Management of Ageing and Modifications for Research Reactors

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Abstract. Egypt has two research reactors, the first reactor was designed by the Former Soviet Union, it has a power of 2MW, tank type, light water moderated and reflected and the fuel type is EK-10 that consists of Uo_2 fuel rods with 10% enrichment.

The reactor was commissioned on 1960, and still working until 2010, from that time it was in extended shutdown state due to ageing of mechanical systems and the termination of the fresh fuel, in the international market. Based on the in-service inspection which was implemented for the 1st reactor the following systems were modernized:

1. Computerized Safety Logic System.
2. Process parameters measurements
3. Neutron parameters measurements
4. Control circuits for the movement of control rods.
5. Control circuits for opening and closing the horizontal channels
6. Power supply systems. (transformer and circuits)
7. Radiation protection system.

A brief description and learned lessons for each modernized activity will be presented, showing the steps which were implemented to achieve the high performance and availability of the first reactor during its operation period. The second reactor was went critical in 1997, which have a good ageing management program, for all the mechanical, electrical, Instrumentation and control systems.

The ageing process may lead to an increase in the failure probability of a safety barrier of a component and ultimately to the failure of the barrier. The ageing mechanism can accelerate the material degradation as, change in physical properties, irradiation embrittlement, thermal embrittlement,Creep, fatigue, corrosion assisted cracking and wear. The safety principles can be achieved by protecting the defense in depth concept and preserving the safety barriers with the implementation of ageing management program.

The ETRR-2 ageing management program includes; periodic maintenance activities, periodic calibration and testing program, in-service inspection. In addition, there is a program to avoid the cooling system ageing effects such as corrosion by using special chemicals to control the water quality. The ageing management program for the second Egyptian research reactor will be presented. This program was the main contributor to avoid operational deviations, anticipated operational occurrences, preserves the high availability and reliability of the reactor, keeps the components and systems in high degree of quality and improves the service conditions.

Key Words: *Maintenance, Testing, Calibration, Management.*

1. Introduction

The first Egyptian Research Reactor was commissioned in June, 1960. This reactor was designed and installed by the former Soviet Union. It is a tank type uses EK-10 fuel rods with

10% enrichment, cooled and moderated by light water. The reactor equipped with nine horizontal beam ports and nine vertical irradiation channels. The reactor used for isotope production, neutron physics, and reactor physics, manpower development and research activities. Since 1985 a modernization plan was designed for life extension of the reactor.

During the last decade, reactor technology, and its relative safety systems have been developed on worldwide. Therefore, it was necessary to upgrade the ageing systems of the reactor based on the following philosophy:

- Fulfilling safety requirements, reliability, standardization and flexibility of servicing and repair.
- Increasing efficiency of reactor operation and utilization.
- Increasing storage capacity of spent fuel.
- Modernization of fuel handling tools and equipment.
- Modernization of secondary cooling electrical and control systems.
- Performing reactor inspection to evaluate the current status of the reactor.
- Rehabilitation of auxiliary systems and reactor building infrastructure.

An effective, high quality ageing management program is essential for safe and reliable operation of a research reactor. To achieve the objectives of this program, the integrated management system must be highly dedicated and motivated to perform high quality work at all levels.

The maintenance program consists of all preventive and remedial measures, both administrative and technical necessary to ensure that the level of reliability and effectiveness of all structures, system and components having a bearing on safety remains in accordance with design assumptions and intent. It also ensures that the status of the reactor is not adversely affected after commencement of operation.

For these reasons, this program has been developed for the second research reactor. The program covers all preventive and remedial measures necessary to perform maintenance activities satisfactorily.

In order to enhance and initiate the preventive maintenance program in the second reactor, it has been taken into account the opinions and suggestion of maintenance skilled personnel during the design stage, thus, substantial benefits can be gained in the equipment acquisition.

It is also important to obtain and evaluate timely and sufficient information on maintenance needs from designers, manufacturers and other operating organizations. It should also ensure that the program is based on good maintenance practice.

2. Modernization and Modifications for the First Research Reactor:

The modernization objectives were based on the development of nuclear technology and achieving safe and reliable operation and utilization of the reactor. The systems that were modernized were:

2.1.Control and Safety Instrumentation Systems

These systems are:

a) Nuclear Control Instrumentation (1984)
b) Reactor Process Parameters Instrumentation (RPI) (1989)
c) Signaling System (1993).
d) Computerize Safety Logic System (CSLS) (1993)
e) New operator consol and Data Acquisition system (DACUS) (1994/95)
f) Fission Chamber Assembly (1996).
g) Horizontal Channels Control Circuits (March 2000)
h) Servo – Drive Control Circuits (1999)
i) Reactor Cover Control Panel (1999)

2.2.Mechanical Systems

The following items were modified:

1. Central Tank Water Level Automatic Compensation (1991).
2. Feed Water Supply System (1997/98).
3. Cooling Tower.
4. Chute channel (1999).
5. Fuel Transportation Cask (1999).
6. Ventilation System Filters Servo-drives Mechanism (2000).
7. Secondary Cooling Circuit Piping System and Valves (2000).
8. Construction of New Wet Spent Fuel Facility (April 2000).

Since the start of operation of the first research reactor, the spent fuel was stored in the old spent fuel storage facility. Nearly after forty years, the problem of accumulated spent fuel became serious and new storage had to be built. It was decided to construct a new fuel storage facility to be within the premises of the reactor facility and as close as possible to the old storage. The design concept justifies simple and safe handling of the transporting cask during loading and unloading from old storage, to the new one.

The design concept based on sub-criticality and takes into consideration the accommodation of all inventory of fuel of the type (EK-10) owned by the operator.

2.3.Radiation Monitoring System

This system was renewed in cooperation with France Company, to achieve the ALARA principle for the radiation level at all places of reactor activities.

2.4.Electric Power System (2008)

A state of art transformers was installed instead of the Russian aged transformers. Also, the distribution lines and network was modernized.

3. Ageing Management System for the Second Egyptian Reactor

The management and control of ageing activities are equally important to performing maintenance. Ageing management may be described as the function of providing policy guidance for maintenance activities, in addition to exercising technical and management control of maintenance programs. Ageing management system was established for the second Egyptian Research Reactor (ETRR-2). This program based on good organized maintenance activities.

3.1.Maintenance Objective

The objective of for the second reactor is to ensure that the systems, structure and components (SSCs) functioning in accordance with the design intents and requirements, and in compliance with the safety analysis report (SAR) and the operational limits and conditions (OLCs), to ensure the long term safety of the reactor. The program for maintenance, periodic testing and inspection should meet the requirements: the SAR; the OLCs, regulatory body, reactor management and manufacture recommendations.

3.2.Maintenance Group Function

A maintenance group has to perform a wide range of functions including:

- Planning and repairing equipment/facilities as in accordance with the SSC's specifications.
- Performing preventive maintenance; developing and implementing a regularly scheduled work program for the purpose of maintaining satisfactory SSC's operation as well as preventing major problems.
- Managing inventory to ensure that parts/materials necessary to conduct maintenance tasks are readily available.
- Keeping records on equipment, services, etc.
- Training maintenance staff and other concerned individuals to improve their skills and perform effectively.
- Reviewing plans for new facilities, installation of new equipment, etc.
- Implementing methods to improve workplace safety and developing safety education related programs for maintenance staff.
- Developing contract specifications and inspecting work performed by contractors to ensure compliance with contractual requirements.

3.3 Maintenance Management Approach

A nine-step approach for managing a maintenance program effectively are:

- Identify existing deficiencies.
- Set maintenance goals.

- Establish priorities.
- Establish performance measurement parameters.
- Establish short-and long-range plans.
- Document both long- and short-range plans and forward copies to all concerned individuals.
- Implement plan
- Report status.
- Examine programs annually.

3.3.Startup of The Maintenance Program

First of all it is necessary to establish a priority in the maintenance of the equipment, machinery or elements. The reason of this priority is due that there is a concept of critical elements. The equipments, parts and systems will be codified in one of the following categories:

i) **Critical elements:** Elements, whose failure represents dangerous ranges of functionality, loss of human life or the shutdown of the plant or an important sector of it.
ii) **Non critical elements:** elements that although they may fail and originate the shutdown of the reactor.
iii) **Nuclear:** all those elements, equipments or machineries that are directly involved in the production of nuclear energy.
iv) **Conventional:** Those elements, equipments or machineries that aren't directly involved in the nuclear process.

3.4.Preventative Maintenance and Strategy

Preventive maintenance consists of regularly scheduled inspections, testing, servicing, overhauls and replacement activities. Its purpose is to enhance the reliability of equipment, to detect and prevent incipient failures, and to ensure the continuing capability of the reactor's systems, structures, and components (SSCs) to perform their intended functions.

Preventive maintenance should be performed on SSCs:

- As specified by designers or manufacturers;
- As specified by law and in regulatory requirements;
- As determined by the reactor management on the basis of safety reviews and previous operational experience or for other reasons.

Preventive maintenance includes periodic, predictive and planned maintenance activities as follows:

- Periodic maintenance activities should be accomplished on a routine basis and may include inspections, alignments or calibrations, overhauls and replacement of SSCs.
- Predictive maintenance activities should involve continuous or periodic monitoring, where possible, to predict failure of SSCs.

Planned maintenance activities should be performed prior to the degradation or failure of SSCs and may be initiated on the basis of the results of predictive or periodic maintenance.

Preventive Maintenance Activities

The preventive maintenance activities should be implemented for, valves, rotating equipments, heat exchangers electrical distribution, I&C, coolant systems and confinement, these activities include:

- Walk-down inspections (looking for leaks, vibration, hot spots, unusual noise, etc.);
- Measurement of operational parameters (e.g. current, temperature);
- Monitoring of conditions; **lubrication;** filter replacement;
- Oil checks and changes, testing of equipment and instrumentation;
- Replacement of parts before their predicted failure age;
- Chemistry control, cleaning, internal inspections,
- Calibration/alignment, testing of equipments,
- Replacement of parts before their predicted failure age,
- Surface treatment and painting.

3.5.Predictive maintenance

The predictive maintenance methods are based on the surveillance of carefully selected parameters and a special analysis of the results. This analysis may be used to justify postponement of remedial actions or anticipation of scheduled maintenance.The predictive maintenance (inspection without shut down) gives a diagnostic to detect problems without interruption in the equipment functioning. The predictive maintenance program includes Detection, Analysis, and Correction.

The predictive maintenance program eliminates catastrophic equipment failures. Then, the maintenance responsible will be able to schedule maintenance activities to minimize or eliminate overtime costs, and reduction in downtime and increase in production.

3.6.Corrective Maintenance

Corrective (reactive) maintenance (sometimes referred to as remedial maintenance) consists of repair and/or replacement activities not occurring on a regular schedule. Reactive maintenance is basically the "run it till it breaks" maintenance mode. The preventive maintenance program will reduce the need for corrective maintenance and may result in extended availability of equipment and systems and cost reductions. However, the need for corrective actions cannot be totally eliminated. Adequate resources, such as human resources, spare parts and funds, should be allocated for corrective maintenance.

3.7.Maintenance Procedure

In the preparation of procedures for maintenance, periodic testing and inspection, attention should be paid to the possible consequences of the use of the procedures for safety systems and for reactor operation.

Some procedures may be performed during reactor operation with no impact on the safety of the reactor; others may necessitate shutting down the reactor. It should therefore be confirmed that these procedures do not cause any action to be taken that reduces reactor safety such that the OLCs are violated. Care should be exercised to avoid the introduction of common cause failures.

3.8.Reports on maintenance

The maintenance group issue numerous reports to perform the maintenance tasks according to the effective maintenance management system of ETRR-2 and in according with the reactor quality management system to achieve the safe operation of reactor. The following table shows different reports within the administrative maintenance activities.

Records	Frequency	Issuer	Addressed to	Frequency to Reactor Manager
Weekly performance report	Weekly	Sector head	Maintenance head	weekly
Monthly performance report	Monthly	Maintenance head	Reactor manager	Monthly
Equipment historical data record	Monthly	Sector head	Maintenance head	Semi annual
Schedule preventive maintenance	Annually	Sector head	Maintenance head	Annually
Lubrication control	3 months	Mech. sector head	Maintenance head	Annually
Inventory & spare parts control	3 months	Sector head	Maintenance head	Annually

3.9.Surveillance and review program

A program of surveillance, review and audit of maintenance shall be established to ensure that the maintenance program meets its purpose.

Inspections may be unannounced and should include direct observation of the specific maintenance activity as well as examination of documentation. The results of these

inspections shall be transmitted to the maintenance supervisor for information and for corrective action if it is required.

The review program shall examine the maintenance program for the following features.

- Adequacy of the preventive maintenance schedule.
- Response to remedial maintenance requirements.
- Satisfactory control of radiation doses.
- Availability and effective use of resources.
- Level of training and experience.
- Adherence to quality assurance requirements.
- Adequacy of procedures and instructions.
- Effectiveness of the reviewing function.

The maintenance groups should make internal audit annually. Consequently the safety committees review and asses the maintenance program and management system annually before sending it to the regulatory authority.

4. Conclusions

The modernization and modifications for the 1st Egyptian research reactor were implemented with the aim of increasing the safety and outage time of the reactor performance, and due to the rapid progress in the nuclear technology. Also, the items of the ageing management system for the 2nd Egyptian research reactor was presented, this program includes, preventive, predictive and corrective maintenance programs in addition to surveillance and review program. The main purpose of these programs is the prevention of components failures during its service life, and to operate the reactor systems with high degree of safety and reliability.

5. References

[1] Safety Considerations for Research Reactors in Extended Shutdown, IAEA-TECDOC-1387, Vienna, 2004.
[2] Maintenance, Periodic Testing and Inspection of Research Reactors, IAEA Safety Standards, Safety Guide No. NS-G4.2, 2008.
[3] Maintainability, Maintenance, and Reliability for Engineers, B.S.Dhillon, Taylor and Francis Group, Boca Raton, 2006.
[4] Management of Research Reactor Ageing, IAEA-TECDOC-792, Vienna, 2013.