Wir schaffen Wissen – heute für morgen

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PSI's Contributions to the International Nuclear Safety Research from the Past to the Future

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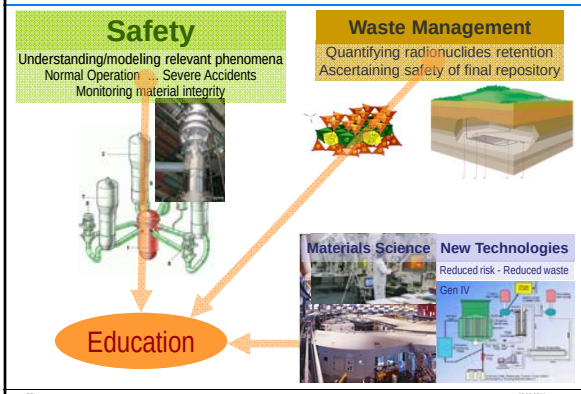
Introduction

PSI is a Swiss national lab (part of the ETH domain) with the following research domains:

- Science of matter and materials
- Energy and environment
- Life sciences
- operates large user facilities (SLS, SINQ, μSR, *SwissFEL*)

NES mission: Maintain Nuclear Competence



Role of international research

Research in the framework of international collaborations helps to increase the impact

- ~90 agreements with international organizations currently in place

International cooperation allows for establishing / maintaining large-scale experimental facilities, typical for nuclear safety related research

International research collaborations help to establish a common basis for the understanding of safety issues

PSI/NES generates experimental data as host for international projects and also participates in international projects

Examples of current international nuclear research

The following selected examples span the whole spectrum of research opportunities in an international framework

Project	facility	Topic
HYMERES	PANDA	Containment TH and hydrogen research
DR field experiment	Mont Terri	Diffusion experiments
Int'l HRA Empirical Study	-	simulator studies to assess HRA methods
STARS	OECD ROSA / PKL	TRACE validation
Halden LOCA	Halden	high-burnup fuel behaviour
STIP	MEGAPIE	SINQ Target Irradiation Program

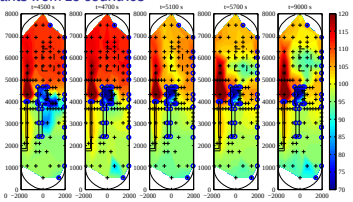
Containment TH & hydrogen research at PANDA

PANDA is a PSI experimental facility which contributes to:

- Gen. III reactor design qualification and licensing
- Gen. II/III safety system response
- Assessment/validation of advanced LP/CFD containment analysis tools

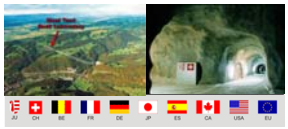
OECD/NEA HYMERES (Hydrogen Mitigation Experiments for Reactor Safety) project (2013-2016) has participants from 13 countries

Containment cooler

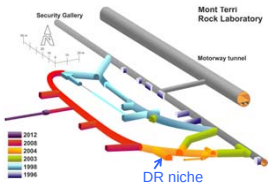


Example: gas temperature maps during a OECD PANDA cooler test
effect of cooler on evolution of hydrogen concentration in the containment

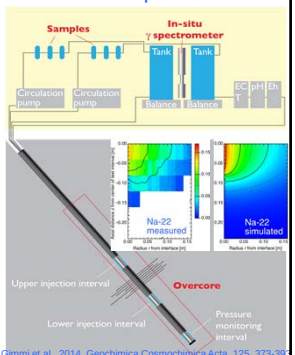
Waste management: Mont Terri Project



Mont Terri underground rock laboratory
Funded by 15 organizations from 8 countries



DR field experiment



Gimmi et al., 2014, Geochimica Cosmochimica Acta, 125, 373-385

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Using dedicated simulator studies to assess HRA methods

Int'l HRA Empirical Study
(NUREG-2127, HPR-373, NUREG/IA-0216)

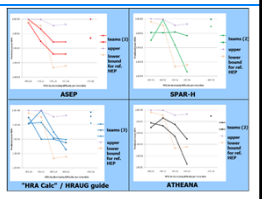
- SGTR (2 scenarios), LOFW (2 scenarios)
- 13 actions (HFEs)
- 14 licensed crews
- method vs. reference data. Could not address inter-analyst method reliability (consistency)

U.S. HRA Empirical Study (NUREG-2156)

- 3 scenarios: SGTR, LOFW+induc. SGTR, Loss of CCW and Seal LOCA
- 4 (+1) actions (HFEs)
- 4 licensed crews
- 2-3 analysis teams per method * 4 methods

- *Int'l study data collected in Halden*
- *U.S. data collected at US NPP by plant & Halden staff*
- *Data analysis from operational, human factors, PRA, and HRA perspectives a major part of the effort*

An effort to set up an international study on quantitative uses of simulator data in support of HRA (analyses) is under way.



Probabilities are the output of interest but analyzing the consistency of rationale/ findings underlying them is essential.

Study steering/assessment group
- USNRC +Sandia+INEL
- OECD Halden
- PSI (participation supported by ENSI)
- EPRI
- EDF (steering only)

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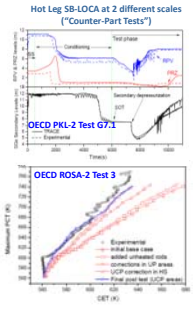
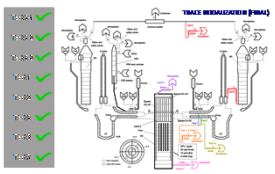
STARS: Using data from OECD projects ROSA and PKL

Validation of US-NRC TRACE Code
using OECD ROSA-1/2 and OECD PKL-1/2/3 Experiments

Hot Leg SB-LOCA at 2 different scales ("Counter-Part Tests")



Code-specific best-practice nodalization schemes validated over different scales & phenomena



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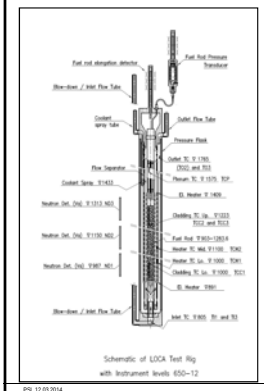
Design support for Halden LOCA experiments



- Experiments address behaviour of high-burnup fuel during LOCA
- PSI/NES helps designing the LOCA experiments using Swiss fuel samples since the beginning
- IFA-650.12 was designed to keep cladding intact despite ballooning;
  - sustained the LOCA-transient, but failed during cooling down
- IFA-650.14 was also designed to not fail the cladding
- Experiment conducted October 2013,
  - NO FAILURE demonstrated by ZERO Activity Release

IFA-650.12: Test conditions and rod design

Fill-pressure, bar (RT)	20
Free volume, cc	2.3
Target temperature,	870
Burst temperature, °C	No burst

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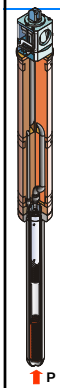
STIP MEGAPIE



SINQ Target Irradiation Program

- Main purposes:
  1) to provide necessary materials data for developing adv. spallation targets;
  2) to understand radiation, He and H effects in different structural materials;
  3) to study liquid metal effects on structural materials in intensive irradiation environments.
- More then 7000 samples from 60+ different materials of Fe-, Al-, Ti- Ni-, Mo-, W-alloys, ceramics (C/SiC, SiC/SiC…) were irradiated in first six experiments (STIP-1 to -6) up to 28 dpa / 2000 appm He (in steels) at temperatures up to ~800° C.
- Main STIP partners are from spallation, fusion and ADS communities in Europe, Asia and USA (e.g. CEA, FZJ, CIAE, IMP, JAEA, LANL, ORNL, UCSB)

Megawatt Pilot Experiment

- MEGAPIE is a joint initiative by six European research institutions (CEN-SCK (B), CEA (F), CNRS (F), ENEA (I), FZK (D), PSI (CH)), the EU, and JAEA (Japan), DOE (USA), and KAERI (Korea) to design, build, operate and explore a liquid PbBi (LBE) spallation target for 1 MW of beam power.
- The irradiation of the target was done at PSI in 2006.
- About 800 samples were extracted from the lower part of the target for post-irradiation examinations (PIE).
- Changes in mechanical properties and microstructure of structural materials, radionuclide inventory produced in PbBi and their precipitation behavior have been investigated In the PIE program

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Summary

International cooperation is necessary for establishing/maintaining large-scale experimental facilities relevant for nuclear safety research.

PSI contributes to the international research infrastructure for nuclear safety with large infrastructure, e.g.: PANDA, MEGAPIE, Hotlab.

Research in international framework helps to establish a common understanding of current safety issues.

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