First recommendations and research needs from a TSO perspective

International Experts' Meeting on Reactor and Spent Fuel Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant

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Germany

Introduction (1)

GRS continuously tracks the progression of the accident

- GRS Emergency Center operated for about two month after accident initiation supporting BMU

- Description of efforts:
  - 24-hour shift work with ~20 persons a day
  - 50 experts were involved at GRS
  - 200 reports and short notes were produced
- Assessment of information available on the accident progression and the source term through
  - NISA and TEPCO official reports
  - IAEA reports
  - JNES and ETSON partners
  - mass media, incl. Japanese media (interpreter Jap. – Ger)
- Presently, observation of Fukushima power plant state is still going on

Introduction (2)

GRS provides interim report

- **Interim report of accident progression for BMU**
  - **Preliminary findings**
    - External hazards were underestimated
    - Detonations in reactor buildings caused loss of technical barriers and complicated Accident Management Measures
    - Long lasting loss of power supply and of ultimate heat sink (UHS) obviously not taken into account during the planning of accident management (AM) measures
    - Destruction of infrastructure not sufficiently regarded at organization and effectiveness of AM measures
  - **open questions related to e.g.**
    - Hydrogen propagation
    - State of core, RPV, and Primary Containment Vessel
    - Validity of measured data and interpretation
- **Need for more detailed investigations to understand the accident and to derive implications for German NPPs**

BMU funded post Fukushima research project at GRS (1)

- **„Questions on safety and risk after the nuclear accident in Japan“**
- **3 Year project (Sept. 2011 – Sept. 2014)**
- **Objectives**
  - Clarification and assessment of the accident sequences as detailed as possible
  - Identification of possible threats to German NPPs under extreme natural hazards
  - Recommendations to improve measures against and during beyond design conditions
  - Updating of interim report including lessons learned, conclusions, and recommendations

BMU funded post Fukushima research project at GRS (2)

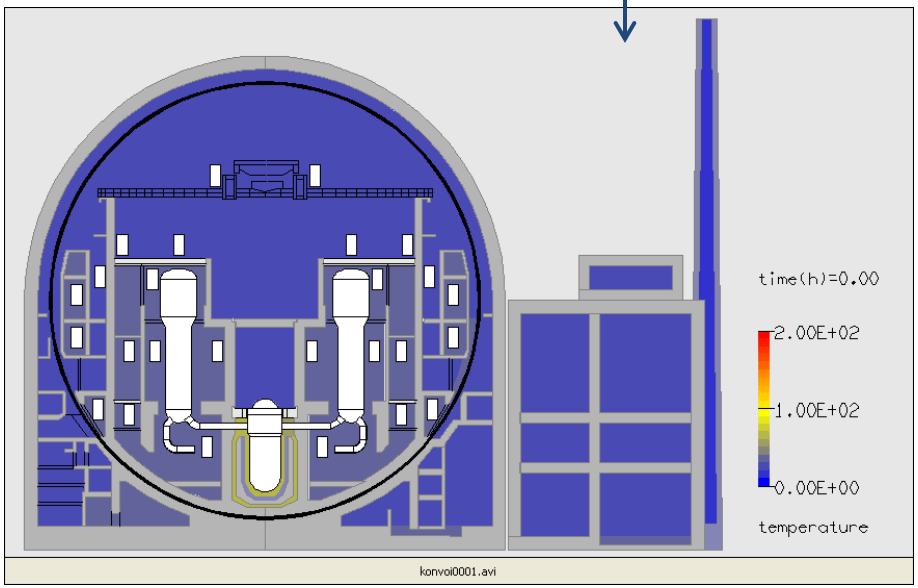
- **In-depth investigation of accident and phenomena**
  - Data collection of plant design, design conditions, natural impact and course of the accident (collaboration with JNES)
  - Analysing data for detailed investigation of accident sequence
  - Plausibility checks
  - Identification of major phenomena occurred

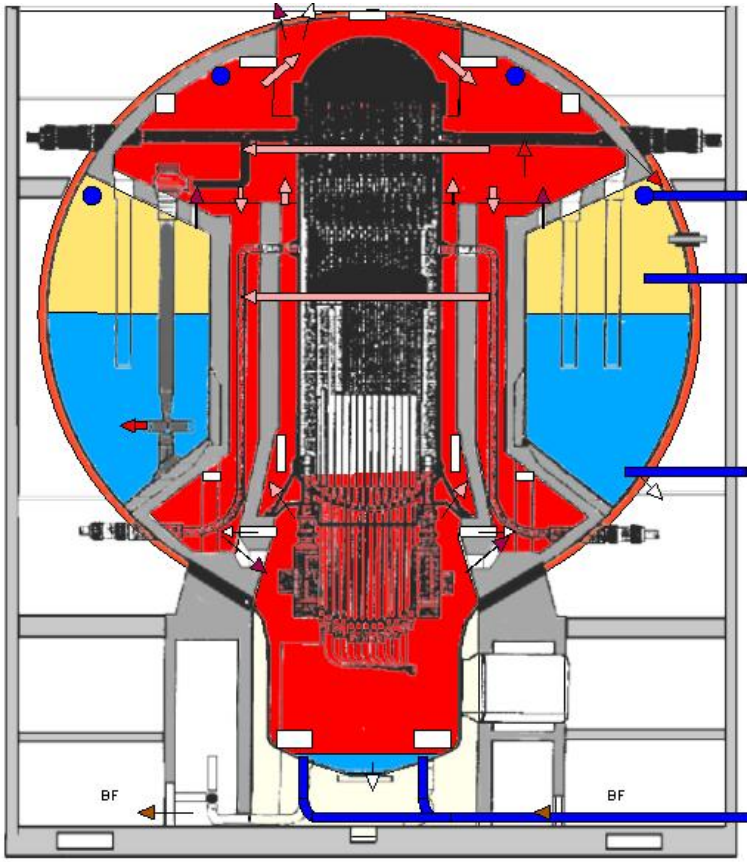
Source, FPL

Source, TEPCO

BMU funded post Fukushima research project at GRS (3)

- **Thermal-hydraulic analyses (ATHLET-CD/COCOSYS)**
  - "Fukushima-like" model based on BWR 69 with boundary conditions from accident analysis
  - Analysis of different accident phases and of their influence / contribution to source term
  - Evaluation of relevance for German NPPs by calculating the behaviour of a German PWR exposed to a similar hazard





Calculation of H_2 in the BWR 69 Containment (before venting)

BMU funded post Fukushima research project at GRS (4)

- **Response to natural external hazards**
  - Study transferability of earthquake and flooding impacts (combination + fire) to German NPPs: specification of beyond design nat. hazards
  - Analysis of design requirements and protections of German NPPs against beyond design impacts
  - Recommendations to improve protection in case of weaknesses identified

Source, TEPCO

- **Vulnerability of electrical power supply**
  - Analysis of layout of Japanese electrical grid
  - Analysis of consequences of earthquake, tsunami and shut down of NPPs for power and emergency power supply
  - Assessment of the behaviour of power supply in German NPPs under analogue conditions
  - Recommendations for German grid and emergency power supply if necessary

BMU funded post Fukushima research project at GRS (5)

- **Analysis of Accident Management Measures**
  - Assessment of feasibility and effectiveness of AM measures in German NPPs under Fukushima-like conditions (long lasting SBO and loss of UHS, damaged infrastructures)
  - Identification of weak points and suggestion of possible improvements and extensions
- **Investigation of cliff-edge effects in AM**
  - Dynamic PSA analyses in combination with MELCOR calculations plus uncertainty analysis for a specific scenario at a German PWR
  - Identification of grace periods for AM actions (bleeding, feeding, venting) to avoid core damage

Source, TEPCO

BMU funded post Fukushima research project at GRS (6)

- **Organisational factors in emergency management**
  - Investigation of organisational requirements, structures, and measures at Fukushima NPP and in relation to utility (TEPCO) and authority
  - Comparison to safety relevant organisation in German NPPs and identification of potential improvements in structures and procedures

- **Development of methods for assessment of decision making processes**
  - Development of an approach to assess the appropriateness of measures and organisational structures to take reliable safety oriented decisions in emergency management
  - Approach includes communication, collaboration and shared decision making of emergency management team and officer-in-charge in extreme situations

Source, TEPCO

BMWi funded post Fukushima research project at GRS (1)

Research on specific phenomena and its modelling in German codes used for analysing German NPPs

- **Test of coupled simulation tools ATHLET-CD/COCOSYS related to Fukushima relevant phenomena (model based on BWR 69)**
  - Cooling of partly molten core and fission product release from core
  - Fission product retention inside the wetwell of BWR plants; pool scrubbing specifically for saturated water conditions
  - Fission product retention in filtered venting, question of adequate filter design
- **Structural mechanics analysis of dynamic containment behaviour**
  - Latest PWR type (KONVOI) under beyond design earthquake loads (primary earthquake and aftershock loads)
  - Determination of floor response spectra and loading conditions on components and piping structures

BMWi funded post Fukushima research project at GRS (2)

- **Spent fuel pool behaviour during severe accident sequences, application of analytical tools ASTEC and MELCOR**
  - Station Black-out at PWRs and BWRs
  - Two operational cases: 1) during normal power operation
    2) core fully unloaded to SFP
  - Phenomena: Evaporation of pool, combined cladding oxidation by steam and air, zircon fire, relocation of molten material, fission product release, containment/ reactor building behaviour
- **Improved fission product inventory determination in BWRs needed for source term prediction for high burn-up fuels**
  - Further qualification of code for BWR by re-computing data from specimens

Other German research activities

- **Karlsruhe Institute of Technology (KIT)**
  - Saltwater cooling experiments at QUENCH facility in co-operation with JAEA
  - Comparison of air-transported radiological dispersion calculations (KIT, UMBW, DWD, BfS)
- **Helmholtz-Centre Dresden-Rossendorf (HZDR) + Dresden TU**
  - Contracted by operators
    - SFP bundle tests: (water, steam, air) coolability at decreasing water level
    - ATLET-CD versus ASTEC calculations on SA scenarios for PWR and BWR
- **Research need actually not addressed**
  - Radiological dispersion calculations in water (ocean, lake, river)

First Recommendations

- **Electrical energy supply in case of SBO**
  - Ensure power supply (e.g. batteries) for 10 hours
    - to keep plant in subcritical conditions and to remove residual heat from core
    - including power for instrumentation and lighting needed
  - Develop accident measures to provide AC power within 10 hours by an additional emergency power generator
    - to feed systems needed for shut down of the plant and removal of decay heat from core and spent fuel pool
    - two physically separated connection points
    - Ensure installation and connection of additional emergency power generator in case of beyond design conditions (earthquake, flooding) and destroyed infrastructure
    - Necessary operating resources, tools and connection cables had to be provided

First Recommendations

- **Cooling water supply**
  - Availability of an independent essential service water systems (ESWS) including power supply and needed auxiliary systems
    - Long term removal of residual heat and heat from needed systems (e.g. diesel)
    - ESWS should be protected against design events
  - Availability of a mobile pump
    - Protected against beyond design events
    - Plant independent power supply
    - Two physically separated connection points to cooling system usable for cooling core and spent fuel pool
  - For PWR creation of a RPV feeding possibility with borated water independent from ECCS
    - Avoid negative effects on existing procedures and equipment

First Recommendations

- **Filtered Venting System**
  - Designed for accidental boundary conditions (SBO+Loss of DC power, unfavourable radiological conditions)
    - Exclusion of hydrogen deflagration/combustion inside of venting system
    - Long term operation has to be foreseen
    - Effective precautionary measures to avoid influence on other neighbour units
- **Destructed area**
  - Provide facilities to ensure access to buildings in case of destructed area (e.g. after external events)
    - If facilities not on site ensure that they can be delivered on time they are needed taken into account a possibly damaged infrastructure
  - By planning emergency measures take into account that on a short time scale access to plant may be impossible

First Recommendations

- **Spent Fuel Pool**
  - Fuel element pools outside containment inside reactor building
    - Proof if flammable hydrogen concentration are possible
    - If necessary provide preferably passively acting installations (e.g. passive autocatalytic recombiners) to ensure operating mode beyond 10 hours
  - As an accident management measure provide fixed installations for spent fuel cooling
    - to avoid the need to enter rooms that may at risk in case of challenge
    - Erroneous operation or inadvertent actuation should be excluded

First Recommendations

- **Emergency control room**
  - If control room is not available, operations and procedures are initiated from emergency control room
    - Ensure that Accident Management Measures initiated by switching operations from control room can be started from emergency control room either
    - A corresponding extension of emergency control room function has to be done (including availability of needed information resources)
  - Provide equipment for communication between emergency control room and the crises team center

Conclusion and Outlook

- **Research projects started at GRS**
  - Detailed investigation of accident sequence
  - Transferability to German NPPs
  - Code applicability on observed SA phenomena
- **Based on current knowledge first recommendations for German NPPs are derived**
- **Further recommendations expected**
  - More detailed information on accident sequence
  - Finalization of EU stress test review process
  - Information exchange on international activities