TITLE

APPLICATION OF THE GRADED APPROACH FOR THE SAFETY OF NIRR-1 HEU TO LEU CORE CONVERSION .

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Topics

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- Objectives
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- Safety Analysis
- Graded Approach (GA) to Safety Analysis & Purpose of a GA
- Aim of applying a GA
- The three(3) ways of applying a GA
- **Graded Approach on NIRR-1 to (LEU) core conversion.**
- Introduction
- Design, Reactor & Thermo-Hydraulic parameters
- Nuclear Safety & Nuclear Security justifications for conversion
- Codes & Standards
- Status of conversion of NIRR-1
- Conclusion

Objectives

- To highlight the Safety Requirements for Research Reactors using the Graded Approach.
- Justifying the Safety and Security of NIRR-1(LEU) Core conversion,
- And ensuring that Safety Objectives and Engineering Design Requirements are met.

Introduction

- The Code of Conduct on the Safety of Research Reactors and the IAEA's Safety Standards recommend that a graded approach with regards to the risk potential be applied throughout all stages of the lifetime of a research reactor, including site evaluation, design, construction, commissioning, operation, **conversion**, extended shutdown and decommissioning.
- The methodology for applying the graded approach includes a general assessment of the **potential risk** of the reactor and classification of the items to which the **safety requirements** apply.
- These items may be the reactor as a whole, the structure, systems, components and activities such as management and verification of safety.

Graded Approach

- **Graded Approach** is a method in which the stringency of the **design measures and analysis applied** are commensurate with the level of **risk** posed by the reactor facility,
- The breadth and depth of analysis and magnitude of accepted uncertainties in the safety analysis shall demonstrate that the safety analysis objectives and the requirements are met.

Safety Analysis

- This is an overall assessment of the reactor facility design, including hazards analysis, deterministic safety analysis and probabilistic safety analysis techniques.
- It analyses and identifies all radiation sources in order to evaluate potential radiation doses to workers at the reactor facility, the public, and to evaluate potential effects on the environment.
- It confirms that the design is capable of meeting the safety requirements, dose acceptance criteria and safety goals.
- It also contributes to demonstrating that the reactor facility satisfies the principles of defense in depth .

Graded Approach to Safety Analysis

- The scope, content and details of the Safety Analysis for small reactor facilities may not be the same as for power reactors **(One size does not fit all).** Different accident scenarios may apply and some scenarios may need only a limited Safety Analysis.
- Application of the graded approach to **Safety Analysis** shall be commensurate with the level of **Risk** of the reactor facility.
- **Factors to be considered when applying GA includes:**
- - reactor power
- - reactor safety characteristics
- - amount and enrichment of fissile and fissionable material
- - fuel design
- - type and mass of moderator,
- - reflector and coolant

Cont.

- - utilization of the reactor
- - safety design features
- - source term
- - Sitting and proximity to populated areas

Purpose of applying a Graded Approach

- The purpose of applying a graded approach is to guide the selection of controls to be applied to activities which pose the greatest risk for significant negative impact on quality.
- This focuses management attention on activities which require control and minimizing the application of controls in areas of low risk.

Other objectives of applying Graded Approach

- - minimizing wasting efforts on non-safety related areas;
- - paying more attention to dose relevant analysis.

SUB-TITLE

GRADED APPROACH ON NIRR-1 TO LEU CONVERSION

Introduction

- This presentation contains details on safety and design analysis performed for NIRR-1 core conversion from 92% Highly Enriched Uranium(HEU) fuel to 12.5% 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).
- The basic changes expected in the core conversion 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 marginal increase in the power level.

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- The design and safety analysis for the conversion of NIRR-1 to LEU was prepared by the Centre for Energy Research and Training (CERT) and the Global Threat Reduction Initiative (GTRI)-Conversion Program, initially called the Reduced Enrichment for Research and Test Reactor(RERTR) Program at the Argonne National Laboratory, Chicago under the aegis of the international Atomic Energy Agency(IAEA) coordinated research program.
- The GTRI conversion program is initiated by the United State Department of Energy(USDOE) in 1978 and it has converted over sixty(60) reactors to LEU in its over thirty(30) years of existence.

Design parameters

DESIGN DATA	HEU CORE	LEU CORE
Type	Tank in pool	Tank in pool
Nominal core power(kW)	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 absorber

Number of irradiation sites	10 sites(5 inner & 5 outer)	10 sites(5 inner & 5 outer)
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

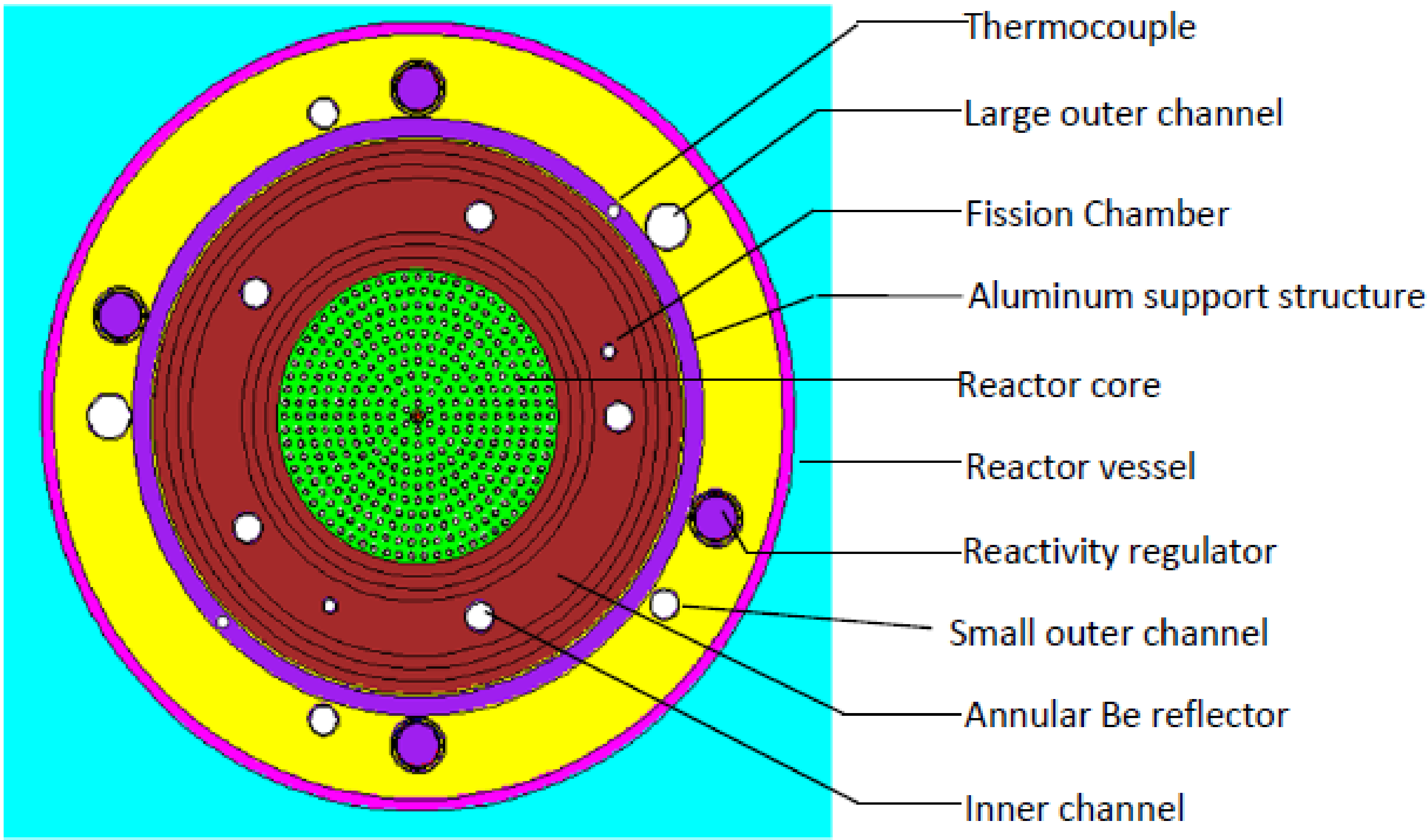
Reactor parameters

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

Thermal hydraulic parameters

Maximum fuel temperature(^oC)	69.6	146.0
Maximum clad temperature(^oC)	68.6	112.7

NIRR-1 core mid-plane structure and irradiation sites



Safety Justifications for (NIRR-1) LEU Core.

- Maintain small compact core structure
- excellent inherent safety features.
- **Fuel integrity** is maintained under all operating conditions
- **Reactivity coefficient** meets required limits and are comparable to the existing HEU core.
- 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, which ensures a shut down margin of 3.72mk, rather than the HEU control rod worth of 7mk and shut down margin of 3mk
- **Dose** to the public from the design bases accident(DBA) and beyond design bases accident (BDBA) are below maximum permissible limits.

Cont.

- The LEU fuel meat is made up of UO_2 sintered pellets cladded with zircaloy-4, the fuel clad has a gap of 50 microns, back filled with **helium gas** which provides good **thermal conduction** between the meat and clad.
- The **melting temperatures** of the LEU fuel meat and cladding are 1850^{o}c and 2800^{o}c while the HEU fuel meat and cladding are 650^{o}c and 650^{o}c respectively. Resulting in better **safety margin** for the LEU core.

Cont.

- 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

Nuclear Security justification

National Nuclear Safety Administration (NNSA) in 2004 Established the Global Threat Reduction Initiative (GTRI) in the Office of Defense Nuclear Non-proliferation to:

- - Identify, secure, remove and facilitate the disposition of high risk vulnerable nuclear and radiological materials around the world that posses a threat to the United States and the international community.
- - Global Threat Reduction Initiative(GTRI's) mission is to reduce and protect vulnerable nuclear and radiological material located at civilian sites worldwide. GTRI achieves its mission via three initiatives which provides a comprehensive approach to preventing **terrorists'** access to nuclear and radiological materials.

Nuclear Security justification - Cont.

- - GTRI is implementing the long-standing U.S. policy to minimize and eliminate the use of highly enriched uranium (HEU) in civilian applications by working to convert research and test reactors and isotope production facilities to the use of low enriched uranium (LEU).
- - The NNSA is also working to prevent proliferation and secure nuclear materials, the Conversion Program demonstrates GTRI’s commitment to protecting the American people and the rest of the world from **nuclear and radiological terrorism.**

GTRI Accomplishments

- Since GTRIs inception it has accelerated its nuclear security efforts and made significant progress to reduce the risk posed by vulnerable civilian nuclear and radiological materials, which could be used by terrorists to make an improvised nuclear device, nuclear weapons or a radiological dispersal device **("dirty bomb").**
- GTRI has converted or verified the shutdown of **88 HEU** research reactors and isotope production facilities and has supported the first successful large scale production of the important medical isotope molybdenum-99 (Mo-99) using LEU targets and supported the development of a reliable, domestic supply of Mo-99 without using HEU.

Domestic Conversions & Shutdowns

In working to minimize the use of **HEU** and prevent **terrorists** from getting **nuclear materials**, GTRI has to date:

- Converted **all U.S. reactors** capable of being converted with existing licensed LEU fuel, including reactors in Florida, Idaho, Indiana, Oregon, Texas, Washington, and Wisconsin.
- Developed a replacement for (LEU) fuel and the associated fuel fabrication capability for the six remaining High Performance Research Reactors in the United States that cannot be converted with existing fuel.

Foreign Conversions & Shutdowns

In addition, GTRI has successfully:

- Converted to LEU fuel, **66 HEU research reactors** in 34 countries, including Argentina, Australia, China, Czech Republic, Hungary, Japan, **Libya**, the Netherlands, Poland, Portugal, South Africa, Ukraine, Uzbekistan, and Vietnam.
- Verified the shutdown of **22 HEU research reactors** in 11 countries, including Bulgaria, Canada, Chile, China, France, Germany, India, Japan, the Netherlands, Russia, and the United Kingdom.

Codes & Standards

The following Codes and Standards were used to calculate **Neutronics** parameters, **Thermal-hydraulic** characteristics and **Radiological** consequences data in the design and analysis of the LEU core for NIRR-1:

- **MCNP** – Is a soft ware packaged for the simulation of Nuclear processes,
- - Design of reactors,
- - The study of behavior and characteristics of Neutrons
- - Dose calculations, etc.It was developed since 1957.
- **WIMS-ANL** – Is used for the design and predictive assessment of reactor physics performance e.g. fuel transport flask.

Codes & Standards

- **RELAPS-3D** – Is a Reactor leak and power safety excursion code.
- **PLTEMP\ANL** – Is used for the calculation of Reactor Thermo-Hydraulic along fuel plates.
- **ORIGEN** – Is a computer code used for calculating the decay and processing of radioactive materials.

Status of conversion of NIRR-1

- Meeting on the Conversion of Nigeria Premier Nuclear Research Reactor (NIRR-1) from HEU to LEU Core under the tripartite initiative between Nigeria, US and China with the support of the IAEA took place on the 14th –15th January 2013. The meeting was attended by the Ag.DG/CEO of the NNRA, Chairman/CEO of NAEC, Two (2) Experts from Argonne National Laboratory (ANL) and One (1) from the United States Department of Energy (US DOE) and Director of CERT, amongst others.
- MNSR Conversion Working Group Meeting @ Vienna, Austria on the 28th - 29th January 2013. This meeting provided update on the key activities coordinated by the MNSR Conversion Working Groups and updates were exchanged on the progress for the individual activities conducted by the working group members, with presentations of individual countries status and preparation for conversion..

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- Presentation on the status of **Pakistan's** Preparation for Conversion by *M. Iqbal*
- Presentation on the status of **Syria's** Preparation for Conversion by *M. Albarhoum*
- Presentation on the status of **Iran's** Preparation for Conversion by *H. Khalafi*
- Presentation on the status of **China's** Preparation for Conversion by *Li Yiguo*
- Presentation on the status of **Nigeria's** Preparation for Conversion by *S. Jonah*
- Presentation on the status of **Ghana's** Preparation for Conversion by *H. Odoi*

Conclusion

- I will like to use this medium to thank The Ag.DG/CEO **Martin Ogharandukun** (Ph.D.), **Directors** and the **Entire Management Staff** of the **NNRA** for the opportunity given to me to attend the Training on the Practical Application of the Graded Approach for the Safety of Research Reactors (5^{th}- 9^{th} December, 2011) and The HEU to LEU Core Conversion Fellowship programme (9^{th} July - 2^{nd} November, 2012) both at the Argonne National Laboratory, Chicago and Los - Alamos National Laboratory, New Mexico.
- This has enabled me to retrieve and fuse knowledge gained from the GA to the Safety Evaluation of the LEU core conversion.

Recommendations

- NNRA should continue to participate in the core conversion program, so that Officers will have adequate technical knowledge on how to review Safety Analysis Report.
- Regulatory Officers should be trained on the use of the codes and standards.
- NNRA may wish to procure all the Codes and Standards required for carrying out regulatory safety assessment including PSA and DSA

THANK YOU…

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- Graded Approach to assuring quality .by Bob Thompson.
- NIRR-1 Final Safety Analysis Report(SAR) 2005.
- Jonah S.A, Balogun G.I, Umar I.M, Maayaki, 2005.Neutron spectrum parameter in irradiation channels of the NIRR-1 for the KO-NAA standardization journal .266,83-88.
- Le R,Hustvert .S."HEU Fuel circle inventories and progress on global minimization "The Non-proliferation Review, July 2008.
- Kyoto University Research Reactor Institute.
- MCNP-A General Monte Carlo N-particle transport code, version 5,LA-CP-03-0245.Los Alamos National Laboratory, USA.

Recommendations

The NNRA may wish to:

Start applying Graded Approach in its regulatory process with concentration on the.

1. Legal infrastructure
2. Regulatory body

- Requirements for staffing
- Resources for in house technical support
- Compliance inspection
- The content and detail of licenses
- Regulations and guides

The detail required of the licensee for submissions of documentation on safety of the facility (e.g safety analysis report)

3. Regulatory body

- Sitting
- Construction
- C commissioning authorization
- Operation
- Renewal
- Decommissioning

4. Inspection and Enforcement

- Structure, systems, components and materials important to safety
- Management systems
- Operational activities and procedures
- Records of operational activities and results of monitoring
- Liason with contractors and other service providers
- Competence of staff
- Safety culture
- Liason with the relevant organization for joint inspection, where necessary

APPLICATION OF GRADED APPROACH ON REGULATORY PROCESS

Introduction

- The regulatory body should :

  - Implement a process of issuing authorizations
  - Undertake regulatory inspections and assessments
  - Enforce the applicable regulations and the authorizations
  - Review and assess submissions on safety
  - Make available, appropriate regulatory requirements and decisions

ITEM 1 : legal infrastructure

- Establish before the project
- **Not gradable**, cause the law is a **binding document** and they are enforceable by law.

ITEM 2 : regulatory body

SUB-ITEM	SMALL REACTOR	LARGE REACTOR
Requirements for staffing	Moderate	Competent
Resources for in house technical support	Moderate	Adequate
Compliance inspection	Infrequently	Regularly
The content and detail of licenses	General	Specific
Regulations and guides	Specific	Specific
The detail required of the licensee for submissions of documentation on safety of the facility (e.g. safety analysis report) -	Specific	Specific
Training and re-training for staff	Moderate	Frequent

ITEM 3 : licensing process

SUB-ITEM	SMALL REACTOR	LARGE REACTOR
Siting	Minor	Major
Construction	Major	Major
Commissioning authorization	Major	Major
Operation	Major	Major
Renewal	Major	Major
Decommissioning	Major	Major

ITEM 4 : inspection and enforcement

SUB-ITEM	SMALL REACTOR	LARGE REACTOR
Structure, systems, components and materials important to safety	Moderately	Adequately
Management systems	Moderately	Adequately
Operational activities and procedures	Adequately	Adequately
Records of operational activities and results of monitoring	Adequately	Adequately
Liason with contractors and other service providers	Moderately	Moderately
Competence of staff	Adequately	Adequately
Safety culture	Adequately	Adequately
Liason with the relevant organization for joint inspection, where necessary	Moderately	Adequately