Reactor Boiler and Auxiliaries - Course 133

SAFETY STANDARDS AND SAFETY MEASURES

Two important factors make it imperative that safety measures be given serious consideration in nuclear power stations:-

1. The extensive casualties that could theoretically result from a nuclear accident and
2. The sensitivity of the public to any risks associated with the production of nuclear energy.

There was a tendency during the early development of nuclear reactors to demand more and more safety measures despite the extremely favourable safety record of the nuclear industry. To combat this tendency an attempt has been made, in Canada, to set a safety standard by which to judge the adequacy of safety measures.

This lesson discusses the development of this standard and the basic safety measures taken to meet this standard in our nuclear power stations.

Safety Standards in our Present Economy

All human activity involves some element of danger and the possibility that persons may be injured or killed. However, the probability of accidents are normally weighed against the benefits from the activity and if the risk appears small enough it is accepted. If the risk appears too high, social and ecomomic pressures result in safety measures being adopted to reduce the risk.

The accepted standard varies quite widely with different activities due to these economic pressures. In the transportation industry a much higher death risk is accepted for travel in private cars than for travel in airplanes or ships. One reason for this is that there is a much greater public reaction when there are a relatively large number of casualties regardless of the low frequency of airplane or ship accidents.

Whenever a new industry is established new risks are introduced. If greater risks are eliminated by the displacement of existing industry our overall safety is improved and the new risks are accepted, particularly if the new industry results in an improvement in our living standard and, hence, in life expectancy.

In the nuclear power industry it is recognized that no absolute guarantee can be given that accidents will not occur. However, a satisfactory safety standard is provided if the new risks introduced are less than the risks eliminated by the displacement of other industry.

Conventional Hazards at Nuclear Stations

Past experience with conventional hazards in other power stations and other industry has resulted in the adoption of various safety practices and safety measures. These measures imply an acceptable risk of conventional accidents and they are followed to provide the same protection against such conventional accidents in nuclear power stations.

Nuclear Hazards at Nuclear Stations

The new risks introduced by the operation of nuclear power stations result from the possibility that there may be a nuclear accident involving the escape of dangerous quantities of radioactive fission products from the fuel to populated areas where it could cause injuries or deaths. No nuclear accidents affecting the general public have occurred. Nevertheless, past experience with the behaviour of radioactive materials is limited. If pessimistic assumptions are made of the results of the escape and distribution of these materials it can be established that a nuclear accident could result in extensive deaths.

A satisfactory safety standard for a nuclear power station may be defined as one where the risk of loss of life due to nuclear accidents is no greater than the risks avoided by the elimination of coal fired power stations. However, since the potential loss of life due to a single accident is much higher, the potential frequency of nuclear accidents must be much lower.

During the early development of the CANDU type reactor statistics were gathered on the total accidental death frequency experienced in the preparation and transportation of coal, construction and operation of a coal fired power station. A comparison of this figure with that experienced in the preparation of fuel and the construction of a nuclear power station indicated that the total risks for each type of station would be similar if the annual fatality rate resulting from the operation of a 200 Mwe nuclear power station did not exceed 0.82 deaths per year. A safety factor of 5 was applied, to provide improved performance during early operation, resulting in a proposed allowable addident risk of 0.17 deaths per year.

Nuclear Safety Standards

This general philosophy for setting an allowable accident risk was used to calculate the required performance standard for equipment provided at NPD. The allowable annual fatality risk was reduced to 0.01 deaths per year since it was considered that the safety standard for the nuclear industry should be higher than that experienced in the replaced coal industry. The maximum potential death toll per accident was estimate to be 1,000, which results in a calculated maximum allowable nuclear accident frequency of once in 100,000 years. Obviously this standard can never be verified by actual accident experience. However, when the standard is expressed as an allowable annual nuclear accident probability of 10^{-5} it provides a basis for judging the effectiveness of the various measures which protect against the accidental escape of radioactive fission products.

Similar annual accident probabilities are being used to judge the effectiveness of safety measures provided at the Douglas Point and Pickering generating stations.

Protection Against Nuclear Accidents

Nuclear accidents which affect the public can only occur if the radioactive materials generated in the fuel escape and travel to a location where they may cause injuries or deaths. Obviously a single barrier cannot be depended upon to provide the required safety standard so the fuel and station equipment are constructed in a manner which provides many barriers against the escape of radioactive materials.

(a) Containment

The term containment, as used in these lessons, is intended to include all barriers which prevent movement of fission products from the fuel to occupied locations. The main containment barriers provided in the CANDU type reactors are:

1. Fuel - The fuel is designed to retain most fission products as long as the fuel temperature remains within its normal range.
2. Fuel Sheath - The fuel sheath provides a protective cover over the fuel and prevents escape of the small fraction of fission products which are released from the fuel in the form of gases.
3. Primary Envelope - This includes the piping and equipment containing the primary coolant. This envelope prevents escape into the building of any fission products which have escaped past the fuel and the fuel sheath.

4. Building - Since the reactor and primary envelope are contained in a normally unoccupied area of the station, the building enclosure provides shielding and prevents the release from the building of fission products, which have escaped past the fuel, fuel sheath and primary envelope. Equipment is provided to control any pressure surge so that the isolation provisions remain intact.

5. Exclusion Area - This is a designated area surrounding a nuclear station from which the public is normally excluded. Thus, all persons may be quickly evacuated from the area if there is any release of fission products from the station.

(b) Protective Systems

The provision of many containment barriers results in a negligible probability of significant quantities of radioactive materials escaping from the station except in circumstances where some fault causes damage to more than one of the containment barriers. Thus, if the fuel is extensively overheated, the fuel, the fuel sheath and the primary envelope may all be damaged and the resultant release of high energy coolant containing fission products may cause a pressure surge which could damage and penetrate the building enclosure.

Since fuel overheating can result only from increased power production or reduced heat removal the most important measure for preventing escape of fission products is to provide reliable process equipment which will control reactor power within a specified range and provide adequate cooling of the fuel.

Since all equipment is subject to failure the process equipment alone may not reduce the annual probability of a nuclear accident to the required standard and, therefore, independent protective systems are provided at each nuclear power station. These protective systems, which are listed below, are designed to prevent or reduce escape of fission products from the fuel into the building, if there is a failure of essential process equipment.

1. Reactor Boiler Protective System - This system independently shuts down the reactor thereby reducing fuel power production whenever various process variables exceed specified limits. The protective system prevents fuel failures, and thus nuclear accidents, following all process equipment failures except those involving loss of cooling. The design and operation of Reactor Boiler Protective Systems is discussed in another course.

2. Emergency Injection Water System - This system provides fuel cooling if the normal heat transport fluid is lost. The

2. injection water supply is obtained from an independent source and may be either light water or heavy water. Injection water equipment is discussed in the following lesson.

3. Emergency Power Supplies such as that obtained from a diesel generator, in the event that normal power supplies are interrupted by a simultaneous loss of line and loss of generator production. Power is, thus, maintained for essential process systems such as calandria spray cooling.

4. Standby Water Supplies such as that obtained from a gasoline engine, in order that essential cooling and fire protection be maintained when normal process water supplies are interrupted. Both (3) and (4) will be discussed in other courses.

ASSIGNMENT

1. On what basis is a safety standard established for a new industry such as the nuclear power industry?

2. Define a "satisfactory safety standard" for a nuclear power industry.

3. In what allowable nuclear accident frequency does such a standard result?

4. What stages of containment are provided in a nuclear station?

5. What is the primary purpose of the protective devices provided in a nuclear station?

R. Kelly