SAFETY OF GHANA RESEARCH REACTOR (GHARR-1)

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Abstract

The Ghana Research Reactor, GHARR-1 is a low power research rector with maximum thermal power lever of 30kW. The Reactor is inherently safe that uses highly enriched uranium (HEU) as fuel, light water as moderator and beryllium as a reflector. The construction, commissioning and operation of this reactor have been subjected to the system of authorization and inspection developed by the Regulatory Authority, the Radiation Protection Board (RPB) with the assistance of International Atomic Energy Agency. The Reactor has been regulated by the preparation of an Interim Safety Analysis Report (SAR) based upon International Atomic Energy Agency Standards. International Safety Assessment peer review and safe inspections have confirmed a high level of operational safety of the reactor since it started operating in 1994.

Since its operation there has been no significant reported incident/accidents. Several studies have validated the inherent safety of the reactor. The reactor has been used for neutron activation analysis of various samples, research and teaching. About 1000 samples are analysed annually. The final Safety Analysis Report (SAR) was submitted after five years of extensive research on the operational reactor to the Regulatory Authority for review in June 2000.

1. INTRODUCTION

The Ghana Research Reactor-1 GHARR-1 is a commercial version of the Prototype Miniature Neutron Source Reactor (P-MNSR) designed and manufactured by China Institute of Atomic Energy (CIAE), Beijing. It is a reactor with a nominal power of 30kW. It is a safe nuclear facility which employed high enriched uranium fuel, light water as moderator, coolant and shield and beryllium as reflector. The reactor is cooled by natural convention. It is designed for use in universities, hospitals and research institutes mainly for neutron activation analysis, production of short-lived radioisotopes and education. It is operated at a thermal neutron flux up to $1x10^{12}n/cm^2.s$. The full description and technical details can be found in following publications [1, 2].

The reactor is inherently safe with a very strong capability for power self-regulation. These characteristics have been confirmed through various transient experiments [3, 4]. The total cold excess reactivity is 4.0mk and is controlled through one control rod of work 6-8mk which ensures a shut-down margin of about 3mk. This is sufficient to maintain the reactor in safe mode during shut-down. A scram is provided such that the reactor will not exceed 120% of nominal power and the temperature difference between the core outlet and inlet must not exceed 120% of the nominal limit. The reactor can be shut-down by inserting cadmium rabbits into the core using pneumatic transfer system or manually.

The inherent safety of the reactor is based upon:
1. its strong negative reactivity coefficient;
2. its core coolability by natural convention;
3. its built-in excess reactivity, which, for clean and cold core is limited to 4mk.

2. REGULATORY FRAMEWORK FOR LICENSING AND INSPECTION OF THE REACTOR

In Ghana, the Radiation Protection Board is the sole regulatory authority for the purposes of nuclear and radiation safety. It was established by Provisional National Defence Council Law 308 of 1993 by amending the Ghana Atomic Energy Act 204 of 1963. The Radiation Protection Regulations LI 1559 of 1993 prescribed the mandate and responsibilities of the Board as a licensing Authority for the radiation Protection and Waste Safety [5, 6, 7].

Pursuant to the regulatory requirements to obtain a license before operating the reactor, the National Nuclear Research Institute applied for following licenses:

(i) constructional license by submitting three chapters of the Safety Analysis report, namely Safety Principles and General Design Criteria, Site Characteristics and Building and Structures. After review of the application a constructional license was issued on 1st March 1994 (GHARR-1-94-01);
(ii) source loading license, GHARR-1-95-04;
(iii) criticality tests license GHARR-1-95-05;
(iv) high power test license GHARR-1-95-06;
(v) operator's license and Senior operators licenses, GHARR-1-95-01-3;
(vi) provisional operational license GHARR-1-95-07.

These stages of the licensing procedures were reviewed by the Board's Technical Committee and upon the advice of this committee all the appropriate licenses were issued by the Board. All these licenses were issued with the proviso that the completed SAR and written procedures be submitted by 31st March 1995. The interim Safety Analysis Report was submitted on 28 April 1995 to the RPB after internal review by the Reactor Safety Committee and Radiation Safety Committee of the National Nuclear research Institute (NNRI). The SAR was written in accordance with IAEA guidelines [8, 9, 10]. The NNRI submitted in addition to the SAR, the following supporting documents 'On-site and zero power experiments for start-up of Ghana Research Reactor, GAEC-NNRI-RT-22', 'Steady State Operational Characteristics of Ghana Research Reactor-1, GAEC-NNRI-RT-23' and 'Dynamic Feedback Characteristics of Ghana Research Reasctor-1, GAEC-NNRI-RT-24'.

The provisional operational license was based upon the terms and conditions as specified in the Operating Limits and Conditions (OLC) as contained in chapter 17 of the Safety Analysis Report and Nuclear and Radiation and Waste Safety regulations applicable in Ghana [11].

The essential elements of the Operational Limits and Conditions (OLC) can be summarized as follows:

1. power limit: < 87kW;
2. temperature at the inlet of the core: < 30°C at 30kW;
3. water level of the reactor vessel: < 460cm;
4. safety system settings for max power: 63kW;
5. minimum water level: 465cm; and
6. maximum difference of temperature through the core: 21°C.

3. INTERNATIONAL CO-OPERATION TO ENSURE SAFE OPERATION OF RESEARCH REACTOR-1, GHARR-1

Ghana Atomic Energy Commission requested International Atomic Energy agency through the Technical Assistance Project GHA/1/010 in 1994 for the provision and installation of a 30kW research reactor.

Under this project IAEA provided all equipment to make the reactor critical. Several experts were provided during the installation, preparation and review of the Interim Safety Analysis Report [11] and licensing of GHARR-1.

Under the Agency Supply Agreement INFCIRC/468 of 1994 an Integrated Safety Assessment of Research Reactor (INSARR) mission was undertaken by two experts in February 1997. They reviewed the regulatory, radiation protection, nuclear safety aspects and the operations of the reactor [12].

The conclusions and recommendations of this mission enabled the Regulatory Authority (Radiation Protection Board) and the licensee (National Nuclear Research Institute) with the assistance of the IAEA to enhance the regulatory oversight and operational safety of the GHARR-1. International Atomic Energy Agency has also provided support for several research contracts to be implemented toward enhanced utilization of the research reactor on the following topics:

1. Calculations for the Core configuration of the Miniature Neutron source Reactor, Research Contract No. 5734/R2/RB.
2. Steady State Operational Characteristics of Ghana Research Reactor-1, IAEA Research Contract No. 8789/RB.
3. Nuclear Core Design Analysis of Ghana Research Reactor-1, GAEC-NNRI-RT-40 (1995).
4. On-site Critical and Zero Power Experiments for Start-up of Ghana Research Reactor-1, GAEC-NNRI-RT-22 (1995).

The recommendations of the INSARR Mission in 1997 and RPB; and the results of the IAEA co-ordinated research contracts have been used to complete the final Safety Analysis Report. The SAR was submitted to RPB for review in June 2000. The Research and Technical committee of RPB is currently reviewing the Final Safety Analysis Report (SAR). [13]

Since the reactor was commissioned in 1995 there has been five safeguards inspection missions to Ghana in 1996,1997,1998 ,1999 and 2000.

4. QUALIFICATION AND TRAINING OF PERSONNEL

The required qualification and training of the operating staff is well established in the SAR and OLC. The training and retraining programme are in general adequate and the licensed operators are examined every two years to renew their licenses. The operators were trained by the supplier. The operators were certified by RPB after passing a written test and oral examination.

Operating staff of reactor undergoes periodic training workshop/seminars organized by IAEA on Research Reactor topics relevant to their jobs. Operating personnel also receive training on the job on procedures for safe operation of the reactor, conduct of routine experiments, handling and storage of all radioactive materials, emergency and security procedures.

5. UTILIZATION OF THE RESEARCH REACTOR

Section 11.1 of the SAR provides description of the experimental facilities of the GHARR-1, in particular rabbit A and B systems. Currently the utilization programme of the reactor includes:

1. Neutron Activation Analysis (NAA);
2. education and training of University students and foreign students; and
3. collaborative research with researchers in the sub-region.

Production of radioisotopes is under development. Yearly annual reports for the operation of the reactor indicate the extent of utilization. [14]

6. CONCLUSION

The successful implementation of the Miniature Neutron Source Reactor (MNSR), GHARR-1 is a clear demonstration of what can be achieved through a collaborative commitment from the Government of Ghana and International Atomic Energy Agency.

The basic radiation protection, nuclear safety and regulatory infrastructure have been well established for the safe operation of the 30kW research reactor.

The operational staff through the Technical and Scientific assistance received from IAEA have undertaken extensive and comprehensive research on the commercial MNSR supplied by China. The final Safety Analysis Report contains current data especially chapter 16 ‘Safety Analysis’ on transient analysis of fresh core replacement and over-addition of ße plates accidents and estimation of neutron and gamma-dose rates for loss-of-coolant accident (LOCA).

The Operational Limits and Conditions (OLC) have been revised as suggested by the INSARR Mission in 1997. The expertise gained by Ghana is being used by IAEA to assist other member states implementing similar research reactor projects.

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