AGEING MANAGEMENT OF PAKISTAN RESEARCH REACTOR-1

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ABSTRACT

Pakistan Research Reactor-1 (PARR-1), a swimming pool, MTR type research reactor, which went critical on 21st December 1965, has faced physical and non-physical ageing issues during last decades. The ageing issues, though having been addressed from time to time in past, require continuous attention. A formal ageing management programme has been introduced in the light of IAEA guidelines. The programme is being implemented under which various actions have been taken and some actions are planned for near future.

1. Introduction to PARR-1

Pakistan Research Reactor-1 (PARR-1), a swimming pool, MTR type research reactor went critical on 21 December 1965 and attained full power of 5 MW on 22 June 1966 with 93 % Highly Enriched Uranium (HEU) fuel. The reactor was shut down in 1990 for core conversion to commercially available < 20 % Low Enriched Uranium (LEU) fuel. During the process of core conversion the reactor power was also upgraded to 10 MW. PARR-1 went critical with LEU fuel on October 31, 1991 and attained the upgraded power level of 9 MW on 07 May 1992. The reactor power was raised to 10 MW on 27 February 1998 after enhancing the primary flow rate.

2. Ageing Issues

The physical ageing of PARR-1, due to the equipment, wear and tear, corrosion, vibration, stressing, thermal and mechanical fatigue and the general deterioration of the plant etc., has been manifested and dealt with timely. The non physical ageing issues have also been considered to maintain the adequate level of staff skills due to retire or organizational changes.

3. Life Limiting Factors

Embedded primary piping is seen as the life limiting factor for PARR-1. The pipe is embedded about 1.5 m deep in concrete and if this pipe becomes leaky due to corrosion, erosion or cracks, the replacement will not be possible and the reactor will have to be shut down permanently. Components like core support structure, grid plate and plenum are theoretically replaceable but, in reality, a replacement may be impracticable due to high radiation doses.

3. Past Ageing Issues

The physical ageing issues tacked in the past include pool civil repairs, heat exchangers descaling, replacement of cooling tower, renovation of instrumentation and control. During core conversion and power upgradation a number of systems were renovated, new systems were installed and visual inspection of key components was carried out.

4. Ageing Management Programme

A formal ageing management programme has been prepared in the light of the IAEA Safety Guide No. SSG-10 entitled “Ageing Management for Research Reactors”[1]. The elements of the programme are: screening / selection of SSCs for ageing management, identification and understanding of ageing degradation, minimization of ageing degradation, detection, monitor-

ing and trending of ageing degradation, mitigation of ageing degradation (corrective measures), review and improvement of the ageing management programme, and record keeping [2].

4.1 Screening of SSCs for Ageing Management

SSCs that can have a negative impact on the safe operation of the reactor and that are susceptible to ageing degradation are identified for ageing management. Identification of SSCs important to safety for which ageing degradation has the potential to cause failure may be based upon the knowledge gained from operating experience. The screening also takes into consideration the ease of replacement of SSCs. For efficiency, consideration is given to grouping similar components that operate in comparable service conditions.

4.2 Identification and Understanding of Ageing Degradation

To understand the ageing degradation of an SSC identified for ageing management review, its ageing mechanism and effects are identified. Existing methods for inspection and testing are also evaluated, taking into account the operating experience, to determine whether they are effective for timely detection of ageing degradation before the failure of the SSC.

4.3 Minimization of Ageing Degradation

Where applicable, preventive actions are taken to limit the effects of ageing degradation which may include: an assessment of the current maintenance methods and practices (e.g. refurbishment and periodic replacement of parts); and establishment of appropriate operating conditions and implementation of practices that minimize the ageing degradation.

4.4 Detection, Monitoring and Trending of Ageing Degradation

The SSCs identified for ageing management review are examined by inspections (in-service inspections), monitoring (of operating parameters indicative of ageing degradation), performance tests, periodic testing (to ensure compliance with OLCs), or non-destructive testing for detecting effects of the identified ageing mechanisms. The results of these examinations are compared with the results of previous examinations, if available, to determine whether the conditions of the SSCs are acceptable for continued safe operation or whether remedial measures need to be taken. The frequency of examination may be adjusted on the basis of the likelihood of failure of a SSC and on the basis of experience.

4.5 Mitigation of Ageing Degradation

If needed, effective mitigatory actions (corrective measures) are taken for mitigation of ageing degradation of SSCs, taking into account the relevant operating experience. The mitigatory actions may include maintenance, refurbishment, periodic replacement of components, modification of SSCs, and altering of operational limits and conditions that may affect the rate of ageing degradation of SSCs.

4.6 Review and Improvement of the Ageing Management Programme

The effectiveness of the ageing management programme will be reviewed periodically or when needed in the light of current knowledge and experience. Current knowledge will be acquired from information on operation of SSCs, maintenance and surveillance records and ageing evaluations and condition assessments (examinations). Periodic performance reviews of SSCs, if performed, may also from a basis for continuous improvement of ageing management programme. Consideration will also be given to arranging peer reviews of the ageing management programme to identify areas for improvement. The ageing management programme will

be updated as appropriate.

4.7 Record Keeping

A record will be maintained of the data required in relation to the ageing management activities. Such data include: baseline information (including results of ageing evaluations and condition assessments (examinations) and any remedial measures); operation records (including testing and failure of SSCs); and maintenance records (including information on condition of SSCs).

5. Management of Obsolescence

When SSCs important to safety become out of date (obsolete) due to changes in technology or changes in regulations and standards, the obsolescence of these SSCs will be identified and corrective actions taken before the occurrence of any decline in reliability.
When documentation becomes out of date (obsolete) due to modifications of SSCs, changes in the utilization programme (installation of a new experiment / changes in an existing experiment), or changes in regulations and standards, the obsolete documents (e.g. operating procedures, drawings, safety analysis report, operational limits and conditions, emergency plan etc.) will be updated.

Conditions	Ageing effects	Management actions
Changes in technology	- Incompatibility between old and new equipment - Unavailability of suppliers - Shortage or lack of spare parts	- Identify useful service life and anticipated obsolescence - Replace obsolete SSCs where possible/important - Identify alternate suppliers - Provide spares for planned service life
Changes in standards and regulations, advances in knowledge	- Deviations from current standards and regulations - Outdated knowledge	- Comply with current standards and regulations - Apply updated knowledge where possible/important
Documentation becoming out of date	Lack of the information needed for safe operation	Update documents

Table 1: Types of obsolescence and associated ageing effects and recommended ageing management actions

6. Interfaces with Other Technical Areas

There are some technical areas of work which interface with or are closely related to the ageing management programme and ageing management activities. In case of PARR-1, these areas of work are: maintenance, periodic testing and inspection programme; and periodic safety reviews.
The objective of the maintenance, periodic testing and inspection programme is to ensure that SSCs work in accordance with the design intent and established OLCs. The activities in this programme are closely related to the activities in the framework of the ageing management programme.

The objective of the periodic safety review is to provide a safety reassessment demonstrating

that the safety measures remain adequate for operations continuing over long period of time. In the framework of the periodic safety review, the effects of ageing on the safety of the research reactor and the effectiveness of the ageing management programme are assessed.

7. Implementation of the Ageing Management Programme

7.1 SSCs Identified for Ageing Management Review and Their Recommended Ageing Management Actions

A list of SSCs important to safety identified for ageing management review, along with their associated replacement ease, ageing mechanisms, preventive actions, monitored parameters, inspections performed, acceptance criteria (if any) and corrective actions (if any), is given in Table 2. A list of abbreviations used for replacement ease and ageing mechanisms is given in Table 3.

Table 3: Structures, systems and components identified for ageing management review

No.	SSC		No. of pieces	Replacement Ease	Ageing Mechanisms	Preventive actions	Parameters monitored / Inspections performed for detection of ageing, acceptance criteria (if any), corrective actions (if any)
1.	***Pool and reactor internals***						
	a.	Core support structure	1	A	1,4	Pool water chemistry control (pH= 6±0.5, Conductivity ≤ 2µS/cm)	Visual inspection every 5 years with underwater camera
	b.	Grid plate	1	A	1,4	Do	Do
	c.	Plenum assembly	1	A	1,4	Do	Do
	d.	Embedded piping	-	A	1,5	Do	Do
	e.	Beam tubes	6	A	1,4,5	Do	Do
	f.	Pool lining	-	A	1,5	Do	Do
2.	***Reactivity Control System***						
	a.	Control rod drive motors	5	D	4,9,10	-	Operability check, control rod travel time measurement every six months Perform necessary maintenance / replacement as required
	b.	Control rod drive (gear system)	5	C	4	Maintain oil level Maintain alignment	Operability check, control rod travel time measurement every six months Inspection for wear every year Perform necessary maintenance / replacement as required
	c.	Control rod blades	5	B	1,4,5,7	Maintain alignment	Visual inspection upon dismantling Replace if required
	d.	Control rod magnets	5	D	9,10	-	Operability check, control rod drop time & control rod release time measurement every year
3.	***Containment***						

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No.	SSC		No. of pieces	Replacement Ease	Ageing Mechanisms	Preventive actions	Parameters monitored / Inspections performed for detection of ageing, acceptance criteria (if any), corrective actions (if any)
	a.	Dome structure	1	A	2,3,4,5	Maintain low humidity in reactor hall	Concrete quality testing if required Perform necessary repair as required
	b.	Isolation dampers	5	B	3,4	Regulate the pressure of compressed air supplied to air cylinders (50 psi)	Containment pressure test every 2 years Operability check before each start up Visual inspection of seals every month Perform necessary maintenance / replacement as required
	c.	Exhaust fans	2	C	4	Keep vanes clean	Noise and vibration check every month Perform necessary maintenance / replacement as required
	d.	Exhaust fan motors	2	C	4,9,10	Do	Noise and vibration check every month Motor insulation resistance, current, and rpm check every six months Perform necessary maintenance / replacement as required
4.	***Primary cooling system***						
	a.	Pumps	2	B	4,5,7	Primary water chemistry control (pH= 6±0.5, Conductivity ≤ 2μS/cm) Maintain alignment Keep bearings lubricated	Gland packing leakage check daily Noise and vibration check every 6 months Perform necessary maintenance / replacement as required
	b.	Motors	2	C	4,9,10	Maintain alignment Keep bearings lubricated	Noise and vibration check every 6 months Motor insulation resistance, current, and rpm check every year Motor temperature check during each full power operation Perform necessary maintenance / replacement as required

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No.	SSC		No. of pieces	Replaceplacement Ease	Ageing Mechanisms	Preventive actions	Parameters monitored / Inspections performed for detection of ageing, acceptance criteria (if any), corrective actions (if any)
	c.	Piping	-	B	3,4,5,7	Primary water chemistry control	Pipe weld inspections (20%) every 2 years Pipe thickness measurements (near selected welds) every 2 years Perform necessary repair / replacement as required
	d.	Heat exchangers	4	B	4,5,7	Do	Shell side ΔP across the heat exchanger measurement during every full power operation Shell side ΔT across the heat exchanger measurement during every full power operation
5.	***Secondary cooling system***						
	a.	Pumps	2	B	4,5,7	Secondary water chemistry control (Hardness ≤ 60 ppm) Maintain alignment Keep bearings lubricated	Gland packing leakage check daily Noise and vibration check every 6 months Perform necessary maintenance / replacement as required
	b.	Motors	2	C	4,9,10	Maintain alignment Keep bearings lubricated	Noise and vibration check every 6 months Motor insulation resistance, current, and rpm check every year Motor temperature check during each full power operation Perform necessary maintenance / replacement as required
	c.	Piping	-	B	3,4,5,7	Secondary water chemistry control Painting from outside	Pipe weld inspections (20%) every 2 years Pipe thickness measurements (near selected welds) every 2 years Perform necessary repair / replacement as

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							required
	d.	Heat exchangers	4	B	4,5,7	Secondary water chemistry control	Tube side ΔP across the heat exchanger measurement during every full power operation Tube side ΔT across the heat exchanger meausrement during every full power operation Clean tubes every year or as required
	e.	Cooling towers	2	C	4,5,7	Secondary water chemistry control Maintain geareducer oil level Keep bearings lubricated Maintain fan-motor alignment	Noise and vibration check every year ΔT across the cooling tower during every full power operation Visual inspection of structural components every month Perform necessary repair / maintenance / replacement as required
6.	***Emergency core cooling system***						
	a.	Pumps	2	C	4,5,7	Primary water chemistry control	Operability check, noise and vibration check every year Perform necessary maintenance / replacement as required
	b.	Motors	2	C	4,9,10	-	Operability check, noise and vibration check every year Motor insulation resistance, current, and rpm check every year Perform necessary maintenance / replacement as required
7.	***Water purification system***						
	a.	Demineralizers	2	C	6	Painting from outside	ΔP across the unit measurement every

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No.	SSC		No. of pieces	Replace-placement Ease	Ageing Mechanisms	Preventive actions	Parameters monitored / Inspections performed for detection of ageing, acceptance criteria (if any), corrective actions (if any)
							month Backwash / perform necessary repair / replacement if ΔP ≥ 15psi
	b.	PVC Fittings	-	C	6	-	Leakage check daily Perform necessary maintenance /repair / replacement as required
	c.	Filters	4	D	8	-	ΔP across the filters measurement every month Backwash / replace the filters if ΔP ≥ 15psi
	d.	Pumps	2	C	4,5,7	Maintain alignment Keep bearings lubricated	Gland packing leakage check daily Noise and vibration check every month Perform necessary maintenance / replacement as required
	e.	Motors	2	C	4,9,10	Maintain alignment Keep bearings lubricated	Noise and vibration check every month Motor insulation resistance, current, and rpm check every year Perform necessary maintenance / replacement as required
8.	***Transfer port***						
	a.	Window seals	2	C	1,3	-	Leakage check every 6 months Replace the gasket / seal if required
	b.	Hydraulic cylinders	6	C	4	Maintain working pressure between 120psi to 240psi	Operability and leakage check every 3 months Perform necessary maintenance / replacement as required
	c.	Pressure fittings	12	C	3	Maintain working pressure between 120psi to 240psi	Operability and leakage check every 3 months Perform necessary replacement as required

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No.	SSC		No. of pieces	Replaceplacement Ease	Ageing Mechanisms	Preventive actions	Parameters monitored / Inspections performed for detection of ageing, acceptance criteria (if any), corrective actions (if any)
	d.	Pumps	2	C	4,5,7	Maintain alignment	Noise and vibration check every 6 months Perform necessary maintenance / replacement as required
	e.	Motors	2	C	4,9,10	Maintain alignment Keep bearings lubricated	Noise and vibration check every 6 months Motor insulation resistance, current, and rpm check every year Perform necessary maintenance / replacement as required
	f.	Control system	1	C	10	-	Operability check every 3 months Perform necessary maintenance / replacement as required
10.	***Instrumentation and control system***						
	a.	Nuclear channels	12	C	1,9,10	-	Operability check before each start up Calibration every year Perform necessary maintenance / replacement as required
	b.	Process channels	24	C	1,9,10	-	Operability check / calibration every year Perform necessary maintenance / replacement as required
	c.	Radiation monitors	10	C	1,9,10	-	Calibration every year Perform necessary maintenance / replacement as required
	d.	Protection system (control logic)	1	C	9,10	-	Operability check before each start up Perform necessary maintenance / replacement as required

Ease of replacement		Ageing mechanisms	
A:	Very difficult	1:	Changes of properties due to neutron or gamma irradiation
B:	Difficult technically or costly	2:	Changes of properties due to temperature service conditions
C:	Normal	3:	Stress or creep (due to pressure and temperature service conditions)
D:	Readily	4:	Motion, fatigue or wear (resulting from cycling of temperature, flow, and/or load, or flow induced vibrations)
		5:	Corrosion
		6:	Chemical processes
		7:	Erosion
		8:	Filter exhaust (resulting from choking or high dose rate)
		9:	Electrical contacts deterioration / motor windings deterioration
		10:	Electronic / electrical component failure
		11:	Changes in technology
		12:	Changes in regulations
		13:	Obsolescence of documentation

Table 3: Abbreviations used in table 2.

7.2 Recent Ageing Issues addressed under Ageing Management Programme

The physical ageing issues addressed under this programme since 2008 include:

- Concrete quality testing using Schmidt hammer and ultrasonic pulse velocity techniques to ensure the concrete integrity
- Coating of outer hemispherical dome surface with fiber glass to provide protection against water seepage
- Replacement of the leaky rubber seats of five isolation dampers
- Visual inspection of core support structure, grid plate, plenum assembly with an under- water camera to ensure their integrity for sustained safe operation
- Replacement of five control rod drive motors with new motors
- Replacement of leaky rubber seal of hot cell side window of transfer port
- Vibration analysis of primary and secondary pumps and motors
- Weld inspections by Radiographic Testing and Dye Penetrant Testing in primary and secondary system piping
- Pipe thickness measurements by Ultrasonic Thickness Meter in primary and second-

ary system piping
- Thermography of electrical contacts with thermal imaging camera to identify over-heated contacts
- Replacement of obsolete control systems with PLC based control systems in transfer port and three rabbit irradiation systems

7.3 Planned Ageing Management Tasks in Near Future

Planned tasks in near future are:
- Epoxy painting on inside of the hemispherical dome.
- Replacement of cooling tower B
- Replacement of both recirculation demineralizer units

8. Conclusion

A formal ageing management programme introduced at PARR-1 has been implemented to ensure its sustained safe operation.

9. References

[1]. IAEA Safety Guide No. SSG-10 “Ageing Management for Research Reactors,” 2010
[2]. Ageing Management Programme for Pakistan research Reactor-1, 2011