


Strategic Re-Orientation and Selected Results of Nuclear Safety Research in Germany

26th Annual Regulatory Information Conference (RIC)
Current Activities in International Research (Part 2)

Frank-Peter Weiss
Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH


12 March 2014




Introduction (1)

Changed Political Framework Conditions in Germany (1)

- 13th Amendment of the **Atomic Energy Act** came into force on August 6th 2011:
 - granted lifetime extensions were revoked
 - licenses of the 7 oldest NPPs and of the Krümmel NPP expired
 - shutdown of the remaining 9 NPPs until 2022 after production of specifically determined amounts of electricity
- ⇒ re-orientation of **nuclear safety research in Germany**:
 - in line with national framework conditions, international obligations and interests



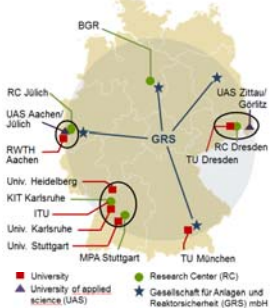
Strategic Re-Orientation and Selected Results of Nuclear Safety Research in Germany, RIC 2014 2



Introduction (2)

Alliance of Competence in Nuclear Technology

- Centered around research centers:
 - Karlsruhe
 - Jülich
 - Dresden-Rossendorf
 - GRS
- Aims:
 - provide programmatic and scientific advice to its partners and to the ministries funding the research
 - to agree on appropriate task sharing among the partners
- In spring 2013, evaluation report on nuclear safety research was published
 - ⇒ re-orientation along **6 strategic research areas**



Strategic Re-Orientation and Selected Results of Nuclear Safety Research in Germany, RIC 2014 3

GRS

Strategic Re-Orientation of Nuclear Safety Research (1)

1) **Technical and scientific research to support the remaining operation of German NPPs and research reactors**

- **Methods and computational tools for safety analyses** (e.g. thermo-mechanic behaviour of fuel rods, multi-physics codes, uncertainty- and sensitivity analyses, severe accident analysis, PSA)
- Improved methods for structural integrity assessment: e.g. studies in damage mechanism affecting the life-time of components
- Investigation of extreme natural hazards
- Human factor and organisation (e.g. human behaviour under accident conditions)
- Fast running tools for the use in emergency centres and support systems for decision making by authorities

2) Research for the safe decommission and dismantling of NPPs

Strategic Re-Orientation and Selected Results of Nuclear Safety Research in Germany; RIC 2014 4

GRS

Strategic Re-Orientation of Nuclear Safety Research (2)

3) Safe final disposal of radioactive waste

- Safety of final repositories (e.g. methods and tools for the demonstration of the safety case, geotechnical barriers)
- Studies on efficient partitioning / transmutation of actinides and on safety of transmuters (international collaboration)

4) Development of methods and tools for the safety assessment of advanced reactor concepts pursued internationally (Gen IV, SMR)

- Support of highest safety standards of nuclear plants developed and built abroad,
- International collaboration (e.g. OECD NEA, IAEA, etc.)

5) Scientific support of the development of international requirements and standards in nuclear safety

6) Safeguards

Strategic Re-Orientation and Selected Results of Nuclear Safety Research in Germany; RIC 2014 5

GRS

Selected Results (1)

GRS:
re-evaluation of acceptance criteria to assure core coolability in a LOCA

Strategic Re-Orientation and Selected Results of Nuclear Safety Research in Germany; RIC 2014 6

Re-evaluation of Acceptance Criteria for Core Coolability in a LOCA (1)

- Till now:
 - > equivalent cladding reacted due to oxidation < 17 %
 - ⇒ exclude fuel rod rupture
 - > H – up-take not considered
 - > entrance of steam through cladding burst opening leads to significantly higher up-take of H in the cladding
- Now:
 - new experiments at Halden and Studsvik show fuel dispersal out of the pin burst opening and the ruptured pin ⇒ coolant channel blockage
 - ANL and KIT experiments proved that **hydrogenation reduces ductility of cladding** ⇒ increases probability of rupture

New fuel rod phenomena require a re-evaluation of the acceptance criteria to assure core coolability in case of loss-of-coolant-accidents (LOCA)

Strategic Re-Orientation and Selected Results of Nuclear Safety Research in Germany; RIC 2014

Re-evaluation of Acceptance Criteria for Core Coolability in a LOCA (2)

Identification of cladding failure stress by means of FEM calculations

- existing MATPRO/FRAPCON correlations describe stress-strain behaviour as a function of oxygen (O) (not of hydrogen) → $\sigma_{yield}(O)$
- implementation of these correlations into the FEM code
- allows stress analyses of ring compression tests at oxidized and hydrogenated samples

- local failure stress $\sigma_{Burst}(\epsilon)$ corresponds to the calculated max. local equivalent stress at burst

Strategic Re-Orientation and Selected Results of Nuclear Safety Research in Germany; RIC 2014

Re-evaluation of Acceptance Criteria for Core Coolability in a LOCA (3)

- Analysis of > 100 RCTs with oxidized and hydrogenated ring samples reveals a multi-linear dependency of the ratio $\sigma_{Burst} / \sigma_{Yield}$ on both oxygen and hydrogen content
- Linear regression: $R = \frac{\sigma_{burst}}{\sigma_{yield}} = a_0 + (a_{ECR} + a_{H,ECR} c(H)) ECR + a_T T + a_H c(H)$
- Picture shows results
 - for ring samples made from ZIRLO
 - for different hydrogen and oxygen contents
 - shaded area covers 95 % of the RCTs
- R = 1 ⇒ zero-ductility materials limit state to be excluded

Strategic Re-Orientation and Selected Results of Nuclear Safety Research in Germany; RIC 2014

Re-evaluation of Acceptance Criteria for Core Coolability in a LOCA (4)

- New acceptance criterion for ECR, taking into account hydriding, results from the zero ductility limit reached at $R = 1$:

$$ECR_{R=1} = \frac{1 - a_0 - a_T T_{RCT} - a_H c(H)}{a_{ECR} + a_{H,ECR} c(H)}$$

- Ongoing work:** Experimental investigations at the QUENCH-LOCA test facility to measure the oxidation (ECR) and the hydrogenation ($c(H)$) during LOCA

Strategic Re-Oriented and Selected Results of Nuclear Safety Research in Germany, RIC 2014 10

Selected Results (2)

Research Center Dresden-Rossendorf, Univ. of Appl. Sciences Zittau:
 impact of chemical effects on the core coolability during LOCA at sump re-circulation

Thanks to Holger Kryk (Dresden) and Wolfgang Kästner (Zittau)!

Strategic Re-Oriented and Selected Results of Nuclear Safety Research in Germany, RIC 2014 11

Core Coolability During LOCA at Sump Re-Circulation (1)


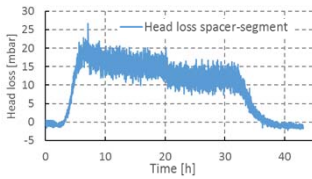
- The reliability of core cooling in case of a LOCA with insulation fibers clogging the sump screens is one of the generic issues, which has been discussed since the Barsebäck event in 1992.
- Chemical effects** (due to erosion, corrosion and dissolution products generated from zinc coated structures in contact with borated water) might affect core cooling.

Strategic Re-Oriented and Selected Results of Nuclear Safety Research in Germany, RIC 2014 12

CRS

Core Coolability During LOCA at Sump Re-Circulation (5)

- Experiments show differential pressure buildup at spacer due to Zinc-Borat deposition



Zinc-Borat deposition at the end of the test

Further experiments needed to clarify:

- influence of the deposits on heat transfer
- influence of the combined effect of Zinc-Borat deposition and additional deposition of dust and / or fibers of insulation material.

⇒ Safety assessment has to consider these phenomena

Strategic Re-Orientations and Selected Results of Nuclear Safety Research in Germany, RIC 2014 16

CRS

Summary

- The phase out of nuclear energy in Germany (till 2022) lead to a re-orientation of the nuclear safety research. Focus will be set on
 - safety research that supports the remaining operation of the German reactors,
 - safety of final disposal of highly radioactive waste,
 - participation in international research on advanced nuclear technologies (e.g. Gen IV, SMR, P&T)
- German nuclear safety research community needs to maintain the international integration.

Strategic Re-Orientations and Selected Results of Nuclear Safety Research in Germany, RIC 2014 17

CRS

THANK YOU !


Strategic Re-Orientations and Selected Results of Nuclear Safety Research in Germany, RIC 2014 18

GRS

Introduction (1)

Changed Political Framework Conditions in Germany (1)

- The Fukushima nuclear accident led to a fundamental reconsideration of the use of nuclear energy in Germany
- An **Ethics Commission** nominated by the Federal Government was asked to provide the ethical base for the decision about the use of nuclear energy
- **German Reactor Safety Commission (RSK)**, supported by GRS, conducted a **Complementary Safety Assessment** of all German nuclear power plants:
German Reactor Stress Test



Strategic Re-Orientations and Selected Results of Nuclear Safety Research in Germany; RIC 2014

19
