



Reliability of Nuclear Power Plants

The growth of interest in nuclear power in recent years has resulted in an increased concern by both power plant utilities and the general public about the safety of power plants and their operational reliability. The answers to these questions are sought through the application of a relatively new engineering discipline, usually referred to as reliability engineering, which attempts to discover causes of equipment failures and to provide information to plant designers and operators on how these causes could be eliminated. A statistical approach to equipment failures and methods of system analysis, which are pertinent to reliability engineering, provides a means to evaluate the reliability of nuclear power plant systems and to contribute to the increase of plant safety and availability.

The Symposium was organized in order to review the present status of reliability of nuclear power plant equipment and to provide an exchange of information among the reliability engineers, power plant designers and operators on present research and development efforts to increase nuclear power plant safety and availability. It has been clearly stated that the safety records from presently operating nuclear power plants have been excellent. The degree of redundancy and the ample safety margins designed, provide a high reliability of those systems and of the components important to safety. However, the reported plant availability is lower than one should expect or require. The average load factor for the plants in operation in 1973 was around 62%, which is much lower than the target figure of 80% usually assumed in nuclear power studies. Plant availability has been affected adversely by the failures of the components and systems which are not safety significant but responsible for a reliable power production. This has resulted primarily in economic losses. An analysis of the reasons for such discrepancies in existing records between safety and availability has shown that the main efforts to improve reliability have been oriented towards systems and components which are safety related. These systems have usually been subject to a thorough reliability analysis aiming to estimate their overall availability and to discover possible causes of failure and deficiencies in design. Examples of application of reliability analysis techniques to such systems as protection, control, power supply, etc., were reported at the Symposium. They demonstrated not only the sophistication of the methods applied but also the great importance of these analyses in order to understand the basic causes of potential failures, and to determine the correction required.

Although several methods for reliability analysis are in use, the papers presented at the Symposium suggest that the fault-tree representation is the most convenient one. This has been recently reaffirmed by studies such as the Rasmussen Report. Three steps are characteristic for this method of analysis:

- System analysis for preparation of a physical and functional description of the analyzed system, accompanied by the formation of system-tree diagrams.
- Reliability analysis which embodies the formation of appropriate mathematical models, and determination of model parameters.

- Safety related analysis, release-risk assessment, whereupon the improvement of reliability of components and systems design may be required.

As reported, the weak point in the analysis is the scarce knowledge of the input parameters. These have to be based on failure statistics which are neither abundant nor adequate for the purpose. The numerical results of analysis therefore can hardly be accepted as an absolute value for overall availability of the analyzed system. Nevertheless, they provide means for intercomparison of different designs from the reliability point of view and indicate weak points which should be corrected. Also, such techniques as sensitivity analysis in respect of input data can give an insight into credibility of the result obtained.

An important improvement in the application of reliability engineering can be achieved by the establishment of a reliability data base which should contain the failure statistics in respect of the failures in all critical systems and components of a nuclear power plant. Reliability data systems are being developed in all countries with an important nuclear power programme. Unfortunately, the acquisition of data from the power industry is very slow and in most cases the data do not provide an adequate understanding of the basic causes of failure. These shortcomings were clearly recognized in the discussions at the Symposium.

The somewhat unsatisfactory records on overall availability of nuclear power plants give an indication that reliability improvement efforts should be oriented towards those systems which are most frequently responsible for plant outages. This cannot be done without weighing the reliability assurance efforts against the economic benefit obtained, or economic penalty caused by plant outages. This includes among others the optimization of efforts under a set of cost constraints with an objective to maximize the overall plant availability. Unfortunately, few applications have been reported of available reliability technology application to the design and maintenance of nuclear power plants for the purpose of optimizing plant availability and economics.

In a number of papers and in the discussions it was reaffirmed that reliability improvement can be obtained through such measures as testing, periodic inspections, maintenance and quality assurance for activities affecting the quality of a nuclear power plant. Reliability engineering can contribute to these measures by means of continued evaluation of the effectiveness with which resources are applied to achieve stated objectives, and demonstration of how they can lead to optimization of operation and maintenance. Thus, it has been demonstrated that by using failure and repair data one can derive, by application of reliability analysis techniques, an optimal periodic testing or inspection frequency, maintenance strategy and operation practices. For wider application of the techniques of reliability engineering in practical plant operation and maintenance the main hindrance is the fact that these techniques are quite novel to the practical engineer. Also, practical engineers are somewhat less inclined to appreciate the direct advantages of this approach because the reliability analysts are sometimes not able to demonstrate that the actual performance of the analysis helps design, maintenance and operational engineers to make practical decisions. The opinion was voiced at the meeting that closer co-operation among these two groups of specialists could help the improvement of nuclear power plant safety and availability considerably.

It was evident from the papers and discussions at the Symposium that the reliability concept is at present the only one which quantifies hitherto qualitative judgements on nuclear power plant safety and availability. The reliability analysis, together with reliability data

collection, therefore represents an indispensable technique for power plant design, operation and maintenance engineers to evaluate their efforts in stated objectives, and to discover weaknesses and deficiencies in design and operation practices.



REPORT OF AN IAEA ADVISORY GROUP MEETING, VIENNA, 14–18 APRIL

An Advisory Group met to consider the up-dating and extension of the Recommendations for the Physical Protection of Nuclear Material, produced in 1972. Twenty-seven experts from 11 countries and EURATOM were present.

Physical Protection of Nuclear Material

Growing concern has been expressed in many countries that nuclear material may one day be used for acts of sabotage or terrorism. Serious attention is therefore being given to the need for States to develop national systems for the physical protection of nuclear materials during use, storage and transport throughout the nuclear fuel cycle which should minimize risks of sabotage or theft.

The revised Recommendations formulated by the Advisory Group include new definitions of the objectives of national systems of physical protection and proposals for minimizing possibilities of unauthorized removal and sabotage to nuclear facilities. The Recommendations also describe administrative or organizational steps to be taken for this purpose and the essential technical requirements of physical protection for various types and locations of nuclear material, e.g., the setting up of protected areas, the use of physical barriers and alarms, the need for security survey, and the need of advance arrangements between the States concerned in case of international transportation, among others.



EIGHTH ANNUAL MEETING OF THE INTERNATIONAL WORKING GROUP ON FAST REACTORS, IAEA, VIENNA, 15–18 APRIL

The meeting was attended by 15 participants from seven countries and two international organizations.

Fast Breeder Reactor Research

The Eighth Annual Meeting of the International Working Group on Fast Reactors (IWGFR) was attended by representatives from France, Fed. Rep. Germany, Italy, Japan, United Kingdom, Union of Soviet Socialist Republics and the United States of America – countries that have made significant progress in developing the technology and physics of sodium cooled fast reactors and have extensive national programmes in this field – as well as by representatives of the Commission of the European Communities and the IAEA.

The design of fast-reactor power plants is a more difficult task than developing facilities with thermal reactors. Different reactor kinetics and dynamics, a hard neutron spectrum, larger integral doses of fuel and structural material irradiation, higher core temperatures, the use of an essentially novel coolant, and, as a result of all these factors, the additional reliability and safety requirements that are imposed on the planning and operation of sodium cooled fast reactors – all these factors pose problems that can be solved comprehensively