Eskom	Technical Requirement Specification	NUCLEAR ENGINEERING

Title: **Technical Requirement Specification for the Procurement of PWR Nuclear Fuel Assemblies for Koeberg Nuclear Power Station from Licensed Fuel Suppliers**

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Compiled by	**Supported by**	**Functional Responsibility**	**Authorized by**
G Nyalunga	**S Steyn**	**T Kana**	**I Sekoko**
Senior Physicist	**Corporate Specialist**	**RFE Manager**	**NAS Manager**
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1. INTRODUCTION

This specification is intended to guide Eskom in its procurement of pressurized water reactor (PWR) nuclear fuel assemblies (FAs)from the broader PWR nuclear fuel market.

The FAs must be compatible with the reactor core components, spent fuel pool fuel racks, and fuel handling tools utilised at KNPS. The fuel must be licensed by the nuclear authority in the country of origin and with the South African nuclear safety authority which is the National Nuclear Regulator (NNR).

The KNPS is of 2 775 MWth rating and utilizes orthogonal PWR fuel assemblies with a square lattice array of 17 x 17 type. The uranium is enriched to levels up to 4.95% w/o ^{235}U. The Gadolinium integrated burnable absorbers (IBA) will be specified by the user. For compatibility with fuel already in use at KNPS, the fuel must have the structure, dimensions and materials as presented in §3.1.

2. SUPPORTING CLAUSES

2.1 Scope of Supply

This specification covers requirements for the procurement of FAs, fuel components and related services from the end-user’s perspective.

The supplier shall provide the following goods and services:

2.1.1 Design fuel that meets the safety and licensing requirements, fabricate, and deliver FAs to Eskom, in accordance with the requirements specified in this document.

2.1.2 Manufacture fuel assemblies in accordance with the specifications, designs, drawings, and Eskom quality control procedure for level 1 suppliers and conform to the design requirements specified in section 3 of this document.

2.1.3 Supply, transport and deliver fuel assemblies and core components as required by Eskom.

2.1.4 Supply reload design (as per request by Eskom), cycle specific studies and supporting documentation.

2.1.5 Provide licensing support and documentation related to fuel design changes, fuel-related codes, methodology, and Koeberg application as required by Eskom.

The supplier must comprehensively follow applicable international, national and local regulations and standards in the design, manufacturing, packaging, storage and shipping of the FAs. The requirements for health and safety are paramount to the sourcing of FAs and will be emphasized in separate specifications.

2.1.6 Purpose

This document serves as a technical specification for the procurement of PWR nuclear fuel assemblies for KNPS unit 1 and 2.

2.1.7 Applicability

This document shall apply to the procurement processes followed by Reactor Fuel Engineering (RFE) and Nuclear Fuel Department (NFD) in the procurement of PWR nuclear fuel assemblies for use at Eskom's KNPS.

2.1.8 Effective date

The technical requirement specification shall be effective from the date of authorisation.

2.2 Normative/Informative References

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

The following documents must be used along with this procurement specification:

[1] ISO 238-101: Quality and Safety Management Requirements for Nuclear Suppliers L1.

[2] 238-219: Level 1 Supplier Safety Culture Enhancement Programme (SECP) Requirements.

[3] 238-54: Radiological Protection Licensing Requirements for Koeberg Nuclear Power Station.

[4] ISO 9001: 2015 Quality Management Systems.

[5] SSR-6: IAEA Safety Standards: Regulations for the Safe Transport of Radioactive Materials, Specific Safety Requirements.

[6] IAEA Safety Standard GSR part 2 (2026): Leadership and Management for Safety.

[7] USNRC 10 CFR Part 71: Packaging and Transportation of Radioactive Material.

[8] RD-0034: Quality and Safety Management Requirement for Nuclear Installations.

[9] ANSI/ASME NQA-1: Quality Assurance Requirements for Nuclear Facility Application.

[10] 0007/04Q: Design, Procurement, Manufacturing, Inspection, Testing, Transportation, Storage and Installation of CSR and SR SSCs, 2016.

[11] IAEA Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities, (INFCIRC/225/Rev 5).

[12] IAEA Safety Series TS-G-1.4: Quality Assurance for the Safe Transport of Radioactive Material.

[13] National Key Points Act 102 of 1980.

[14] Nuclear Energy Act 131 of 1993.

2.2.2 Informative

[15] 240-89294359: Standard Nuclear Safety, Seismic, Environmental, Quality and Importance Classification (KSA-010).

[16] 331-195: Koeberg Accident Analysis Manual (GGM-0907).

[17] 331-93: Guide for Classification of Plant Components, Structures and Parts.

[18] KAA-501: Modifications to Plant, Plant Structures or Operating Parameters that affect the Design Base.

[19] KAA-637: Access Control to Radiological Controlled Zones.

[20] 240-143604773: Process for Performing Safety Evaluations, Screenings, and Safety Justifications.

[21] KAA-737: Process for The Review of Fuel Management Strategy, Fuel Design or Other Changes Affecting Nuclear Fuel.

[22] 331-86: Design Changes to Plant, Plant Structures or Operating Parameters.

[23] KAA-777: Process for Access to Koeberg Nuclear Power Station.

[24] KWS-SK-005: Site Security Measures for Delivery of Fresh Nuclear Fuel at Koeberg Nuclear Power Station.

[25] KWH-X-001: Radiation Protection Responsibilities for Receiving or Transporting Unirradiated Fuel or Empty Fuel Casks at Koeberg and at Other Points in Cape Town.

[26] KAF-003: Preparation for Fuel Container Reception and Dispatch.

[27] 240-142639998: Screening and Safety Evaluation Guide.

[28] KGF-001: Guidelines for the Independent Review of Fuel Related Codes, Methods and Applications.

[29] 331-87: Design Engineering Guide.

[30] KSA-069: Foreign Material Exclusion and the Requirements for System Cleanliness Control.

[31] 331-83: Standard for Plant Changes Affecting the Design of Koeberg Nuclear Power Station.

[32] NIL-01: Koeberg Nuclear Installation Licence.

[33] NNR RG-0016: Guidance on the Verification and Validation of Evaluation and Calculation Models used in Safety and Design Analyses.

2.3 Definitions

2.3.1 Enrichment: Any process that artificially increases the fraction of ^{235}U in a mixture of uranium isotopes to levels higher than what is found in nature. Natural Uranium constitutes about 99.3% of ^{238}U and about 0.7% ^{235}U.

2.3.2 Integrated Management System: A single coherent management system in which all the organisational processes are integrated to enable the organisation's goals strategies, plans and objectives to be achieved. The Integrated Management System integrates the Quality Management and Safety Management and shall consider Nuclear Safety Culture aspects.

2.3.3 Licensing Documents/Application: Documents to be submitted to the NNR in support of licence application, or variations to the licence, or modifications of operating nuclear installations.

2.4 Abbreviations

Abbreviation	Explanation
ASME NQA	American Society of Mechanical Engineers – Nuclear Quality Assurance
CoC	Certificate of Conformance
CoQ	Certificate of Quantities
CQMP	Contract Quality Management Plan
DSE	System Design Files
EUP	Enriched Uranium Product
FA	Fuel Assembly
FR	Fuel Rods
Gd_2O_3	Gadolinium oxide/Gadolinia
GSR	General Safety Requirements
GW.d/MTU	Gigawatt-days per metric ton of uranium
GT	Guide Thimble
IAEA	International Atomic Energy Agency
IBA	Integral Burnable Absorbers
IMS	Integrated Management System
INPO	Institute of Nuclear Power Operations
IT	Instrumentation Thimble
KNPS	Koeberg Nuclear Power Station
MWth	Megawatt thermal
NAS	Nuclear Analysis and Siting
NE	Nuclear Engineering
NFD	Nuclear Fuel Department
NNR	National Nuclear Regulator
OE	Operational Experience
OTS	Operating Technical Specifications

Abbreviation	Explanation
PQE	Procurement Quality Engineering
PWR	Pressurized Water Reactor
QA	Quality Assurance
QCP	Quality Control Plan
RFE	Reactor Fuel Engineering
RCCA	Rod Control Cluster Assembly
SAR	Safety Analysis Report
SCEP	Safety Culture Enhancement Programme
SSR	Safety Standards Series
SGR	Steam Generator Replacement
TRS	Technical Requirement Specification
UO_2	Uranium Dioxide
w/o	weight percent
WANO	World Association of Nuclear Operators

2.5 Roles and Responsibilities

The RFE group shall control this document as the end-user and NFD shall act as the nuclear fuel sourcing agent for KNPS.

2.6 Process for Monitoring

This specification will be kept as a controlled document to be used in the procurement package for nuclear fuel assemblies and related services when such a procurement process is embarked upon.

3. DETAILED SCOPE REQUIREMENTS

KNPS utilizes orthogonal PWR fuel assemblies (FAs) with a square lattice array of 17 x 17 type. The uranium is enriched to levels up to 4.95% w/o ^{235}U and contains Gadolinium-IBA. Typically, a PWR fuel assembly consist of:

- Fuel Rods
- Top Nozzle
- Bottom Nozzle
- Grids
- Guide and Instrumentation Thimble Tubes

This section provides a description of the nuclear fuel design requirements for nuclear fuel that is compatible with the currently used fuel at KNPS. The nuclear fuel assembly design, and its structural support and all dimensions are given in the below subsection.

The nuclear fuel must be able to cope with:

- At least three (3) 18-month cycles.

- A fuel rod burn-up of at least 62 GW.d/MTU.

The materials of the FA and its structural supports must be selected for high performance with regard to irradiation-assisted stress corrosion cracking, dimensional stability at high burnup rate, as well as low neutron absorption rate. Deviation from standard fuel fabrication materials and practices should be supported by tests and analyses in a safety analysis report that would accompany the first consignment.

The fuel must be licensed by the nuclear authority in the country of origin and with the South African safety authority (NNR).

3.1 General Nuclear Fuel Design Specifications

3.1.1 Fuel Assembly specification

The FA specification is provided in the below Table 1.

Table 1: Fuel Assembly Type

FA Orthogonal structure	17 x 17
Assembly Pitch (mm)	215
Number of fuel rods per fuel assembly	264
Number of instrumentation thimbles	1
Number of control rod guide thimbles	24
Number of mid span mixing grids	3
Number of mixing grids	8
Number of grids in active fuel height	10
Overall length of fuel assembly - with Spring not compressed (mm)	~4 100
Mass of Uranium (kg)	~464

3.1.2 Fuel assembly structural specification

The FAs structure specification is described as follow:

a) The top nozzle assembly functions as the upper structural element of the FA and is used for handling.

b) The bottom nozzle is the bottom structural member of the FA whose function is to:

   (i) Prevent debris from being entrapped amongst fuel rods by means of an incorporated debris trap.

   (ii) Positioning the FA onto the bottom core plate.

c) Both the top and bottom nozzles are connected to guide thimbles.

d) The top nozzle guides the transmitted loads to the guide thimbles and limits axial shifting of the fuel rods. It is integrated with the hold-down spring whose function is to:

(i) Counteract the lift-up hydraulic forces and

(ii) Maintain the FA contact with the bottom plate

e) The FA has two types of grids, viz.: structural and midspan mixing grids

(i) The structural grids are for ensuring that fuel rods are equally interspaced. They also provide lateral and vertical supports for fuel rods.

(ii) The mixing vanes of the mixing grid and midspan mixing grids ensure good distribution of flow channel and temperature distribution for effective cooling of FR, both laterally and vertically.

Table 2 below provides design specifications for top nozzle, bottom nozzle and grids of the FA.

Table 2: FA structural specifications

Top nozzle	
Adaptor plate	Yes
Number of hold down springs	4
Bottom nozzle	
Anti-debris device	Yes
Mesh	Yes
Mixing grids	
Number of mixing grids	6
Mid span mixing grids	
Number of mid-span mixing grids	3
Top and bottom grids	
Number of structural grids	2

3.1.3 Fuel Rod Specification

The 264 fuel rods consist of a stack of enriched and sintered uranium dioxide (UO_2) pellets with or without Gadolinium-IBA (UO_2-Gd_2O_3). These pellets should be manufactured according to the required theoretical density. To prevent slippage of pellet column during fuel handling and manoeuvring, a helical stainless steel plenum spring is loaded between the upper face of the last pellet and the lower part of the top end plug. The fuel rod is helium-pressurised to reduce the compressive stress and creep caused by coolant pressure during operation.

The fuel rods are supported at the grid assemblies which are integrated onto the FA's skeleton and spaced at intervals. To allow room for fuel rod growth during operational conditions, clearance is left between the fuel rod ends and top and bottom nozzles. The following Table 3 – 4 provides the fuel rod and fuel pellet specifications.

Table 3: Fuel Rod

Fuel material	UO_2 and UO_2-Gd_2O_3
Total fuel rod length (mm)	~3 875
Active fuel rod height (mm)	~3 658
Pitch between fuel rod – cold (mm)	12.6
Clad outer diameter – cold (mm)	9.5
Clad thickness (mm)	0.57

Table 4: Fuel Pellet

^{235}U enrichment UO_2 pellets UO_2-Gd_2O_3 pellets	 ≤4.95% Apply 5% cut-back rule, depending on Gd content
Pellet diameter (mm)	8.19
UO_2 density (%th.d.*)	≥95.5%
UO_2-Gd_2O_3 density (%th.d.*)	≥95%

*th.d.: theoretical density

3.1.4 Guide and Instrumentation Thimble

The 24 guide tubes (GT) allow for the insertion of rod control cluster assembly (RCCA) absorber rods and thimble plugs into the FA. The one instrumentation tube (IT) is used for the insertion of the in-core neutron flux detectors during core monitoring.

The GT and IT also support the fuel structure and form an integral part of the FA structure and integrity, and their specifications are provided in Table 6 below.

Table 5: Instrumentation and guide thimble

Number of Instrumentation tubes per FA	1
Number of guide tubes per FA	24
Outer diameter (mm)	≥12
Thickness (mm)	≥0.5

3.2 Fuel Assembly Fabrication

The FA's skeletons are fabricated using guide thimbles, structural and mixing grids, as well as top and bottom nozzles with the dimensions as described in §3.1. The cladding material used for the fuel rods would be sourced and made available for the fuel assembly. These fuel components are typically sourced from sub-suppliers.

These components must be inspected against a fabrication plant's quality control parameters. The procuring agent must also have access to sub-supplier's premises for the purpose of quality assurance.

3.2.1 In addition, the supplier shall:

a) Procure of raw materials, as agreed with Eskom.
b) Supply burnable poisons required for the Reload Batch as per the reload design agreed with Eskom.
c) Draw-up of certificates for manufacturing inspections and for the uranium content of the FA's.
d) Ensure chemical composition of each FA component as per product specifications of the fabricator and as prescribed to the sub-supplier.
e) Ensure uranium content and purity requirements of (EUP) as per enricher's specification.
f) Supply Certificates of quality upon request.
g) Provide all applicable technical documentation related to the fuel assemblies being delivered.

3.2.2 The material for FAs components must be selected based on:

a) Resistance to irradiation-assisted stress corrosion cracking.
b) High strength and wear resistance.
c) Potential chemical interaction.
d) High dimensional stability.

3.3 Fuel Delivery, Handling and Transportation

3.3.1 For each Reload Batch, the fuel transport containers utilised to deliver KNPS fuel must be licensed by the NNR.

3.3.2 The transport containers must comply with Regulation for the Safe Transport of Radioactive Materials, IAEA Safety Standard Series No. SSR-6.

3.3.3 KNPS fuel must be delivered in time to meet Eskom's 10-year production plan requirements.

3.3.4 The supplier must provide the equipment/tools required for unloading the FA from the transport containers.

3.3.5 The supplier must provide support during fuel transportation and delivery to KNPS reactor site.

3.3.6 Packaging

a) The FA package must be such that it remains subcritical under normal conditions and hypothetical accident conditions of storage and transport.
b) Shipping containers must be designed and constructed to meet applicable regulatory requirements from the country of origin and must be licensable in South Africa.
c) The manufacturer shall assist in the licensing of transport containers with the NNR.

d) Each fuel transport container shall bear, as a minimum:
   (i) Manufacturer's name
   (ii) Material in container
   (iii) Lot number
   (iv) Gross, tare and weights
   (v) Other markings and information required for safe shipment of FA and components.

3.3.7 Documentation to be submitted to Eskom:

a) Certificate of Conformance (CoC).
b) Certificate of Quantity (CoQ) must be provided to the client by the FA manufacturer.
c) Safety Analysis Report (SAR) for the transport containers.
d) All applicable technical documentation related to the fuel assemblies being delivered.

3.3.8 Safeguards

The Republic of South Africa acceded to the Nuclear Non-Proliferation Treaty on 10 July 1991 and entered into the Comprehensive Safeguards Agreement and the Additional Protocol with the IAEA on 16 September 1991 and 03 September 2002 respectively. It is specifically agreed that the nuclear fuel and any other fissile material used, sold, purchased or produced for KNPS shall be used solely for the promotion and development of the peaceful use of nuclear energy.

To this effect, such nuclear fuel and any other fissile materials used, sold, purchased or produced for KNPS shall be subject to safeguards in accordance with the Comprehensive Safeguards Agreement (INFCIRC/394) between The Government of Republic of South Africa and the IAEA and the Additional Protocol (INFCIRC/394 Add.1).

3.3.9 Compatibility with fuel and core components

All FAs at KNPS have to interface with fuel components, fuel handling tools & equipment and core internals, therefore the FAs must be compatible with:

a) RCCAs used at KNPS.
b) Thimble plugs used at KNPS.
c) Fuel handling tools & equipment used at KNPS, such as but not limited to:
   (i) Fuel handling cranes and applicable software
   (ii) RCCA tool
   (iii) Thimble plug tool
   (iv) Long handling tool
   (v) Short handling tool
   (vi) Flow plug tool

3.4 Fuel Related Studies

3.4.1 For each Reload Batch, the supplier shall provide to Eskom:

3.4.1.1 A reload design (if required by Eskom).

3.4.1.2 Cycle specific studies and supporting documentation viz:

a) Nuclear and Thermal-Hydraulic Design Report.
b) Specific Reload Safety Evaluation Report.
c) Zero Power Physics Test Report.

3.4.2 Licensing Support

The supplier shall provide support and documentation related to fuel design changes, fuel-related codes, methodology, and KNPS application as required by Eskom.

a) Safety Analysis Report (SAR) and all plant related documents updates, such as but not limited to System Design Files (DSEs) and Operating Technical Specification (OTS).
b) Compatibility Report and Compatibility Data.
c) Neutronic Design Report.
d) Mechanical Design Report.
e) Thermal-Hydraulic Design Report.
f) Fuel Rod Design Report.
g) Licensing Summary Report.

3.4.3 Operations Support

a) Technical support during start-up.
b) Technical support during refuelling.

4. QUALITY ASSURANCE

4.1 The engineering classification assigned to the works associated with the design and manufacturing of nuclear fuel is RD-0034 Level 1 (L1/Q1). The Contractor shall implement and maintain an Integrated Management System (IMS) that meets the requirements of Eskom's Quality Specification 238-101 (Quality and Safety Management Requirements for Nuclear Suppliers Level 1). The management system shall be certified to the requirements of ISO 9001: 2015 or equivalent and shall comply to the requirements of a nuclear quality standard such as ASME NQA-1 or IAEA GSR Part 2.

4.2 The contractor shall implement and maintain a Safety Culture Enhancement Programme (SCEP) based on international guidelines such as WANO/ INPO/IAEA, and as per the Eskom guidelines in document 238-219 (Level 1- Supplier Safety Culture Enhancement programme requirements).

4.3 After contract award, a Contract Quality Management Plan (CQMP) will be required in accordance with the of Eskom's Quality Specification 238-101.

4.4 All manufacturing processes will be governed by a Quality Control Plan (QCP) in accordance with the Eskom Quality Specification 238-101.

4.5 Product quality surveillance and release inspections will be performed by Eskom on each consignment to Eskom as planned for and organised with the contractor.

5. ACCEPTANCE

This document has been seen and accepted by:

Name	Designation
R Tshitahe	Chief Engineer - NE
P Xotyeni	Manager – PQE
H Kesonk	Senior Manager – NF (Acting)

6. REVISIONS

Date	Rev.	Compiler	Remarks
September 2022	0	R Tshitahe	First issue of Technical Specification for PWR Fuel Assemblies for Koeberg Nuclear Power Plant - **Superseded**
May 2025	0	G Nyalunga	Revised Technical Specification for PWR Fuel Assemblies for Koeberg Nuclear Power Plant

7. DEVELOPMENT TEAM

The following people were involved in the development of this document:

N/A

8. ACKNOWLEDGEMENTS

N/A.