

## **Internal Peer Review (IPR) of Pakistan Research Reactor-I (PARR-I)**

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### **Abstract**

The lessons learned from Fukushima Daiichi accident helped the nuclear community to revisit the design of nuclear installations and identify vulnerabilities for preventing accidents involving large releases of radioactive materials. In this context, corporate office of Pakistan Atomic Energy Commission (PAEC) conducted Internal Peer Review (IPR) of Pakistan Research Reactor-I (PARR-I). Objective of IPR was to conduct operational safety review and safety assessment of PARR-I and to prepare them for the proposed IAEA (INSARR) Mission. Review of PARR-I was based on IAEA safety standards, national regulations and international best practices. For IPR of PARR-I mutually agreed 19 areas were selected for review. Various issues were identified during the review process and recommendations and suggestions for rectification of these issues were made by the reviewers. As a result, Corrective Action Plan (CAP) was prepared for implementing necessary measures to enhance safety/robustness of PARR-I, which has recently completed 50 years of successful operation.

## 1. INTRODUCTION

On 11th March 2011, due a severe earthquake and subsequent tsunami, an accident at the Fukushima Daiichi nuclear power plant in Japan occurred. This accident resulted in extended station blackout, loss of core cooling, fuel melting, hydrogen explosions and releases of radioactive material to the surrounding region. The lessons learned from this accident helped the nuclear community to revisit the design of nuclear installations and identify vulnerabilities for preventing accidents involving large releases of radioactive materials. In 2011, IAEA prepared an Action Plan [1] which proposed a number of measures learned from Fukushima Daiichi accident for strengthening of nuclear safety focusing on safety assessments of Nuclear Power Plants (NPPs) in the light of Fukushima accident, Peer reviews, emergency preparedness and response, national regulatory bodies, operating organizations, capacity building, protection of people and the environment from ionizing radiation, communication and information dissemination, etc.

In Pakistan there were three operational NPPs at the time of Fukushima Daiichi accident. Under the guidelines of IAEA action plan, comprehensive safety reassessment of the design of these nuclear power plants was carried out to assess their ability to withstand the effects of extreme external events. Pakistan Atomic Energy Commission (PAEC) in collaboration with other stockholders identified corrective actions for improvements in different areas for NPPs under the framework Fukushima Response Action Plan (FRAP). Most of the proposed actions of these action plans have already been completed successfully [2].

Pakistan has two research reactors with the names Pakistan Research Reactor-I (PARR-I) and Pakistan Research Reactor-II (PARR-II). Due to the lower hazard potential, FRAP program is not yet extended to these research reactors. In 2015, corporate office of PAEC conducted an Internal Peer Review (IPR) [3] of PARR-I. Objective of IPR was to conduct operational safety review and safety assessment of PARR-I and to prepare PARR-I for the proposed IAEA (INSARR) Mission. Review of PARR-I was based on latest IAEA safety standards [4], national regulations [5] and international best practices. Ensuing sections will present brief description of IPR of PARR-I.

## 2. PAKISTAN RESEARCH REACTOR-I (PARR-I)

PARR-1 [6] is located at Pakistan Institute of Science and Technology (PINSTECH) complex some 20 km south-east of Islamabad. PARR-1 is a swimming pool type Research Reactor which was first commissioned in December 1965 and went critical on December 21, 1965. After carrying out detailed study of reactor performance with several core configurations, reactor attained its full thermal power of 5 MW on June 9, 1966. PARR-1 was converted from Highly Enriched Uranium (HEU) fuel to Low Enriched Uranium (LEU) fuel in 1991 with power increase to 9 MW after major modifications in reactor core and associated equipment and facilities. In 1998 PARR-I power was further increased to 10 MW by increasing coolant flow rate.

PARR-I has been used for radioisotope production, beam tube experiments, neutron radiography, and the training of nuclear reactor operators and nuclear engineering students. Some important milestones, main specifications and schematic diagram of PARR-I are given below:

TABLE-1: Milestones of PARR-I

Contract signed	05 March 1962
Contract Parties	IAEA, Pakistan and USA
Construction started	May 1963
Construction Completed	1965
Initial Criticality with HEU fuel	21 Dec 1965
First Full Power Operation at 5 MW	09 June 1966
Renovation of Instrumentation and Control	1986
Dismantling of Last HEU Core	Nov 1990
First Criticality with LEU fuel	31 Oct 1991
First High Power Operation at 9 MW with LEU fuel	07 May 1992
First Full Power Operation at 10 MW with LEU fuel	27 Feb 1998
First Irradiation of Fuel Plates for <sup>99</sup> Mo Production	16 July 2010

TABLE-2: Main Specifications of PARR-1

Type	Swimming Pool
Nominal core power (MW)	10
Lattice pitch (mm)	81.0×77.11
Fuel material and enrichment	U <sub>3</sub> Si <sub>2</sub> -Al (19.99 % by wt)
Cladding material	Aluminum
Coolant/Moderator	Light water (H <sub>2</sub> O)
Coolant flow rate (m <sup>3</sup> /hr)	950
Reflector	Light water and Graphite
Fuel element description	Straight plate MTR type fuel element
U <sup>235</sup> contents per fuel plate (g)	12.61
Control rods	Oval shaped 5 rods
Composition of control rods	80% Ag, 15% In, 5% Cd
Operational Modes	Manual and Automatic
Neutron Flux:	
Max. Flux (th) (n/cm <sup>2</sup> -s)	~9.0×10 <sup>13</sup>
Max. Flux (fast) (n/cm <sup>2</sup> -s)	~2.6×10 <sup>14</sup>

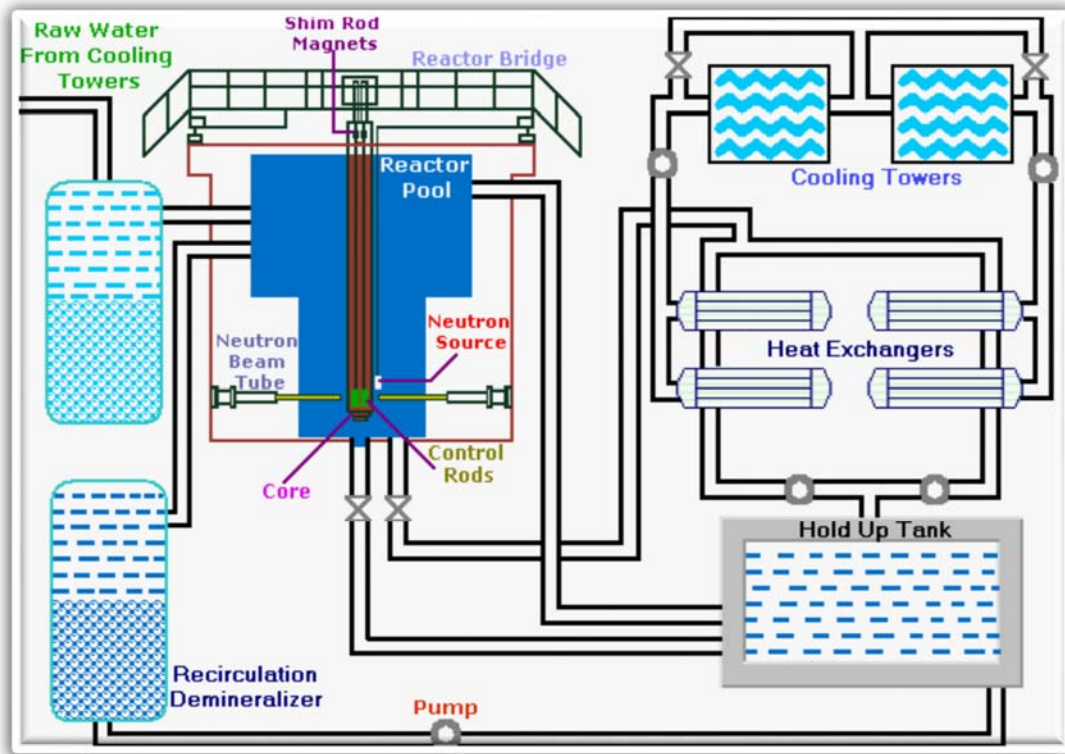


FIGURE-1: Schematic diagram of PARR-1 cooling system

### 3. OBJECTIVE AND SCOPE OF INTERNAL PEER REVIEW (IPR)

Objective of this IPR was to conduct operational safety review and safety assessment of PARR-1 and to prepare them for the proposed IAEA (INSARR) Mission. Sharing of information and learning from each other's experience was the additional benefit to IPR team and the reactor personnel. For IPR of PARR-1, mutually agreed review areas are listed below:

- i. Safety Analysis (SAN)
- ii. Safety Analysis Report (SAR)
- iii. Siting and Protection against External Events (SPE)
- iv. Modifications (MOD)
- v. Utilization and Experiments (UEM)
- vi. Operational Limits and Conditions (OLC)
- vii. Conduct of Operations (COP)
- viii. Operating Organization and Reactor Management (OOR)
- ix. Management System (MSY)
- x. Safety Culture (SCU)
- xi. Radiation Protection (RPP)
- xii. Safety Committees (SCO)
- xiii. Emergency Planning (EMP)
- xiv. Radioactive Waste Management (RWM)
- xv. Training and Qualifications (TRQ)

- xvi. Regulatory Supervision (REG)
- xvii. Maintenance and Periodic Testing (MPT)
- xviii. Decommissioning (DEC)

#### **4. CONDUCT OF INTERNAL PEER REVIEW**

##### **4.1 REVIEW CRITERIA**

IPR team assessed the documents including Safety Analysis Report (SAR), Policies, Plans, Procedures and Practices of PARR-I against IAEA Safety Standards, national regulations and international best practices. This process resulted in identification of safety Issues based on observed facts. Reviewers also offered recommendations and suggestions, for rectification of the issues.

##### **4.2 WALK DOWN VISIT**

As part of IPR process, review team performed facility walk down along with area counterparts to take first impression about PARR-1. PARR-1 Buildings and associated labs were visited by the team include:

- Cooling Tower
- HVAC Room
- Reactor Hall
- Analytical Lab RW-5,
- Spent Fuel Storage Bay
- EMG Lab
- Pump House
- Emergency Diesel Generator Area
- Solid Waste Storage Area
- Solid Waste Conditioning/ Compaction Hall
- SSDL Lab
- Radio Chemistry Lab

#### **5. ISSUES AND RECOMMENDATIONS**

IPR process was stretched over two weeks of strenuous efforts of the nineteen of Area Reviewers and Area Coordinators from PARR-1. IPR team identified thirty-four (34) Safety Issues related to 19 review areas. These issues were based on facts and agreed by the relevant area coordinators. Corrective measures to rectify the safety issues were also discussed between reviewers and counterparts. PARR-1 management showed commitment to chalk out a Corrective Action Plan (CAP) for resolution of the issues within due course of time. Some of the issues and recommendations related to Safety Analysis, Safety Analysis Report and Siting and Protection against External Events (SPE) are discussed in the following section.

##### **5.1 SAFETY ANALYSIS**

Mitigation actions should be planned for any incident or accident situation; additional safety barriers could be added to prevent or to mitigate their consequences. For this reason, all the possible consequences of incidents and accidents should be well analysed. Accidents or incidents which are not addressed in the SAR, but which may occur, could likely lead to higher public doses, different from those estimated in existing calculations.

It was recommended by IPR team that the chapter on Safety Analysis in the SAR should consider the following:

- Comprehensive list of Postulated Initiating Events including human errors, specialized internal events and external events (including fire events)
- The criteria and safety principles regarding single failure criterion and common cause failure.

- Methods of identification and selection of initiating events. Methods of analysis for each postulated initiating event including qualitative and quantitative information.
- Complete spectrum of accident (DBA/BDBA) initiating events considered in the analysis, and justification for the rejection of particular initiating events.

## **5.2 SAFETY ANALYSIS REPORT**

Safety Analysis Report (SAR) is a regulatory document and was not revised since 2001. As SAR serves as a major source of information on the current plant design and supporting analyses and is considered as part of the current licensing basis. It was recommended by IPR team that SAR should be updated as per current IAEA Safety Guide IAEA SSG-20 (2012) and National Regulation PNRA PAK/923 (2012).

In this regard, PARR-I has revised the SAR as per IAEA safety guide SSG-20 and is submitted to corporate office for review before submission to the regulatory body.

## **5.3 SITING AND PROTECTION AGAINST EXTERNAL EVENTS (SPE)**

According to NS-R-4 Chapter 5 on Site Evaluation, site shall be adequately investigated with regard to all the characteristics that could affect safety in natural and human induced events. The hazards associated with external events (and combinations of events) that are to be considered in the design of the reactor.

It was recommended by IPR team that internal events (internal fires or explosions, internal flooding and exothermic chemical reactions) and external events (explosions, aircraft crashes, fires, toxic spills and effects from adjacent facilities) should also be analysed.

## **6. CONCLUSION**

Most of the corrective actions proposed, in the light of lessons learned from Fukushima Daiichi accident, have already been completed successfully at nuclear power plants of Pakistan under FRAP program. Due to lower hazard potential of research reactors this program is still not extended to the two research reactors of Pakistan. During IPR of PARR-I, special emphasis has been made to assess design conformance of the reactor with current national regulations and IAEA safety standards. Corrective actions recommended for the identified safety issues were made keeping in view the lessons learned from Fukushima Daiichi accident. But due to the old design of PARR-I (more than 50 years), need for a comprehensive reassessment program like FRAP cannot be ruled out. IAEA may help member states (as in case of NPPs) to plan a standardize action plan for evaluation and strengthening of Research Reactors against extreme natural events.

**6. REFERENCES**

- [1] IAEA Action Plan on Nuclear Safety.
- [2] Progress Review of the Fukushima Action Plan.
- [3] Internal Peer Review of PARR-I, PINSTECH, February 2016.
- [4] International Atomic Energy Commission, Safety Reassessment for Research Reactors in the light of the Accident at the Fukushima Daiichi Nuclear Power, IAEA Safety Report Series No. 80, Vienna (2014).
- [5] PNRA Regulatory Guide, PAK 923.
- [6] Safety Analysis Report of Pakistan Research Reactor-I, March, 2001.