Analysis of the IEA-R1 reactor startup procedures

An application of the HazOp method

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Abstract. The management of operational safety rests on a number of factors such as technical competence of managers and operators, periodic maintenance, written procedures etc. Examination of various incidents in nuclear installations reveals that operational procedures play an important role. Plant modifications can also be a source of unsafe conditions, if safety issues are not properly incorporated into the operational routines. So, it is not only important for the operators to follow operational procedures, but also to review them, from time to time, to verify if improvements in safety can be made. The purpose of this paper is present the results of the an to analysis of the operational procedures of the IEA-R1 research reactor to identify potencially unsafe conditions. The HazOp methodology was chosen for this study. The application of the HazOp methodology resulted in a comprehensive review of the reactor startup procedures, and in the identification of the potential hazards associated to deviations in following these procedures. Up to 53 activities of the IEA-R1 reactor startup procedures were investigated. The study produced 24 recommendations to improve the operational safety of the reactor. Ten of these recommendations have been implemented so far.

1. Introduction

As stated in the IAEA Safety Series publications, the safe operation of a nuclear reactor rests on a proper design, construction, management, and supervision. The operating organization shall have a set of general operating rules, complemented by specific operating procedures. Although, for many operators, the importance of following operational procedures is clear, deviations from it may occur, resulting in potencially unsafe conditions.

A number of different methods for identifying unsafe conditions in nuclear installations are available today, but the selection of a method must be based on the process being analysed. In this study it was decided to apply the Hazop and Operability method (HazOp) to analyse the startup procedures of the IEA-R1 reactor.

The HazOp methodology [1] is a simple qualitative technique conceived to identify hazards and operational anomalies in process plants. In the conventional chemical industry, where HazOp is widely used, it proved to be an important tool in the design stages as well as in the safe operation of a facility. Although HazOp is widely applied to identify problems in systems and components of a plant, this methodology can also be used to identify problems in operational procedures [2,3].

Potencial hazards and operational problems resulting from deviations in following the startup routines of the IEA-R1 reactor were identified and analysed. This study provided recommendations to increase the operational safety of the IEA-R1 reactor by identifying 24 items with potential problems. Ten recommendations have been implemented so far.

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2. A Brief description of the IEA-R1 Operation

The IEA-R1 is a 5 MWth Babcok Wilcox pool research reactor operating in IPEN/CNEN-SP, Brazil, since 1957. The reactor is used mainly for the production of radioisotopes, as a neutron source for experiments in physics, chemistry and biology, and for training of operators.

The CRO (Operation and Maintenance Sector), from the Research Reactor Center (CRPq), is the group responsible for the IEA-R1 operation.The SPP (Radiological Protection Sector) is the group responsilble for the radiological safety of the facility. The SPP is organizationally independent of the IEA-R1 CRO group.

The operation of the IEA-R1 reactor meets the requirements of the Brazilian Regulatory Body set by the CNEN-NE-1.04 [4] and CNEN-NE-3.01 [5] standards to protect site personnel, the general public and the environment. Since the first criticality, the IEA-R1 reactor has been operating without any incident.

Written operating instructions are issue by te CRPq Center, covering all the safety related to the activities of the IEA-R1 reactor, such as startup, operation and shutdown of the reactor. These instructions are part of a written operational program approved by, both groups, the CRO and the SPP.

A Checklist provides the necessary instructions to startup the reactor [6]. Basically, this list contains 29 initial items to be checked. For operations below 200 kW, another 8 items are required. Above 200 kW, there are 17 adittional items to be checked.

During the startup procedure, the following members of the CRO and SPP groups must be present in the control room : one licensed Senior Operator; one or two licensed operators; one Radiological Protection Supervisor; one Radiological Protection Techinician. All participants in the startup process must sign the Checklist. A final verification of the list is made by the Senior Reactor Operator.

The HazOp methodology requires knowledge of the process, its instrumentation, and its operation. In this study, the HazOp group included members of the CRO and SPP groups, as well as a safety analyst, and members of the electronics and maintenance services.

3. Application of HazOp method

The HazOp study consisted in a systematic review of each step of the startup procedure described in the Checklist of the IEA-R1 reactor [4]. The analysis considered all the activities required to achieve criticality, and for the operation of the reactor below and above 200 kW [7-8].

3.1. Establishing main steps of study

The application of the HazOp method involved the following main activities:

(1) Definition of objectives: Identification of deviations in the startup routine that could lead to potencially unsafe conditions; and the evaluation of the effectiveness of the HazOp method to analyse operational procedures.

(2) Submission of the proposed HazOp study to the to the Safety Review Committee, for comments and approval.

(3) Definition of the HazOp study group.

The HazOp study group was formed by the following members: 1 safety analyst (group leader); 1 licensed senior reactor operator; 1 specialist in electronics; 1 specialist in reactor maintenance; 1 specialist in termo-hydraulics and accident analysis; and 1 radiological protection supervisor.

(4) Familiarization with the startup procedures.

Acquaintance with the reactor startup process involved the reading of the technical documentation related to the reactor operation and interviews with the reactor operators. The following documentation were used as reference:

— Operation Manual of the Reactor IEA-R1 - General Preparation for Operation IEA-R1 [6].

— Reactor Operation Procedure - above 200 kW [8].

— Reactor Operation Procedure - bellow 200 kW [7].

— Instrumentation System - Operation and Maintenance Manual [9].

— Safety Analysis Report of the IEA-R1 (Reactor Instrumentation and Control [10], Reactor Ventilation and Air Conditioning System [11], Reactor Protection and Fire Protection System [12]).

— Technical Specifications of the IEA-R1 reactor [13].

(5) Definition of the nodes and the HazOp Worksheet:

At this stage, the team leader defined the nodes to be analysed and the format of the HazOp study worksheet. The nodes were considered as the items to be checked in the startup procedure Checklist. The worksheet consisted of five columns containing: key words, deviation observed, consequences, existing means to minimize the consequences, and suggested actions.

3.2. Analysis of start-up procedures

The following steps were used in the study:

(1) Selection a node to be analyzed. In this step, the nodes of the HazOp study were selected according with the sequence established in the Checklist. For each node, key words were defined. These words were associated with the operator's actions for the selected node;

(2) Identification of a possible deviation of the operator's action included in the selected node. Deviations were determined by combining key words with operator's actions. Deviations considered non credible were discarded from the study;

(3) Consequence analysis of the observed deviation;

(4) Analysis of existing means available to cope with possible operational and safety problems resulting from the observed deviation. Verification if these means were adequate for the intended purpose;

(5) Recommendations, when necessary, of measures to eliminate or minimize the risks arising from the deviations observed;

(6) Repetition of steps 2 to 5, for the same node, until all possible deviations have been identified and examined; and

(7) Repetition of steps 1 to 6 until all nodes have been covered.

3.3. Assumptions made in the study

The following assumptions were made in this HAzOp study:

(a) A deviation was defined as any operator's action that did not followed the written startup procedure; and

(b) It was considered undesirable, any deviation in the reactor startup process that could contribute for the occurrence of: Damage to the reactor core; Erroneous operation of the reactor Protection and Control Systems; Disturbances in auxiliary systems required for operation of the reactor; Undue exposure to radiation of operators and public in general; and Environmental release of radioactivity above of the limits prescribed by the CNEN-NE-3.01 standard [5].

4. Results and Discussion

The HazOp study was accomplished in 13 formal meetings, resulting in a total of 172 hours of discussions, analysis and review of the data collected. The team leader was responsible for the writing a report describing the findings of the study [14], adding 60 more hours to complete the study.

The study consisted in the review of the 53 start-up instructions of the IEA-R1 reactor. Seventy four procedures deviations were observed. These deviations resulted in 24 recommendations (17 to revise the startup operational procedures, and 7 to implement modifications in a few systems of the installation).

The HazOp report was sent to the Safety Review Committee for comments and decision. The implementation of the 24 recommendations was dependent on technical and economical viability. The CRPq and the Safety Review Committee, both agreed with 23 recommendations made by the HazOp team. Ten of them were actually implemented.

The recommendations were grouped in 3 levels of priority according to their importance to the operational safety of the reactor:

— Priority 1: Measures related to the integrity of the reactor core and/or to the actuation of the reactor protection system. In this category four recommendations were made. One recommendation was implemented:

  Additional interlocks in the reactor protection system. Installation of period scram interlock for power levels in excess of 200 kW, to compensate for possible operator errors during trip channels tests and the safety channels tests, which could result in the violation of the 110% power level limit specified.

  Recommendations approved for future implementation:

  (1) Modernization or replacement of the reactor control console.

  (2) Introduction of on-line water level monitoring system in the reactor pool.

  (3) Interlocks in the protection system to assure that the reactor will not be operated at power levels in excess of 200 kW, without forced circulation.

— Priority 2: Measures to improve the startup and surveillance procedures, and the monitoring systems of the reactor. In this category, 16 recommendations were made. One of these recommendations was discarded, and five have being implemented:

(1) Written procedures for local inspection of the two cooling towers during the startup process. Assure proper operation of these towers (alignment, water level, cooling fans operability etc.).

(2) Repair and activate the monitoring system of the Reactor Building personnel access doors. Avoid overloading of the Ventilation and Air Conditioning System.

(3) Additional surveillance means in the Emergency Room. Assure continuous surveillance of the reactor pool area by television cameras.

(4) Additional interlocks in Radiation Monitoring System: Introduction of a redundant sound alarm in the control room panel, to indicate air contamination in the Reactor Building, using the radiation detectors installed in the ventilation system.

(5) Return to the procedure initially used to measure the primary water conductivity. The present manual sampling procedure is prone to errors. This was minimized by reinstalling the original on-line condutivimeter of the Water Treatment System.

The CRPq established a schedule to implement ten remaining recommendations: eight are related to the need of additional operational routines for reactor inspection; one to install visual and audible alarms, linked with the radiation detectors installed in the hall leading to the nuclear physics experimental facilities; and one involving a revision of the Emergency Plan of the reactor.

— Priority 3: Items not directly related to the reactor operational safety. This involved the revision of four items of the startup procedures Checklist, to include more precise instructions to the reactor operators.

5. Conclusions

In this paper we attempted to illustrate briefly the enhancement in the operational safety of the IEA-R1 research reactor as a result of a systematic review of the startup procedures of the reactor.

A number of deviations were identified and corrective actions were recommended, some of which were actually implemented.

The HazOp method proved to be an excellent tool to identify potencially unsafe conditions. The primary advantage was the interaction among the team members with diverse background. The CRPq Center and the Safety Review Committee also played an important role, by giving the necessary support to develop the HazOp study, and to implement some recommendations made by the team members.

As a general remark we could say that, apart from the formal requirements of the study, the HazOp meetings were an excellent opportunity for the team members to know each other's experiences and difficulties. This certainly will promote their understanding of how important is to follow operational routines.

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