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Practical Application of the Graded Approach on the Safety of NIRR-1 HEU to LEU Core Conversion

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ABSTRACT

Objective

- To bring out the Fundamental safety requirements of Research Reactors using the Graded approach, to justify the safety and security of NIRR-1(LEU) Core conversion and to ensure that the same Safety Objectives and Engineering design requirements are met.
- Graded approach is a method in which the stringency of the design measures and analyses applied are commensurate with the level of risk posed by the reactor facility.

Introduction

- This paper contains details of safety and design analysis performed for the NIRR-1 core conversion from Highly Enriched Uranium(HEU) fuel to Low Enriched Uranium(LEU) fuel.NIRR-1 is a 31 (kw) MNSR sited at the Centre for Energy Research and Training(CERT), Ahmadu Bello University, Zaria. It is essentially designed for Neutron Activation Analysis(NAA) and few radioisotope production, the facility basic changes are the replacement of the HEU Core with LEU, enriched with 12.5% U^{235},increase in diameter of the cadmium centre control rod absorber ,as well as the increase in the power level.

DESIGN PARAMETER

DESIGN DATA	HEU CORE	LEU CORE
Type	Tank in pool	Tank in pool
Nominal core power(kwth)	31	34
Coolant\moderator	De-ionised light water	De-ionised light water
Reflector	Metallic beryllium	Metallic beryllium
Control rod	1,stainless steel, cadmium absorber	1,stainless steel, cadmium absorb

Number of irradiation sites	10 sites(5 inner & 5 outer)	10 sites(5 inner & 5 c
Reactor operation	Manual\automatic	Manual\automatic
Neutron flux level	1×10^{12} cm^{-2} s^{-1}	1.04×10^{12} cm^{-2} s^{-1}
cooling	Natural convection	Natural convection

Fuel pins	**347**	**348**
Fuel type	**U-Al Alloy**	**UO_2**
Cladding	**Aluminum**	**Zarcaloy-4**
Fuel meat diameter(mm)	**0.6**	**0.6**
Outer diameter of cadmium(mm)	**3.9**	**4.5**

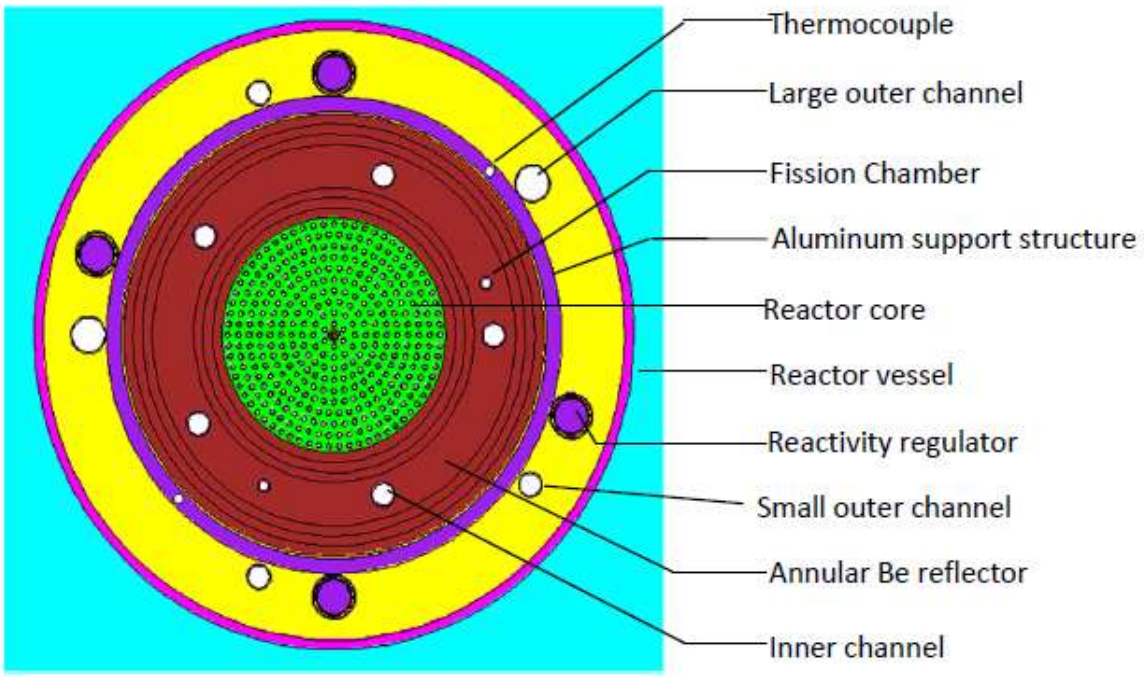
REACTOR PARAMETER

Fuel meat height(mm)	**3**	**2**
Gap size	**NA**	**0.05**
Fuel enrichment	**92.0%**	**12.5%**
Excess reactivity(mk)	**3.77**	**3.98**
Shut-down margin(mk)	**3**	**3.7**
Control rod worth(mk)	**7.0**	**7.7**

THERMOHYDRAULIC PARAMETER

Maximum fuel temperature(^{o}C)	69.6	146.0
Maximum clad temperature(^{o}C)	68.6	112.7

NIRR-1 core mid-plane structure and irradiation sites



Safety justification

- Increase ratio of neutron flux in the irradiation site to the core thermal power
- The LEU has a better shut down margin, because it has a central control rod worth of 7.7mk.

- Fuel integrity & Dose to public are maintained under all operating conditions
- Reactivity coefficients meets required limits and are comparable to the existing HEU core.
- The melting temperatures of the LEU fuel meat and cladding has a better safety margin. The operating temperature of the NIRR-1 is below 100^{o}C, therefore cracking of the LEU fuel is not expected, if for some reasons the fuel did crack, fission product will be contained in the gap of the cracked fuel and fuel will tend to expand until it comes in contact with the cladding, resulting to better heat transfer.
- The length of operation at full power mode of the LEU core is 6.5 hr, compared to the HEU core which is 4.5 hr. Thus conversion to LEU will improve utilization, as NIRR-1 can operate longer

Codes & Standards

- MCNP5(3)
- REBUS-PC\ANL(4)
- WIMS-ANL(5)
- RELAPS-3D(6)
- PARET\ANL(7)
- PLTEMP\ANL(8)
- ORIGEN(9)

References

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- MCNP-A General Monte Carlo N-particle transport code, version 5, LA-CP-03-0245.Los Alamos National Laboratory,USA.