UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

LOOSE OTSG PLUGS

GPU NUCLEAR CORPORATION, ET AL

THREE MILE ISLAND NUCLEAR STATION, UNIT 1

DOCKET NO. 50-289

Introduction

In July 1984, following plant hot functional testing in TMI Unit 1, it was discovered that seven rolled plugs developed by Westinghouse to plug the Once-Through Steam Generator (OTSG) tubes had dislodged from their installed positions. Four of the plugs were from the bottom tubesheet of OTSG "A"; two were from the bottom tubesheet of OTSG "B"; and one was from the upper tubesheet of OTSG "A". The plug from the upper tubesheet of OTSG "A" has been recovered but the remaining six plugs are still missing. By letter dated October 23, 1984, the licensee submitted safety analysis reports documenting its review, in accordance with the provisions of 10 CFR Part 50.59, of the Westinghouse rolled plug qualification program, the cause of the dislodged plugs, and the test and repair program to ensure that the installed plugs have adequate integrity under postulated transient and accident conditions. The reports also address the effects of the loose plugs on the core and other reactor coolant system components and on the safety of plant operation.

The purpose of this SER is to:

1. Evaluate the GPUN program to identify and correct defective W rolled OTSG plugs, and
2. Evaluate safety aspects of operation with loose/missing W rolled OTSG plugs.

Background

Intergranular stress assisted cracking caused primary side damage to the TMI-1 steam generator tubes in 1981. Eddy current tests (ECT) indicated that most of the defects were located within the upper tubesheet and could be isolated and satisfactorily repaired by the kinetic expansion process. Other tubes with defects which could not be satisfactorily repaired by kinetic expansion and did not require stabilization were plugged with a rolled plug developed in 1982 by the Westinghouse Electric Corp. for use in the TMI-1 OTSG's. Approximately 1013 rolled plugs were installed as of May, 1984.

Evaluation

1. Identification and Repair of Defective Plugs.

As Described in the attachments, to its letter of October 23, 1984, the licensee conducted a comprehensive investigation and repair program in this matter. A qualification program for testing the installed plugs was prepared, tooling and procedures for performing the tests were developed, acceptance criteria were established, and all the W rolled plugs were tested. Twenty-five plugs were pulled completely out of the tubes, and an additional number which did not pull out were judged unsatisfactory. We have reviewed the test program and conclude that it is adequate to identify defective rolled plugs.

The licensee then performed an investigation to determine the cause of the plug failures, including examination of the pulled-out plugs and testing to determine the effects of variations in installation parameters and procedures. It was concluded that the failed plugs had not been adequately rolled, which was attributed to inadequate consideration of the adverse effects of using a universal joint in the rolling tool and of sidewise loading on the tool. We have reviewed the updated investigation and conclude that the investigation was adequate, and that the licensees conclusion as to the cause of the problem is correct.

The repair method selected by the licensee for the remaining unsatisfactory plugs was rerolling. To provide additional assurance of acceptability, it was decided to re-roll those plugs which had passed the pull test. Tubes from which plugs had pulled out were re-plugged using the original rolling tool, and rerolled. All rerolling was done with newly qualified improved tooling after completion of a testing program, under increased quality assurance surveillance. All previously unsatisfactory plugs were again pull tested. The licensee also simulated LOCA conditions by conducting a hydrostatic plug ejection test demonstrating that a plug is unlikely to be ejected under LOCA conditions. The licensee has concluded that all improperly installed plugs will be restored to their originally acceptable condition and that after repair, all plugs will meet their design objectives and therefore integrity of the primary pressure boundary (with regard to the plugs) will be maintained. We agree with the licensee, and conclude that the repair of the defective plugs is adequate.

In summary, we conclude that the GPU program to identify and correct the defective W rolled OTSG plugs is adequate, and that there is reasonable assurance that the repaired plugs will meet their design objective and thus maintain primary pressure boundary integrity.

2. Safety Aspects of Operation with Loose/Missing Plugs

2.1 Effect of Loose OTSG Plugs on Nuclear Fuel

Each of the OTSG tube plugs is basically a thin-walled hollow cylinder closed at one end, which is 3.5 inches long and 0.5 inch in outside diameter, and weighs 1.5 ounces. The plugs are made of Inconel 600. The licensee has determined, based on the ductility and toughness properties of Inconel 600, that it is very unlikely that the loose plugs will fracture or fragment.

In order to evaluate potential damage and safety effects of the loose plugs, the licensee provides a detailed description of the scenario of possible flow paths of the loose plugs. Because of the size and configuration of the loose plugs, the open areas of flow paths, and the direction and velocity of RCS flow, the most probable flow path for a loose plug is to flow out of the lower dome of the OTSG, through the cold legs, RC pumps, into the reactor downcomer, lower plenum, lower internals and finally to be entrapped in the lower end fittings of the fuel assemblies. This would result in inlet flow blockage affecting the hydraulic lift force and thermal hydraulic performance of the fuel assemblies. However, it is very unlikely that more than one loose plug would lodge in a single fuel assembly because the RCS flow will distribute the loose plugs in a random pattern within the core. Because of the small size of the loose plugs, one plug can block only a small percentage of the inlet flow area of a fuel assembly. Even if all six loose plugs lodged in a single assembly, it would only result in partial blockage of the flow area. Partial blockage of a single assembly would have little effect on pressure drop and hydraulic lift force. The licensee's calculation shows that even conservatively ignoring compensatory pressure drop effects from diversion cross flow among the neighbouring assemblies, the static flow force on an intact loose plug entrapped in the lower end fitting inlet is about 1 pound under the worst case flow condition of four-pump operation.

This is less than one percent of the fuel assembly holddown force margin of over 100 pounds for TMI-1. Therefore, there is sufficient holddown force to overcome the lift force due to the flow blockage effect of the loose plugs.

The thermal hydraulic effect of partial flow blockage due to loose plugs is insignificant. Because of the open lattice fuel assembly configuration, the flow redistribution downstream of the blockage will result in full recovery of flow in the lower portion of active core region where DNB is not limiting. Test data performed on open lattice fuel assemblies have shown that with 41 percent of subchannels completely blocked, the stagnant zone behind the flow blockage essentially disappears after a length of about two times the hydraulic diameter. As shown in the Midland FSAR, B&W has calculated the effect of hot channel flow blockage on fuel rod behavior. It shows that the DNBR as calculated with the BAW-2 critical heat flux correlation decreases with increasing flow blockage, but the DNBR limit of 1.3 is not reached until about 70 percent of blockage has occurred. Therefore, flow blockage from the loose plugs would not have significant effect on DNB.

The effect on the loss of coolant accident (LOCA) of the loose plug entrapped in the lower end fitting is also insignificant. The limiting large break LOCA is a guillotine break in the cold leg piping. LOCA analysis shows this event to be characterized by an almost instantaneous flow reversal during blowdown phase. The flow reversal would carry away the loose plugs entrapped in the lower end fittings into the lower plenum without affecting the system response. Therefore the loose plugs will have no effect on the results of a postulated large break LOCA.

Though fragmentation of the loose plugs is unlikely to occur, the effect of the plug fragments is considered in the analysis. A small fragment could enter the fuel assembly and wedge against a fuel rod. Should this happen, it would only have point contacts, due to rough configuration of the fragments, allowing flow between the contact points. Therefore, no overheating would occur due to localized hot spots. However, if the small fragments were to enter the fuel region, it is conceivable that some fuel rod fretting wear could occur. The worst result of such wear would be the release of fission products from the perforated rods. However, since plug fragmentation is unlikely, and there are only a total of 6 missing plugs, there would be only a small number of fragments wedged against fuel rods. Simultaneous perforation occurring at many fuel rods would be unlikely and therefore the fission product release would be gradual. Such release would be detected by the activity monitor. The release would not be permitted to exceed the maximum coolant activity specified in the TMI-1 Technical Specification 3.1.4.1, the limiting condition for operation, which specifies the total coolant activity limit. Table 4.1-3 of Surveillance Requirement 4.1 also specifies the minimum frequency of the reactor coolant activity check. Therefore, we conclude that there is reasonable assurance that the number of reactor fuel failures from fretting wear due to loose plug fragments would be small, and that in the unlikely event that such fuel rod failure should occur, it will be detected in a reasonable time under the provisions of the existing Technical Specifications to assure action to limit the amount of fuel failure.

2.2 Loose Plug Effect on Control Rod Operation:

Neither the licensee nor B&W has developed a scenario where a whole loose plug could interfere with the control rods. In the unlikely event that a loose plug is fragmented, there is a small possibility that the fragments could enter and become trapped within the control rod guide tube to cause restriction or jamming of control rod motion or cause the control rod cladding to fail. Should the control rod cladding be breached, some poison material (Ag-In-Cd) might leach into the reactor coolant. Any poison isotopes in the coolant would likely be detected by normal chemical sampling analysis (Table 4.1-3 of Surveillance Standard 4.1 of the TMI-1 Technical Specification specifies the minimum frequency of chemistry sampling to be 5 times per week). This would not be a safety concern because only a small amount of poison would be lost and the reactivity effect is insignificant. Even if a control rod is jammed to prohibit its motion, this would not constitute an unresolved safety question. This is because the safety analyses were performed with the assumption that the highest worth control rod was stuck in the fully withdrawn position. The results of analyses have shown that the reactor can be safely shutdown. In addition, the TMI-1 Technical Specification 4.7, "Reactor Control Rod System Tests", requires that each control drive mechanism shall be exercised by a movement of approximately two inches of travel every two weeks. If a control rod cannot be exercised, the rod shall be declared inoperable and corrective action is taken as required by the Technical Specification. Therefore, there is a reasonable assurance that the loose plugs will not result in undetected control rod inoperability. Based on these observations, we conclude that there is no significant safety concern over control rod operation due to the loose plugs still remaining in the RCS system.

2.3 Loose Plug Effect on Incore Instrumentation:

There is a system of 52 incore detector assemblies (strings) with 7 axially spaced detectors per assembly in TMI-1. In the highly unlikely event that the loose plug fragments enter and become wedged in an incore instrumentation guide tube, the wedging could cause damage to the instrument sheath. As a worst case, the string might be partially or totally severed causing functional loss of detectors. Detector loss would be monitored by the plant process computer. TMI-1 Technical Specification 3.5.4, Incore Instrumentation, specifies that at least 23 individual incore detectors should be operable to check gross core power distribution and to assist in the periodic calibration of the out-of-core detectors with regard to the core imbalance trip limits. Therefore functional loss of a few incore detectors would not be a safety concern. In the highly unlikely event that functional loss of too many incore detectors results in violation of the minimum requirements for the number and arrangement of detectors, corrective actions would be taken per the Technical Specifications requirement. Therefore, the safety effect of the loose plugs on incore instrumentation is insignificant.

2.4 Other Components

The licensee has reviewed comprehensively the RCS components, reactor vessel internals, and connecting systems through which the plugs would or could pass or in which they could remain. The licensee concludes that the most probable path will result in all loose plugs being confined to the lower portions of the reactor vessel and fuel assemblies. It concludes that the likelihood of plugs following any secondary flow paths is very small and that the safety effect of such occurrence is not significant. We have reviewed the licensee's analyses and agree with its conclusions.

2.5 Summary

We have reviewed the safety analyses reports prepared by the licensee and B&W with regard to the operation of the TMI-1 plant with loose OTSG tube plugs in the reactor system. Based on our review, we have concluded that (1) the flow blockage effect of the loose plugs would not result in a significant adverse effect on DNB and fuel assembly holddown force; (2) the number of reactor fuel failures from fretting wear caused by unlikely loose plug fragments would be small and detectable; (3) the control rod operation would not likely be affected, and if affected, it will not constitute an unresolved safety question; (4) if incore instrumentation is damaged by the loose plug fragments, this would be monitored and the damage of a few incore detectors would not be a significant safety concern; and (5) the liklihood of other flow paths for the loose plugs is small and if the plugs were to follow such secondary path, no significant safety concern would result.

Therefore, there is reasonable assurance that continued operation of the TMI-1 plant with the missing OTSG plugs remaining in the reactor system will not result in a significant safety concern.