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Management of maintenance and modernisations at the BR2 material test reactor





At Europe's heart

Our Belgian Nuclear Research Centre is based in Mol and Brussels. Our pioneering research is **internationally renowned**

At the forefront of progress

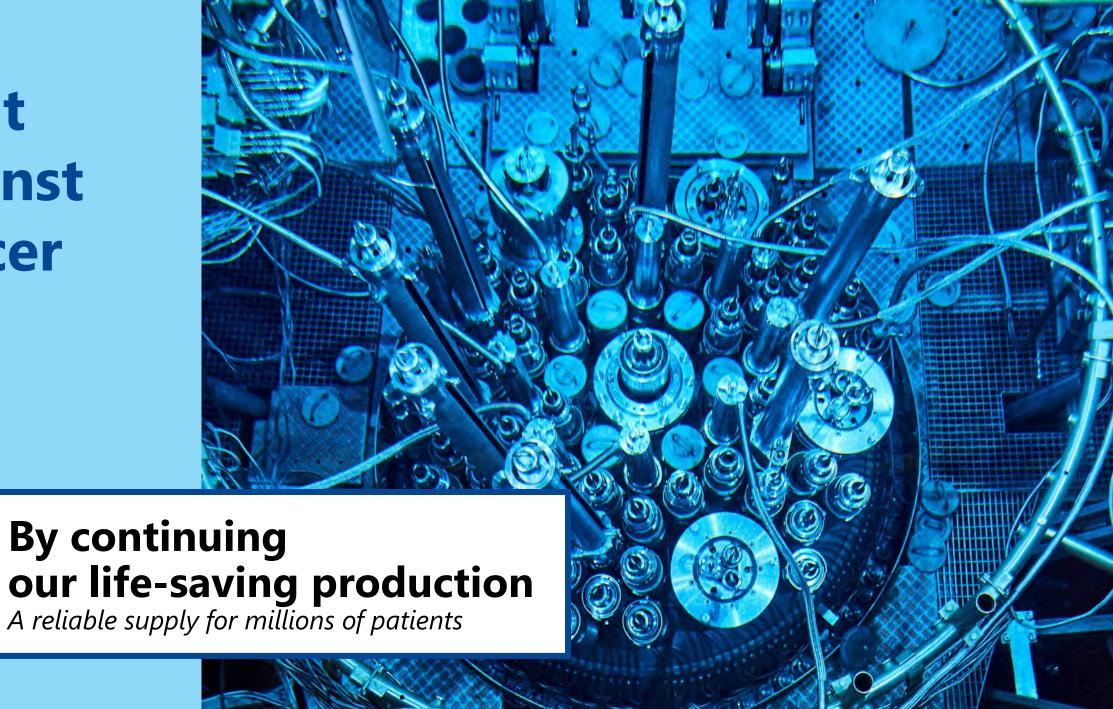
In 1952, we started to explore the possibilities of nuclear science and applications that could **significantly change the world**

Mirroring societal needs

- Climate change
- Circular economy
- Fight against cancer



Fight against cancer



By continuing



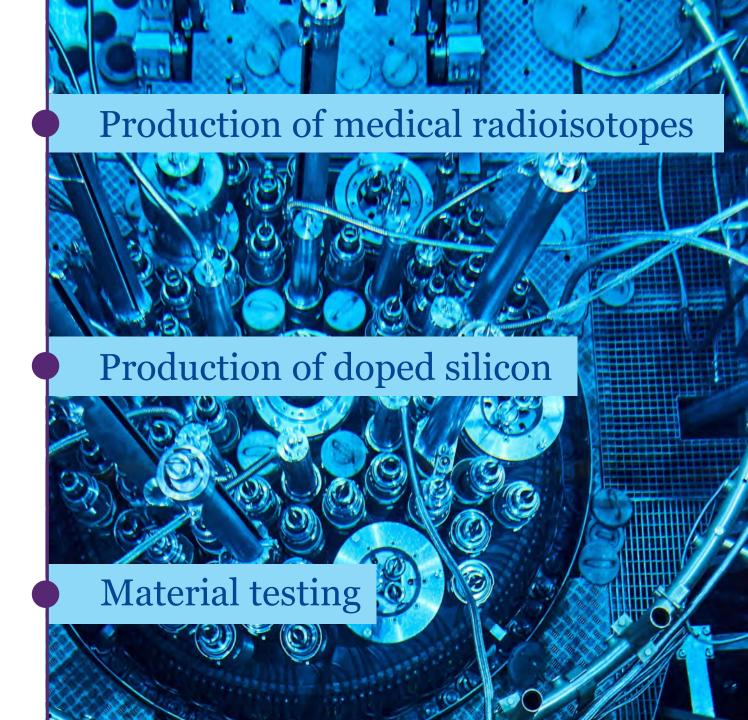
Fact

Infrastructure is crucially important

to perform pioneering research and to contribute to societal development

Belgian Reactor 2

SCK CEN is converting its Research Reactor from HEU to LEU Fuel. This is a major step to ensure the continuation of our production





NDA

III. INTRODUCTION

A. PURPOSE OF PROJECT AND PHASE I

Under terms of a contract with the Centre d'Etudes pour les Applications de l'Energie Nucleaire (CEAN), the Nuclear Development Corporation of America (NDA) undertook the design of an engineering test reactor for Belgium. This reactor is intended to provide CEAN with a test facility of greatest overall usefulness in a future power reactor development program. Inasmuch as the present CEAN graphite reactor, BR I, already provides low neutron flux facilities, a basic objective of this program was to provide high flux test facilities of ready accessibility.

Mission of the BR2

Enable SCK CEN to provide top level irradiation services

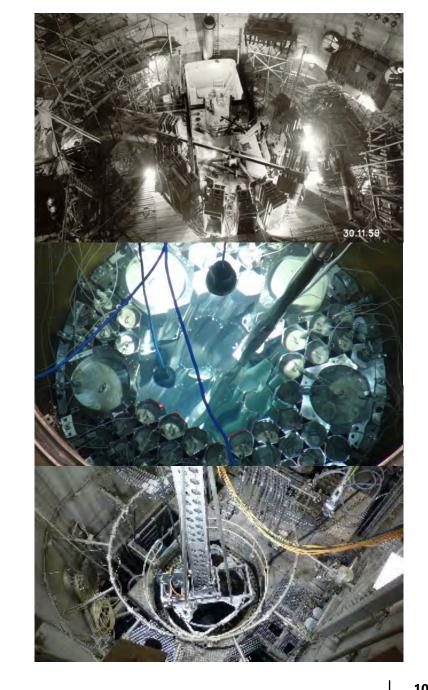
- High level of performance
 - High flux available for irradiation, both thermalized and fast
- Allow for ease of access to neutrons
 - Access during operation, infrastructure for fast and safe handling
- Provide flexibility in utilization
 - Configuration and operation parameters can be varied, multiple irradiation devices can be installed



Major historic milstones

Technical and regulatory status

- Design & construction: 1956-1961
- Power upgrade from 75 to 125 MW: 1971
- 1st Replacement of Be matrix: 1979
- Start of periodic safety reassessment: 1986
- First refurbishment (2nd Be change) & reduction of operation: 1997
- Second refurbishment (3rd Be change): 2016
- Enhancement of operational availability: 2020
- Next Periodic Safety Reassessment: 2026



General features of the BR2 reactor



Core characteristics

- Heterogeneous core
 - Fueled with HEU UAIx MTR fuel
 - Moderated by light water + metallic beryllium
- High flux available
 - Thermal flux up to 1 E15n/cm²s
 - Fast flux up to 8 E14n/cm²s
- Operation with shim rods
- Flexible configuration to achieve cycle length, flux levels and fuel economy



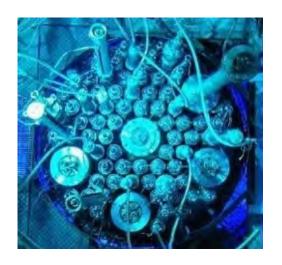
Reactor characteristics

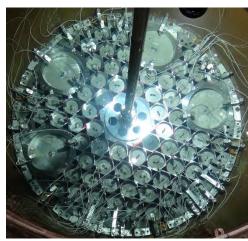
- Light water cooling in closed, pressurised loop
 - Heat flux up to 600W/cm² allowed, nominal 470W/cm²
 - 1,2MPa pressure, 40-50°C, 7000m³/h
- Open secondary loop with modular cooling tower
 - Thermal power up to 125MW
- Safe shut down in natural convection cooling mode
- Tank in pool with containment building which can be isolated from environment using electricity independent valves.

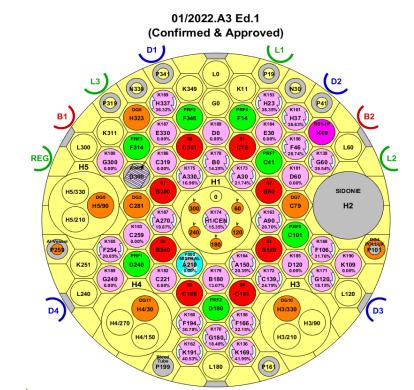
Core lay out

79 channels in tank

- Length about 7 meter;
 - 84, 50 and 200 mm diameter
- Central 1000mm made of Be block
- Channels are loaded with fuel, control rods, irradiation devices or plugs (Be or Al)
 - Adaptive configuration with # fuel, CRs, Rigs as needed per cycle
 - Cilindrical fuel elements can host irradiation rigs
 - Cycle length up to 5 weeks



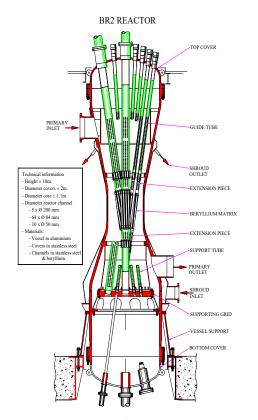




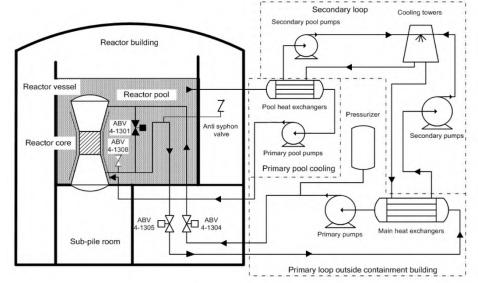
Reactor lay out

Cooling loops – irradiation environment and safety

- Primary loop:
 - high heat evacuation capacity
 - closed barrier for release of contamination
 - continuous operation for entire reactor cycle
- Pool cooling loop:
 - Reduced heat evacuation capacity
 - Open loop; large heat sink
- Secondary cooling:
 - No safety function; protected by activity monitoring



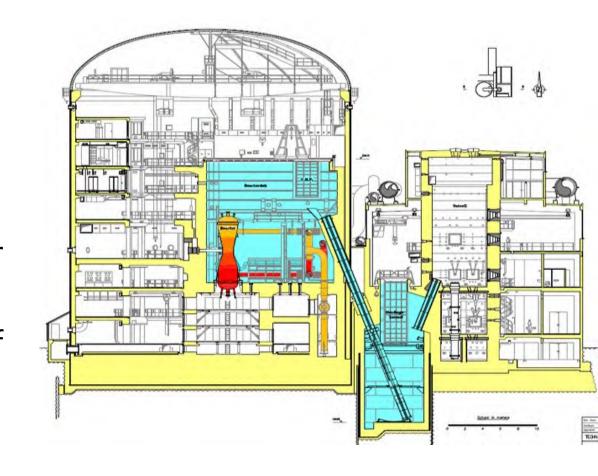




Reactor pool & building

Shielding and barrier against spreading of contamination

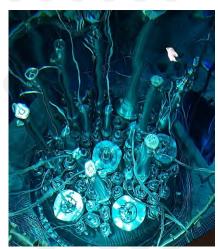
- Open pool: easy access for manipulations
- Transfer from reactor pool to hot cell or storage channel in shielded condition
- Access to reactor building through staff and vehicle locks
- Cranes with large capacity available



Utilisation of BR2

- Production activities for radio-isotopes and NTD-silicon
 - Leading irradiation facility for medical radio-isotopes
 - Largest irradiation capacity for Mo-99 in the world
 - High specific activity for activation isotopes
 - 4 to 8 inch crystals of silicon can be irradiated, up to 40 tonnes/year
- Experimental utilisation
 - BR2 is one of the leading reactors for fuel testing today
 - MTR fuel testing up to heat flux of 600W/cm² for LEU based fuel development
 - Transient testing of pre-irradiated LWR fuel pins for safety margin demonstration
 - Enhanced availability adds to attractiveness of BR2 for long term experiments
 - Development of Advanced Technology Fuel claddings
 - Selection of materials for fusion, SMRs, GEN 3+ and GEN 4



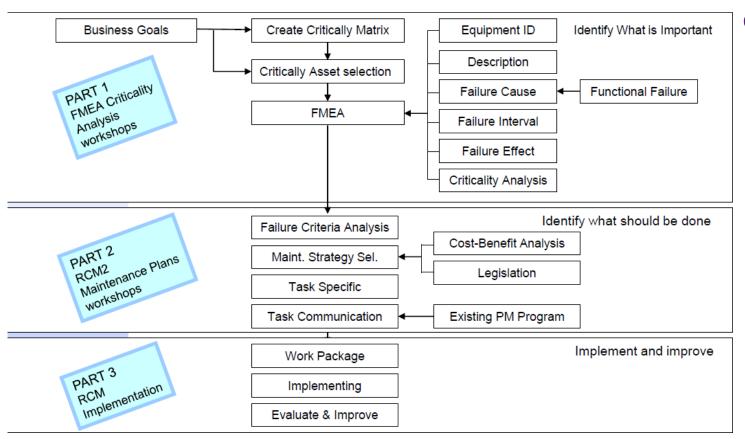




3 step process for ageing management

- Objective: maintain safety, availability and cost efficiency
- Classification of Structures, Systems and Components
 - 4 classes to apply graded approach
 - Class A: avoid critical failure by preventive inspection, testing and replacement
 - Class B: limit impact of failure by ease of repair or replacement
 - Class C: optimize cost between simple maintenance and replacement
 - Class D: no preventive measures needed
- Assessment of ageing risks
 - Identify critical failure modes, their frequency and precursors
- Define mitigating measures to reduce ageing risk to acceptable level
 - Integrate physical and economic ageing into inspection repair and replacement strategy

Plant asset management as living process



Ageing risks in a dynamic environment

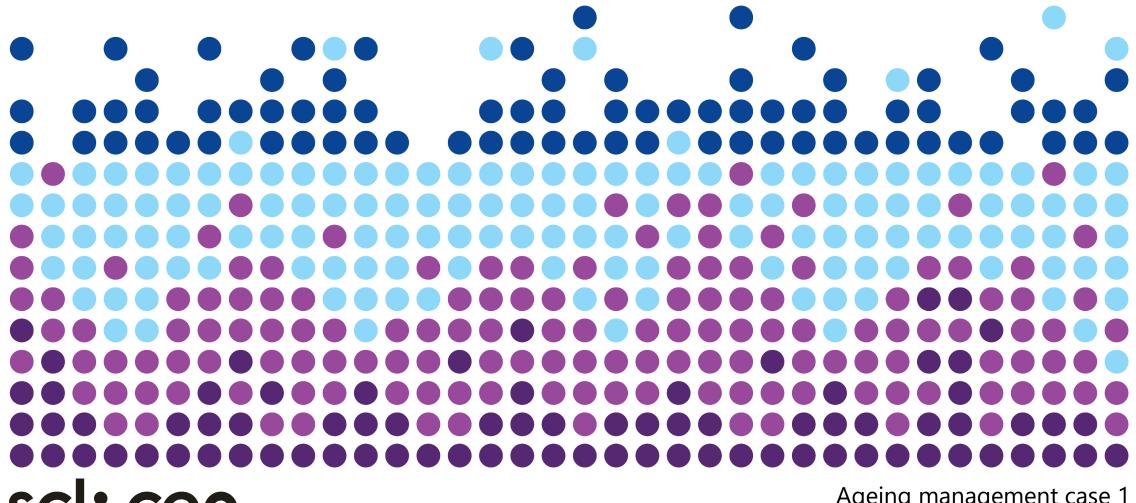
- Integrate results of in service inspections
- Feed experimental data on material ageing with sufficient lead factor
- Prevent obsoleteness by periodic review of standards, regulation and technology

Review of PAM as part of PSR



The BR2 is considered having the best Overall ageing management program and is the only research reactor to not have any challenges and AFI in the draft report. BR2 received several Good Performance and one Good Practice. So, in consequence, the current Action Plan is enough and does not need to be update/upgrade following the TPR workshop."

ENSREG Topical Peer Review on Ageing Management, May 2018



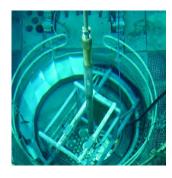
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Ageing management case 1

The BR2 Beryllium matrix



Ageing management of the Be matrix



Ageing issues

- Transmutation
- Radiation induced swelling
- Cracking of matrix blocks



Countermeasures

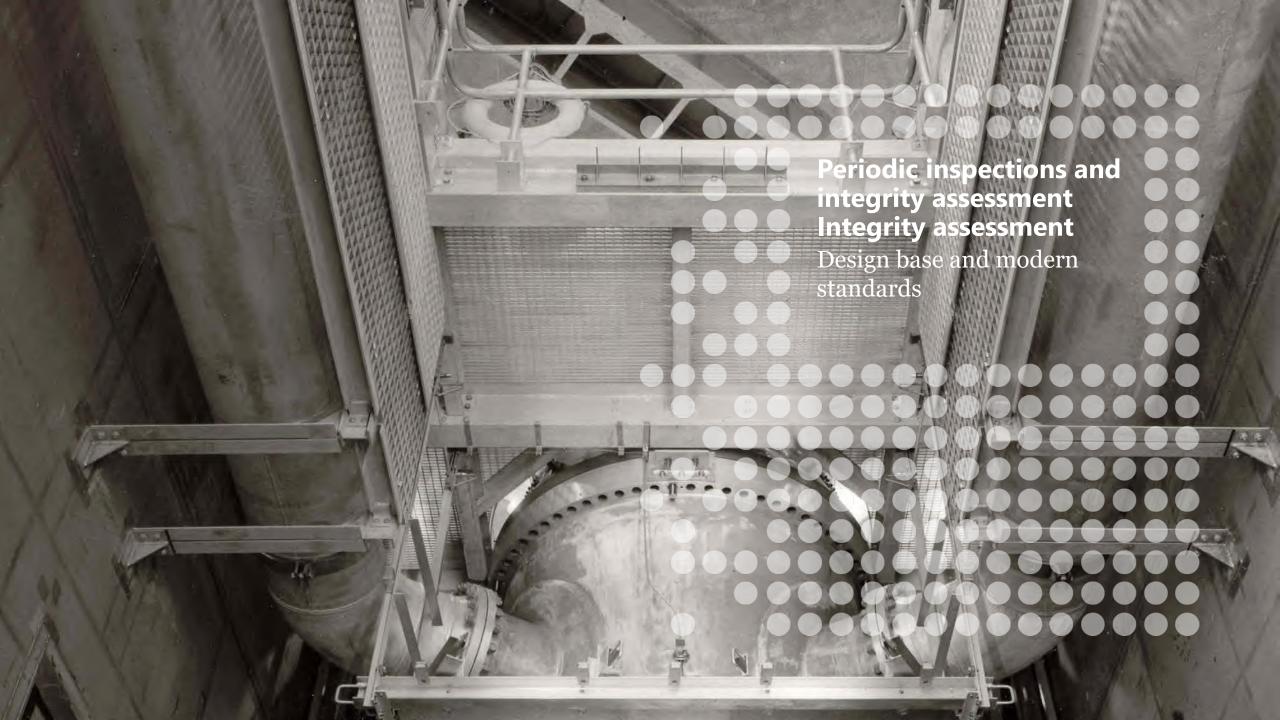
- Restrict shut down with age of matrix
- Inspect channels periodically
- Replace matrix at end of life (fluence < 6,4 10²² n/cm²)

Review design, qualify components and revisit construction and operation procedures for matrix replacement



The primary cooling loop

Ageing management case 2



Ageing management of the primary system



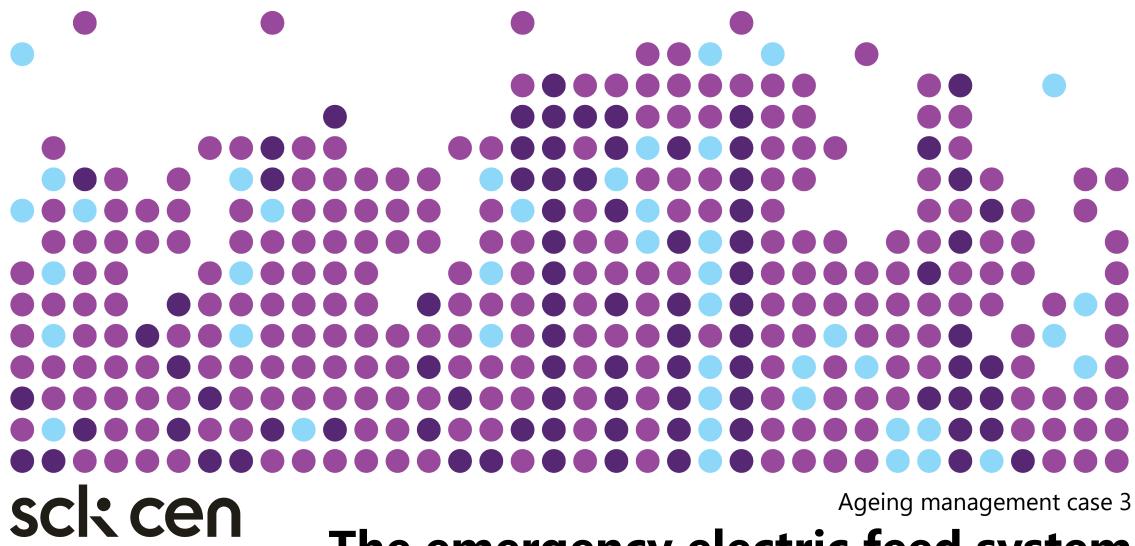
- Irradiation embrittlement
- Fatigue
- Standard evolution



Countermeasures

- Material irradiation program with lead factor
- Record on transients and structural integrity assessment
- Periodic inspection for construction defect and evolution

Review design and original construction file, assess defects according to modern standard, use calibrated inspection techniques to ensure integrity of primary loop and vessel – perform qualified repair scl; cen | SCK CEN/81288206



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The emergency electric feed system



Ageing management of the electric emergency feed



Ageing issues

- Safety requirement evolution
- Reliability degradation with age
- Increase defense in depth against internal & external hazards



Countermeasures

- Review design base
- Replace obsolete components with modern technology
- Separate support systems for redundant components and design for enhanced fire safety and seismic resistance

New state of art system in new building with separation of components from generator and UPS up to user



Electric feed of secondary mains

Obsoleteness

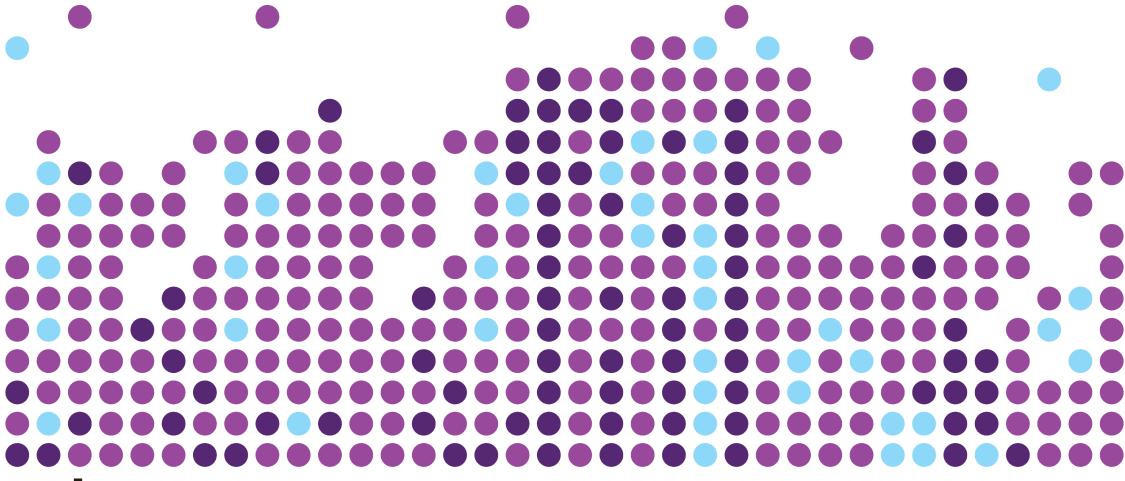
- Shift in standards and technology
- Enhanced personal safety
- Increased diagnostics



Modernisation according to standards







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Ageing management case 4

Civil structures

Ageing management of civil structure



Ageing issues

- Exposure to environment
 - Threat to containment/confinement functions
 - Possible loss of pool water inventory
 - Possible contamination of environment
- Compliance to new environmental standards for coating materials



Countermeasures

- Select and validate coating removal and replacement techniques
- Manage streams of waste and water supplies
- Modernisation of water transfer systems between buildings

Pool water transfer

New











Renewed ventilation piping



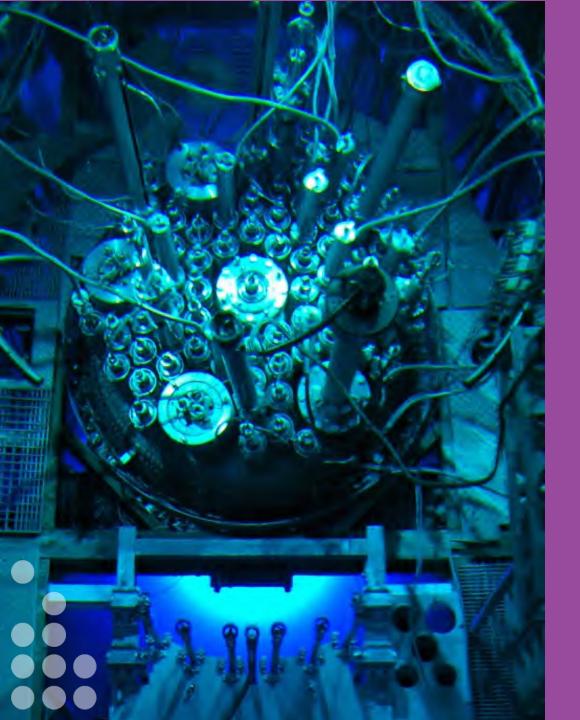






Successful ageing management of the BR2

- Relies on a continuous integration of plant observation, evolving knowledge and pro-active replacement
- Enhances reliability and economy of the operation
- Allows for an increased availability of the reactor: > 200 days per year as of 2020
- Paves the road to the next periodic safety reassessment, covering the 2026-2036 period



2025 status and challenges

Successful modernization to ensure mission success of BR2

- Ageing management and upgrades to support mission
- Progress to conversion of fuel from HEU to LEU
- Preparation of periodic safety reassessment 2026

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