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NRC INSPECTION MANUAL

ILPB

PART 9900: TECHNICAL GUIDANCE

FPLUGS.TG

MECHANICAL - FREEZE PLUGS

A. PURPOSE

To provide guidance on the use of freeze plugs during system maintenance or modification on reactor fluid systems, which, for various reasons, cannot be isolated through the use of existing valves.

B. DEFINITIONS

Freeze Plug - Freeze Seal. A method of preventing fluid flow in a piping system by freezing the fluid. The area of fluid frozen performs the same function as a valve. The terms freeze plug and freeze seal are synonymous.

C. BACKGROUND

On April 19, 1989, at the River Bend Station, a freeze plug failed on a 6-inch service water line. The freeze plug had been established to allow inspection and repair work on manual isolation valves to a safety-related auxiliary building cooler. The failure of the freeze plug resulted in flooding portions of the auxiliary building. Approximately 15,000 gallons of service water covering portions of the 141-foot level discharged through a disassembled isolation valve. A portion on the water flowed through holes in the floor under safety-related 480 VAC motor control centers on to non-safety-related cabinets on the 114-foot level containing disconnect links and a 13.8/480 VAC transformer. Since the cabinets were not designed to shed the water, an electrical fireball resulted that damaged the cabinet and components.

During an Oconee 1 shut down for a refueling outage, a freeze plug was used to facilitate replacement of a 3-inch diameter section of low pressure injection piping, because no valves were available to isolate the affected piping. The freeze plug was in a line connected to the borated water storage tank, which has a 388,000 gallon capacity, and supplies borated water for the low pressure injection system. The freeze plug failed, and approximately 30,000 gallons of water leaked into various areas of the auxiliary building and a portion drained through the station yard drainage system and unintentionally flowed past the site boundary before the leak was brought under control 8 hours after the freeze plug failed.

Information Notice 91-41, "Potential Problems With the Use of Freeze Seals," identified potential problems related to the freeze seal in PWRs and BWRs, specifically including both the River Bend and Oconee 1 incidents. The information notice indicated that freeze seal failure in a PWR reactor boundary system could result in immediate loss of primary coolant. In BWRs, failure of a freeze seal in a system connected to the vessel's lower plenum region, such as the reactor water cleanup (RWCU) system, could result in the water level in the reactor vessel falling below the top of the active fuel. The estimated time for this to occur is less than 1 hour if the seal failed completely and makeup water was not added to the reactor. The information notice indicated concerns that freeze seal failures in secondary systems can also be significant because of the potential for consequential failures, such as the loss of RHR in the River Bend event. The information notice identified procedural inadequacies that resulted in a failure to install and monitor a temperature detection device, and a lack of personnel training in the use of freeze seals. Other important considerations identified in the notice included: "examining training, procedures, and contingency plans associated with the use of freeze seals, and evaluating the need for and availability of additional water makeup systems and their associated support systems."

D. DISCUSSION

Freeze plugs are routinely used in nuclear reactor fluid systems to drain or isolate components which for various reasons cannot be conveniently isolated by valving. Basically, a freeze plug is produced by chilling the outside of a pipe, usually by immersing a portion of the pipe in liquid nitrogen. Eventually, the water at the inner surface of the chilled pipe freezes and the ice/water interface grows towards the center of the pipe and also along its axis. Although this description is rather simplified, there exists certain problem areas about which care must be taken, both for the establishment of an effective freeze seal and for the assurance that the freeze seal will be adequately maintained for the period of time it is required. It is essential, therefore, that written procedures be established and followed, and that adequate training be conducted for personnel to correctly implement these procedures.

In the course of the NRC staff's evaluation of shutdown and low-power operations (NUREG-1449), the staff identified and examined plant configurations used during shutdown operations involving temporary seals in the reactor coolant system. This includes freeze seals that are used in a variety of ways to isolate fluid systems temporarily, temporary plugs for nuclear instrument housings, and nozzle dams in PWRs. The staff has identified instances in which failure of these seals, either because of poor installation or an overpressure condition, can lead to a rapid non-isolable loss of reactor coolant. This concern is of special importance in PWRs because the emergency core cooling system (ECCS) is not designed to automatically mitigate accidents initiated at pressures below a few hundred psig and is not normally fully available for manual use during these conditions. In BWRs, the ECCS is required to be operable during cold shutdown, and during refueling when there is fuel in the reactor vessel and the vessel water level is less than 23 feet above the reactor pressure vessel flange. In addition, the ECCS is actuated automatically when water level is low in the reactor vessel.

At the River Bend Station (RBS), freeze seals were being produced by both outside contractor personnel and plant maintenance personnel. Each organization had its own freeze seal procedure. The RBS procedure permitted a freeze seal contractor to use his own procedure. Much of the licensee's knowledge on freeze seal production was gleaned from observation of the freeze seal contractor during the first refueling outage. There had been no formal training or a list of personnel qualified on freeze seal techniques established for RBS maintenance personnel.

The RBS and contractor procedures had some notable differences. The freeze seal contractor's procedure required installation of a temperature measuring device into a sleeve in the freeze seal chamber. The RBS procedure did not require installation of a temperature measuring device. While the RBS procedure discussed use of such a device, it was ambiguous in that it required a resistor temperature sensor probe be taped to the pipe surface, but showed a sketch with a thermocouple protruding from the chamber. The freeze seal contractor required recording temperature every 5 minutes during establishment of the freeze plug and every 15 minutes while the plug was being held. There were no temperature monitoring or recording requirements in the RBS procedure. The freeze seal contractor utilized a manifold boot and controlled flow by dripping liquid nitrogen from a vent, whereas the RBS procedure vented gaseous nitrogen (which is not considered to be a very reliable method). In addition to temperature measurement, there are other indications of freeze conditions. These indications are frosting of the pipe at each end of the boot and observation of water flow downstream from the freeze seal. Neither of these methods are very reliable, but both were used in the RBS procedure. In addition, the freeze seal contractor prohibited multiple seals from a single nitrogen bottle, but no such prohibition was stated in the RBS procedure.

In the RBS incident two freeze seals were produced from the same nitrogen bottle. Nitrogen flow was controlled by observation of the nitrogen plume at the vent, and some valve manipulation was required to produce equal plumes from both vents and to maintain roughly uniform plume size for the duration of the freeze. Temperature indication was estimated by the axial length of frosting on the pipe on either end of the boot. The freeze plug failed even though vapor flow out of the jacket vent was observed and frost lines indicated that a plug had formed.

At Oconee the freeze plug procedure did not provide adequate guidance for determining the amount of liquid nitrogen required. Two bottles of liquid nitrogen were considered by the supervisor to be a sufficient supply for the task and were available at the freeze site. When the first bottle was depleted, personnel took it away to be refilled. After refilling the first bottle, it was subsequently returned to the freeze site. When the first bottle was next used, it was determined that it had been only partially refilled due to operator and maintenance personnel unfamiliarity with the refilling process. The refilled first bottle lasted for about 15 minutes, which did not allow enough time to refill the second bottle. While the second bottle was being refilled, the freeze seal failed.

As a result of these events, the inspector should ensure that the licensee has considered the following items in establishing procedures and controls:

1. Maintenance procedures ensure that an adequate supply of liquid nitrogen is available prior to commencing the freeze seal operation.

2. Personnel are trained in the filling of nitrogen bottles.

3. Each freeze plug will be supplied by a single source of liquid nitrogen.

4. Freeze plug installation and maintenance will be performed by plant personnel who have been trained on freeze plug installation and maintenance techniques and procedures.

5. The licensee has a documented contingency program with implementing procedures to use in the event that a freeze plug fails.

6. Freeze plug procedures require communications between the control room and the maintenance personnel performing the work to keep the control room apprised of the status of ongoing work.

7. Prior to establishment of a freeze seal, the area of pipe scheduled to contain the seal should be subjected to surface inspection (MT or PT) to assure that no surface defects are present.

8. The equipment used to establish and maintain the seal should be designed to provide uniform distribution of coolant. Provision should be provided for temperature monitoring instrumentation and dependable flow monitoring of some sort (Observation of gaseous plume is not considered an adequately dependable flow monitoring method).

9. Freeze seals should not be performed within some minimum distance (e.g., a minimum of 3 pipe diameters) from piping discontinuities.

10. Freeze plug jacket temperature will be monitored to ensure that liquid nitrogen flow is maintained.

11. Provide adequate ventilation to assure adequate circulation of volatile coolants. In confined areas, an air analyzer should be in operation and frequent observations performed.

12. During freeze plug thaw, a minimum Δ p across the seal is necessary to prevent downstream damage from movement of the plug.

13. Recommended modifications to basic freeze seal procedure for variations in seal orientation (i.e. pipe axis horizontal or vertical) should be provided where needed (i.e. temperature and flow monitor locations).

14. Adequate measures have been taken to protect electrical equipment and other systems whose operation could be impacted by a failure of the freeze plug.

15. Planning and supervision of freeze seal operations should be conducted by qualified and experienced personnel. In many cases, contractors with special expertise and experience in conducting freeze seal operations will be used. A more in-depth inspection may be warranted if a recognized specialist in the area of freeze sealing is not being used.

16. Planning for freeze seal operations should include consideration for the potential for causing structural damage to the piping based on the evaluation of a qualified engineer.

END