Reactor Boiler and Auxiliaries - Course 133

EMERGENCY INJECTION AND CONTAINMENT SYSTEMS

Protective devices, in a nuclear station, prevent or reduce the escape of fission products from the fuel into the building enclosure, if failure of process equipment has occurred. Containment provisions prevent or reduce escape of radioactive material from the building if both process equipment and protective devices fail.

One protective device, the emergency injection system, and all the containment devices will be discussed further in this lesson.

Emergency Injection Systems

If there is an appreciable loss of the normal heat transport fluid during reactor operations, there is a decrease in pressure and the remaining fluid boils. This reduces the heat transfer from the fuel. If the Reactor Boiler Protective System responds rapidly enough to shut down the reactor, heat generation in the fuel is reduced to that provided by fission product decay. However, if the fluid is not replaced fuel temperatures may rise sufficiently to cause the fuel to melt and allow the release of fission products into the heat transport system. The emergency injection system automatically provides a separate alternative supply of cooling water, in such an event, so that heat removal from the fuel is restored and the rise in temperature is restricted.

The most obvious separate source of heavy water for such an injection system is the moderator system. In NPD, Douglas Point and Pickering, there are interconnections between the moderator system and the heat transport system. The arrangement in NPD is shown in Fig. 1. In the event of a serious loss of heat transport fluid, heavy water, from the moderator system is pumped into the reactor inlet headers by the "charging" pump, P.

Floor drainage is arranged so that spilt heavy water is collected in a recovery sump. It is then possible to return the recovered water to the moderator system or directly into the charging pump suction, through remotely operated valves.

A similar system is used in Douglas Point and Pickering with minor differences. No charging pump is used so that D_2O

injection takes place under moderator pump pressure, through a check valve and an isolating valve. Therefore, D_2O injection will not occur until the heat transport system pressure drops below the moderator pressure. Recovered heavy water is returned to the moderator pump suction.

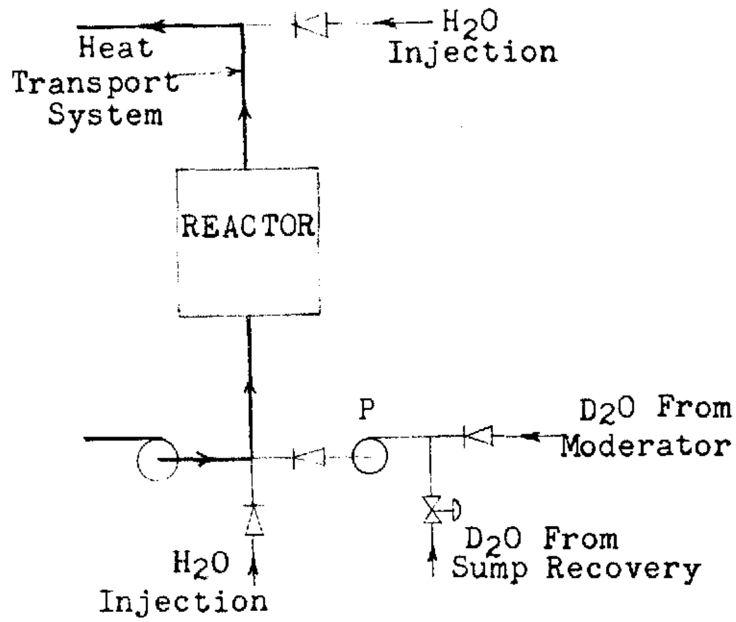

Fig. 1

An alternative supply of water may be required if the D_2O injection cannot cope with the situation or if the moderator water level drops too low to supply emergency injection. In NPD a light water injection system is provided as an alternative. Pipes from a 250,000 gallon storage tank are connected, through check valves, to the inlet and outlet headers. If the loss of heat transport fluid is extensive enough to drop the system pressure below the static head in the storage tank, light water will be admitted into the system. In Douglas Point and Pickering, provisions are made to connect a light water supply to the system if and when it is required.

Containment Provisions

It was stated in the previous lesson that there are four stages of containment of fission products, the fuel itself, the fuel sheath, the heat transport system and the building. The building and other containment provisions are required to prevent escape of radioactive material into the environment in the event that the first three stages of containment fail. All systems containing, or potentially containing, significant quantities of radioactive material and operating at elevated temperatures or pressures are placed within a containment structure designed to:

1. limit the release of radioactive material to a value set by the exposure criteria for a particular site,

2. withstand any calculated pressure increase, which may occur as a result of an accident, without exceeding the specified leak rate,

3. have adequate provisions for testing at predetermined intervals.

Since such a structure contains the reactor boiler plant and the associated shielding and material handling facilities, it would, of necessity, be very large. Such a structure is usually made of steel or concrete.

The potential energy release inside such an enclosure would cause a pressure increase beyond the capabilities of most practical structures. Severe thermal stresses would also result from such a release. Therefore, additional measures are required to absorb part of the released energy. These additional measures are:

(a) Use of Pressure Relief Systems

In this type of system the building itself may be used to contain the radioactive materials. However, to avoid the effect of the initial pressure increase on the structure, the initial blast resulting from the explosion is allowed to escape through a relief duct into the atmosphere.

Such a relief duct, as used in NPD, is shown in Fig. 2. This relief of pressure reduces the pressure build-up from the explosion and the structural thicknesses required to withstand such a pressure. It is assumed that the initial escape of steam and air only contains tritium, since fuel failure will only occur subsequent to the loss of heat transport fluid. Immediately following the initial blast, a door closes in the relief duct, preventing escape of fission products released after fuel failure.

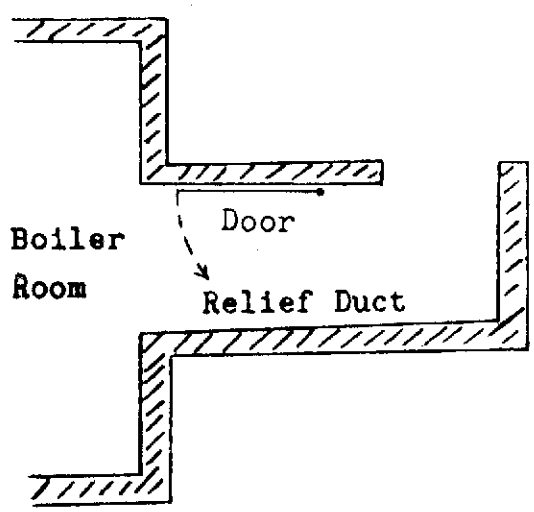

Fig. 2

Pressure relief may be used, as in Pickering G.S., as a means of reducing the pressure build-up even though a containment shell is used. Such a pressure relief would reduce the thickness of the containment shell required. The type of arrangement proposed is as shown in Fig. 3. Each reactor and associated heat transport system will be housed in a 4 ft thick cylindrical concrete containment building.

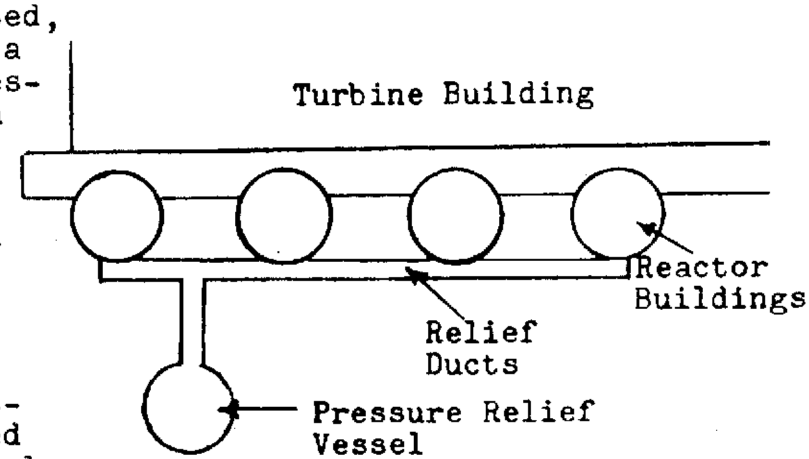

Fig. 3

The various rooms, in the reactor building, are isolated by blowout panels so that increase in pressure in one area will relieve into the rest of the building. This arrangement is also used in Douglas Point. However, in Pickering, a pressure increase in the reactor building will cause relief louvers and valves to open allowing pressure relief into the pressure relief building. This building is maintained at a pressure of 1 psia by vacuum pumps. No such pressure relief exists at Douglas Point.

(b) Use of Pressure Suppression

Since most of the accidents that can be contemplated result in a violent release of steam containing radioactive material, containment of the radioactive material is effected if all the steam can be condensed. Such pressure suppression can be obtained by allowing the pressure buildup to initiate a dousing system which spray-cools the steam. The dousing system may have to be used with a pressure relief system or a containment shell. However, the shell would be thinner and less expensive. It was estimated that, without dousing, a containment system for NPD would have to withstand a 40 psia increase in pressure with 10^6 Btu of heat released. In one Pickering unit around 2.4×10^8 Btu of heat would have to be dissipated during the type of accident envisaged. Yet at Douglas Point, with dousing but no pressure relief, the maximum internal pressure estimated in the containment vessel is only 6 psi. Consequently the containment vessel walls can be made of 4 ft thick concrete with a corresponding thickness of steel in the dome. The leakage rate out of this enclosure can be kept down to 0.1% of the total volume per hour.

A dousing tank, containing 400,000 cu ft of water is located in the roof of the vacuum building at Pickering.

Pressure suppression has an added advantage since some radioactive iodine will be absorbed.

ASSIGNMENT

1. Explain how water from the moderator system is used to provide emergency injection water for the heat transport system.
2. Why is an alternative light water supply also provided?
3. What is the purpose of a containment structure in a nuclear station and what are its design requirements?
4. Explain the use of Pressure Relief Systems and Pressure Suppression Systems in a nuclear station.

R. Kelly