OPERATIONAL APPROACH ON AGEING MANAGEMENT AT THE GHANA RESEARCH REACTOR-1(GHARR-1) FACILITY

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Abstract

The GHARR-1 reactor has been operational since it attained criticality in 1994. The reactor is located at National Nuclear Research Institute at the Ghana Atomic Energy Commission. It is a tank in pool type reactor using HEU fuel assembly, with light water as moderator and coolant, and beryllium as reflector. The reactor has a nominal power of 30KW. The main utilizations of the reactor are neutron activation analysis and human resource development. Twenty years of operation has registered several ageing issues such as physical and non physical challenges which has led to several refurbishment and modernization projects being undertaken .These include core management , Obsolesce management , improvement of the containment building security, installation of large slant tube and lastly the process of implementation is core conversion from HEU to LEU fuel regime. Detailed descriptions of these diverse activities are presented in the paper.

1.0 Introduction

GHARR-1's successful and continuous operational years have not been isolated from ageing, together with its potential premature failures which are relevant to reactor safety. In order to mitigate ageing effects, the facility has had to deal with several issues due to the time-dependent degradation of its structures, systems and components (SSCs). Assessment of SSCs conditions and the identification of ageing mechanisms during the past years have lead to several activities which were successfully carried out. The routine practices and operational procedures have been outlined with clear emphasis on the ageing management programme at the facility.

1.1. General description

The Ghana Research Reactor-1 (GHARR-1) is a commercial version of the Miniature Neutron Source Reactor (MNSR) and has operated at different power levels since its commissioning in March 1995 [1]. The facility is designed as a low power, pool-in-tank-type research reactor with a compact core consisting of a single fuel assembly comprising 344 U-Al (admixed in aluminum matrix) pins enriched to 90.2%. The fuel assembly consists of ten concentric zones or rings of 354 fuel and structural lattices distributed about a central control rod guide tube. The core is under-moderated with an H/U atom ratio of 197. Thermal power is rated at 30kW with a corresponding peak thermal neutron flux of 1.0E+12n/cm2.s. Cold clean excess reactivity for fresh core is limited to about 4mk. Cooling is achieved by natural convection using light water. The integral reactivity worth of the control rod is about -7mk, providing a core shutdown margin of -3mk of reactivity. The small HEU core has a low critical mass (<1kg). However, it has a relatively large negative temperature coefficient of reactivity to boost its inherent safety properties. The small size of the core facilitates neutron leakage and escape in both axial and radial directions. To minimize such loses and thereby conserve neutron economy, the core is heavily reflected respectively on the side and underneath the fuel cage by a thick annulus and slab of beryllium alloy material.

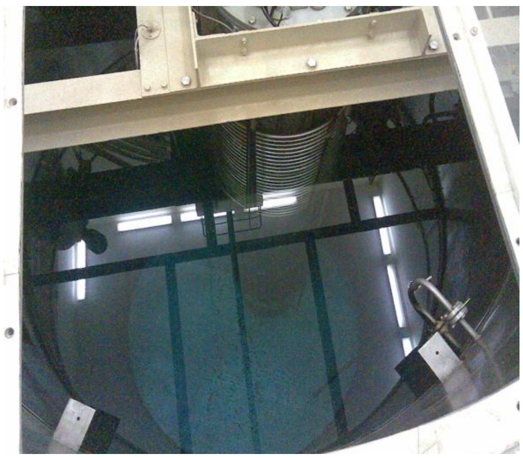

Fig.1a Pictorial view of GHARR-1

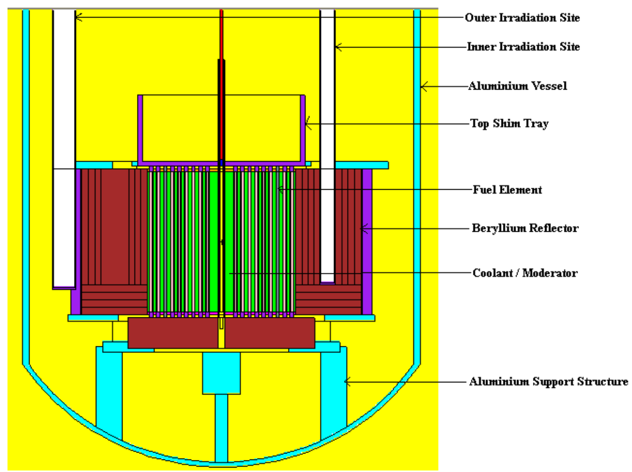

Fig.1b Vertical cross section of GHARR-1

2.0 AGEING MANAGEMENT PROGRAMME OF GHARR-1

Ageing management is defined according to IAEA specific safety guide SSG-10 as engineering, operation, and maintenance strategy and actions to control within acceptable limits the ageing degradation of structures, system and components (SSCs). Ageing management includes activities such as repair, refurbishment and replacement of SSCs, which are similar to other activities carried out at a research reactor in maintenance and testing or when a modification project takes place. Effective management of ageing requires the use of a methodology that will detect and evaluate ageing degradation as a consequence of the service conditions, and involves the application of countermeasures for prevention and mitigation of ageing degradation [2].

The National Nuclear Research Institute (NNRI) is the Operating Organization of GHARR-1 through the Nuclear Reactors Research Centre (NRRC). The Radiation Protection Board (RPB) which was established by the legislative instrument LI 1559 of PNDC Law 308 is the Regulatory Body that has issued license for the operation of the reactor amongst other regulatory activities. The Reactor Manager, the Reactor Safety Committee and the Radiation Safety Committee report to the Director of the Institute. The scope of programme for GHARR-1 ageing management focuses on the management of physical and non physical ageing of SSCs. Ageing is as a general process in which the characteristics of SSCs gradually change with time or use. Research reactors experience two kinds of time dependent changes:

- Degradation of SSCs (physical ageing), i.e. gradual deterioration in their physical characteristics;
- Obsolescence of SSCs (non-physical ageing), i.e. their becoming out of date in comparison with current knowledge, standards and technology.

The following are major components of ageing management programme put in place to mitigate ageing of SSCs of the GHARR-1 facility:

- Operational Procedures
- Maintenance Procedures
- Periodic Testing and Inspection Procedures
- Radiation Protection Procedures
- Utilization and Modification Procedures.
- Administrative Procedures

The operation and maintenance (O&M) group are trained to carry out corrective and preventive maintenance on the facility to ensure smooth operation of the reactor. The maintenance programme include; daily testing and inspection, weekly and annual general maintenance [3].

2.1 SERVICE CONDITION MONITORING

Service condition monitoring is one ageing management strategy used at GHARR-1. Examples of applied service condition monitoring are:

- Conductivity of water coolant;
- PH value of water coolant;
- Water level of the reactor pool;
- Water radiochemical analysis;
- Non-dissolved elements level in coolant water
- Insertion and withdrawal speed and time
- Scram

3.0 Modernization, Refurbishment and upgrading Activities

3.1 Micro Computer Closed Loop System

Two independent control systems are used to operate the reactor; control console (CC) and micro-computer closed loop system (MCCLS). Several parts and components have been replaced, as a result of ageing and obsolescence. The MCCLS was replaced with a new one in 2008 with the operating system changed from Disk Operating System (DOS) to Windows "eXPerience" (Win XP). The interface board sockets have been changed from Industrial Standard Architecture (ISA) to Peripheral Component Interconnect (PCI) making the system user friendly. The new system has been improved based on the original system. Some circuits have been adjusted and some monitoring parameters added to make the new system more efficient. The new version provides the neutron flux, inlet and outlet temperatures, control rod position, reactor water and pool water conductivity, pool water temperature, preset options, data analysis tools and a lot more features that allows for an interactive use of the system. After shutdown, the operating data are stored in EXCEL SHEET.

3.2 Control Rod Drive Mechanism

The control rod drive mechanism was replaced in August 2009. The installation was performed by the staff of GHARR-1, following procedures approved by the regulatory authority. The installation of the new control drive mechanism started on 4th August, 2009 and completed on the 19th August, 2009

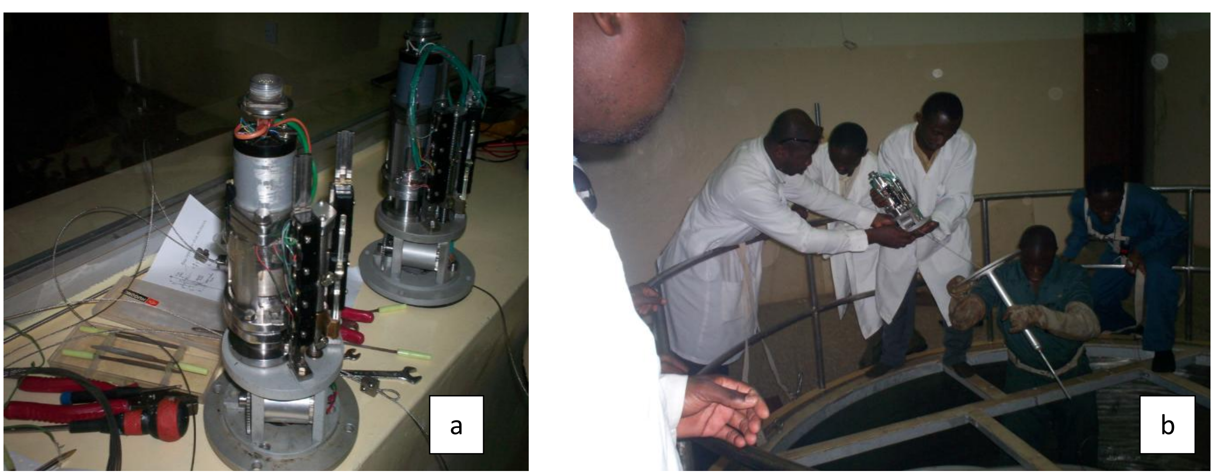

Fig 3a and b. Replacement process of controlled rod drive mechanism

3.3 Construction of Slant Tube (Irradiation Site) For Large Sample Neutron Activation Analysis

The existing irradiation facility is limited in terms of the mass, volume and shape of the sample to be irradiated. Samples require homogenization and representative small samples are taken and wrapped into the polyethylene capsules for irradiation. The pneumatic transfer system is capable of transferring samples a maximum mass of 5.0 g [4]. The limitation of the size of the analytical portion (sample) becomes a problem when the amount of material collected for the analysis is larger, for example, soils, rocks, plant materials and food. Large portion of these materials (a few grams to a few kg) can easily be collected and analyzed using the Large Sample Instrumental Neutron Activation Analysis (LS-INAA) technique and are more closely representative of the entity for which analytical data are required. The LS-INAA technique has unique advantage

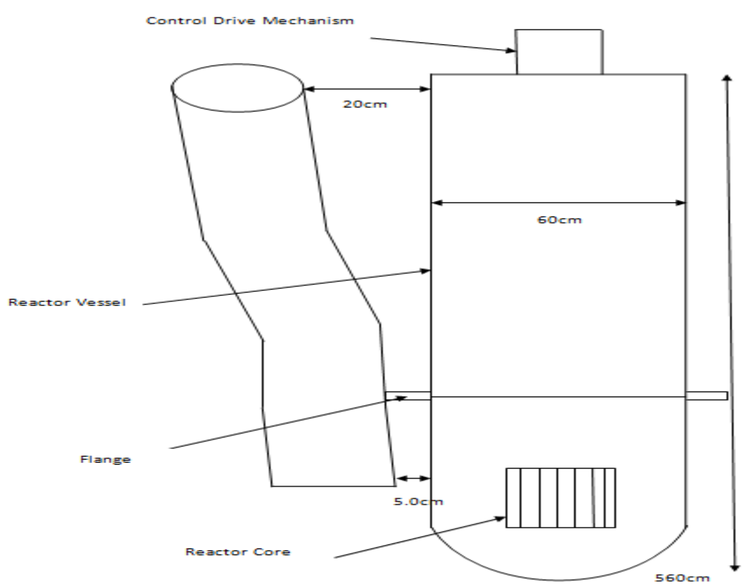

Fig 5. Vertical cross section schematic diagram of the reactor showing the slant tube

3.4 Refurbishment of Deionized water plant

The facility is designed for production of deionized water to top up the reactor and the pool water respectively. The main design parameters to be satisfied for providing quality pure water for the miniature reactor are:

- Water flow rate: 0.5 – 0.7 m^3/h
- Conductivity $\leq 1 \mu S/cm$

- pH = 6.0 ± 0.5

The content of ions such as Fe^{+3}, Cu^{+2}, Cl^{-} are less than 0.1 mg /L respectively. The resins in the plant columns were replaced in December 2012. The columns were repainted; pipes and the valves were also replaced in November 2012 as a result of brittleness due to ageing. Storage tank was also replaced due to leakage.

Fig 3c. Old deionized water plant

Fig.3b Refurbished deionized water plant

4.0 OPERATIONAL SAFETY

4.1 APPROACH AND PRACTICES

Three different sessions of beryllium plate addition of 9 mm thickness have been performed to compensate for reactivity loss due to Samarium poisoning and fuel burn up. An aluminum tray on top of the core is used for Be shim addition to compensate for loss of excess reactivity. The top reflector is of variable thickness and assembled by stacking semi-circular plates within an aluminum tray. It is composed of a group of semi-circular beryllium shims with internal diameter of 243 mm. Long-term reactivity control is exercised by periodically increasing the thickness of this reflector to compensate for reactivity loss caused by fuel burn-up and samarium poison. Under normal operating conditions of the reactor, the top shims need to be added less frequently than once every one and half years based on worth curve of GHARR-1 Beryllium Shim Pieces. The maximum thickness of top shims is 109.5 mm for a cold clean reactor, which is equivalent to 18 mk [5]. In addition to the initial excess reactivity of the core, the presence of the shims ensures that the core life of the reactor fuel elements shall be longer than 10 years. So far the total thickness of Be shim added is 9 mm (3 of 3.0 mm thickness). Prior to Be addition exercise a work plan was developed which includes Procedures, Quality assurance programme (QAP), Radiation protection programme, Emergency response plan and a final clearance from the regulatory authority.

5.2 Core Conversion of GHARR-1

The International Atomic Energy Agency's Coordinated Research Project on "Core Conversion of MNSR facilities" was initiated in 2005. And in 2006, this was approved and studies started in 2006 to formulate work plan. Four phases of work was scheduled as follows: The first phase is to characterize current HEU core, Perform LEU feasibility study and select an LEU fuel. The second phase is review existing SAR to identify necessary changes and review OLCs and PIEs. The third phase is to complete Conversion SAR and prepare startup (Commissioning Plan) for the LEU Core. And finally, phase four is to prepare documentations for shipping and receiving spent HEU core and fresh LEU core. The fuel selected under that study is UO_2 with an enrichment of 12.45 %. The enrichment has now been fine tuned to 12.5% at a Technical Meeting on the Core Conversion Project [6].

The current parameters for the proposed core are compared with the current HEU core parameters in table 1.

Parameter	**HEU**	**LEU**
Fuel meat	UAl_4 in Al matrix	UO_2 pellets
Fuel clad type	303-1 Al alloy	Zircaloy-4
Enrichment (U-235 wt %)	90.2	12.5
Density of fuel meat (g/cm^3)	3.456	10.6
U-235 loading per pin / Core (g)	2.9 / 998.12	3.9/1357.86
Uranium wt. (%)	27.5	88
No. of fuel Pins/Power	344/30 kW	348/34 kW

4.3 Obsolescence Management Approach

Most of the electronics components used in designing the various control circuits have been found to be obsolete and not in used anymore. It becomes very problematic when a component in a particular circuit in the instrumentation and control fails. Most of the components are not found at the local market. Obsolescence approach adopted is the listing of all the ICs, Transistor, and other active components. A search is conducted to find their equivalents from catalogs and internets as a means to mitigate against the components failure and scarcity [7]. These ageing practices have enabled the research reactor to be operated to date.

5. Security

Security activities have been implemented in the GHARR-1 Facility in order prevent possible access to the controlled areas by unauthorized persons. These improvements in reactor security were performed by the IAEA and the regulatory agency in 2012. The frame of this project included fabrication and installation of a reinforced steel door at the reactor hall and vault, installation of closed circuit television in reactor hall and main corridor to the control room and reactor hall. Installation of reinforced steel window grates over windows to the reactor from the control room, addition of infrared and microwave sensors, installation of a balanced magnetic switch on doors to the control room and turnstile to the main corridor.

Conclusion

The paper introduced the ageing management approach which GHAAR-1 has implemented over the twenty years of operation. We hope to enhance international exchange and collaboration. It is challenging to do research on how to manage ageing effectively, but its required in enhancing the safety of reactor operation, extend the life of the reactor and improve the quality of operation, making this work very relevant.

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