UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

METROPOLITAN EDISON COMPANY
JERSEY CENTRAL POWER AND LIGHT COMPANY
PENNSYLVANIA ELECTRIC COMPANY
GPU NUCLEAR CORPORATION

THREE MILE ISLAND NUCLEAR STATION, UNIT NO. 1

DOCKET NO. 50-289

1.0 Introduction

In late November 1981, while increasing reactor coolant system (RCS) pressure to 45 psid for equipment testing, primary to secondary system leakage was detected. The system was then depressurized and partially drained to conduct steam generator leakage tests. In early December 1981, approximately 130 steam generator (SG) tubes were determined to be leaking and non-destructive examination of the once through steam generator (OTSG) tubes was commenced using eddy current testing (ECT) techniques. The initial ECT examination indicated that there were thousands of potentially defective tubes. As a result, GPU Nuclear established an internal task force to investigate the mechanism and cause of the tube failures, the extent of the problem and acceptable methods of repair. Subsequently, as a result of metallographic examination of portions of removed tubes, it was confirmed that the cause of the tube failures was intergranular attack (IGA) initiated from the primary side (ID) of the tubes resulting in the formation of stress assisted intergranular cracks. The active chemical impurity causing the corrosion was sulfur in reduced forms. Initial ECT results indicated approximately 8-10,000 tubes contained defects with the vast majority (approximately 95%) of the defects occurring within the top

2-3 inches of the 24 inch upper tubesheet (UTS). Subsequent ECT using special probes and techniques has verified that many more defects exist at the very top of the tube (top 1/2 inch).

To repair the SG tubes which have defects within the UTS, the licensee has decided to perform an explosive expansion repair technique which will expand and tightly seal the tubes within the tubesheet, thereby establishing a new leak limiting/load carrying seal. After determining that many more tubes (from the 8-10,000 tubes originally thought to be defective) had defects at the very top of the tube, the licensee has decided to apply the explosive expansion repair technique to all tubes within the UTS.

The NRC staff has met with the licensee on numerous occasions since the SG problem was first discovered to monitor the various aspects of the licensee's SG recovery program. With respect to the explosive expansion repair procedure, which is the subject of this Safety Evaluation, the staff first learned of the licensee's inent to use a tube expansion repair technique at a meeting on April 7, 1982. By letter dated April 30, 1982, the licensee indicated, among other things that in their opinion, the proposed repairs and subsequent return to service of the SGs can be accomplished under 10 CFR ¶50.59 concluding that the process does not represent an unreviewed safety question. The following evaluation documents the staff review of the licensee's August 20 submittal as modified by the licensee's October 5, 1982 submittal.

The staff and its consultants met with the licensee on June 15 and July 21, 1982 at Parsippany, New Jersey to discuss various aspects of the repair process qualification program which was ongoing at Foster Wheeler and B&W. Meetings were also held June 29 and September 15, 1982 in Bethesda, Maryland to brief the staff on the status of the repair program. On August 5, 1982, the staff and its consultants witnessed the full scale test of the repair process conducted on the B&W OTSG in Mount Vernon, Indiana.

This Safety Evaluation is limited to an evaluation of the acceptability of performing the explosive expansion repair. Prior to the authorizing restart of TMI-1, the staff will provide an additional Safety Evaluation evaluating the overall SG program based on additional information to be provided by the licensee.

2.0 Discussion and Evaluation

2.1 Description of the Repair Method

The as-built OTSG has two twenty-four-inch thick tubesheets, one at the top and one at the bottom. The once through (straight) tubes are nominally fifty-six feet and one half inch long, with fifty-two feet of heat transfer surface between the tubesheets. The remaining four feet and one half inch includes two feet in each tubesheet and one-quarter inch protruding into the primary head at each end of the OTSG. To provide structural integrity and leak tightness, all tubes are hard rolled to a nominal depth of one and one-quarter inches, and seal welded on the primary side of the tubesheet surface. The remainder of the twenty-four inch tubesheet has a nominal twenty-two and three-quarters inch, eight mil radial gap (crevice) between the outer tube surface and the drilled tubesheet hole. The majority of defects within the OTSG have been found in the UTS. The preponderance of defects are located within the top two inches of the UTS with rapidly decreasing numbers of defects down through the depth of the tubesheet.

The repair method utilizes a kinetic (explosive) expansion process to form the tube against the tubesheet (i.e., close the eight mil radial gap). The kinetic expansion process is used to close the eight mil gap and to achieve a leak tight, load carrying joint. Developmental testing is being conducted to demonstrate that a kinetically expanded six-inch defect free area can provide the necessary leak tightness and load carrying capabilities required for operation. Therefore, all tubes which have defects down to a depth of sixteen inches into the tubesheet can be repaired (16" plus 6" defect free).

The repair technique consists of inserting polyethelene sheath into each tube. The polyethelene sheath contains a prima-cord which, when ignited, forces the polyethlene sheath against the tube and the resultant force expands the tube. The polyethelene sheath and prima-cord assembly is called a candle. The candles are detonated by a blasting cap which is maintained outside the steam generator in a sealed container and ignited electrically by a licensed blaster. All 31,000 tubes will be expanded using either 16" or 22" candles.

2.2 Repair Qualification Program

A qualification program has been implemented by the licensee to demonstrate that the proposed repair technique will not adversely affect the structural integrity of the OTSG's and will provide the required load carrying and leak tightness capabilities. The licensee's qualification program consists of numerous laboratory tests utilizing the kinetic repair process on mock-up assemblies, plus full scale demonstrations in an actual once-through steam generator. Prior to initiation of production repairs, the licensee will conduct a final demonstration in the actual TMI-1 steam generator. Subsequent to the final demonstration, extensive non-destructive examinations, including eddy current testing and profilometry, will be conducted to verify that no unanticipated problems exist with the kinetic expansion process.

The qualification program includes materials properties, surface conditions and geometries which are representative of the actual steam generators. Test results to date have shown no adverse effects on the structural integrity of the OTSG's. Preliminary test results have shown pull out loads approximately 800 to 1500 pounds in excess of the required maximum load carrying capability of 3140 pounds. Preliminary leak tight testing has demonstrated that leakages can be predicted to be a small percentage (less than one hundredth) of the plant Technical Specifications limit of one gallon per minute per steam generator. The staff witnessed some of these preliminary tests. Based on the results to date of the OTSG repair qualification program, we conclude that the proposed repair technique has a reasonable probability of being successful.

2.3 Effects of Repair

During the SG repair operation, the Reactor Coolant System (RCS) will be drained to the level of the upper reactor vessel nozzles to remove the coolant from the SG tubes. Plugs will be installed in the reactor coolant piping to prevent foreign materials from the repair process from entering the reactor coolant system. The reactor core will continue to be cooled and reactor vessel level maintained through the use of the Decay Heat Removal System (DHRS) which consists of redundant pumps (capable of being powered from emergency power supplies) and heat exchangers. The DHRS takes a suction from the reactor outlet piping and pumps the coolant through one of the DHR heat exchangers, where heat is removed by the DHR Closed Cycle Cooling Water System, and back to the reactor vessel injection nozzle. This mode of cooling is frequently employed in PWRs during RCS maintenance and is currently being utilized successfully at TMI-1

Based on the full scale steam generator qualification test, in conjunction with other extensive experience, we do not anticipate any adverse structural effect due to either the explosion or its concurrent shock wave. At TMI-1, the licensee will utilize the kinetic expansion process on up to two hundred tubes per detonation. In other applications, larger numbers have been successfully detonated. In application of the kinetic expansion process to feedwater heater tubes up to five thousand tubes are expanded in one detonation with no adverse structural effects. One steam generator vendor who uses the kinetic expansion process on all nuclear steam generators, typically expands at least three hundred tubes per detonation with no adverse structural effects.

To facilitate cleanup after the repair, the licensee will first coat the steam generator tubes and primary head with an approved non-stick compound such as Immunol.

Based on the above evaluation, we conclude that the proposed kinetic expansion repair technique will not increase the probability of a rapidly propagating failure of the primary pressure boundary, meets the criteria of GDC 14 and, therefore, is acceptable.

2.4 Environmental Considerations

A. ALARA

General Public Utilities (GPU) has committed to perform all steam generator repair work in accordance with ALARA guidelines and all required radiation protection practices. GPU has incorporated the ALARA guidance provided in Regulatory Guide 8.8, Rev. 3, "Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable" into its job planning.

In accordance with the guidelines of Regulatory Guide 8.8, GPU has built a full-scale mock-up of the upper portion of a once-through steam generator (OTSG) for use in training of repair personnel. This mock-up has been used to maximize worker efficiency during the OTSG repair operation. Prior to working in the OTSG, all workers receive three days of radiation protection training and a minimum of one day of training in the OTSG mock-up in a simulated work environment. Extensive use of the OTSG mock-up at TMI-1 has resulted in the discovery of more efficient methods of performing some of the OTSG repair tasks.

GPU will utilize local shielding inside the OTSG to reduce the OTSG dose rates by approximately 25%. Airborne activity will be kept to a minimum by use of a ventilation system drawing air from the upper head through HEPA filters, and exhausting it to the containment. This exhaust air from the work areas will be monitored by continuous air monitors both upstream and downstream of the HEPA filter. A tent erected at the OTSG manway will serve to minimize the spread of contamination. These tents and the steam generator platform areas will be routinely surveyed for contamination. Workers will dress out in protective clothing in a low radiation zone before entering the tent. Once inside the tent the steam generator workers will don supplied air hoods and wet suits before entering the steam generator head area. The air supplied hoods that will be used have been NIOSH/MESA certified. All workers will wear a series of TLD's to record their doses. Following each steam generator jump, a worker's total dose will be updated, based on his current pocket dosimeter reading. In addition, a grab sample will be taken from the steam generator head area prior to each jump. In order to minimize worker time spent in radiation fields, GPU has installed video systems in the steam generator head to remotely locate any inserts which may have misfired after each detonation. Once located using the T.V. scan, these misfires will be manually removed by a steam generator jumper and replaced with new inserts. The remote video systems will also be used to remotely observe worker performance.

In accordance with the guidance of Regulatory Guide 8.8, GPU has performed a person-rem dose estimate for the OTSG repairs. The OTSG repair work was broken down by individual tasks to be performed and the total person-rem dose associated will each of these tasks was estimated. These estimates were based on time and motion studies done in an actual OTSG at B&W's test facility. GPU's person-rem estimate for the entire OTSG repair job is approximately 310 person-rems (370 person-rems if remote cleaning is not possible).[1]

Based on our review of the information provided by the licensee, we conclude that the estimated person-rem dose estimate for the OTSG repair project appears to be reasonable and that GPU intends to implement appropriate occupational ALARA actions. We conclude that GPU has provided reasonable assurance that individual radiation doses will be maintained within the limits of 10 CFR Part 20. GPU's dose assessment for the OTSG job was performed in accordance with the guidelines of Regulatory Guide 8.8, and the total person-rem estimate is acceptable. Based on the above, the staff finds the proposed occupational dose control aspects of the proposed OTSG repair project to be acceptable.

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[1] Licensee's initial person rem estimate as reported in the August 20, 1982 evaluation was 268 person-rems (327 person-rems if remote cleaning is not possible). At a meeting on September 15, 1982, we were advised that the licensee's estimates should be modified by approximately 50 man rem to account for actions involved with precoating and cleanup. Hence, the estimates have been revised as shown.

B. Safe Handling of Explosives Onsite

The major difference between this prcposed repair metnod and other steam generator repair procedures is the fact that explosives are involved. Even one acceptable method of repairing steam generator tubes, explosive plugging, involves the use of explosives, but in **lesser** quantities than the explosives associated with this kinetic expansion process.

The explosives used in this repair technique have a long history of reliable, safe use. Explosives are used in the boosters, prima cord inserts, the ordance transfer cord which connects the booster to the detenator, and the blasting caps which are used to detonate the insert assembly. The explosives used with the insert, booster and transfer cord are low level, very stable and not subject to sympathetic detonations. The blasting caps are separated from the insert assemblies until needed for use.

The licensee's program is based upon careful procedures for safe handling of explosives, including protection of employees from detonation noise hazards. The procedures to be followed when receiving, storing, transporting, and detonating the inserts for the TMI-1 steam generator repair will comply with Commonwealth of Pennsylvania Title 25, Rules and Regulations, Part 1. Department of Environmental Resources, Subpart D. Environmental Health and Safety Article IV. Occupational Health and Safety, Chapter 210. Use of Explosives and Chapter 211. Storage Handling, and Use of Explosives, as implemented and modified by the formal Blast Plan approved by the Commonwealth of Pennsylvania.

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All explosives will be detonated by a licensed blaster in accordance with the above regulations as modified by the Blast Plan. Each blaster will bring with him into containment at the start of each shift, only the number of detonators required for that shift. The amount of candle insert assemblies stored in containment will be minimized by procedures. All other explosives will be stored in two Pennsylvania State approved magazines outside containment in areas away from decay heat removal systems.

3.0 CONCLUSIONS

Based on the above evaluation, we conclude that the proposed kinetic repair process:

1. Does not degrade the capabilities for core decay heat removal as required by the plant Technical Specifications,
2. Meets the criteria of GDC-14 by not increasing the probability for a rapidly propagating failure of the primary pressure boundary,
3. Incorporates the ALARA guidelines of Regulatory Guide 8.8 and provides reasonable assurances that individual radiation dose limits will be maintained within a small fraction of the limits of 10 CFR 20, and
4. Based on qualification programs results to date, has a reasonable probability of returning the OTSG's to an operable condition.
5. Adequate controls to ensure the safe use of explosives have been implemented.

We find that the proposed repair process does not involve an unreviewed safety question or a modification to the Technical Specifications and hence, may be conducted without NRC approval.