STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Periodical Safety Review and Long Term Operation for the BR2 Reactor

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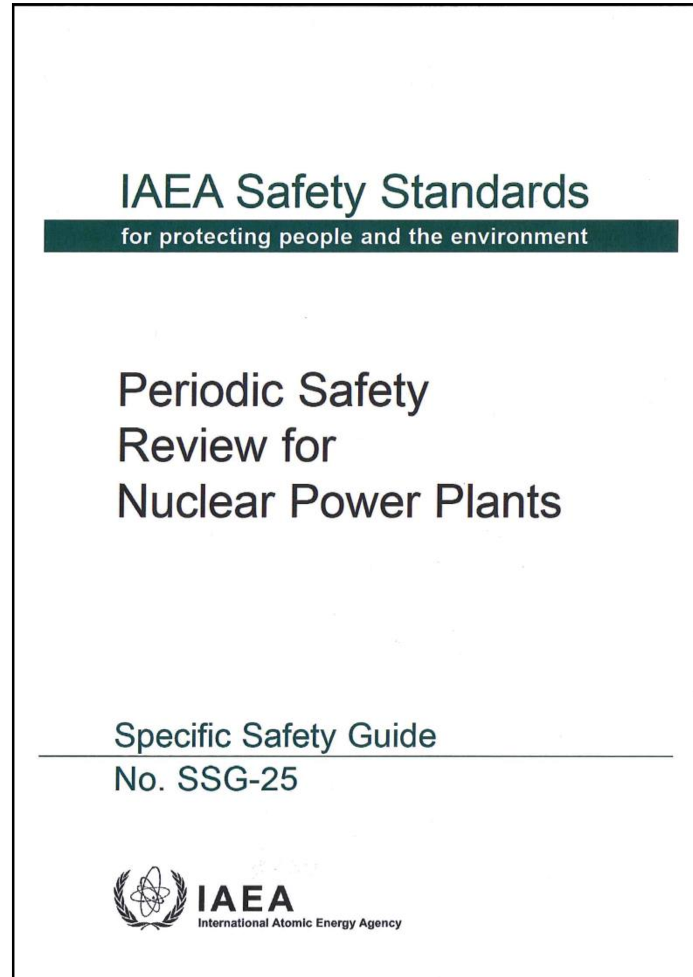
Periodical Safety Review

- Licence requierement every 10 year (previously every 5 year)
  - Licence itself has no end date.
  - Valid as long as safe operation can be guaranteed.
- Obligation by regulator to consider all 14 Safety Factors as in IAEA document SSG-25
  - + 1 additional on radiation protection.
  - Detail described in instruction by regulator (20 page document)
- Requierement also formulated by Western Europe Nuclear Regulators.


IAEA Safety Standards
for protecting people and the environment

Periodic Safety Review for Nuclear Power Plants

Specific Safety Guide
No. SSG-25

IAEA
International Atomic Energy Agency

WENRA requierements

The review shall confirm the compliance of the plant with its licensing basis and any deviations shall be resolved.

- *The review shall identify and evaluate the safety significance of deviations from applicable current safety standards and internationally recognised good practices currently available.*
- *All reasonably practicable improvement measures shall be taken by the licensee as a result of the review.*
- *An overall assessment of the safety of the plant shall be provided, and adequate confidence in plant safety for continued operation demonstrated, based on the results of the review in each area.*

Obligation for Ageing Management

- Ageing Management of nuclear installations Class I is obliged by Royal Decree 30 Nov. 2011 (Safety prescriptions for Nuclear Installations.
  - Nuclear reactors
  - Installations with potential criticality risk
  - Nuclear waste treatment plants
- Art. 10 deals with ageing where both the ageing (physical and economic) as well as the ageing management programmes need to be addressed. This ageing management programme shall be reviewed at least during each periodic safety review.
  - Safety classification of systems, structures and components important for safety
  - Definition of maintenance and programs

BR2 Periodical Safety Review 2016

- BR2 PSR same period as shutdown for Be matrix replacement (management decision).
  - Lifetime Be matrix limited due to
    - Swelling and cracking (due to He formation)
    - Formation of Tritium and poisoning by He3 (decay product of Tritium and a very strong neutron absorber)
  - Be matrix use would have been possible up to ~ 2022.
    - Loss of flexibility in operation: formation of He3 during shutdown (limits shutdown time)
- Non destructive vessel inspection requiered by licence.
  - Vessel wall only accessable after Be core removal
- Together with investments for protection against severe accidents (stress tests).
- Restarted (first cycle with new matrix): 19 July 2016

Project summary PSR

- The periodic safety review is divided in 3 successive stages
  - ***Preparation (1 year)***
    - Methodology report
    - Investigation of applicable safety factors and methodology
    - (Provisional) approval by safety authorities
  - ***Evaluation (3 years)***
    - Detailed evaluation of safety factors as described in methodology report
    - Synthesis reports
    - Global assessment report – Finished 30 June 2016
  - ***Implementation (3 years) – The actual activity***
    - Implementation of the action plan resulting from the safety factor evaluation

15 Safety factors (SSG-25)

Categories	Safety factor
Plant	Plant Design
	Actual condition of SSCs
	Equipment qualification
	Ageing
Safety analyses	Deterministic safety analyses
	Probabilistic safety analyses
	Hazard analyses
Performance and feedback of experience	Safety performance
	External return of experience
Management	Organisation, management system, safety culture
	Procedures
	Human factor
	Emergency planning
Environment	Radiological impact on the environment
Radiation protection	Radiation protection

Long Term Operation Issues

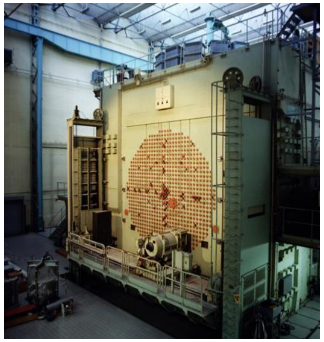
For each facility (if applicable)

At site level

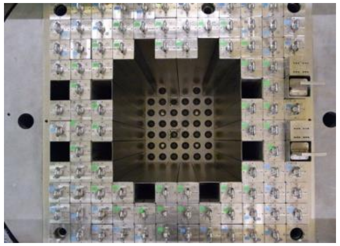
Additional safety factor (site level)

Concerned Installations: Graded approach

BR2: MTR reactor (125 MW)



BR1: Air cooled reactor (4 MW)



Critical facility

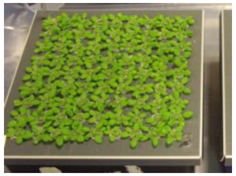
Hot cell facilities

Radiochemistry

Interim Waste Storage

Nuclear Calibration

BR3 Reactor (dismantled)

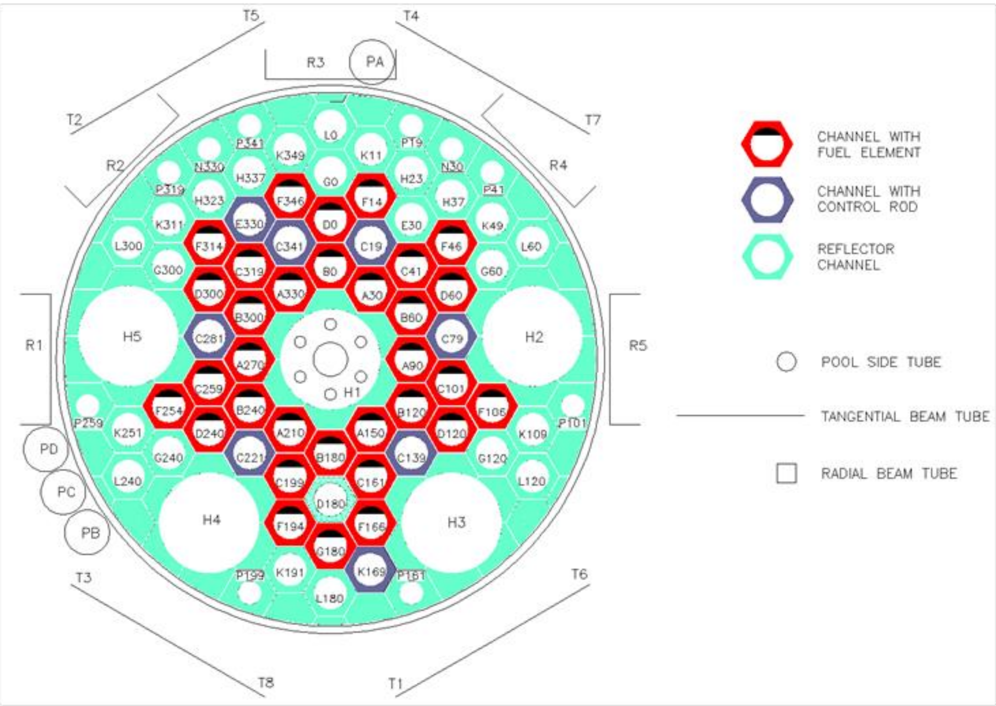


Radiobiology

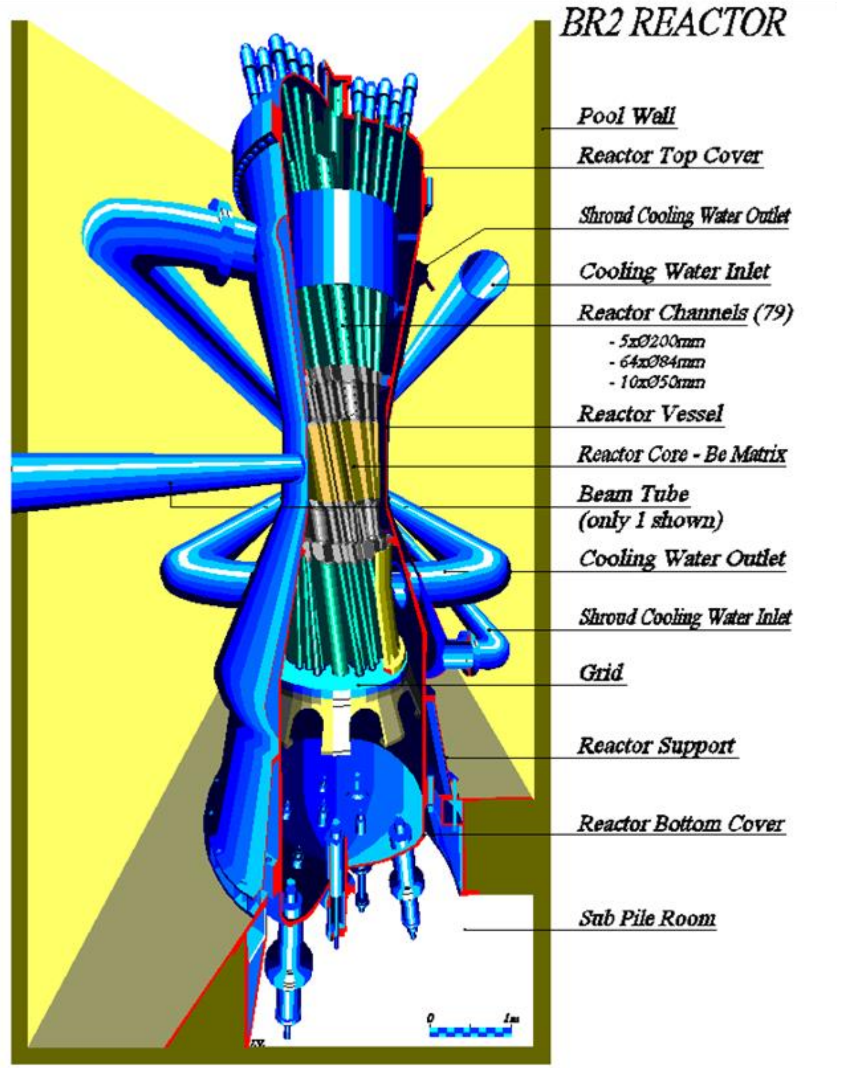
The SCK·CEN Nuclear Reactors: BR2 Reactor

- Material Test Reactor - tank in pool
  - Maximal thermal power 125 MW
    - Capacity of primary heat exchangers
  - Licence limit: power density:
    - 470 W/cm^2 hot spot in routine operation
    - Up to 600 W/cm^2 hot spot special conditions
- Pressurized water (12 bar)
- Fuel:
  - Actual fuel: HEU – UAlx plates
  - Conversion to LEU high density ~ 7.5 gU/cm^3
- Moderator: water and beryllium
- Containment building
  - design pressure 1 bar (relative)
  - volume about 30 000 m^3

The SCK·CEN Nuclear Reactors: BR2 Reactor - vessel



Typical core configuration



Plant: SF 1 to 4

- SF1: Compare current plant design with actual requierements
  - Safety of RR’s (IAEA NS-R-4)
  - Code on Safety of Nuclear Research Reactors (Safety Series 35-S1)
  - → Definition of design upgrades.
    - To increase reliability of systems and components
    - To decrease impact of failure (stress test)
- SF2 (actual condition), SF3 (equipment qualification) and SF4 (ageing)
  - Plant Asset Management Program (PAM)
    - Definition of safety critical systems and components
    - Development of maintenance and inspection programs
    - Definition of replacement strategy
  - Link with long term operation (LTO) project – requierement of the regulator.

How is PAM executed?

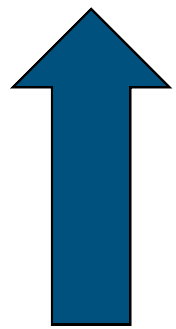
- 3 phases
  1. ACM – Asset Class Management
     - Complete inventory of all the SSCs included in the study, dividing them according to the system classification of BR2
     - Score all the SSCs regarding "how important/critical they are to the installation"
     - Divide all the SSCs in 4 Asset Class categories (A, B, C, D)
  2. ICM – Installation Concept Management
     - Define maintenance concepts for every SSC in the inventory based on RISK profiles.
  3. WMS – Workorder Management and Skills
     - Write maintenance procedures according to the maintenance concepts defined in the ICM phase.
     - Gradually introduce and integrate the procedures into the operation of BR2.

Implementation of PAM for BR2

- Identification of all SSC's (2304 items for BR2)
- Scoring of alle SSC's on 3 criteria
  - Safety
    - Score 0: Safety critical
    - Score 1: Important to safety
    - Score 2: Not safety significant
  - Availability
    - Score 1: Failure causes stop > 1 month
    - Score 2: Failure causes stop between 5 days and 1 month
    - Score 3: Failure causes stop < 5 days.
  - Economy and replacebility
    - Score 1: Not replaceable
    - Score 2: Replacement cost > € 100 000
    - Score 4: Replacement cost between € 10 000 and € 100 000
    - Score 6: Replecement cost < € 10 000

ACM – Asset Class Management

- It would take too much time to perform complete risk analysis for all assets
- Apply philosophy of "graded approach" → Define Asset Classes
  - Multiply SS x OS x RS for Total Impact (TI):
    - Asset class A ($0 \leq TI \leq 4$)
    - Asset class B ($5 \leq TI \leq 18$)
    - Asset class C ($19 \leq TI \leq 24$)
    - Asset class D ($25 \leq TI \leq 36$)



Most important SSCs → Most intensive maintenance approach

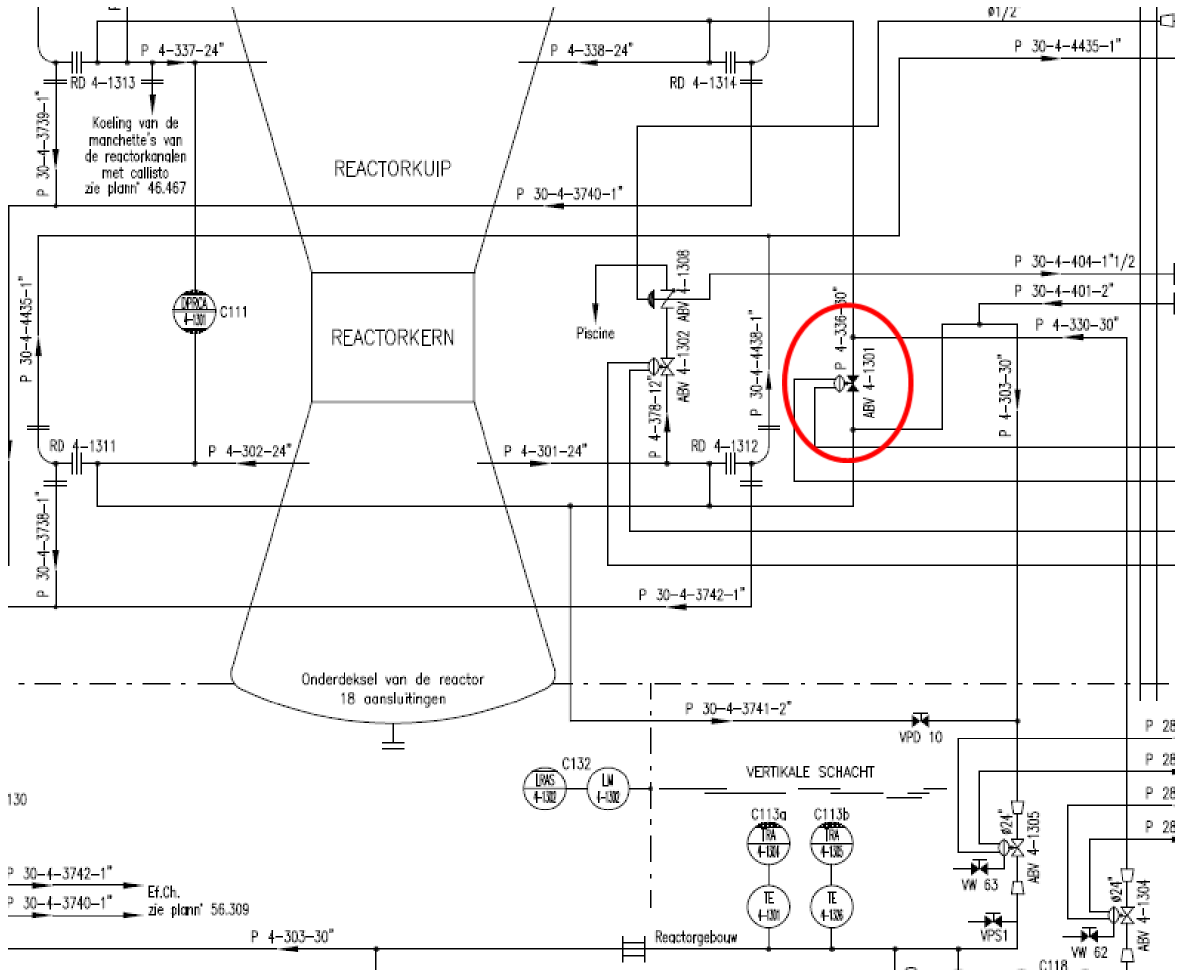
Least important SSCs → Least intensive maintenance approach

- Method takes also operational aspects into account
- Assurance that safety critical component is always in highest class

ACM – Asset Class Management

Example: ABV 4-1301

- By-pass Automatic Block Valve of the primary circuit
- Its main function is to open in case of a LOCA in the primary circuit and by-pass the rest of the primary circuit in order to keep the coolant inventory in the RPV and allow for coolant circulation by natural convection.



ACM – Asset Class Management

- Example: ABV 4-1301
  - Worst case scenario: The valve does not open when it is supposed to
  - SS = 0, because the residual heat removal of the core by natural convection would become more difficult, leading to higher temperature of the fuel elements and increased risk for damage. According to the SAR it is one of the safety critical components.
  - OS = 1, because the reactor would not be allowed to resume operations until the component would be fully functional again, and this could easily take months (more than a cycle of operation)
  - RS = 1, because it is a tailor made (one of a kind) component and given its location in the plant, its replacement would be very costly and inconvenient.

  - TI = 0 x 1 x 1 = 0 → **ASSET CLASS A**

ACM – Asset Class Management

- What are the results?

Code	System	AC A	AC B	AC C	AC D	Total	AC A %	AC B %	AC C %	AC D %
A	Buildings	25	40	5	5	75	33%	53%	7%	7%
B	Reactor	25	28	33	58	144	17%	19%	23%	40%
C	Primary Circuit	44	268	5	145	462	10%	58%	1%	31%
D	Pool and canal	19	25	33	129	206	9%	12%	16%	63%
E	Secondary Circuit	12	32	47	111	202	6%	16%	23%	55%
F	Experiments Circuit	0	9	7	37	53	0%	17%	13%	70%
G	Radiation monitoring	34	27	101	24	186	18%	15%	54%	13%
H	Electricity	31	23	28	60	142	22%	16%	20%	42%
K	Water and gas supply	1	4	38	161	204	0%	2%	19%	79%
L	Compressed air	7	28	11	151	197	4%	14%	6%	77%
M	Ventilation	11	21	41	92	165	7%	13%	25%	56%
N	Heating	5	40	13	22	80	6%	50%	16%	28%
Q	Solid waste disposal	0	0	0	3	3	0%	0%	0%	100%
R	Liquid waste disposal	2	93	16	38	149	1%	62%	11%	26%
S	Gas waste disposal	2	30	0	4	36	6%	83%	0%	11%
	Total	**218**	**668**	**378**	**1040**	**2304**	**9%**	**29%**	**17%**	**45%**

ICM – Installation Concept Management

- Graded approach to maintenance concepts and risk profiles:
  - Asset class A
    - Detailed risk analysis in multidisciplinary meetings
    - Time-dependent evaluation of failure modes and related measures (ageing)
  - Asset class B
    - Global risk analysis by the person responsible
    - Focus on preventive maintenance
  - Asset class C
    - Corrective maintenance
    - Impact limited by pre-defined repair/replacement procedure
  - Asset class D
    - Corrective maintenance (unprepared)
- Safety: risk not always equal to fail to function
  - Example: primary pump
    - Operation not requiered safe shutdown, but
    - Pump house part of pressure retaining boundary

Safety Analysis: SF 5 to 7

- Ageing of safety analysis: old calculation method no longer available (computer codes)
- SF5 revision of safety analysis, now based on
  - Neutron calculation MCNP
  - Steady state thermohydraulics: PLTEM
  - Transient operation: PARET-ANL
  - Anticipated transients: : PARET-ANL and RELAP
  - Unanticipated transients: RELAP
    - Remark: use of RELAP tricky for a RR!
- SF6: Review of Probabilistic Safety Assessment – check if conformity with PAM.
- SF7 Hazard analysis
  - Update status
  - Overview of stress test

Performance and Feedback of exerience: SF8 and 9

- SF8: Definition of Safety Performance Indicators

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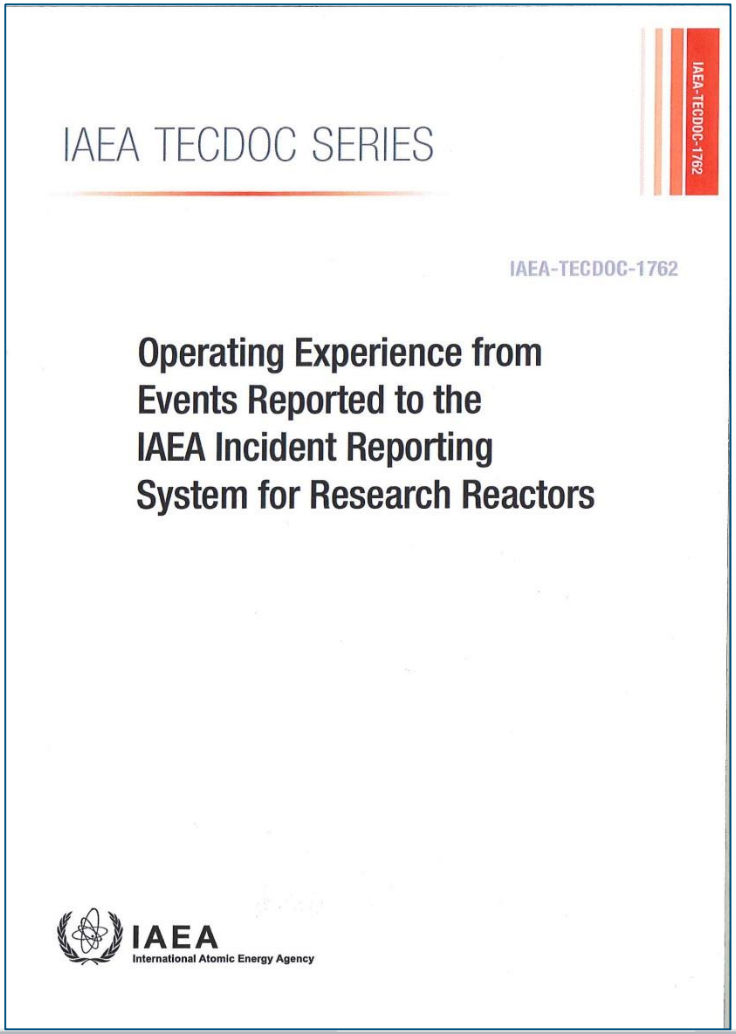
- SF9: Return of experience - sources
  - Stress stress report of other RR's
  - Historic accidents in experiment and non-power reactors
  - Internal database on operating experience
  - Information from IAEA IRSRR
    - Use of overview report



Management: SF 10 and 11

- SF 10: Development of Integrated Management System
  - IAEA Safety Requierement GS-R-3: The Management System for Facilities and Activities.
- SF 11 Procedures
  - Focus on
    - Safety critical operating procedures
    - Emergency procedures
    - Severe accident management
  - Current inventory and description
  - Propose improvements (procedure content and operator training)
    - Based on user experience
    - Based on stress test conclusions

Conclusion

- 3 major projects executed during last years for improvement of safety and reliability:
  - Stress test
    - Installation of a number of systems
    - Additional safety review
  - Long term operation
    - Inventory and classification of all sytems, structures and components
    - Defined maintenance strategy.
    - Replacement of Beryllium matrix and vessel inspection
  - Periodical safety review of 2016
    - According to IAEA standard SSG-25.
- Reactor restarted on July, 19, 2016
- Next Operation period:
  - Technical: Beryllium matrix life time: between 15 and 25 years
  - Next Periodical Safety Review: 2026