A REVIEW OF THE PROBABILISTIC SAFETY ASSSESSMENT APPLICATION TO THE TR-2 RESEARCH REACTOR

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ABSTRACT

A review of the Probabilistic Safety Assessment (PSA) to the TR-2 Research Reactor is presented. The level 1 PSA application involved: selection of accident initiators, mitigating functions and system definitions, event tree constructions and quantification, fault tree constructions and quantification, human reliability, component failure data base development, dependent failure analysis. Each of the steps of the analysis given above is reviewed briefly with highlights from the selected results.

PSA application is found to be a practical tool for research reactor safety due to intense involvement of human interactions in an experimental facility. Insights gained from the application of PSA methodology to the TR-2 research reactor led to a significant safety review of the system.

INTRODUCTION

The TR-2 is a 5 MW swimming pool type reactor designed for radioisotope production. It is also utilized as a training facility. The reactor core consists of 10 standard fuel elements, 4 control fuel elements and 6 beryllium elements as a reflector.

PSA application of the TR-2 was initially carried out as a part of the IAEA's coordinated research program on "Probabilistic Safety Assessment for Research Reactors" between 1986-1990. Major insights gained from the earlier study are outlined. The current review of the PSA will provide a supplement to the Deterministic Safety Analysis report as well as including main safety topics related to the seismic conditions.

ASPECTS OF A RESEARCH REACTOR PSA

There are several important aspects of a research reactor PSA in Turkey from the point of view of a developing country as outlined below:

- The full review of TR-2 systems and procedures will provide the definition and the understanding of the safety issues of the research facility.
- The PSA document will be used as supplement to the safety analysis report of TR-2 based on the deterministic analysis.

- It will assist to identify cost-effective solutions for redesigning systems, changing components and designing new experimental facilities.
- It will provide a means for carrying out full PSA program on a small system, which is much simpler and cheaper than a complex plant.
- It will help to accumulate knowledge of PSA and build up expertise and manpower for future uses in power reactor safety.
- It will enable the project team to obtain and develop data base on component failure rates by utilizing two research reactors (TR-1 and TR-2) operational experience accumulated during the past 25 years.
- It will aid improving operational procedures of the research reactor and also understanding and modeling of the human behavior in safety related matters.

METHODOLOGY FOR CONDUCTING THE TR-2 PSA STUDY

PSA of the TR-2 research reactor consisted of a large scope study. It has included several major task which were:

Information and document gathering

Initiating event identification (internal and external)

Accident sequence delineation (event tree analysis)

System analysis (fault tree analysis)

Data base development

Procedural analysis and human reliability

Accident sequence evaluation

Interpretation and use of results

Recommendations

The identification of the internal initiating events for the TR-2 accident sequences is made through the use of:

-The generic data for initiating events (1) and

-The determination of the system-specific initiating events.

Since Istanbul district is in the seismic area (2) and TR-2 reactor site is located close to the International Istanbul Atatürk (Yesilköy) Airport (3), earthquake and aircraft crashes are incorporated into the study as major external events.

Systemic event trees are developed qualitatively for a certain groups of generic initiating events in order to delineate the accident sequences to be considered in the analysis.

As an example, event-tree developed for “loss of flow accident” is shown in Fig. 1. Preliminary calculations and experiments carried out at low power (300 kW) indicate that there will be no clad damage in any of the 15 event sequences obtained. In the worst cases (S-5, S-10, S-15) it is

expected that there will be boiling in the early phase of the accident and then the power will drop due to negative void effect. The event will continue as power oscillation. Low power experiments showed that the failure of flappers to open has no effects on natural circulation due to the fact that the passageways between fuel elements, and grid plates can provide sufficient circulation of cooling water through the core.

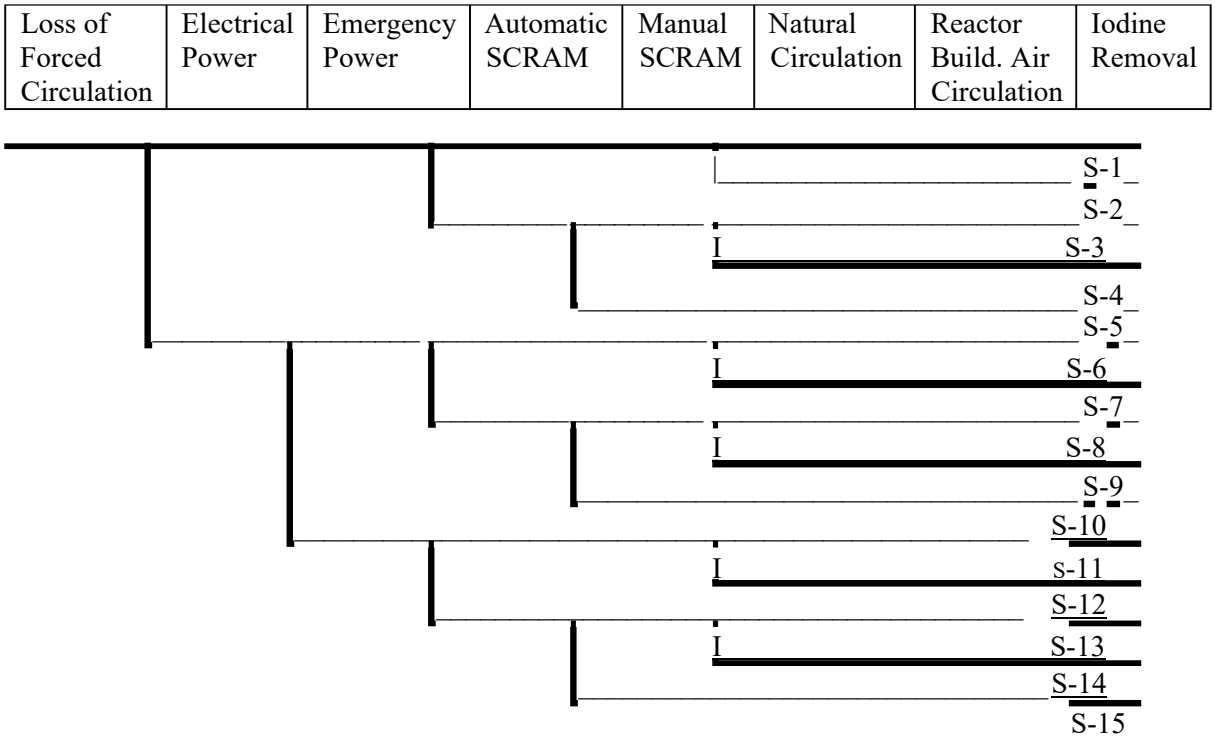

Figure 1. Event tree - Loss of flow accident (forced circulation unavailable)

PSA application to TR-2 is found to be a practical tool for studying human attitudes and behavior in safety related matters. This is due to intensive involvement of human interactions in an experimental facility.

The human factor study covers the following topics.

- Identifying critical operator actions.
- Evaluating human errors.
- Developing human error data collecting scheme.
- Searching for human error dependencies.
- Initiating ergonometric modifications.
- Reviewing operational procedures.
- Investigating human behavior under normal conditions.
- Examining human performance under emergency (stress conditions).

With the initiation of the TR-2 PSA project, the need and the importance of developing/ compiling component reliability data base and human reliability analysis in Turkey has been recognized and started as an integral part of the project.

The effort of the data base development is focused on the TR-1 (1 MWth power old research reactor) operating experience. The detailed investigation of electronics, electromechanical and mechanical component failures, tests and maintenance errors was undertaken. 8 large volumes of operator log books kept during the operation of TR-1 reactor between January 1962 December 1976 and the monthly status reports issued during that period were examined and failure types and the number of failures determined.

Some preliminary estimates of failure rates of certain component calculated are given in table 1.

Component (Mode)	Failure Rate ($hours^{-1}$)
Flapper (open)	$7.5 10^{-4}$
Control rod magnet	$8.0 10^{-4}$
Air compressor	$1.5 10^{-4}$
Pump (mechanical)	$1.0 10^{-4}$

Table 1. Component Failure Rate Estimates.

INSIGHTS GAINED FROM THE TR-2 PSA

The TR-2 PSA although it was limited in scope by the unique features of the research facility, included all major PSA topic areas (2,3). Some of these such as system analysis, initiating event identification, information gathering, accident sequence evaluation, data base development etc. were covered systematically. Some other topics like uncertainty and sensitivity analysis could not be covered fully. Yet it helped to accumulate knowledge of PSA and built up expertise and manpower for future use in power reactor safety and in industry (4,5).

Major aspects for safety (4,6,7) and outcomes of the level 1 PSA of the TR-2 can be summarized as follows:

Within the coordinated research program of the IAEA, “The Case Study for the TR-2 Reactor” provided a means for carrying out a full PSA program on a small system which is much simpler and cheaper than a complex plant.

The PSA document was prepared as a supplement to the safety analysis report of the TR-2 based on the deterministic analysis.

The systematic review of the TR-2 systems and procedures provided a new approach to definition and understanding of the probabilistic safety issues of the research facility.

It has provided a way to identify cost effective solutions for redesigning of old systems, changing components and designing new experimental facilities.

The initiation of the component failure data base development, based on the operational experience of the two research reactors (TR-1 and TR-2) was one of the most important outcomes of the study.

Furthermore with regard to human factors, the case study has provided a framework for methodological approach to investigate human role in a nuclear research facility.

CONCLUSIONS

Level 1 PSA results obtained earlier and the current review work have provided a systematic way to handle the main safety issues of the research facility. That is for defining main safety issues of the research reactor operation, modeling of systems and accident scenarios, development of component failure data base, the role of human interactions and a framework for the practical application of procedures for dependency analysis.

The overall results imply that the accident sequences (dependent or independent) are not necessarily risk significant in terms of their consequences as it might be in the case for power reactors. On the other hand earthquake is found to be the major common cause initiating event for TR-2 Reactor. Which might have risk significant consequences. This subject requires further analysis.

Main problem areas are those related to the lack of expertise and a comprehensive data base. However the expected outcome of the study in the field of PSA in particular human reliability is accomplished.

The experience gained has a potential for further use in Turkey, in industrial facilities as well as in future power reactor safety assessment.

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