Enclosure

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

PRESSURIZER HEATER SLEEVES, ROLL REPAIR PROPOSAL

BALTIMORE GAS AND ELECTRIC COMPANY

CALVERT CLIFFS NUCLEAR POWER PLANT, UNIT NOS. 1 AND 2

DOCKET NOS.: 50-317 & 50-318

1.0 BACKGROUND

By letter dated November 1, 1993, Baltimore Gas and Electric Company (BG&E), the licensee, proposed an alternative to the repair requirements of the American Society of Mechanical Engineers (ASME) Code under the provisions of 10 CFR 50.55a(a)(3)(i). The licensee proposed to perform roll repairs of leaking pressurizer heater sleeves and instrument nozzles. This was proposed as an alternative to the flaw removal requirements and weld repair methods of the ASME Code. The licensee contended that the method would restore the structural integrity and operability of leaking heater penetrations or instrument nozzles.

The subject components are ASME Code Class 1, unisolable primary pressure boundary parts. They were made from alloy 600 tubing or pipe, furnace annealed prior to shop fabrication. No post welding/post fabrication heat treatment was applied. They provide a corrosion barrier between the borated reactor coolant and the structural carbon-manganese steel of the pressurizer vessel at the heater or instrument penetrations.

Alloy 600 in a pressurized water reactor (PWR) pressurizer environment is susceptible to intergranular stress corrosion cracking (IGSCC). One of the major causes of cracking is the residual stress of welding or cold work. Failures (leaks) of pressurizer sleeves or nozzles are typically the result of short, longitudinal through-wall cracks in the tube at the tube to cladding weld on the inside of the pressurizer. The crack provides a leak path to the outside by way of the annulus between the tube and the bore hole in the vessel.

The licensee's proposed repair method purports to restore a leaking tube to operable condition by providing an alternate means for insuring leak tightness and structural integrity. This would be accomplished by performing a roll expansion of a leaking tube in conjunction with the insertion of an Inconel 690 tube inside the alloy 600 tube. Such a repair would eliminate the need for the weld on the inside of the pressurizer by making the tube penetration a rolled joint. Addition of the Inconel 690 insert would provide some isolation of the rolled portion of the alloy 600 tube from the borated reactor coolant environment. The original tube and weld, along with any flaws, would remain in place.

The licensee contends that performance of such a repair would benefit as low-as-reasonably achievable (ALARA) concerns by eliminating the time consuming steps involved in removal of a leaking alloy 600 tube and associated weld and replacing them with IGSCC resistant materials.

Additionally, the licensee also requests that special leakage rate criteria be allowed for roll repaired penetrations. This allowable leakage rate criteria was based upon the premise that a leaking rolled joint does not constitute a structural failure or Code pressure boundary failure. Instead, it would be treated in a manner similar to a gasket or packing leak.

In conjunction with this proposal, the licensee requests lead plant status for this alternative repair method.

2.0 EVALUATION OF ALTERNATIVE REPAIR METHOD

The essence of the licensee's proposal is the substitution of a rolled joint for a welded joint. The rolled joint is intended to provide a seal against further leakage through the original alloy 600 stub tube and maintain structural integrity in the event of a postulated failure of the alloy 600 tube to cladding weld. Thus, central to evaluating this proposal is the experience of rolled joints in related service.

2.1 Operational Experience With Rolled Joints

The licensee's submittal references several applications of rolled joints as demonstrating the validity of the proposed alternative. The staff has reviewed the referenced applications along with several others and finds the overall history of rolled joints in high pressure service is problematic.

The referenced applications principally involve roll repairs at boiling water reactor (BWR) control rod drive (CRD) penetrations at Nine Mile Point Unit No. 1. Here, a roll repair was employed to mitigate leakage through BWR "J" tubes at the "J" tube to CRD housing weld. A "J" tube is a short length of pipe inside the reactor which forms an extension of the bore hole through the reactor head. It sits on and is welded to the cladding on the inside of the vessel, but does not extend down through the bore hole. The CRD is, in turn, inserted through the bore hole and "J" tube. The CRD housing is welded to the free end of the "J" tube inside the reactor. Leaks in the stainless steel "J" tubes were caused by furnace and weld induced sensitization and subsequent IGSCC. The tube would fail (leak) by way of circumferential cracks in the weld heat affected zone (HAZ) of the "J" tube to CRD weld. Leakage was sealed off by rolling the CRD housing into the vessel bore hole.

Several significant differences between the licensee's proposal and the BWR applications exist. The most important one is the fact that the repairs at the BWRs are not required to resist the forces of the pressure loading which would cause ejection of the CRD. Such restraint is provided by two means. First, the geometry is such that a full circumferential crack leaves the "J" tube to CRD weld attached to the CRD. This acts as a restraining collar preventing ejection of the CRD. Secondly, a BWR has an external frame upon which the CRD's are mounted, the so called "anti-shoot-out steel," which is designed to fully resist the ejection forces on the CRD. Thus, in the event of a complete failure of the rolled joint, the "J" tube to CRD weld and the "anti-shoot-out steel" both restrain the CRD. Consequently, the roll is only required to provide a seal against leakage. It is not required to provide restraint against CRD ejection. This substantially reduces the structural demands upon the rolled joint.

Another significant difference between the BWR application and the proposed one is in the disparate effect of cold work on alloy 600. Stainless steel was used for the BWR CRD tubes. Unlike the "J" tubes, it was not furnace sensitized. Unsensitized, cold worked stainless steel is not highly susceptible to IGSCC in a BWR environment. This is entirely different from the effect of cold work on alloy 600. Cold work is one of the most serious contributors to IGSCC in alloy 600.

This difference in material behavior when cold worked has a significant effect on postulated failure modes of rolled joints. For the BWR stainless steel case, there is no envisioned, or to date, actual cracking at the roll transition step. This means there is no significant concern about the rolled joint separating at the roll step and consequently being separated from the supporting fillet weld between the "J" tube and the CRD.

In the case of the licensee's proposal, the existing pressurizer sleeve/nozzle is alloy 600. For this material, PWR steam generator (SG) experience has demonstrated the roll transition area to be highly susceptible to circumferential cracks. Thus, for the alloy 600 case, separation of the rolled area from the sleeve to cladding weld can be expected to occur. The weld would no longer restrain the longitudinal pressure loading and thus the rolled joint must resist those forces.

Although the licensee provided tube pull-out test results demonstrating the capability of the rolled joint to withstand several times the design load, the staff notes that several significant unknowns exist. Among them are:

1. uncertainties of the effect of the differential coefficients of expansion between the tube materials and the pressurizer material. The long-term effects, if any, are not quantified.

2. uncertainties of variations in bore hole dimensions and degree of corrosion on the load carrying ability of a rolled joint. The staff notes that tube pull-out tests are conducted with good joint cleanliness to ensure leak tightness and maximum strength. The effect of the inevitable presence of corrosion products in the actual application (as opposed to the laboratory samples referenced in the submittal) on the ultimate strength of a rolled joint are unknown.

An anti-ejection measure is included in the licensee's proposal, in the event of a failure of the rolled area to resist the push-out forces. This consists of an extension of the Inconel 690 sleeve in beyond the penetration tube to cladding weld. This free end of the Inconel 690 tube would be rolled to form a bell type of flare at the tube end with a large enough diameter to prevent passage (ejection) through the alloy 600 tube. No demonstration tests were referenced by the licensee to verify the concept. Because of possible uncertainties in the location of the end of the alloy 600 tube with respect to the inside of the pressurizer, some clearance is desired between the bell expansion roll area and the end of the alloy 600 tube. This creates the likelihood that the expanded area of the Inconel 690, which is highly work hardened, would be subject to significant dynamic (high strain rate) loads during an ejection incident. It is not clear whether the material could withstand such a loading.

Due to the substantial differences between the licensee-referenced BWR applications and the licensee proposal, the staff sought to review a more closely related application of rolled joints. A more similar one exists in the use of Inconel 690 tube plugs rolled into SG tubes (note: the details of the plug designs and rolling methods are vendor proprietary). The methods employ an Inconel 690 plug inserted into the alloy 600 SG tube. The plug is rolled to provide a leak tight seal. This design/material combination was first used in 1991.

Some problems have been experienced in this application. Some of the rolled plugs have failed by either developing leaks or falling out. Control of the rolling process is the primary reason for the failures. This difficulty is not restricted to a single unit or vendor.

A contributing factor in the failure of a few of the failed plugs was surface roughness in the roll area. Irregularities in the alloy 600 tube, resulting from previous plug removal operations, created poor contact and leakage past newly installed Inconel 690 plugs. There would presumably be no such surface roughness between the Inconel 690 plugs and the alloy 600 tube of the proposed application. However, this problem reinforces the NRC staff's concern regarding cleanliness and roughness in the vessel bore and the consequent effect on the integrity of the alloy 600 to bore hole roll region.

An additional materials concern involves the performance of Inconel 690 in a deeply creviced joint exposed to the borated primary water, such as would result if the proposal were employed. The NRC staff finds that laboratory and operational experience strongly indicate the superiority, but not immunity, of Inconel 690 in resisting IGSCC. However, the NRC staff finds no experimental evidence or operational experience with this material in deeply creviced, cold worked, borated primary water situations. The NRC staff is aware that deeply creviced geometries have made the difference between the onset of cracking or not in some alloy 600 applications.

2.2 <u>Request for Relief From Technical Specification Limits Regarding Leakage</u>

Included in the licensee's submittal was proposed leakage criteria for the rolled joints. The proposed leakage limits were predicated upon the argument that the rolled joint did not constitute a structural boundary and, therefore, was exempt from the Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 and 2, Technical Specifications prohibiting pressure boundary leakage. Based upon the fact that the rolled joint would be required to perform a structural function with respect to preventing ejection of the penetration tube, the staff finds that the rolled joint is a pressure boundary and not just a leak seal such as a gasket.

3.0 CONCLUSION

In accordance with the requirements of 10 CFR 50.55a(a)(3)(i), the NRC staff has determined that the proposed alternative, a roll/plug type of repair, would not provide an acceptable level of quality and safety to that of flaw removal and weld repair specified in the ASME Code. Therefore, the requested alternative is denied. This determination is based on the following:

Industry experience with similar rolled joints has been unsatisfactory from both a leakage and structural integrity standpoint. Employment of such methods has been limited to special cases where alternate load paths are in place for maintaining the structural integrity, or, in the case of SG tubes, leakage is between the primary and secondary side of a pressure vessel, and not external to the vessel.

The evolving experience with rolled Inconel 690 SG tube plugs demonstrates that such measures have inadequate reliability. Clearly, the numerous variables involved in the execution of a rolled joint have not yet been adequately addressed by industry, nor the licensee's submittal. Additionally, industry experience has amply demonstrated that no rolled joint is reliably leak tight or structurally sound on a long-term basis. To the contrary, such joints have proven to be among the most problematic in the industry, regardless of where they have been used.

Additionally, the staff is unable to find current uses of rolled joints in high pressure systems wherein the rolled joint provides the pressure boundary between the vessel and the outside.

The staff further finds the licensee's argument that the proposed rolled joint would not perform a pressure boundary function to be invalid. Employing the conservative assumption of an eventual separation of the rolled portion of the alloy 600 tube from the tube to cladding weld would leave the rolled portion as the sole load bearing member providing resistance against heater sleeve or nozzle ejection. For that reason leakage through the rolled joint would constitute pressure boundary leakage, and violate the unit technical specifications. The staff finds no compelling reason to relax such requirements.

With respect to the argument for permitting leakage through the rolled joint, the staff finds the justification to be invalid. Although such technical specification leakage is permitted, within limits, at certain old BWR units, the staff finds no compelling reason to entertain a relaxation of the rules governing structural integrity and radiological release.

The staff observes that it is not apparent this method of constructing a pressure boundary would be favorably viewed unless extensive evaluation and demonstration testing were performed by an appropriate institution.

Principal Contributor:
G. Hornseth

Date: March 7, 1994

not provide an acceptable level of quality and safety, therefore, the request is denied. The basis for this determination is provided in the enclosed SE.

This completes our action related to the referenced TAC numbers.

Sincerely,

Original signed by:

Robert A. Capra, Director
Project Directorate I-1
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

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Safety Evaluation

cc w/enclosure:
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