South African Regulatory Perspective on Nuclear Graphite Qualification and Manufacturing

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1. Introduction

- In terms of the South African legislation, the NNR Act (Act No 47 of 1999), any person wishing to site, construct, operate, decontaminate or decommission a nuclear installation may apply to the NNR Chief Executive Officer for a nuclear installation licence.
- In July 2000 the NNR received a Nuclear Installation Licence (NIL) application from Eskom for a PBMR Demonstration Power Plant.
- The NNR also developed a number of documents detailing the requirements and recommendations for the licensing of the PBMR.

2. Regulatory Framework

(NNR Licensing Documents - 1)

The scope of regulatory assessment for licensing of the PBMR is based on the licensing requirements and safety criteria defined by the NNR in a number of regulatory documents.

#	Title
RD-0018	Basic Licensing requirements for PBMR
RD-0019	Requirements for the Core Design of the PBMR
RD-0024	Requirements on Risk Assessment and Compliance with Principal Safety Criteria for Nuclear Installations
RD-0034	Quality and Safety Management Requirements for the Nuclear Installations
LD-1096	Fuel qualification requirements for PBMR

2. Regulatory Framework

(NNR Licensing Documents - 2)

#	Title
LD-1097	Qualification Requirements for the Core Structure Ceramics of the PBMR
RD-0014	Emergency Preparedness and response requirements for nuclear installations
RD-0016	Requirements for licensing submissions involving computer software and evaluation models for safety calculations
RD-0026	Decommissioning of Nuclear Facilities
LG-1045	Guidance for licensing submissions involving computer software and evaluation models for safety calculations

2. Regulatory Framework

(Dose and Risk Criteria)

Initiating Event Frequency	Limits
Category A	**Plant Personnel:** • annual individual accumulated design dose limit of 20 mSv **Members of the Public (critical group):** • annual individual design dose limit of 250 μSv (per site)
Category B	**Plant Personnel (outside of exclusion areas):** • 50 mSv individual design dose limit for the total accumulated exposure after one single event **Members of the Public (critical group):** • 50 mSv individual design dose limit for the total accumulated exposure after one single event
Category C	Limitation of risk to the values set by the risk criteria: **Plant Personnel:** • $5 \times 10^{-5}\ y^{-1}$ peak individual risk due to all nuclear installations, and • $10^{-5}\ y^{-1}$ average risk due to all nuclear installations **Members of the Public:** • $5 \times 10^{-6}\ y^{-1}$ peak individual risk due to all nuclear installations, and • $10^{-8}\ y^{-1}$ average risk per site

2. Regulatory Framework

(Licensing Approach)

A multi-staged licensing process has been adopted by the NNR, which includes the following major licensing stages:

- **Stage 1: Acceptance of Concept Safety Case**
- **Stage 2: Site preparation, construction and manufacturing phase**
- **Stage 3: Fuel on Site, Fuel Loading, Testing and Commissioning**
- **Stage 4: Plant operation**
- **Stage 5: Decommissioning**

2. Regulatory Framework

(RD-0034: Quality and Safety Management Requirements for Nuclear Installations)

- **This RD details the requirements of the NNR for quality and safety management systems for licensees, designers and suppliers of nuclear installations in South Africa.**
- **All parties and organisations that are in any way involved in activities important to nuclear safety of a nuclear installation must comply with the applicable requirements of this document.**
- **This RD defines the principles for an Integrated Management System Approach, General Requirements on Organisation and Documentation, Management Responsibility, Resource Management, Process Realisation, Measurement, Analysis and Improvement and Safety Culture.**

2. Regulatory Framework

(Supplier Qualification Process)

- **The regulatory process for the PBMR requires that the applicant must ensure compliance with several requirements on Quality and Safety Management before design, manufacturing, testing and commissioning of safety important components can be initiated .**

- **To this effect the NNR performs joint monitoring activities with the applicant and its designer and is involved as part of its assessment process in the Qualification of PBMR (Pty) Ltd as designer, the Qualification of the applicant (Eskom Client Office) and the Qualification of PBMR suppliers**

2. Regulatory Framework

(Manufacturing of Long Lead Items)

- **The procurement process requires that interventions are identified by the applicant, designer, independent inspector (if the code or standard requires the involvement of an independent inspector) and the NNR.**
- **The NNR oversight activities are to ensure that the characteristics of the product being produced are consistent with the material and design specifications.**

2. Regulatory Framework

(Third Party Independent Inspections)

- **No internationally recognized standards for graphite such as ASME III for metallic components with inherent QA measures and independent third party inspection exist for Graphite.**
- **The NNR therefore requires that PBMR implements a framework where independent third party inspection is ensured with the necessary certification processes.**

3. Graphite Requirements: LD-1097

- **The NNR developed a Requirement Document, LD-1097: "Qualification Requirements for the Core Structure Ceramics of The Pebble Bed Modular Reactor".**
- **This LD stipulates the requirements for the qualification of the CSC materials and structures, and the quality control related to the manufacturing processes of the CSC components.**
- **It also covers the requirements and recommendations for surveillance of the CSC from the construction stage up to the decommissioning of the plant.**
- **The objective of a CSC-QP is to provide confidence in the qualification of the CSC and to ensure that scientifically sound standards and specifications will be applied.**

3. Graphite Requirements: LD-1097

(Selection of material and definition of required properties)

The LD requires that specific safety functions of the CSC be defined to accommodate the functions and characteristics of the CSC. The specific safety functions of the CSC are related to the FSF, which are Heat removal, Reactivity control and Radioactivity confinement.

This section also addresses the following aspects:

- **Safety Classes and Quality Classes**
- **Past Experience**
- **Specification of Basic Material**
- **Material Data Sheets**

3. Graphite Requirements: LD-1097

(Manufacturing Processes and Quality Assurance Preconditions for Manufacturing)

The LD states that as a precondition for manufacturing, the manufacturers of the CSC basic materials must be capable of meeting the principal QA requirements.

In addition to the principal QA requirements, the following specific requirements must be considered:

- **Geometrical Control**
- **Surface inspections**
- **Clean Conditions during handling and manufacturing**
- **Marking of the components**
- **Treatment of deficiencies**

3. Graphite Requirements: LD-1097

(Qualification of material and irradiation testing)

- **A Test Programme consisting of physical, mechanical and Irradiation testing must be carried out that addresses the CSC design criteria.**
- **The Requirements for Basic Material Testing are for Statistics; un-irradiated Material; Material Data Correlation; Material Utilisation; Irradiated Material; In-Situ-Tests and Surveillance During Operation.**
- **If credit is taken from previous qualification programs, the tests must also demonstrate compliance with the properties and characteristics found in the past.**

3. Graphite Requirements: LD-1097

(Qualification of structures and assembly)

This LD stipulates the following requirements for the Qualification of structures and assembly:

- **Requirements for Design**
- **Positioning and Sealing**
- **Definition of Loads**
- **Definition of the Load Cases and the Stress Categories**
- **Structural Analysis**
- **Stress analysis of un-irradiated CSC**
- **Stress Analysis of irradiated CSC**
- **Fatigue Analysis and Lifetime Assessment**

4. Current Research Work by the NNR

(Development of a Graphite Material Model)

The NNR is developing its own model on the irradiation behaviour of graphite in order for the claims made by the PBMR CSC designers to be independently assessed.

- **Task 1 involves the development of a graphite material model, which simulates the changing graphite material properties due to fast neutron irradiation over the required fluence and temperature ranges.**
- **Task 2 will use the GMM and appropriate finite element models of the individual components of the side and central reflectors to determine the component distortions and the internal stresses that may arise over life.**
- **Task 3 work will involve the generation of a model of the CSC over the height of the active core using solid model representations of individual components.**

4. Current Research Work by the NNR

(Position Paper on Graphite Waste)

- **Waste treatment, storage and disposal under strict consideration of shielding aspects, protection of workers and environmental impact in terms of the South African context are defined in the "Radioactive Waste Management Policy and Strategy for the Republic of South Africa 2005" published by the Department of Minerals and Energy of South Africa.**
- **The NNR is in the process of developing a position paper on graphite waste taking the current international status of graphite waste management into account. The first stage of the process is to gather all available information and compile an overview report on international requirements, approaches, and positions on minimization, management and disposal of graphite waste.**

6. Conclusions

- **Not only the qualification of CSC material, but also the manufacturing process and associated assurance process has an impact on safety of the Pebble Bed Modular Reactor. The NNR regulatory framework considers all these aspects in detail.**
- **The NNR is developing independent measures and models to confirm the claims within the safety case.**
- **The NNR is confident that adequate measures have been implemented towards addressing these issues mentioned and that a rigorous process has been developed that will ensure the safety of the PBMR DPP.**

- The End -