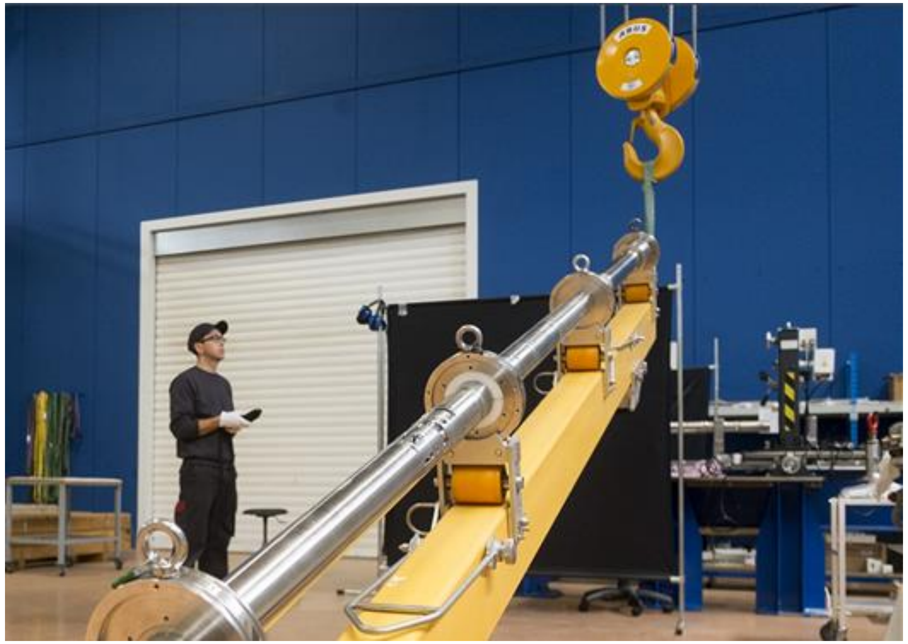
MAIN OUTCOMES AND BENEFITS

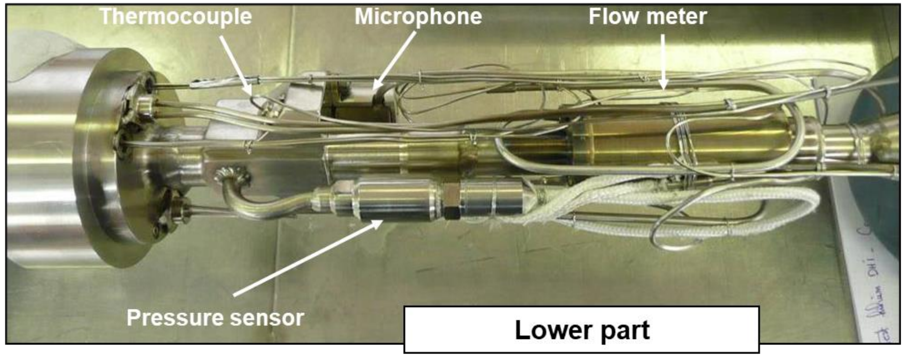
CIP : TEST DEVICE

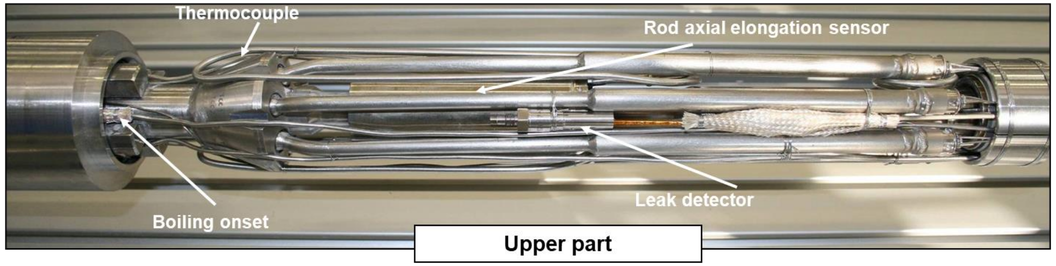
A unique test device

- Tube: 5 meters in length,
- 140 kg
- average diameter of approximately 100 mm
- Nominal operating conditions : those of the pressurized water loop (155 bar/280°C),
- But also, experimental conditions of the test during the transient (up to 500 bar/350°C).

- The instrumentation embedded in the test device is specific that meets very tough constraints and required **several years** of development.
  - ~ 50 detectors inside the test device
  - 2 Million EUR per test device





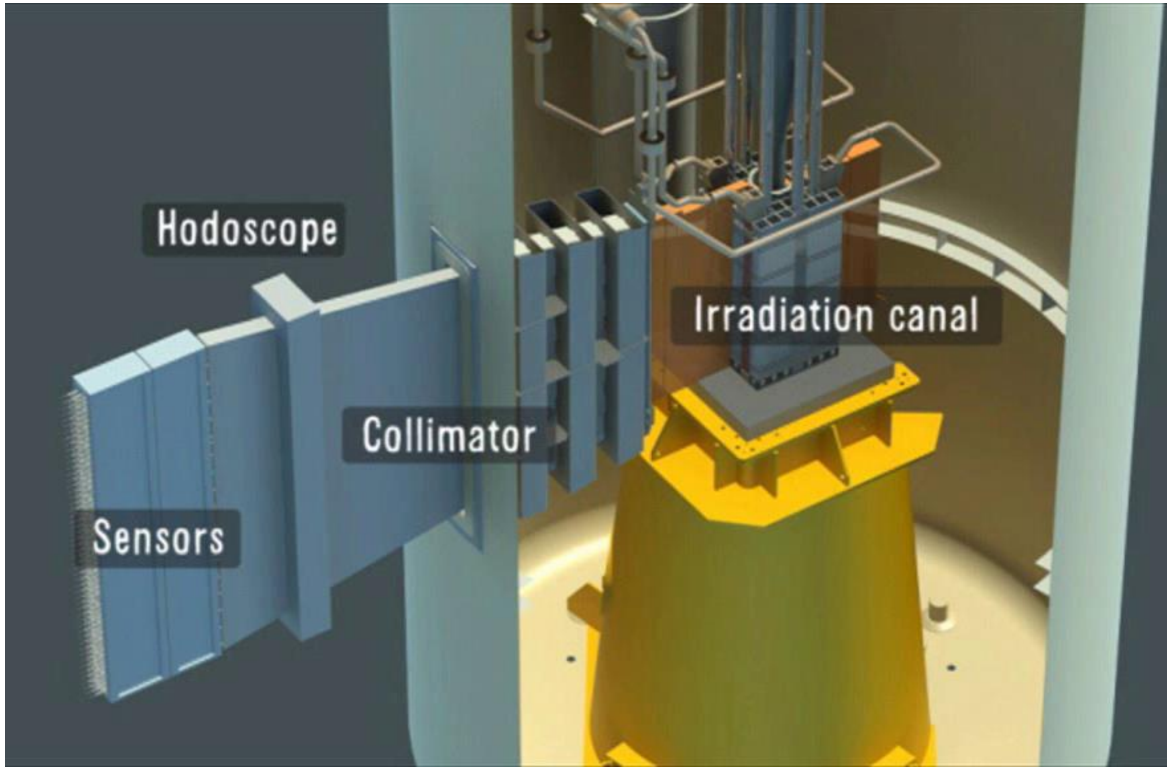


MAIN OUTCOMES AND BENEFITS

CIP : OBSERVATION OF FUEL IN REAL TIME

Hodoscope system

- On-line fuel motion detection (displacement, ejection, relocation)
- measurement of the test rod fissile length
- measurement of the core power profile
- measurement of the pulse width



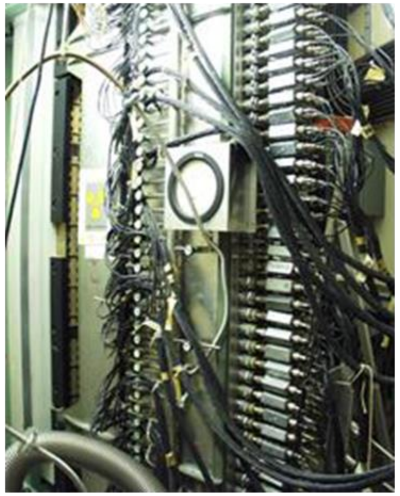
306 counting tracks:

- 51 rows x 3 columns collimator
- up to 1 ms acquisition rate

153 Fission Chambers (FC)
➔ power transient measurement

153 Proton Recoil Counters (PR)
➔“low” power measurement (up to ~100 MW).

Collimator

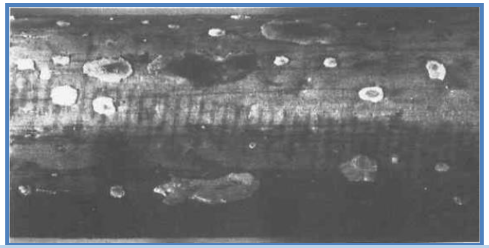


Detectors

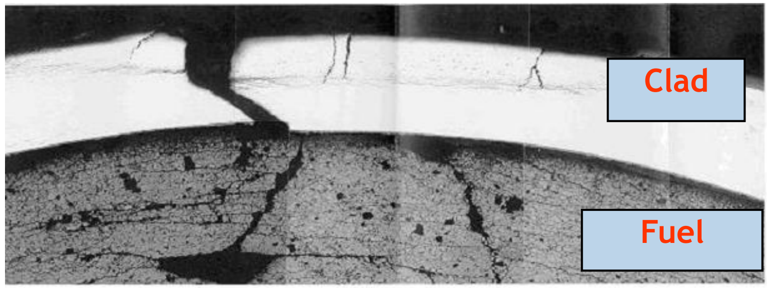
NUCLEAR SAFETY APPLICATION

CABRI REP-Na program performed during the 1992-2002 period

- Tests performed in the CABRI facility with the sodium loop → Study limited to the PCMI (Pellet Clad Mechanical interaction) phase and on both UO2 and MOX (high BU up to 64 GWd/t, Zr-4 cladding) of the RIA situation
- Beyond an external corrosion layer thickness of 80 microns, cladding integrity for Zircaloy-4 (material used historically for PWRs) can't be guaranteed



Highly corroded cladding with spallation



CABRI REP-Na 8

- At the international level, results from CABRI REP-Na induced and provided input to considerations on the necessity to revisit safety criteria established on lightly irradiated fuel.

- In France, pending the complete deployment of cladding materials with improved performance, IRSN recommended to limit the operating conditions for Zircaloy-4 containing cores in order to mitigate the risk

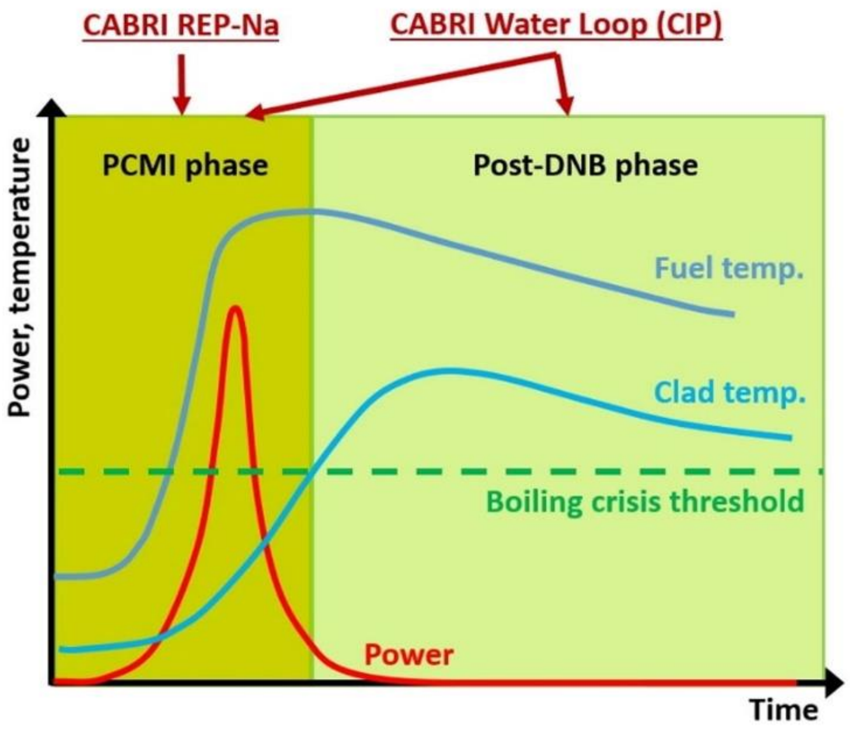
NUCLEAR SAFETY APPLICATION

CIP

- Study fuel rod behavior of PWR under **RIA condition**
  - **Integrity** of fuel rods in prototypical irradiation conditions (pressurized water loop)
  - **Post-DNB** and **post-failure fuel behavior** : main phenomena studied → Risk of rod **failure** / criteria
  - **Consequences in case of rod failure**

- **Content**:
  - 12 experiments (3 tests already performed 2002/2018)
  - UO_2 and MOX Fuel Rods (BU up to 100GWd/t) with:
  - Current cladding materials (M5, Zirlo,…)
  - New cladding Materials (Optimized Zirlo, M-MDA)

- **Validation** of models in code (FUEL+/SCANAIR software, …)



NUCLEAR SAFETY APPLICATION

CIP Matrix

Test	Rod	Objective	Completed in Na	Test in NSRR	Completed in CABRI
CIP0-1	UO2 Zirlo 70 GWd/t	Reference test in sodium loop			2001
CIP0-2	UO2 M5 75 GWd/t				2002
CIPQ	MOX Zr4 47 GWd/t	Loop qualification - Boiling crisis	X		2018
CIP1-2B	UO2 M5 77 GWd/t	UO2 - Boiling crisis	X	X	2022
CIP3-1R	UO2 Zirlo 75 GWd/t	Post failure events	X	X	
CIP4-1P	MOX M5 65 GWd/t	MOX - Boiling crisis		X	
CIP4-1PHP	MOX M5 65 GWd/t	Effect of filling pressure 90b vs 50b in other tests		X	
CIP4-2	MOX-SBR Zr4 60 GWd/t	Post failure events			
CIP3-3	UO2 Opt. Zirlo	New cladding material			
CIPX	UO2 M-MDA SR	New cladding material		X	
CIPY	UO2 doped Cr_2O_3	New fuel (PCI-remed)			
CIPZ	Optimized Zirlo with liner	New cladding material			

NETWORKING

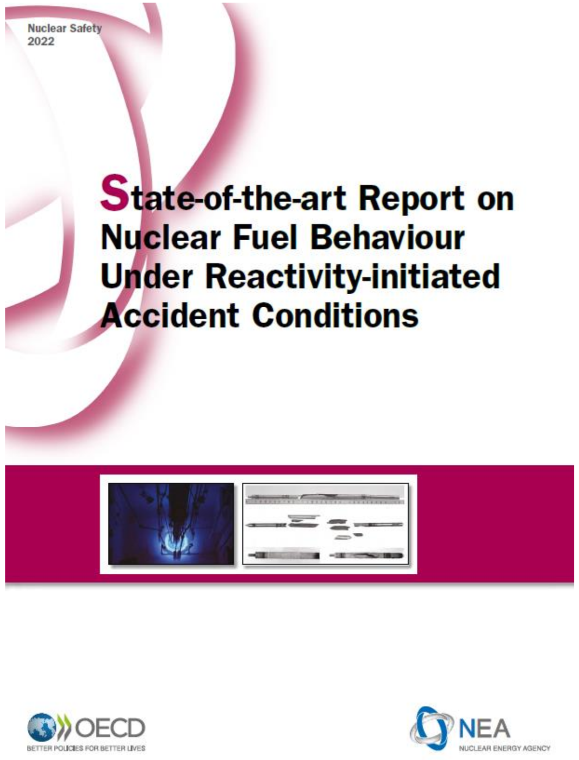
- **Stakeholders** with different roles in their countries: Operators, Safety authorities, TSO
- **Collaboration required** with industrial partners (EPRI, EDF, …) to provide irradiated material to be tested.
- **RIA activities** in the frame of WGFS

RIA benchmark	CIP Analytical Group (CIP partners)

- **R&D complementary programs** involving some of partners : FGD (IRSN/JAEA), PROMETRA (IRSN/CEA/EDF)

VALUES

- **Several Publications** to share results with scientific community
- **Formation of young researchers** throughout the project: many PhD thesis, Post-doctoral positions in fuel safety connected to RIA issues
- **CIP Partners are main contributors of the SOAR RIA** Working Group on Fuel Safety (WGFS) / NEA
- CIP will provide **experimental data for code validation**



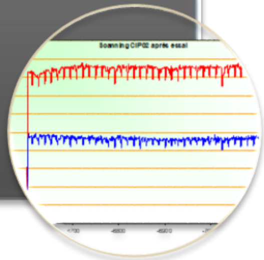
FEEDBACK ON MAIN CHALLENGES RELATED TO THE PROJECT DEVELOPMENT

- To maintain the CABRI experimental platform at a high level of operability for the whole duration of the project with a high constraint of irradiated material
- Difficulties to cover financial aspects in case of technical issues on the CABRI reactor

Experimental Platform

- **To maintain**, throughout the project, the **skills** at a high level of competence on the experimental devices, including instrumentation and advanced experimental techniques on irradiated materials.

Experimental analysis



- To ensure that the **objectives of the test remain** as high interest for partners from the beginning of the project (Safety authorities, TSO, operator – different countries)

Safety analysis

CABRI is licensed by IAEA as Capacity Building: formation of young researchers, PhD Thesis, Post-doctoral.

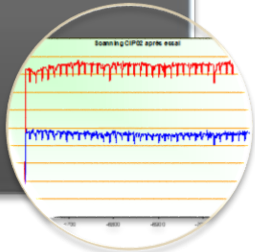
INSGHTS ON FUTURE R&D NEEDS AND TRENDS

- Keep opportunity of completing **in-pile special tests for improving knowledge on fuel safety studies.**

FIDES-II,…

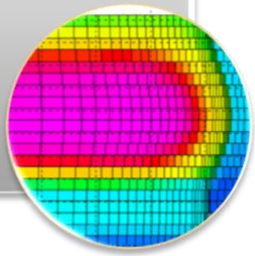
- Need of **qualification of new advanced cladding and fuel materials** (ATF, …), in particular the behavior in DBA-RIA transient

Materials



- **Simulation** implies models that requires more data to enable validation of numerical tools.

Validation of codes



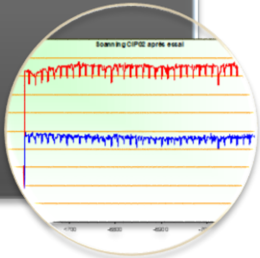
CONCLUSIONS

- Safety topic complex to address
- Technical complexity of the refurbishment
- Budget challenges to cover all technical hazards
- Integral tests : irradiated conditions, Pressurized Water Loop
- Several experimental ways (instrumentation, hodoscope system, IRIS pre & post-test examinations)

Complex

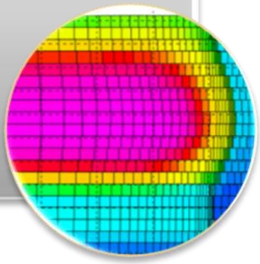
- <u>**Throughout the project**</u>
- Human capital investment
- Advanced relevant skills
- Discussions with partners to define the test matrix
- Formation of young researchers throughout the project

Skills, Networking



- Improvement of the safety approaches in RIA conditions
- Improvement of the understanding and the modelling of RIA
- Development of specific software

Use for safety analysis



Thank you for your attention

For more information on IRSN website :
https://www.irsn.fr/EN/Research/Research-organisation/Research-programmes/CABRI-International-program/Pages/CABRI-CIP-program.aspx

Session 2

Joint Projects for Safety in Design, Learnings and Perspectives

► Examples of Primary and Secondary Side Circuit Thermal-Hydraulics, Passive Safety Systems Projects

ATLAS

Dr Kyoung-Ho KANG

Principal Researcher, Director, Korea Atomic Energy Research Institute (KAERI), Korea

Dr Kyoung-Ho KANG is a principal researcher at KAERI since 1995. His major research interests include thermal hydraulic integral effect testing and system-scale safety analysis for pressurised water reactors. He was also involved in the experimental programme for the verification of new safety systems implemented on advanced light water reactors such as the APR1 400, APR+ and iPOWER. Since 2014 he has played a leading role in co-ordinating the NEA ATLAS international joint project with the aim of enhancing safety analysis technology and resolving safety issues. Dr Kang is currently working as director of the KAERI innovative system safety research division at KAERI and is fully responsible for thermal-hydraulic safety R&D.

Examples of Primary and Secondary Circuit Thermal-Hydraulics, Passive Safety Systems Projects

ATLAS

10 January, 2023

Kyoung-Ho KANG (khkang@kaeri.re.kr), Director
Innovative System Safety Research Division

KAERI 한국원자력연구원 Korea Atomic Energy Research Institute

Contents

Overview of ATLAS Project (1)

❖ OECD/NEA ATLAS International Joint Project

- Operation of OECD/NEA ATLAS international joint project(2014.04. ~ present; now 3rd project is on-going)
  - With an aim of safety evaluation of LWR and validation & improvement of safety analysis codes
- Overview of 3rd OECD/NEA ATLAS international joint project
  - Period: 2021.01.01.~2024.12.31.
  - Participants: 19 organizations from 11 countries
  - Contribute to resolution of safety issues and advancement of safety analysis technology

: Pre-test Analysis
: Post-test Analysis
: Test
: PRG/MB Meeting

Tests	2021	2022	2023	2024	# of tests
C1-RCS-CTMT Integrated IET					
(C1.1) SLB with ATLAS-CUBE					1
(C1.2) IBLOCA with ATLAS-CUBE					1
C2-Passive Safety Systems					
(C2.1) SBLOCA with PECCS					1
(C2.2) IBLOCA with PECCS					1
(C2.3) SLB with PAFS					1
C3-Natural Circulation					
(C3.1) Asymmetric Natural Circulation					1
C4-Design Extension Conditions					
(C4.1) SBLOCA under SBO condition					1
(C4.2) Total Loss of Heat Sink					1
C5-Open Item					
(C5.1) Counterpart Test of LSTF TR-LF-15					1
(C5.2) CUBE Characterization Test					1
Total	1 2	3 4	5 6	7 8	10

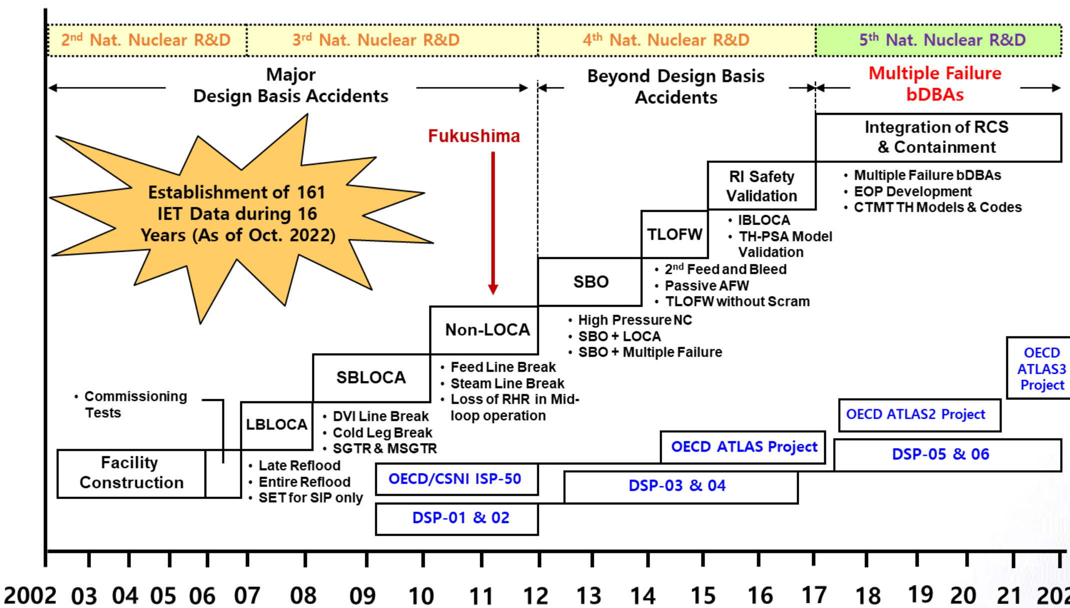
Overview of ATLAS Project (2)

KAERI

ATLAS

❖ ATLAS Integral Effect Test Facility

- Reference NPP: APR1400
- Geometric Scale: 1/288 V
  - 1/2 H, 1/144 A → 1/288 V
- Loop Configuration:
  - 2 Hot Legs & 4 Cold Legs
  - Integrated annular downcomer
- Operating Conditions:
  - Full Pressure/Temperature
  - Max. 10% of Scaled Power
- Measurements: > 1,600
- Safety injection systems:
  - DVI and CLI

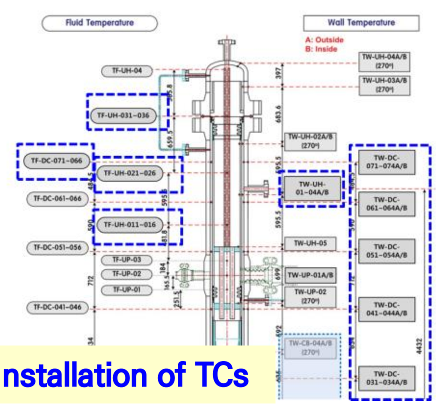


Facilities and Competences Development (1)

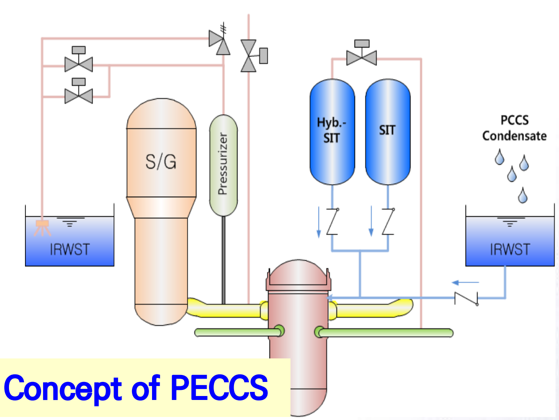
❖ ATLAS Upgrade (1)

- ATLAS project has helped maintain and upgrade the ATLAS facility including instrumentation.
  - Manufacturing of a new heater rod bundle and RPV (‘17)
    - The TC locations were shuffled and capability to capture the CET behavior was improved.
    - A profile TC was installed inside the RPV upper head to observe 3D flow behavior.
  - Replacement of existing safety injection tanks (SITs) with Hybrid SITs (‘17)
    - Passive ECCS concept can be investigated by utilizing Hybrid SITs.
  - Revamping steam generators (‘21)
    - U-tube bundles were replaced with new ones with additional fluid temperature measurement.

New heater rod bundle



Installation of TCs



Concept of PECCS

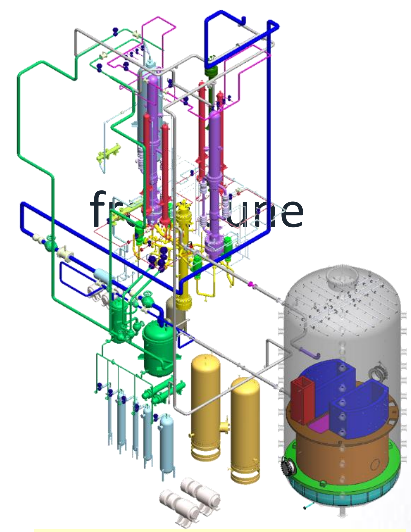
Facilities and Competences Development (2)

❖ ATLAS Upgrade (2)

- ATLAS project has sustained development of highly qualified competences of experiment.
  - Reactor coolant system (RCS)-containment integrated IET
  - Multi-dimensional thermal-hydraulic behaviors inside RPV, SG, containment, and various passive safety systems such as PAFS and PECCS

❖ Collaboration with University

- One doctorate student stayed at KAERI from June 2019 to October 2019.
  - Ms. Lorduy Alos Maria (Polytechnic Univ. of Valencia, Spain)
- Work scope under framework of PhD thesis
  - Scaling method between test facilities
  - Evaluation of code predictive capability based on test data
- KAERI is open to collaborate with universities under the framework of ATLAS project.



RCS-containment IET

Nuclear Safety Applications (1)

❖ Operation of Benchmark Activities

- ATLAS project has operated benchmark activities to allow participants to gain more insights into code capabilities through sharing relevant information and experiences.
  - Demonstration of code/model applicability to simulation of transient and relevant phenomena
  - Identification of the modelling options and uncertain parameters which have significant impact on code prediction of main phenomena

- Test items for benchmark activities
  - ATLAS-1: A5.1 (1% cold leg break SBLOCA: Counterpart test of LSTF SB-CL-32)
    - 15 participants adopting 8 different codes
  - ATLAS-2: B5.1 (1" RPV top break LOCA: Counterpart test of LSTF SB-PV-07)
    - 11 participants adopting 8 different codes
  - ATLAS-3: C2.3 (Steam line break with operation of PAFS)
    - 9 participants adopting 5 different codes

- Recommendations for future benchmark exercise
  - During the preparation of benchmark activity, there should be a compilation of the list of key parameters and identification of potentially significant parameters.
    - Define clearly all requested parameters in advance
    - The OA should provide a list of physical phenomena significant for the designated test
  - Combined uncertainty and sensitivity analyses are recommended for evaluation of code performance

Nuclear Safety Applications (2)

❖ Application of ATLAS Test Data

- ATLAS data have been used to assess the design of NPP under challenging accident scenarios including DBA and DEC and also to assess the new design features like the passive safety systems.
  - Contribute to improvement of analytical applicability to get further steps in V&V of system safety analysis codes and methods (BEPU, scaling etc.)
- Especially in Korea, ATLAS data have been used to improve the phenomena-based SPACE model and the scale-up applicability of SPACE code.
  - CCFL, loop seal clearing, critical flow, liquid off-take, NC effect, etc.
  - Compare other scale IET facilities
- ATLAS data have been used in the system code sensitivity crosswalk led by US-NRC and EDF under the framework of ATLAS-3 project.
  - Analyze and compare the sensitivities across several system codes as opposed to the traditional system code sensitivity study that aims to find the sensitivities of a single code
  - Comparison of figure of merit (FOM) predictions over time

Networking

KAERI

ATLAS

❖ Participants of OECD/NEA ATLAS Project

- Various stakeholders have participated in the ATLAS project.
  - Regulators: NRC (USA), CSN (Spain), FANR (UAE)
  - TSO: BelV (Belgium), GRS (Germany), KINS (Korea)
  - Research Institutes: CEA (France), PSI (Switzerland), UJV (Czech), NPIC (China), KAERI (Korea)
  - Industry: EDF (France), CNPRI (China), Tractebel (Belgium), KHNP (Korea), KEPCO E&C (Korea), KEPCO NF (Korea), DOOSAN (Korea)
- Modality of establishment of a common basis on safety issues
  - For each test item, OA performed a pre-test analysis with a system analysis code to define initial & boundary conditions of test and to confirm major thermal-hydraulic responses of interests.
  - Very active pre- and post-analyses have been done by the project participants with their analysis codes.
  - Test specifications for each test item were finally settled by lively discussion between participants.

Values

❖ Dissemination of Major Outcomes

- ATLAS data have been transferred to the NEA Data Bank for potential distribution to NEA members.
  - Final integration reports including benchmark activity report are available at the NEA Data Bank.
- Joint workshops between ATLAS and PKL/ETHARINUS projects have been organized to share experiences and practices among both project participants.
  - 1st workshop: Lucca, Italy (13-15 April 2016)
  - 2nd workshop: Barcelona, Spain (7-9 November 2018)
  - 3rd workshop: Barcelona, Spain (7-9 November 2023)
- "OECD/NEA international programs" was organized as a special session of NUTHOS-11 conference ('16): 12 papers were presented.
- Journal papers (8 papers) and many conference papers (11 papers) have been published by OA and participants under the framework of ATLAS project.

Feedback on Main Challenges related to the Project Development (1)

❖ Main Challenges in Establishing New Project

- Decline of needs for developing a new/advanced large PWR
  - The trend has been changing from a large PWR to a SMR.
    - Key phenomena in the SMR still need to be investigated to validate the system analysis codes.
    - Experimental investigation for the SMR-specific safety systems can be strongly related to the knowledge from the PWR research: Natural convection, boiling, condensation, and performance of passive safety systems
- System analysis codes have reached an advanced state of development so that nowadays, they are not being as actively developed as they were before.
  - Investigation of multi-scale and multi-physics phenomena with the high-precision data and analysis will be essential to enhancing the technology of reactor safety analysis.
- Identification of test topics from a nuclear safety enhancement point of view
  - Essential to launching a new joint research project
  - Feedback from potential participants are very important to establish research priorities.

Feedback on Main Challenges related to the Project Development (2)

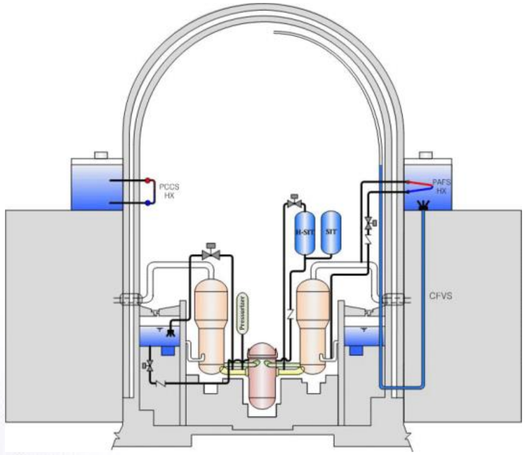
❖ Main Challenges: Project Initiation & Development

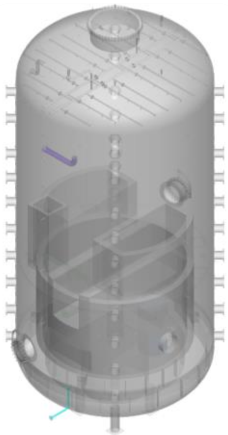
- Delay or cancellation of participation in the international cooperation project can occur as a result of political issues.
- Earlier set-up of the budget and project agreement among partners could make project launching more efficient.
  - Declaration in time from promising participants will be helpful to set-up the budget and agreement.
- The chance to share and discuss program scope should be provided prior to initiating a project.
  - Identification of experimental topics from a safety enhancement point of view

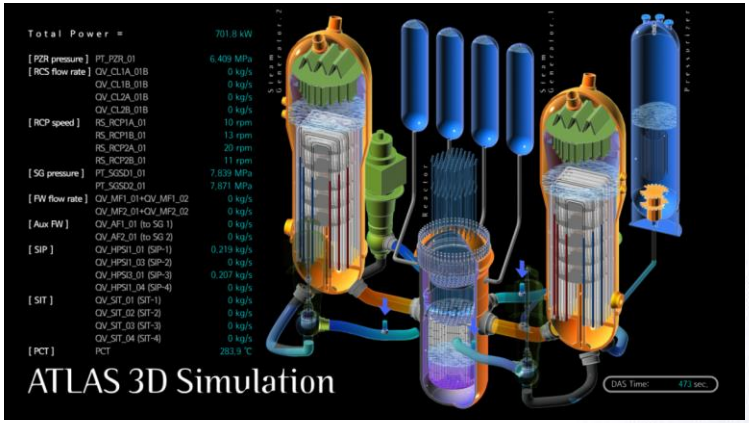
Insights on Future R&D Needs and Trends (1)

❖ Follow-up Phase of ATLAS Project

- KAERI has a plan to continue the ATLAS project in order to contribute to advancement of safety analysis technology and resolution of safety issues.
  - Further investigation of the thermal-hydraulic phenomena in the RCS-containment integrated IET
  - Effectiveness of operator's action against design extension conditions
  - Performance optimization of passive safety systems in PWR and SMR
    - Passive residual heat removal system; Passive ECCS
    - Passive containment cooling system





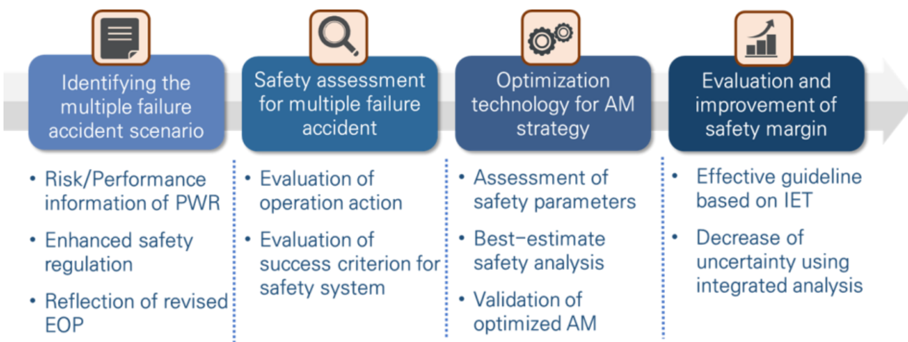


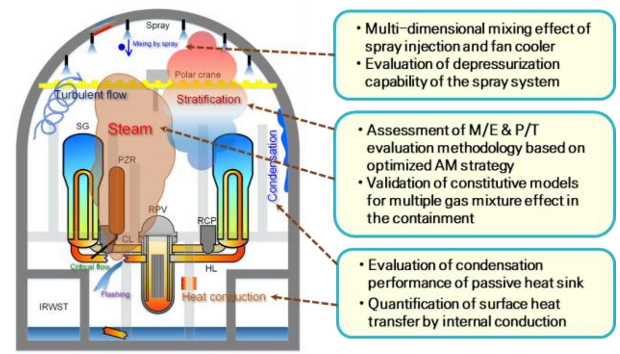
Insights on Future R&D Needs and Trends (2)

ATLAS

❖ Future Research Program utilizing the ATLAS Facility

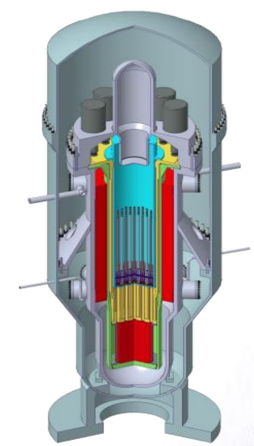
- Long-term domestic national R&D program: ‘22 ~ ‘29
  - Optimization technology for accident management (AM) strategy
  - Validation for performance of containment safety systems





❖ IET for Validation of Innovative SMR Safety

- Long-term domestic national R&D program: ‘23 ~ ’28
  - Construction of new IET facility
    - Commissioning test will be performed in 2027.



Conclusion

KAERI ATLAS

❖ Perspectives for Nuclear Safety Research

- Although the numerical solution technology of thermal-hydraulic system codes has matured, the uncertainty of the physical models is still large and needs to be improved.
  - Experiments *that can be applied to physical model development by involving code developers from experimental design* are important.
  - Development and V&V of multi-scale and multi-physics code system including uncertainty quantification are essential to enhance nuclear safety analysis technology.
- Exchange of information and experience in the field of SMR research would be valuable by organizing network among experts (experimental & analytical side)
  - Provide the best guideline for the design of an integral effect test facility simulating SMR, code qualification process, methodology development for advanced technologies of SMR.

Thank you for your attention

KAERI 한국원자력연구원
Korea Atomic Energy Research Institute

RBHT

Dr Stephen M. BAJOREK

Senior Technical Advisor for Thermal Hydraulics, Nuclear Regulatory Commission (NRC), United States

Dr Stephen M. BAJOREK is the Senior Technical Advisor for Thermal-Hydraulics at the US Nuclear Regulatory Commission (NRC) in the Office of Nuclear Regulatory Research, and has forty years' experience in the nuclear industry. He provides guidance for development of the TRACE state-of-the-art thermal-hydraulics code, advanced reactor analysis, and the NRC's thermal-hydraulic test programmes. He is currently leading the NRC's efforts to develop simulation capabilities for advanced non-light water reactors. Prior to joining the NRC staff, he was a member of the faculty at Kansas State University and has over 15 years of industrial experience with Westinghouse as a code developer and analyst. He has authored or co-authored over 200 publications in areas ranging from boiling and two-phase flow, reactor safety, natural convection, and boiling of multi-component fluids. Dr Bajorek received his PhD from Michigan State University, and MS and BS degrees in Mechanical Engineering from the University of Notre Dame.

NEA Joint Project on Rod Bundle Heat Transfer (RBHT)

Stephen M. Bajorek, Ph.D.
Senior Technical Advisor
Office of Nuclear Regulatory Research
United States Nuclear Regulatory Commission

2023 NEA Nuclear Safety Research Joint Projects Week
January 10, 2023

Introduction

- The RBHT joint project was a 3-year effort involving 20 organizations from 12 countries.
- The test facility is located at the Pennsylvania State University. It was designed primarily to produce detailed data to assist in code development and assessment. RBHT is heavily instrumented.
- The present joint project was a combined experimental / analytical study. The project conducted a series of coordinated reflood experiments and benchmark activities.
- Safety Benefit: Improved accuracy in simulation of large and small break LOCA. Supports power uprates.

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

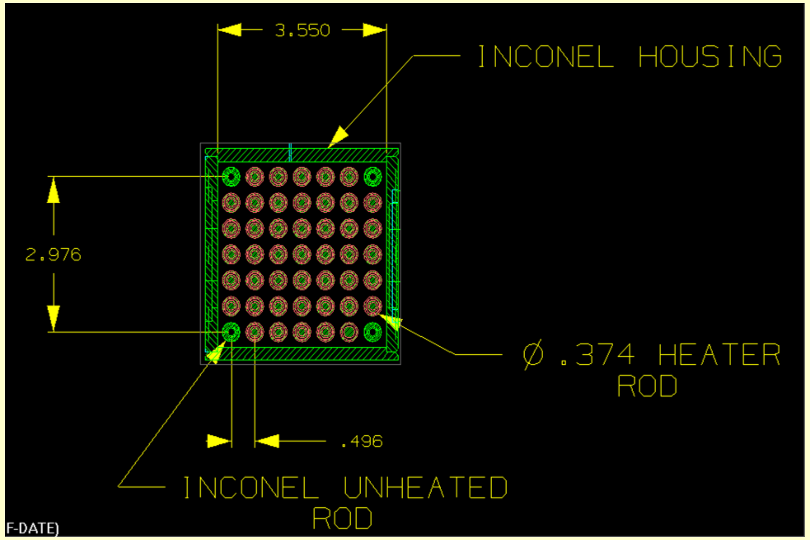
Project Member Organizations

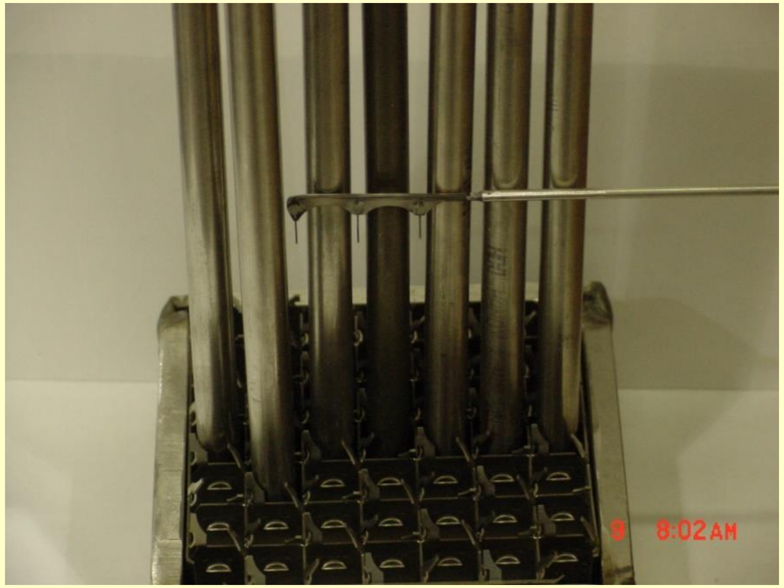
- The United States Nuclear Regulatory Commission (USNRC), USA
- Tractebel Engineering S.A., Belgium
- Bel V, Belgium
- UJV Rez, Czech Republic
- Teknologian tutkimuskeskus VTT Oy (VTT), Finland
- Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France
- Commissariat à l’Energie Atomique et aux énergies alternatives (CEA), France
- Electricité de France (EDF), France
- Framatome, France
- Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Germany
- Nuclear and Industrial Engineering (NINE), Italy
- Nuclear Regulation Authority (NRA), Japan
- Korea Atomic Energy Research Institute (KAERI), Korea
- Korea Institute of Nuclear Safety (KINS), Korea
- Korea Hydro and Nuclear Power – Central Research Institute (KHNP CRI), Korea
- KEPCO Nuclear Fuel (KEPCO NF), Korea
- Consejo de Seguridad Nuclear (CSN), Spain
- Swedish Radiation Safety Authority (SSM), Sweden
- Swiss Federal Nuclear Safety Inspectorate (ENSI), Switzerland
- The Paul Scherrer Institute (PSI), Switzerland

Project Schedule

- Initial Proposal: 2018
- Expert's Meeting: July 2019 at PSU. (In-Person)
- Test Series 1: 2019 – 2020 (testing & QLR prep)
- Workshop #1: October 2020 (test series 1 results, series 2 planning) (Virtual)
- Test Series 2: 2021 (testing & QLR prep)
- Workshop #2: March 2021 (test series 1 benchmark, distribution of test series 2 results) (Virtual)
- Workshop #3: November 2021 (test series 2 results) (Virtual)
- Workshop #4: May 2022 (test series 2 benchmark and finalization) (Virtual)
- Two Volume Final Report : November 2022

Bundle Cross-Section



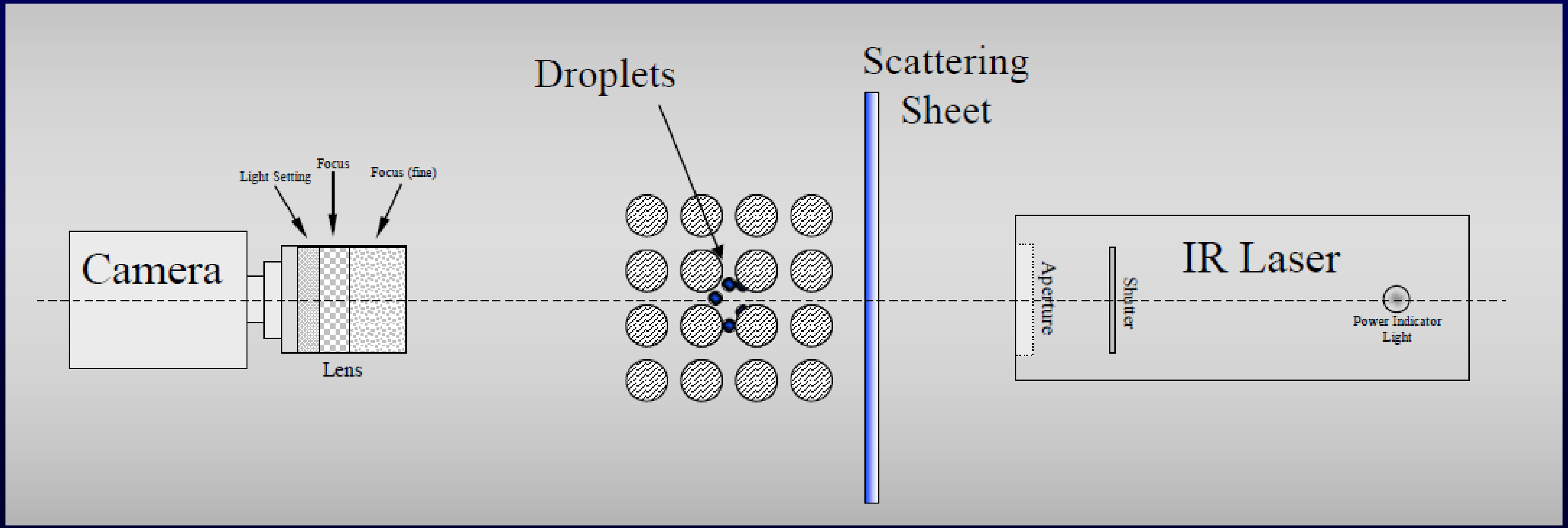


Instrumentation

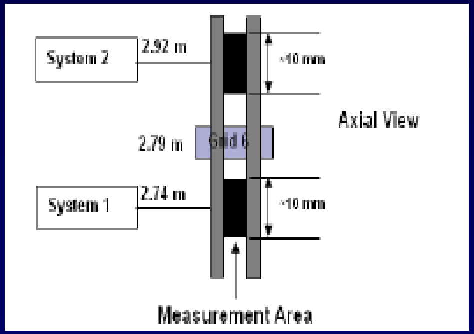
- (280) embedded heater rod thermocouples - ***high detail***
- (50) spacer grid strap and steam thermocouples - ***unique***
- (39) steam probe rake thermocouples - ***high detail***
- (~75) other miscellaneous thermocouples throughout system
- (21) fine span DP cells on flow housing - ***high detail***
- (6) pairs of quartz window openings, spanning grid locations
- Pressure measurement throughout system
- Carry-over tanks with temperature and level measurements
- Flow meters on inlet and exhaust lines
- HP (512) channel data acquisition system, up to 20Hz data rate
- (2) Laser illuminated, high speed droplet cameras ***- unique***

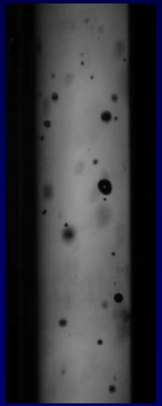
U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Spacer Grid Droplet Breakup



Rapid measurement of drop size and velocity enables improved models and correlations . . .





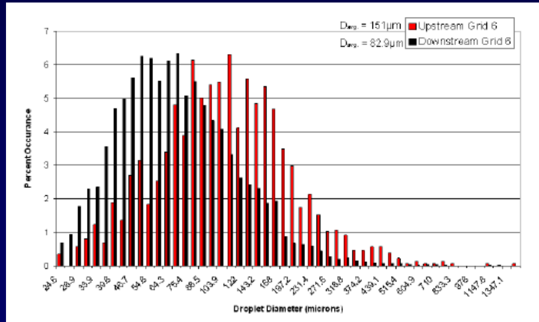


Figure 3-16: Droplet Size Distribution across Grid 6 for 2.54 cm/s (1 in/s) Reflood.

$$\frac{d_{32}}{d_0} = \left[1 + 0.1803\varepsilon We_0^{0.558}\right]^{-1}$$

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Test Series / Benchmark Studies

- Two test series with Two benchmark studies

- "Open" Tests
  - Wide range of tests considered. Provide basic assessment.
  - Data provided to all participants as it became available.
  - Benchmark 1 simulations for wide range of conditions.

- "Semi-Blind" Tests
  - Test conditions similar to Open Tests, but with additional complexity.
  - Only initial and boundary conditions released to participants.
  - Benchmark 2 simulations included uncertainty methods.

Products

Products of the Project:

- Volume 1: Facility Description, Open Tests and Simulations
- Volume 2: Blind Tests and Simulations, Uncertainty Results
- Quick Look Reports
- Experimental Data
- Data on spacer grid phenomena.

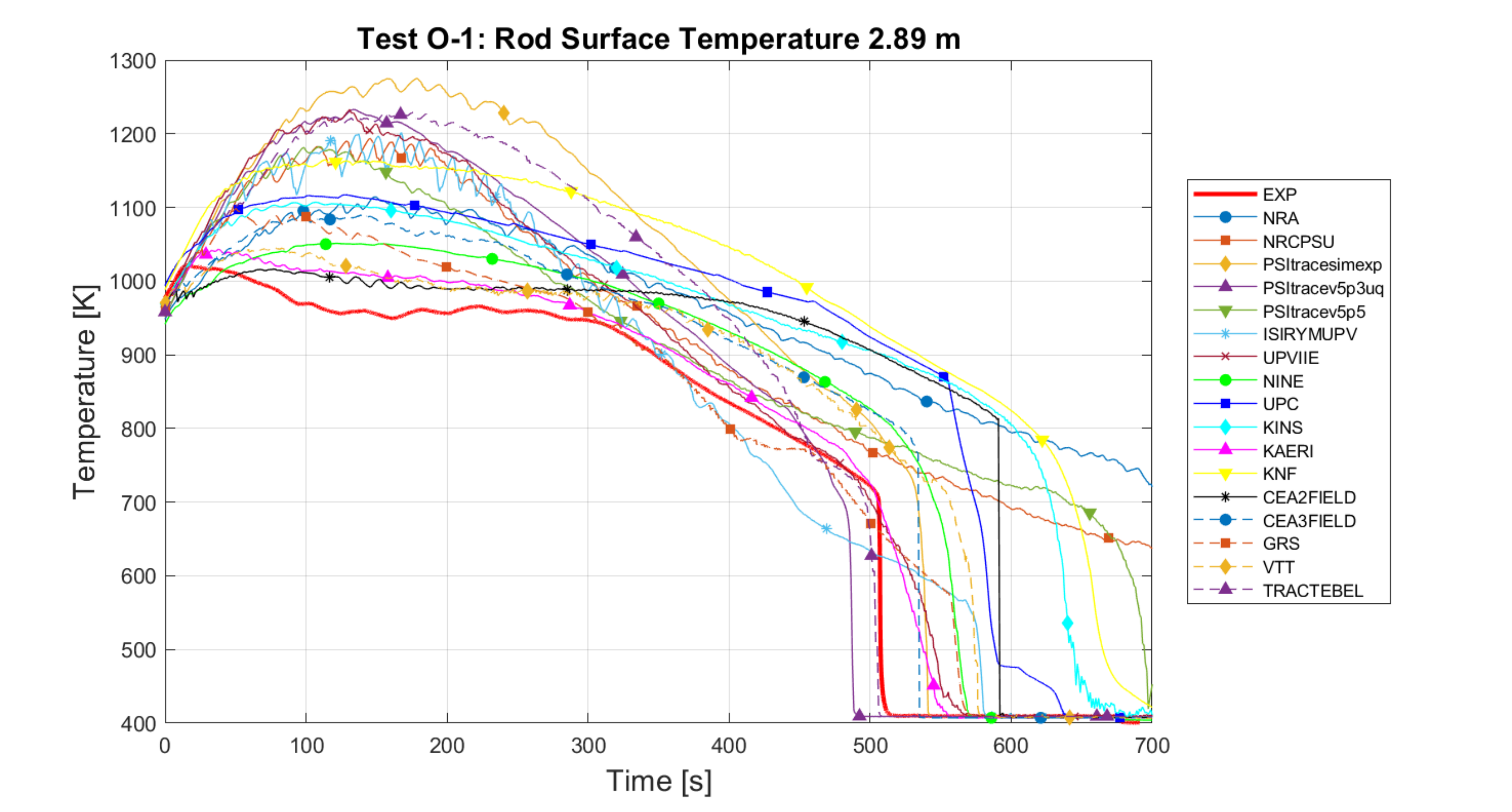
Code Assessment
Correlation Development

Benchmarks

- Identified several potential deficiencies in thermal-hydraulic codes, which may affect:
  - Large Break LOCA prediction of PCT
  - Thermal-Hydraulic predictions for low flow rates (i.e. SMRs and Passive Cooling Systems)
- Allowed participants to improve code uncertainty methodologies (important to simulation of LOCA and power uprates).

Simulation Findings II

Overprediction of Peak Temperatures:



Conclusions / Findings

- Reflood thermal-hydraulics remains a challenge. Modeling some phenomena such as entrainment and spacer grid effects are difficult.

- The RBHT project has provided new and unique data for code assessment and model development.

- Benchmark studies identified areas where analysis codes and BEPU can be improved.

- Safety benefits include more accurate thermal-hydraulic codes and a better understanding of accident phenomena.

Challenge Question #2

- **Challenge 2 –** How safety research joint projects could better serve development and maintenance of key competences and research infrastructures, including education of new talents for the future of the nuclear energy sector?

(1) Joint projects help preserve the research infrastructure by spreading the cost to several organizations. No single organization must provide all of the resources.

(2) Education and new talents are enhanced by providing research opportunities to younger staff members.

(3) Innovation is important for the future. Solving "old" problems with new instrumentation or new computational methods is something joint projects can support (and possibly require).

Challenge Question #3

- **Challenge 3 –** What could be the new approaches and arguments for facilitating decisions from public and private stakeholders of the nuclear energy sector to fund the future safety research joint projects for the benefit of nuclear innovation and safety in general?

There is a large variety of stakeholders in the nuclear sector, and what is important to a regulator may or may not be important to vendors/utilities, or of interest to academic community.

Consider the formation of an international advisory board to suggest research needs and joint projects. Board members should be independent and represent a range of stakeholders.


Questions?

Panel SESSION 2: Joint Projects for Safety in Design, Learnings and Perspectives

Dr-Ing Th. Walter TROMM

Head of NUSAFE Programme, Karlsruhe Institute of Technology (KIT), Germany

Dr François BARRÉ

Deputy Director of Safety Research, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France

Dr Kyoung-Ho KANG

Principal Researcher, Director, Korea Atomic Energy Research Institute (KAERI), Korea

Dr Stephen M. BAJOREK

Senior Technical Advisor for Thermal Hydraulics, Nuclear Regulatory Commission (NRC), United States

Mr Jonathan WRIGHT

Head of the Fuel Materials Centre of Excellence, Westinghouse Electric Company, Sweden

Dr Ki Yong CHOI

Senior Vice-President of Intelligent Nuclear Safety Research Department, Korea Atomic Energy Research Institute (KAERI), Korea

Jonathan WRIGHT

Head of the Fuel Materials Centre of Excellence, Westinghouse Electric Company, Sweden

Mr Jonathan WRIGHT is a Fellow Engineer and since 2020 head of the Westinghouse Fuel Materials Centre of Excellence. His current work involves co-ordinating global R&D and membership of international programmes. He has worked with nuclear fuel development for over 20 years in a variety of roles including technical leadership, strategy development and departmental management. Prior to joining Westinghouse in 2005 he helped develop MOX fuel at BNFL and was for three years a secondee at the Halden Reactor Project. He continued to work on advanced fuel pellets at Westinghouse, BWR cladding development and more recently ATF coated cladding plus Triso fuel for micro reactors. Mr Wright, a dual UK and Swedish citizen, holds a Masters and undergraduate degree in Chemistry from Oxford University and an MBA from Warwick University.

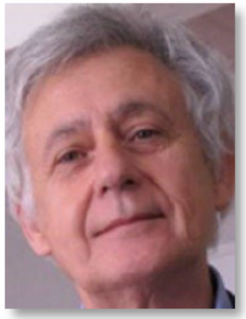
Dr Ki Yong CHOI

Senior Vice-President of Intelligent Nuclear Safety Research Department, Korea Atomic Energy Research Institute (KAERI), Korea

Dr Ki Yong CHOI has been working as a principal researcher at Korea Atomic Energy Research Institute (KAERI) since 2000. His major research interests include experimental and analytical works on thermal-hydraulic phenomena and model development related to the advanced light water reactors such as APR1 400, APR+ and SMART. He was also involved in the development of system-scale safety analysis code SPACE and modelling a heat transfer package. He has expertise in the design, operation, control, and scaling analysis of thermal-hydraulic experimental facilities. Code uncertainty analysis is also one of his research interests. He served as director of nuclear thermal-hydraulic safety and severe accident research division in KAERI until 2019. His responsibilities included managing more than 30 domestic and international projects. During this time, he was engaged in many international co-operation projects. In particular, he played a leading role in co-ordinating the 50th NEA international standard problem (ISP-50) and NEA joint projects. He also served as a Working Group on Analysis and Management of Accidents bureau member from 2017 to 2020, where he reviewed and provided expert opinions on the ongoing projects and newly proposed R&D activities. He is currently serving as Dean of the UST-KAERI school which he joined as a faculty member in 2012. He also served as Executive Editor of the journal *Nuclear Engineering and Technology* (2015-2021) and is now serving as associated editor of the Board of Nuclear Energy section of *Frontiers in Energy Research* since 2020. He is a Chair-elect of the Thermal-Hydraulic Division (THD) of the Korean Nuclear Society. Dr Choi is currently working as a senior vice-president of intelligent nuclear safety research department of KAERI and is fully responsible for the nuclear safety R&D. The operation of the research reactors, including HANARO and international research reactors, are also his responsibility.

Dr François BARRÉ

Deputy Director of Safety Research, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France



Since obtaining a PhD in neutronics, **Dr Francois Barré** has spent his career working in the area of nuclear reactors. He has been Deputy Director of Safety Research at France's Institut de Radioprotection et de Sûreté Nucléaire (IRSN) since 2011.

Dr Barré has participated in various research activities in the field of experimental thermal-hydraulics with the Commissariat à l'énergie atomique et aux énergies alternatives (CEA) for 12 years, and with the Japan Atomic Energy Agency (JAEA). He was responsible for the development of the CATHARE code, which was sponsored by Électricité de France (EDF), Framatome, CEA and IRSN and is widely used in several countries for safety analysis.

Within IRSN, he was the Head of a research department involved in severe accidents, nuclear fuels and thermal-hydraulics. As Deputy Director for Safety Research, he participates in the definition of R&D programmes in the field of nuclear safety and fosters international collaboration with most of the countries involved in nuclear energy. He is also actively involved in the European Sustainable Nuclear Energy Technology Platform (SNETP) and in the European Union Framework Programmes for Research and Technological Development.

He has collaborated closely for several years with the NEA; he was Co-chair of the Accident Management Working Group and is currently involved in the Committee on the Safety of Nuclear Installations (CSNI), in particular as a member of the CSNI Programme Review Group, as well in the FIDES Governing Board and in several Joint Projects.

NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK

Success Stories and Opportunities for Future Developments

9-13 January 2023

NEA NUCLEAR ENERGY AGENCY

Day 3 – Wednesday, 11 January 2023

Session 3: Joint Projects for Safety in Operation, Learnings and Perspectives

Moderator: Alex VIKTOROV, Canadian Nuclear Safety Commission (CNSC), Canada, Director-General, Directorate of Power Reactor Regulation

Introduction 13:00-13:10
- **Markus BEILMANN**, NEA/SAF, Nuclear Safety Specialist
- **Alex VIKTOROV**

13:10-14:00 ▸ **Examples of Fire Research Projects**

*FIRE-DB, **Marina RÖWEKAMP**, Senior Expert, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), Germany*

*PRISME, **Sylvain SUARD**, Head of Fire Experimentation Laboratory, (IRSN), France*

14:00-14:25 ▸ **Example of a Human Technology and Organisation Project**

*Halden HTO, **Andreas BYE**, Chief Scientist, Programme Manager of the OECD NEA Halden Human-Technology-Organisation (HTO) Project, Institute for Energy Technology (IFE), Norway*

14:25-14:50 ▸ **Example of a Material Ageing Project**

SMILE, **Lotta NYSTRAND**, Senior Technical Sales Manager, Studsvik, Sweden

14:50-15:00 **Break**

15:00-16:00 ▸ **Panel Discussion:** Perspectives for Nuclear Safety Research Programmes and Frameworks to Support Safe Operation of Nuclear Facilities

▸ **Panellists:** Marina RÖWEKAMP; Sylvain SUARD; Andreas BYE; Lotta NYSTRAND; Jean SMITH, Electric Power Research Institute (EPRI), US; Raoul AWAD, Federal Authority of Nuclear Regulation (FANR), UAE; Wei GAO, Nuclear Power Operations Research Institute (NPRI), China

Day 4 – Thursday, 12 January 2023

Session 4: Joint Projects for Safety in Accidental Situations, Learnings and Perspectives

***Moderator:** Hideo NAKAMURA, Japan Atomic Energy Agency (JAEA), Japan, Technical Associate*

Introduction 13:00-13:10
- **Martina ADORNI**, NEA/SAF, Nuclear Safety Specialist
- **Hideo NAKAMURA**

13:10-14:00 ▸ **Examples of Containment Thermal-Hydraulics, Mitigation Systems and Hydrogen Risk Management Projects**

*THAI/THEMIS, **Sanjeev GUPTA**, Deputy General Manager, Head of Reactor Safety & Engineering, Becker Technologies, Germany*

*HYMERES/PANDA, **Domenico PALADINO**, Leader Experimental Thermal-Hydraulics group at the Paul Scherrer Institute, Switzerland*

14:00-14:25 ▸ **Example of an Accident Progression and Melt Coolability In-Vessel and Ex-Vessel Project**

*ROSAU, **Jeremy LICHT**, Nuclear Engineer, Principle Investigator for the ROSAU Project, Argonne National Laboratory, US*

14:25-14:50 ▸ **Example of a Source Term Project**

STEM/ESTER, **Christophe MARQUIE**, Deputy Head of the Experimental Department, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France

14:50-15:00 **Break**

15:00-16:00 ▸ **Panel Discussion:** Perspectives for Nuclear Safety Research Programmes and Frameworks to Enhance Management of Accidents

▸ **Panellists:** Sanjeev GUPTA; Domenico PALADINO; Jeremy LICHT; Christophe MARQUIE; Katharina STUMMEYER, Head of Division, Project Management Agency, Gesellschaft für Anlagen- und Reaktorsicherheit, (GRS), Germany; Won-Pil BAEK, Senior Research Fellow, Korea Atomic Energy Research Institute (KAERI), President of the Korean Nuclear Society, Korea

Day 5 – Friday, 13 January 2023

Session 5: Future Needs for International Co-operation in Nuclear Safety Research

Moderator: William D. MAGWOOD, IV, Director-General, Nuclear Energy Agency

Introduction 13:00-13:10
- Didier JACQUEMAIN, NEA/SAF, Senior Nuclear Safety Specialist
- William D. MAGWOOD, IV

13:10-13:30 ▸ ***Post-Fukushima Daiichi Co-operative Safety Research Projects and Opportunities for Future Research**, Toyoshi FUKETA, Advisor, Nuclear Regulation Authority (NRA), Japan*

13:30-13:50 ▸ ***Nuclear Innovation-2050: An NEA Initiative to Foster Innovations in the Nuclear Sector**, Fiona RAYMENT, OBE FREng, Chief Science and Technology Officer, National Nuclear Laboratory (NNL), the United Kingdom*

13:50-14:10 ▸ ***Addressing Future Research Prioritisation under the NEA Committee on the Safety of Nuclear Installations (CSNI) Auspices**, Vesselina RANGUELOVA, Deputy Head of the NEA Division of Nuclear Safety Technology and Regulation*

14:10-14:30 ▸ ***Better Addressing the Challenge of Joint Projects Data Preservation and Dissemination**, Didier JACQUEMAIN*

14:20-14:35 **Break**

14:35-14:50 ▸ **Brief summary of the key outcomes of workshop sessions,** Didier JACQUEMAIN

14:50-16:00 ▸ **Concluding panel discussion**

- *What mechanisms to establish priorities for future international co-operation in nuclear safety research? Which frameworks to address future safety research?*
- **Panellists:** William D. MAGWOOD, IV; Jess GEHIN, Associate Laboratory Director, Nuclear Science and Technology, Idaho National Laboratory, United States; Fiona RAYMENT; Jean-Christophe NIEL; Toyoshi FUKETA; Aline DES CLOIZEAUX, Director, Division of Nuclear Power, Department of Nuclear Energy, International Atomic Energy Agency (IAEA); Roger GARBIL, Head of the Fission Section, Euratom Research Unit, Directorate General for Research and Innovation, European Commission

NEA NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK:

Success Stories and Opportunities for Future Developments

9-13 January 2023

Thank you for your participation today and see you all tomorrow!

Questions, feedback and suggestions link available in the registration confirmation email

Event public page: Nuclear Energy Agency (NEA) - NEA Nuclear Safety Research Joint Projects Week: Success Stories and Opportunities for Future Developments (oecd-nea.org)