MAINTENANCE AS A TOOL FOR THE ENHANCEMENT OF SAFETY IN THE OPERATION OF NIGERIAN RESEARCH REACTOR

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Abstract

The first and only nuclear research reactor in Nigeria is operated by Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria. The Nigeria Research Reactor-1 (NIRR-1) is a Miniature Neutron Source Reactor (MNSR) that attained initial criticality on February 03, 2004. As part of the measures put in place to ensure safe operation of the facility is the strict adherence to the routine (preventive) and corrective maintenance activities established since its commissioning, and improved upon over the years. Easy access to the reactor top is especially ensured to facilitate rapid corrective maintenance response in case of emergency during reactor operation. The paper would discuss the details of the routine and corrective maintenance activities and their respective relation to the safe operation of NIRR-1

1.0 INTRODUCTION

NIRR-1 has a tank-in-pool structural configuration and operates at a nominal thermal power of 31 kW corresponding to a maximum neutron flux of 1×10^{12} $cm^{-2}s^{-1}$. The reactor core is cylindrical with height and diameter of 230 mm, fuelled by U-Al_4 enriched to about 90% in aluminium alloy cladding. It has a total number of 347 fuel elements and 3 dummies in its fuel lattice. It uses light water as moderator and coolant, with beryllium as reflector. It has one control rod serving as regulating rod as well as safety rod. An alternative means of reactor control is provided using external cadmium materials encapsulated in vials for transfer into the inner irradiation sites of the reactor, which ensure reactor sub-criticality in case of rod stuck accidents [2,3,4].

Measures put in place to ensure safe operation of the facility include standard procedures developed for pre-start-up, start-up and shutdown; and strict adherence to the routine maintenance and prompt response for corrective maintenance. These maintenance activities are carried out by a team of engineers and technicians who are also reactor operators under the authority of the Reactor Manager. Defending on the complexity and importance to safety, routine maintenance activities scheduled for the reactor and its auxiliary systems are being carried out on weekly, quarterly and annual bases.

2. MAINTENANCE PROGRAM OF NIRR-1

The maintenance structure adopted for NIRR-1 is *PROACTIVE* and *REACTIVE* based. The proactive component is based on preventive and predictive maintenance, while the reactive component is executed by corrective maintenance activities. The maintenance program developed for the reactor is hence divided into two: routine maintenance, during which preventive and predictive maintenance are carried out; and corrective maintenance. Maintenance logbooks for routine and corrective maintenance activities are properly kept to keep track of maintenance records of systems and components.

2.1 Routine maintenance

Because of the importance attached to maintenance, the last day of the working days (Friday) is dedicated for routine maintenance of NIRR-1. This is to ensure that the reactor is always ready for safe operation in the week to come. Routine maintenance activities for the reactor and its auxiliary systems are scheduled and carried out on weekly, quarterly and annual basis, defending on their importance to safety and complexity. The preventive maintenance activities are relied upon for predictive maintenance, especially where consumables are required [6].

2.1.1 Weekly maintenance

Weekly maintenance is scheduled for systems that provide limiting conditions for safe operation (LCOs) as enshrined in the Final Safety Analysis Report (FSAR) of the facility [1,5]. Details of system checks for weekly routine maintenance are tabulated in Table 2.1. These systems and their bearing to safety in the operation of NIRR-1 are as follows:

— Rabbit Transfer System: This is a pneumatic control system used for the transfer of vials into the irradiation channels of the reactor for the purpose of utilization. The system comprises of an air - compressor, air-pressure meter, sample positioning equipment (Type A and Type B) and connecting tubes. It is necessary for the system to be functional during reactor operation because it provides the alternative means of bringing the reactor to sub-criticality (by sending cadmium rabbits into the reactor) in the event of rod failure;
— Gas Purge System: The gas purge system is operated once a week, for one minute. The system injects clean air into the reactor vessel to purge out radioactive gasses and hydrogen that might have accumulated during the reactor operation within the week. The system is made up of a vacuum pump, mechanical filter, radioactive filter, pressure level indicator, valves and connecting tubes. It is necessary to ensure the functionality of the system before its next operation. This would ensure that hydrogen gas generated in the reactor vessel is maintained below explosive level, and radioactive effluents are filtered before being released to the environment;
— Ventilation System: The ventilation system is operated continuously during reactor operation. This keeps the reactor hall at a negative pressure in relation to the adjourning rooms. The system comprises of the stack, ventilation fan and the ventilation ducts;
— Reactor Water Monitoring System: The reactor water monitoring system ensures that the quantity and quality of the water in the reactor vessel is within the acceptable limits. The system comprises of reactor vessel water level HIGH and LOW indicators, water conductivity meters and water purification equipment. Of utmost importance to safety are the reactor vessel water level indicators which are ensured to be within acceptable limits prior to any operation;
— Pool Water Monitoring System: The pool water monitoring system ensures that the quantity and quality of the water in the reactor pool is within the acceptable limits. The system comprises of reactor pool water level HIGH and LOW indicators, water conductivity meters, water purification equipment and pool water cooling equipment (chiller). Of utmost importance to safety is the reactor pool water level indicators which are ensured to be within acceptable limits prior to any operation.

2.1.2 Quarterly maintenance

Quarterly routine maintenance is mainly conducted on the reactor control console and the associated control instrumentation. Table 2.2 provides the details of the activities carried out in these maintenance exercises. The importance of the control console and the closed -

loop computer control system to the safety in the operation of the reactor can not be over emphasized.

2.1.3 Annual maintenance

The annual maintenance activities involves the servicing of the control rod drive mechanism in addition to all the systems and components involved in the weekly and quarterly maintenance schedules. During this exercise also, the calibration checks on systems related to safety settings (including radiation monitors) are carried out. Table 2.3 provides the details of the activities carried out during the maintenance exercise.

2.2 Corrective maintenance

Corrective maintenance is performed to overcome anomalies observed during routine maintenance and at breakdowns. The breakdown experienced which had bearing on safety occurred while the reactor was in operation, and was caused by control rod stuck at a position 185mm from bottom of the core (height of core is 230mm). This accident occurred when the reactor neutron flux exceeded 1.2×10^{12} $cm^{-2}s^{-1}$ (corresponding to 37.2 kW) and the reactor safety system was automatically actuated with the control rod position at 220 mm. The automatic shutdown signal de-energized the electro-magnetic clutch of the control rod drive mechanism, which allowed the control rod to fall freely (due to gravitational influence. However, due to some broken pieces of gear teeth in the gears of the control rod drive mechanism, the free fall was intercepted and the rod was stocked at the position 185 mm. The reactor was controlled using the alternative means, by sending cadmium rabbits into the inner irradiation sites, which brings it to sub-criticality, while corrective maintenance was carried out.

TABLE 1: SYSTEMS SCHEDULED FOR WEEKLY MAINTENANCE

Systems	Details of Maintenance Checks
Rabbit Transfer System	i. Air-compressor oil level. ii. Automatic compressed air regulator settings: Auto trip and Auto restart iii. Operation of glove - box air exhaust pump. iv. Operation of samples stripper. v. Operations of dividers and transformer. vi. Draining of condensed water from the collection points in the system.
Gas Purge System	i. Oil level in gas purge pump. ii. Noise and vibration level of gas purge pump. iii. Pressure difference during gas purging.
Ventilation System	i. Oil level in ventilation pump check. ii. Noise and vibration level of ventilation pump iii. Air leakage in the ventilation system.
Reactor Water Monitoring System	i. Zero and Full-scale check for reactor water conductivity meter. ii. Reactor water flow rate meter. iii. Reactor water purification pump noise and vibration level iv. Water leakage checks in the reactor water purification loop.
Pool Water Monitoring System	i. Zero and Full-scale check of pool water conductivity meter. ii. Pool water flow rate meter iii. Pool water purification pump noise and vibration level iv. Water leakage checks in the pool water purification loop.
Provisional Pool Water Cooling	i. Chiller water inlet and outlet temperature control and control indicators. ii. Chiller pressure and water level

TABLE 2: DETAILED SCHEDULE FOR QUARTERLY MAINTENANCE

Item	Maintenance details
Computer closed-loop Control System	i. Confirm communication of control interface card (control transfer switch) ii. Operate reactor in Automatic and Manual Mode iii. Test for all trip settings (including SCRAM)
Main Control Console	i. Cleaning of dust and contact points for contactors (power supply off) ii. Visual inspection of solder points iii. Confirmation of voltage levels between identified points iv. Manual and Automatic Start-up, Shutdown and SCRAM functions v. Response of all warning lights vi. Response of reactor overpower and over ΔT lights (trip condition) vii. Confirmation of control of reactor access (via rabbit systems) viii. Functionality test for uninterruptable power supply (alternative power supply)

TABLE 2.3: DETAILED SCHEDULE FOR ANNUAL MAINTENANCE

Item	Maintenance details
Control Rod Drive Mechanism	i. Servicing in accordance with a written procedure, approved by Reactor Safety Committee. ii. Self-lock test, Sensitivity test, Rod drop test, operation performance test, and position indicator test.
Main Control Console and closed – loop computer control system	As in Table 2.2
Calibration Checks	i. Water conductivity meters; ii. Water level (upper and lower) sensors; iii. Temperature difference monitor; iv. Neutron flux monitor; v. Control rod limiting position preset; vi. Gamma probes settings
Others	i. Cleaning of resins for reactor water and pool water purification systems ii. Testing of public address system iii. Testing of fire alarm and fire control system

3. CONCLUSION AND ACKNOWLEDGEMENT

The strict adherence to maintenance activities in the NIRR-1 and the diligence of the engineering maintenance personnel is the backbone of the safe operation of the facility. The routing maintenance activities provides the best way to confirm most of the LCOs, which are adhered to at all times before any reactor operation commences.

ACKNOWLEDGEMENTS

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