Periodic Safety Review of the BR2 Reactor

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BR2: General description

- Material Test Reactor - tank in pool type
  - Maximal thermal power 125 MW (heat exchangers)
  - Licence limit: power density:
    - ♣ 470 W/cm² hot spot in routine operation
    - ♣ Up to 600 W/cm² hot spot special conditions
- Pressurized water (12 bar)
- Fuel:
  - HEU – UAlx plates
  - Conversion to LEU with UMo – min. 7.5 g/cm³
- Moderator: water and beryllium
- Containment building
BR2: General view
The BR2 reactor vessel
Utilization

- Originally designed as Material Test Reactor
  - Material irradiation
  - Fuel testing
  - Beam tubes foreseen – limited use
- Extensive program on fast reactors ‘70 and ’80
  - Fuel failure tests
- Actual use
  - PWR fuel test – dedicated high pressure loop
  - Possibility for transients
  - Material irradiation (vessel steel, fusion, ADS)
  - Isotope production (Mo99, Ir192, ...)
  - Silicon doping (2 devices, up to 5” in the vessel and 8” blocks in the pool)
Requirements for Periodic Safety Review.

- Operating licence (Royal Decree of 29 June 1986) valid for undetermined period.
  - Licencing authority Federal Agency for Nuclear Control
- Requirement for Periodic Safety Review (article 2, §5.)
  - Up to 2008: every 5 year for reactors
  - Actually: every 10 year for all installations (practice for power reactors).
- Detailed followed by technical support organisation of FANC (BEL V).
- Final report (with action plan) to approved by BEL V.
- Summary published on website of FANC (in Dutch or French)
  - http://www.fanc.fgov.be
General list of topics

• Follow up material of structural components
• New safety practices
• Advanced safety analysis
• Organisation
Selection of subjects

- “Brain storm” list proposed by operator (more than 70 potential subjects).
- Selection by safety department according to criteria for PSR
  - Maintain and improve safety
  - Application of new safety practices
  - Return of experience (own/other installations)
  - No short term “urgent” issues
- Final list in discussion between operator, department nuclear safety and BEL V.
  - 19 items in final selection
Conversion to LEU

- Feasibility selected as topic
  - Conclusion: LEU with density ~ 8 grU/cc
  - UMo dispersed – still to be qualified
- No change in fuel configuration
- Further project not under PSR (long term)
- Actual tasks:
  - Review of all safety analysis using up to date codes (MCNP, RELAP, PARET, PLTEMP)
  - Test irradiation of fuel elements with burnable poison in the stiffeners, in stead of in fuel meat.
Ageing: The Beryllium Core

- Hexagonal beryllium blocks
- Ageing due to helium formation
  - Swelling, cracking
  - Poisoning due to helium
- Licence limit
  - Significant material loss
  - $6.4 \times 10^{22}$ fast neutrons per cm$^2$
- Replacement possible
  - Done twice: 1979 and 1996
  - Actual matrix up to
Ageing: The Reactor Vessel

- Material Al 5052-O
- Inspection required by licence in case of Be matrix replacement:
  - Ultrasonic and eddy current of irradiated part
  - Welds of other parts.
  - Low cycle fatigue analysis
- Material follow up program since 1997 (irradiation of samples from shroud)
  - Actual extrapolation up to 2016.
Ageing: Replacements

- **Control rods:**
  - Cadmium absorbers replaced by hafnium
  - Position indicators (redundant system with resolvers)
  - Drive mechanisms

- **Instrumentation (flow, pressure, temperature):**
  - Difficulties with maintenance and spare parts

- **Radiation control equipment (activity of primary water):**
Inspections

- **Primary circuit (non irradiated parts)**
  - Inspection program base on the ASME XI code
  - Problem: original design basis not known.

- **Devices for production** (Mo99, Silicon, ...)
  - Originally designed as experimental device (limited use)
  - Upgrade as reactor component.

- **High pressure water test loop (Callisto)**
  - Review of safety documentation (nearly 20 years of service)
  - Non destructive inspection of irradiated pressure tubes (ASME III class 1 components)
  - Inspection of rest of the loop (welds, pressure relieve valves)
Check if modifications are necessary due to changes in reglementation.

Two subjects identified:

1. The protection against explosion risk (European ATEX directive).
   - Limited risk – no significant modification

2. Single failure proof of hoisting cranes
   - Replacement of the trolleys (up to 25 tonne for loaded TN-MTR container)
   - Major investment
Competence Management

- BR2 more than 50 years in operation: all persons with the original design knowledge are no longer available
  - Collection of original documentation (up to now 90% recovered)
  - Formal training program for operators and other personnel
  - Learning from experience (own or foreign installations) – good practices included.

- Probabilistic safety assessment
  - Further interpretation of the result of the assessment
Resistance against severe external events

- Request of FANC to study the protection against severe external events
- Use of WENRA list + additional man made events
  - Seismicity (qualification in 1997)
  - Flooding (low risk in the region)
  - Heavy storm and whether conditions
  - External fire thread (forest fire)
  - Terrorist attack using missile
  - Cyber attack
- Time schedule – after power plants
  - Subjects and work plans by mid December
  - Final report June 2010
- No international review foreseen
Conclusion

- Periodic Safety Review is a major task.
- Main topics:
  - Ageing
  - Changing regulation
  - Knowledge management
- Important investment could be involved