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PRACTICAL APPLICATION OF LEU FUEL FOR NIRR-1 SAFE OPERATION

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Objective

- This Presentation is primarily aimed at highlighting the safety measures taken during the NIRR-1 Core Conversion to LEU fuel and its Operation by providing proper regulatory scrutiny and ensuring compliance to Nigerian Nuclear Safety Requirements.

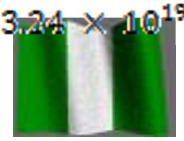
Background

- The NNRA provided oversight of NIRR-1 with HEU Fuel from Feb. 2004 and December 2018
- Plans for the conversion of MNSR to LEU and the return of the HEU spent fuel to China were initiated in 2006 when the IAEA established a CRP to coordinate individual activities.

Background

- NNRA verified and validated the conversion safety analysis carried out at the ANL
- NNRA Officers participated actively in conversions related meetings, conferences, etc between 2014 and 2021.
- The regulatory oversight of nuclear safety and radiation protection was carried out by the NNRA in line with sections 4 and 6 of the Act.

Map of Nigeria



NIRR-1 Parameters with LEU fuel

Type :Tank-in-pool

- Nominal Power: 34kW
- Core fluence lifetime > 3.2 * 10^19 n/cm^2
- Coolant/Moderator: Deionised light water
- Reflector: Metallic Beryllium
- Fuel material: 13% enriched UO_2
- Control rod: 1, Stainless steel clad, Cadmium absorber
- Reactor operation mode: Manual and Automatic

Regulatory Reviews

The Safety Submittals from CERT included:

- Core Conversion Safety Analysis Report
- Core Displacement Safety Analysis Report
- Procedure and Loading of HEU Core into SKODA Cask
- Core Loading and Initial Test Procedures
- Emergency Preparedness Plan
- Fire Safety Plan
- Radiation Protection Plan
- Transport Preparation Plan

Authorization

- The authorizations issued for the Core Conversion include permits, certifications, & licenses.

The permits issued for the Core Conversion are

- ✓ Import Permits for ES3100
- ✓ TUK/MNSR-C with SKODA cask
- ✓ ITC
- ✓ LEU fuel
- ✓ Export Permits for TUK/MNSR-C
- ✓ HEU fuel
- ✓ ES3100
- ✓ Storage of HEU, LEU and Transport permits.

Under water camera Inspection

- The under water camera was used for the inspection of the inner and outer surfaces of the reactor vessel,
- the inner and outer surfaces and tubes in the reactor vessel were checked,
- the He-3 neutron detector was used for the background neutron measurement.
- the neutron counting was measured. He-3 detector voltage: 1320v; Threshold value: 0.62v,
- the average neutron counting was: 3.5 neutron/10s.

Screen view Outer and inner surface of vessel and tube

Neutron Measurement

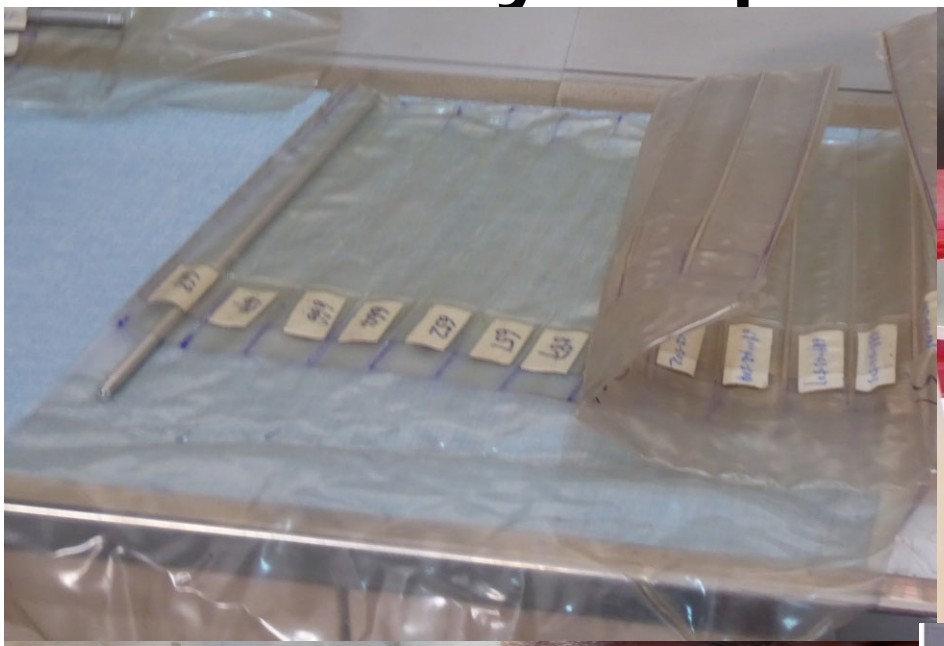
Under water camera Inspection Result

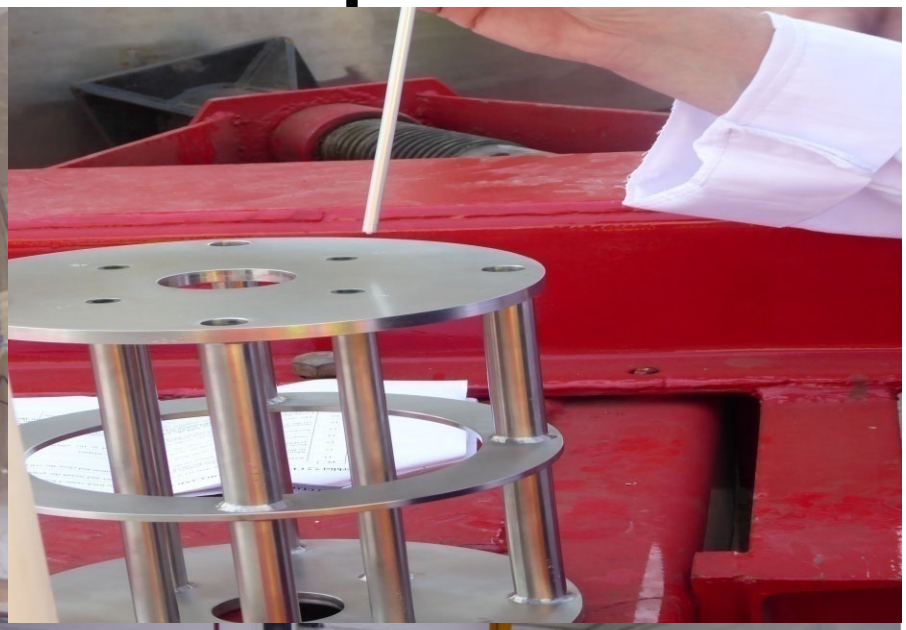
- The inspection of inner and outer surfaces of vessel and neutron measurement was completed by CIAE team and CERT team, under the supervision of the NNRA team. The vessel was in good condition and can be used for LEU core.

Loading of LEU Core, Detectors Installation & Instrumentation Connection & Criticality Test

- NNRA Inspectors observed the Core loading exercise & confirmed that;
- the installation of the control rod and its mechanism was successfully done on the 31st October 2018
- the preliminary criticality test was started at on 31st October 2018 by introduction of the AmBe source through one of the irradiation channel to activate a nuclear reaction

Preliminary core loading & criticality experiment procedure





Reactivity Adjustment Exercise I

- The reactor safely reached criticality under initial loading & the water level of reactor & pool water met designed requirements
- Cadmium absorbers 1, 2, 3 & the emergency Cadmium string were all taken out of the reactor

Reactivity Adjustment Exercise I

- Cadmium rabbits were available & Cadmium string inserted in the inner irradiation tube 5 in accordance with the approved procedure.
- The reactor was started in auto mode at neutron flux of $5x10^9$ n/cm^2s & the position of the control rod was measured to be 88mm,which was taken as the critical height

Reactivity Adjustment Exercise I

- Measurements were take to ensure the periods were within the range of interpolation & extrapolation.
- The worth of reactivity of the Cadmium rabbit, Emergency Cadmium string and irradiation tube ranges in the various positions range from 0.66 to 2. 42.
- the reactor power was raised above zero power for the first time on 22nd November 2018.

Reactivity Adjustment Exercise II

- Reactor power was doubled for the increment of the neutron count at different changes of the Control Rod Position, which was taken at **Zero Power** to attain **34KW** in the Fission Chamber.
- The cadmium rabbit or string was inserted to determine the neutron flux that heat up to determine either low/high reactivity in the vessel so as to know the worth of the neutrons present

Safety of LEU fuel

- Increase ratio of **neutron flux** in the irradiation site to the core thermal power
- The LEU has a better **shut down margin**.
- **Fuel integrity & Dose** to public are maintained under all operating conditions
- **Reactivity coefficients meets required limits and are** comparable to the existing HEU core.

Safety of LEU fuel

- LEU fuel has improved utilization, as NIRR-1 can operate longer
- The **LEU fuel has** better **safety margin**, resulting to better **heat transfer**.

Challenges

- Preliminary reports were done by the Chinese counterpart in Chinese language, therefore the need for translation to English language before submission, which hindered proper documentation
- Long project time that spanned from 2012 to 2018.

Conclusion

- The Conversion assisted in revealing some of the anticipated challenges for oversight activities associated with other nuclear installations such as the planned Nuclear Power Programme in Nigeria.
- Top priority of the NNRA is to ensure the safety of the nuclear facility, personnel and the environment before, during & after the conversion process.

Conclusion

- NNRA ensured the Licensee complied with national and international regulations with respect to radiation protection, nuclear safety, safeguards and physical protection during storage, packaging, transportation and export of nuclear fuel for relevant authorization to be issued by the Authority.
- Licensee provided a detailed work-plan of the entire exercise

Thank you