November 7, 2001

Mr. Mark E. Warner
Vice President - TMI Unit 1
AmerGen Energy Company, LLC
P.O. Box 480
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SUBJECT: THREE MILE ISLAND NUCLEAR STATION, UNIT 1 (TMI-1) - SAFETY EVALUATION FOR THE THIRD 10-YEAR ISI INTERVAL REQUEST FOR RELIEF NOS. RR 01-14 THROUGH RR 01-17 (TAC NO. MB2323)

Dear Mr. Warner:

By your application dated September 12, 2001, AmerGen Energy Company, LLC (the licensee) submitted inservice inspection Relief Requests 01-14, 01-15, 01-16, and 01-17 for TMI-1. The Nuclear Regulatory Commission (NRC) staff has evaluated the four relief requests and found them to be acceptable. Thus, the licensee's proposed alternatives in Relief Requests 01-14 and 01-16 are authorized pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.55a(a)(3)(i) on the basis that they would provide an acceptable level of quality and safety. The licensee's proposed alternatives in Relief Requests 01-15 and 01-17 are authorized pursuant to 10 CFR 50.55a(a)(3)(ii) because compliance with the specified requirements would result in hardship and unusual difficulty respectively without a compensating increase in the level of quality and safety.

Your September 12, 2001, application also requested that the enclosed relief requests be withheld from public disclosure pursuant to 10 CFR 2.790. It also should be noted that this application supercedes, in its entirety, previous applications dated August 9, 2001, and July 2, 2001, which address the same subject. In a letter to you dated October 15, 2001, the NRC concluded that the submitted information sought to be withheld by the licensee contains proprietary commercial information and should be withheld from public disclosure. A nonproprietary copy of this document has been placed in the NRC's Public Document Room and added to the Agencywide Documents Access and Management System's Publicly Available Records System (ADAMS PARS) Library.

Because TMI-1 is currently in a refueling outage, and immediate implementation of these relief requests was necessary to prepare for possible weld repairs which can only be conducted during a refueling outage, verbal approval of the four relief requests alternatives was authorized on Friday, October 12, 2001, at 3:30 p.m. Delays in granting approval would have resulted in delays in critical path efforts which would have delayed reactor startup. The information contained in the enclosed safety evaluation is consistent with the verbal approval.

Details of the NRC staff's evaluation and the applicable durations of these alternatives and reliefs are delineated in the enclosed safety evaluation.

Sincerely,

/RA/

L. Raghavan, Acting Chief, Section 1
Project Directorate I
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-289

Enclosure: Safety Evaluation

cc w/encl: See next page

Details of the NRC staff's evaluation and the applicable durations of these alternatives and reliefs are delineated in the enclosed safety evaluation.

Sincerely,

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cc w/encl: See next page

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Three Mile Island Nuclear Station, Unit No. 1

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO INSERVICE INSPECTION RELIEF REQUESTS

NUMBERS 01-14, 01-15, 01-16, AND 01-17

AMERGEN ENERGY COMPANY, LLC

THREE MILE ISLAND NUCLEAR STATION, UNIT 1 (TMI-1)

DOCKET NO. 50-289

1.0 INTRODUCTION

The inservice inspection (ISI) of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) Class 1, Class 2, and Class 3 components is to be performed in accordance with Section XI of the ASME Code and applicable edition and addenda as required by Title 10 of the *Code of Federal Regulations (10* CFR), Section 50.55a(g), except where specific relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). The regulations in 10 CFR 50.55a(a)(3) state, in part, that alternatives to the requirements of paragraph (g) may be used, when authorized by the NRC, if the licensee demonstrates that: (i) the proposed alternatives would provide an acceptable level of quality and safety, or (ii) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Pursuant to 10 CFR 50.55a(g)(4), ASME Code Class 1, 2, and 3 components (including supports) will meet the requirements, except the design and access provisions and the preservice examination requirements, set forth in the ASME Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," to the extent practical within the limitations of design, geometry, and materials of construction of the components. The regulations require that inservice examination of components and system pressure tests conducted during the first 10-year interval and subsequent intervals comply with the requirements in the latest edition and addenda of Section XI of the ASME Code incorporated by reference in 10 CFR 50.55a(b) twelve months prior to the start of the 120-month interval, subject to the limitations and modifications listed therein. The ISI Code of record for TMI-1 is the 1995 Edition with the 1996 Addenda of Section XI of the ASME Boiler and Pressure Vessel Code. The third 10-year interval for TMI-1 began April 20, 2001.

By letter dated September 12, 2001, AmerGen Energy Company, LLC, the licensee, requested relief from certain ultrasonic testing (UT) requirements pertaining to weld material, nondestructive examination (NDE) coverage, minimum time before initiating NDE, and interpass weld temperature requirements related to reactor pressure vessel (RPV) head penetration repairs for the third 10-year ISI interval at TMI-1. Specifically, the licensee requested relief to use Alloy 690 (Unified Numbering System N06052 and W86152) weld material, to reduce the NDE coverage for the repaired and surrounding area, to reduce the hold time before starting NDE, and to reduce monitoring interpass weld temperatures. The licensee's letter dated September 12, 2001, superceded its letter dated August 9, 2001, which had superceded its letter dated July 2, 2001.

2.0 <u>EVALUATION</u>

2.1 General Repair Process

The Alloy 600 partial penetration (J-Groove) welds used to attach Control Rod Drive Mechanisms (CRDMs) to the reactor pressure vessel (RPV) head as well as CRDM nozzles have been shown to be susceptible to failure by primary water stress corrosion cracking (PWSCC). In the event nozzles show evidence of leakage, they will be repaired. For those nozzles requiring repair, the licensee's process is to remove the lower portion of the CRDM nozzle to include the areas containing the crack(s), and then reweld the penetration to the reactor pressure vessel head, thus creating a new pressure boundary weld. Since the welded repair will be conducted in accordance with the ASME Code, Section XI, Construction Code requirements, and the licensee has not requested any reliefs to Code requirements other than those specifically identified in its submittal, the repair process will be subject to all specified Code flaw evaluation and post-repair nondestructive examination requirements.

Because the repaired configuration results in a portion of the RPV head being exposed to reactor coolant, the licensee evaluated the effects of corrosion on the structural integrity of the RPV head during operating and shutdown conditions. The licensee's evaluation indicated that the effects of corrosion would have negligible impact on the structural integrity of the RPV head for the remainder of the term of its current operating license. The Nuclear Regulatory Commission (NRC) staff has reviewed the licensee's evaluation and has determined that the results are appropriate, and therefore, are acceptable.

The licensee has also performed a fracture mechanics analysis for the as-left J-groove weld, to demonstrate that even if flaws were not removed from the J-groove weld, crack growth resulting from operational and accident conditions would not propagate to a size that would affect the integrity of the RPV head for the remainder of the term of its current operating license. For those instances where a postulated flaw would exceed the criteria allowed by ASME Code, a portion of the weld would be removed to ensure that ASME Code requirements would not be exceeded. Based on the results of the licensee's evaluation, the NRC staff find this acceptable. Furthermore, IWB-3132 requires that areas containing flaws of components which are accepted by repair or by analytical evaluation must be subsequently reexamined in accordance with IWB-2420(b) and (c), "Successive Examinations," to ensure that cracks which are allowed to remain in service continue to remain within the limits permitted by the ASME Code. The licensee did not request relief from these portions of the ASME Code; therefore, the licensee's performance of successive examination of those areas in which flaws are left in place, is acceptable.

2.2 RR 01-14, Use of Alloy 690 Weld Filler Material

The applicable components affected by RR 01-14 are the CRDM nozzles and thermocouple nozzles on the RPV head.

2.2.1 ASME Code Requirements for Which Relief is Requested

The ASME Code for the repairs to thermocouple (TC) nozzles and CRDM nozzles is the ASME Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1995 Edition through 1996 Addenda.

ASME Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1995 Edition through 1996 Addenda allows, by reference, the use of Alloy 600 based weld filler material (Alloy 82/182) but does not include the use of Alloy 690 (Alloy 52/152) based weld filler material.

2.2.2 Licensee’s Proposed Alternative to the ASME Code (as stated)

> In lieu of the [ASME] Code requirement, the use of Alloy 690 weld filler material is proposed for the repair of all TC nozzles and CRDM nozzles located on the TMI-1 Reactor Vessel (RV) head.
>
> Pursuant to 10 CFR 50.55a(a)(3)(i), an alternative is requested on the basis that the proposed alternative provides an acceptable level of quality and safety.
>
> ASME Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1995 Edition through 1996 Addenda allows, by reference, the use of Alloy 600 based weld filler material (Alloy 82/182) but does not include the use of Alloy 690 (Alloy 52/152) based weld filler material (Alloy 52/152).
>
> [ASME] Code Cases 2142-1 and 2143-1 introduce and classify new nickel based weld metals that closely match Alloy 690. [ASME] Code Case 2142-1 establishes welding classifications and other requirements for bare wire filler metal (UNS N06052 Ni-Cr-Fe). [ASME] Code Case 2143-1 establishes welding classifications and other requirements for a coated electrode (UNS W86152 Ni-Cr-Fe). These two [ASME] Code Cases have not been incorporated by reference into the regulations; therefore, their use requires NRC approval.

2.2.3 Licensee’s Bases for Requesting Relief

Alloy 690 material has been shown to be superior to Alloy 600 material in resisting primary water stress corrosion cracking (PWSCC). The NRC approved the use of Alloy 690 material in the construction of the replacement steam generators to be installed at Oconee Nuclear Station, Units 1, 2, and 3, McGuire Nuclear Station, Units I and 2, and Catawba Nuclear Station, Unit 1. The NRC also approved requests for use of Alloy 690 material in the repairs of the Oconee Unit I thermocouple and CRDM nozzles, and the Unit 3 CRDM nozzles. At TMI-1, Alloy 690 has been approved for use as steam generator plugs and sleeves.

ASME Code Cases 2142-1 and 2143-1 establish the chemical and material properties and the classification of the weld material with respect to its welding characteristics. ASME Code Case 2142-1 establishes the F-No. for the American Welding Society (AWS) specification AWS A5.14 and Unified Numbering System (UNS) designation UNS N06052 (Alloy 52) as F-No. 43 for both procedure and performance qualification purposes. ASME Code Case 2143-1 establishes the F-No. for AWS A5.11 and UNS designation W86152 (Alloy 152) for a coated electrode as F-No. 43 for procedure and performance qualification purposes. These specifications and F-No. assignments completely describe this material for welding purposes as similar in their welding characteristics to other ASME Code approved nickel-based weld metals.

In conclusion, the use of Alloy 690 welding filler material (Alloy 52/152) and the associated ASME Code Cases 2142-1 and 2143-1 for the repairs to TMI-1 TC and CRDM nozzles will provide superior corrosion protection over that provided by Alloy 600 (Alloy 82/182) material. The use of Alloy 690 has been previously authorized for new construction and other repair activities. Therefore, the proposed alternative provides an acceptable level of quality and safety.

2.2.4 Evaluation

Alloy 600 type weld metals (Alloy 82/182) were widely used during the construction of nuclear power plants. Operating experience showed that Alloy 182 was susceptible to intergranular stress corrosion cracking (IGSCC), although primarily in boiling water reactor (BWR) environments. Recently, the cracking of Alloy 82/182 in primary water environment has been reported in a number of pressurized water reactors (PWR). In anticipation of repairs to weld and base metal cracks which may be discovered on the CRDM nozzles at TMI-1 during its next outage, the licensee had proposed a repair of the potential cracks in the CRDM nozzles. To ensure the integrity of the new welds, the licensee proposes the use of alternative materials of Alloy 52/152 materials for the fabrication of the new welds. Laboratory test data have shown that Alloy 52/152 materials are resistant to stress corrosion cracking in simulated PWR and BWR environments. The NRC staff has approved the use of Alloy 52/152 in the replacement of steam generators and the repair of thermocouple and CRDM nozzles for a number of PWRs. Therefore, the proposal to use Inconel 52/152 filler materials in the repair of the affected CRDM nozzles is acceptable, as it will provide an acceptable level of quality and safety.

The purpose of a weld metal ASME Code case is the establishment of uniform chemical and material properties, and the classification of the weld metal with respect to its welding characteristics. This classification of welding characteristics is known as an “F-No.” Weld metals with like characteristics are grouped together for welding and welder qualification purposes in order to eliminate unnecessary duplication.

ASME Code Case 2142-1 lists AWS specification AWS A5.14 and UNS designation UNS N06052 as conforming to Inco 52 (Alloy 52). It establishes the F-No. of this weld metal as F-No. 43 for both procedure and performance qualification purposes. ASME Code Case 2143-1 lists appropriate AWS and UNS specifications for a coated electrode matching Inco 152 (Alloy 152) and establishes F-No. 43 for this material for welding purposes. By this set of specifications and F-No. assignments, these materials are completely described for welding purposes as similar in their welding characteristics to many other ASME Code nickel-based weld metals. Thus, these two weld metals (Alloy 52/152) are exempted from the requirements for specific procedure and performance qualifications for non-ASME Code materials.

The NRC staff finds that these two ASME Code cases appropriately specify and classify the necessary weld metal parameters, and are acceptable for use. The NRC staff has approved the use of these two ASME Code cases in the replacement of steam generators and the repair of thermocouple and CRDM nozzles for a number of PWRs.

2.2.5 Conclusion

Based on the above evaluation, the NRC staff concludes that the proposed alternative to use Alloy 690 welding filler materials (Alloy 52/152) and associated ASME Code Cases 2142-1 and 2143-1 for the fabrication of the repair welds at the affected CRDM nozzles will provide an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the NRC staff authorizes the proposed alternative for TMI-1, for the third 10-year ISI interval.

2.3 RR 01-15, Reduce 5-Inch NDE Band Surrounding the Repaired Area

The components affected by RR 01-15 are the CRD nozzle-to-RPV and thermocouple nozzle-to-RPV head penetration welds.

2.3.1 ASME Code Requirements for Which Relief is Requested

The ASME Code requirement for the repairs is the ASME Code, "Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components," 1995 Edition through 1996 Addenda.

Paragraph IWA-4634 states that "The weld as well as the preheated band shall be examined by the liquid penetrant method after the completed weld has been at ambient temperature for at least 48 hours. The weld shall be volumetrically examined."

Paragraph IWA-4610(a) states that "The area to be welded plus a band around the area of a least 1-1/2 times the component thickness or 5 in., whichever is less, shall be preheated and maintained at a minimum temperature of 350 degrees F for the (shielded metal arc welding) SMAW process and 300 degrees F for the (gas tungsten arc welding) GTAW process during welding." The 5-inch requirement is applicable for these components.

2.3.2 Licensee's Proposed Alternative to the ASME Code (as stated)

> "Pursuant to 10 CFR 50.55a(a)(3)(ii), Compliance [sic] with the requirements of IWA-4634 and IWA-4610(a) of ASME Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1995 Edition through 1996 Addenda would result in hardship and unusual difficulty without a compensating increase in the level of quality and safety. Due to the unique geometry of the CRDM inside Reactor Vessel (RV) head repair, it is not practical to volumetrically examine, as required by IWA-4634, the 5 inch band around the weld area as defined by IWA-4610(a). The repairs to the CRDM nozzles involve severing the existing J-groove partial penetration weld from the CRDM nozzles, removal of the lower portion of the nozzle and relocating the pressure boundary attachment weld up into the bore of the RV head. Post-repair inspections of the repaired areas will be done by a combination of remote and manual methods. In lieu of inspecting the [ASME] Code required band area, the proposed alternative is that the repair area be inspected by UT and penetrant testing (PT).
>
> The UT coverage volumes are shown in Figures 1 through 6 for the various scans. Approximately 70% of the weld surface will be scanned by UT. Approximately 83% of the closure head ferritic steel HAZ [heat affected zone] will be covered by the UT.

The exposed ferritic steel portion of the CRDM penetration plus the weld preparation bevel on the lower end of the remaining portion of the CRDM nozzle as well as the adjacent portion of the CRDM nozzle ID, ½ inch above the weld preparation, will be liquid penetrant examined prior to welding. This examination provides assurance that no flaws exist on the surface in the bore and remaining portion of the CRDM nozzle in the region to be welded.

The final weld surface and adjacent base material at least ½ inch above the toe of the weld at the nozzle and ½ inch below the toe of the weld (Figure 8) in the ferritic steel closure head base material will be liquid penetrant examined after welding. The liquid penetrant examination below the bottom toe of the weld will cover all the exposed closure head base material weld heat affected zone. Figure 7 shows the PT coverage area prior to welding and Figure 8 shows the PT coverage area subsequent to welding.

The proposed alternative will also utilize remote enhanced video during the welding operation to insure welding quality. The remote inner diameter temper-bead welding system has two built-in camera systems. One camera is set to view the weld puddle from above the one from below. Using filters and camera iris controls, the remote vision systems are used for both molten puddle, "hot" viewing and as-deposited, solidified, "cold" viewing. This provides an excellent means for assuring good quality weld beads have been placed appropriately during and after each weld pass."

2.3.3 Licensee's Bases for Requesting Relief (as stated)

"The configuration of the new pressure boundary welds limits the ability to examine the band area as defined by IWA-4610(a). For the repairs, the GTAW process will be utilized. Due to the thickness of the RV head, the 5-inch minimum is utilized for definition of the band area. The 5-inch band area is not directly applicable to the interior surfaces of the RV head CRDM bores that are to be repaired. It is proposed that in lieu of inspecting the 5 inch band, the surfaces of the new pressure boundary weld receive both the PT and UT inspections.

UT inspections of the RV head base material above the new weld through the nozzle would not be effective due to the interface between the nozzle and RV head low alloy steel. Thus, no UT inspections will be attempted above the new weld. The UT coverage volumes are shown in Figures 1 through 6 for the various scans and the transducers to be used are shown in Table 1 [included in the licensee's September 12, 2001, submittal]. The UT transducers and delivery tooling are capable of scanning from cylindrical surfaces with inside diameters near 2.75 in. The UT equipment is not capable of scanning from the face of the taper. Approximately 70% of the weld surface will be scanned by UT. Approximately 83% of the closure head ferritic steel HAZ will be covered by the UT.

The effectiveness of the UT techniques to detect and characterize flaws in the inner diameter temper-bead (IDTB) repair weld have been qualified by demonstration on a mockup of the IDTB involving the same materials used for repair. Notches were machined into the mockup of the IDTB involving the same materials used for repair. Notches were machined into the mockup with depths of 0.10", 0.15", and 0.25" in order to quantify the ability to characterize the depth of flaw penetration through the nozzle well and weld thickness. The depth characterization is done using tip diffraction UT techniques that have the ability to measure the depth of a reflector relative to the nozzle bore. Each of the notches in the mockup could be measured using the 45-degree transducer. During the examination, longitudinal wave angle beams of 45 degrees and 70 degrees are used. These beams are directed along the nozzle axis looking up and down. The downward looking beams are effective at detecting flaws in the weld root area because of the impedance change at the ferritic low alloy steel head, Alloy 600 CRDM nozzle and the Alloy 52 weld. The 45-degree transducer is effective at depth characterization by measuring the time interval to the tip of the reflector relative to the transducer contact surface. The 70-degree longitudinal wave provides additional qualitative data to support information obtained with the 45-degree transducer. Together, these transducers provide good characterization of detected flaws. These techniques are routinely used for examination of austenitic welds in the nuclear industry for flaw detection and sizing. In addition to the 45 and 70-degree beam angles described above, the weld is also examined in the circumferential direction using 45-degree longitudinal waves in both the clockwise and counterclockwise directions to look for transverse flaws. A 0-degree transducer is also used to look radially outward to examine the weld and adjacent material for evidence of under bead cracking in the low alloy steel weld HAZ. Detection of flaws has also been demonstrated on mockups fabricated during the welding qualification activities.

Due to the unique geometry of the CRDM penetration modification, it is not practical to perform a surface examination of the band area. Space restrictions and the final configuration do not allow liquid penetrant examination of the ferritic steel 5 inch band.

The exposed ferritic steel portion of the CRDM penetration plus the weld preparation bevel on the lower end of the remaining portion of the CRDM nozzle as well as the adjacent portion of the CRDM nozzle ID, ½ inch above the weld preparation, will be liquid penetrant examined prior to welding. This examination provides assurance that no flaws exist on the surface in the bore and remaining portion of the CRDM nozzle in the region to be welded.

The final weld surface and adjacent base material at least ½ inch above the toe of the weld at the nozzle and ½ inch below the toe of the weld (Figure 8) [included in the licensee's September 12, 2001, submittal] in the ferritic steel closure head base material will be liquid penetrant examined after welding. The liquid penetrant examination below the bottom toe of the weld will cover all the exposed closure head base material weld heat affected zone. This examination provides assurance that no flaws exist on the surfaces in the bore and remaining portion of the CRDM nozzle in the region affected by welding as well as the weld. Figure 7 [included in the licensee's September 12, 2001, submittal] show the PT coverage area prior to welding and Figure 8 shows the PT coverage area subsequent to welding.

The requirement for the band NDE is specified to assure all unacceptable flaws in the area of the repair have been removed or addressed, since these flaws may be associated with the original flaw and may have been overlooked. The original rules were written within the context of repairing a detected flaw in base metal. As such, there was a concern for other existing flaws in the immediate area. Another purpose of the examination is to detect unacceptable flaws that may be revealed as a result of the repair. This examination extent is consistent with the [ASME Code} Construction Code requirements.

Remote enhanced video will be used during the welding operation to insure welding quality. The remote inner diameter temper-bead welding system has two built-in camera systems. One camera is set to view the weld puddle from above and one from below. Using filters and camera iris controls, the remote vision systems are used for both molten puddle, “hot” viewing and as deposited, solidified, “cold” viewing. This provides an excellent means for assuring good quality weld beads have been placed appropriately during and after each weld pass. The combination of the UT and PT examinations on the weld surfaces and weld procedure qualification will provide an acceptable level of quality and safety.

Compliance with the post-repair examination areas to the requirements of IWA-4634 of ASME Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1995 Edition through 1996 Addenda presents a hardship due to the unique geometry of the CRDM nozzle to RV head interface in the bore region.”

2.3.4 Evaluation

The licensee identified cracking in CRDM nozzle-to-RPV head welds. The CRDM is press-fitted through a penetration in the RPV head and secured with a J-groove weld on the inside surface (water side of the RPV head). The licensee’s proposed repair is to remove the cracks by machining away the CRDM nozzle to a location above the affected area. After verifying with a PT examination that the cracks in the CRDM and welding area are removed, the licensee uses a specially designed pressure boundary, structural weld to reestablish the pressure boundary between the CRDM nozzle and RPV head. The weld configuration is not addressed by the ASME Code. For analysis purposes, the weld meets the structural requirements of a partial penetration weld, and for integrity purposes, the weld is surface and volumetrically examined. The weld, HAZ, and limited preheat areas are nondestructively examined using UT and PT methods.

Paragraph IWA-4636 requires that the weld and preheat area be examined by PT and the weld be examined by UT (volumetric). Paragraph IWA-4610(a) identifies the preheat area as 5 inches around the weld. The ASME Code-required PT examinations of the weld and preheat areas are unattainable because of the configuration. As such, the surface of the nozzle, which penetrates into the vessel, and the surface of the vessel mating the nozzle is inaccessible for liquid penetrant testing. In order to perform an ASME Code-required examination, the licensee would have to redesign the configuration and eliminate the press-fit between the CRDM and RPV head which is a hardship without a compensating increase in the level of quality and safety. The licensee proposed an alternative examination area that redefines the CRDM nozzles-to-RPV head weld PT examination area to accommodate the configuration. The redefined area consists of the machined CRDM and vessel surfaces, the inside diameter of the CRDM prior to welding, and the welded surface plus 0.5 inch extending away from the weld on the accessible surfaces after welding. The portion of the preheat area not examined is furthest away from the weld.

The proposed UT examinations will be performed using 0°, 45°, and 70° refracted longitudinal wave transducers from the inside diameter of the penetration, weld, and CRDM. The 45°and 70° transducers are used in two axial directions to find circumferential flaws and the 45°

transducer is used in two circumferential directions to find axial flaws. The 0° transducer is used to detect laminar flaws such as the lack-of-bond between the weld and original parent material and inter-bead lack-of-fusion. The 45° and 70° transducers are used to detect welding defects such as lack-of-fusion between weld beads and cracks perpendicular with the weld surface and cracks in the HAZ of the base metal. The UT will essentially examine 70 percent of the weld surface and 83 percent of the HAZ in the base metal. Essentially 100 percent of the weld volume and HAZ will be examined for circumferential flaws in one direction.

In addition to using UT to detect subsurface and surface flaws, the licensee will monitor the welding process with two remotely operated, enhanced video cameras. By using filters and iris controls, the operators will perform real time visual examinations of the welding. The cameras are set to view the weld puddle and solidifying deposit. This provides a means for assuring weld bead quality and minimizes welding defects.

Based on the PT, UT, and visual coverage of the weld and portions of the preheat area, the NRC staff believes that any evidence of cracks would be detected, if cracks were present, thereby assuring the integrity of the weldment.

2.3.5 Conclusion

Based on the discussion above, the NRC staff concludes that the proposed alternative PT coverage of the subject CRDM nozzle-to-RPV head weld and preheat area will assure the integrity of the weldment. Therefore, pursuant to 10 CFR 50.55a(a)(3)(ii), the NRC staff authorizes the proposed alternative for TMI-1, for the third 10-year ISI interval.

2.4 RR 01-16, Reduction of 48-Hour Hold Time Before Performing NDE

The components affected by RR 01-16 are the CRDM nozzle-to-RPV and thermocouple nozzle-to-RPV head penetration welds.

2.4.1 ASME Code Requirements for Which Relief is Requested

The ASME Code requirement for the repairs is the ASME Code, "Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components," 1995 Edition through 1996 Addenda.

Paragraph IWA-4634 states that "The weld as well as the preheated band shall be examined by the liquid penetrant method after the completed weld has been at ambient temperature for at least 48 hours. The weld shall be volumetrically examined."

2.4.2 Licensee's Proposed Alternative to the ASME Code (as stated)

> "Pursuant to 10 CFR 50.55a(a)(3)(i), an alternative is requested to the requirements of IWA-4634 of ASME Code, Section XI, Rules of Inservice Inspection of Nuclear Power Plant Components, 1995 Edition through 1996 Addenda on the basis that the proposed alternative provides an acceptable level of quality and safety.
>
> The 48-hour hold is specified to assure that no delayed cold cracking in the ferritic steel Heat Affected Zone (HAZ) has occurred. In lieu of the 48-hour hold time, the proposed alternative will maintain the preheat temperature of 300 degrees F [fahrenheit] during the post-weld soak for four hours in accordance with IWA-4633.2(d) of ASME Code,

Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1995 Edition through 1996 Addenda. The time between the end of the welding operations and the beginning of the UT and PT examination is estimated to be approximately 12 hours with an ambient temperature no greater than 125 degree F. This estimate includes the PSHT [post soak heat treatment] period and the cool-down period.

The weld consumables to be used in the new pressure boundary weld consist of bare wire with no flux. The welding will be performed at 300 degrees F minimum preheat temperature using the GTAW process, as required by IWA-4610(a). The supporting welding PQR's [procedure qualification records] for this work, PQ7109-00 (Reference 3) and PQ7153-00 (Reference 4), are given in Attachment 1 and 2 [of the licensee's September 12, 2001 submittal] respectively.

The Framatome field repairs utilizing temper-bead welding will be performed with procedures that require cleaning and visual inspection of the weld joint and surrounding area for contaminants (hydrocarbons). Framatome weld operating procedures specify shielding gas flow rates, pre-purge and post purge gas shielding requirements. The shielding gas will be procured to a TMI site specification specifying the minimum dew point and gas purity. Shielding curtains will also be erected, when needed, for weld locations that are subject to drafts to prevent a loss of shielding gas during welding.

The combination of the low moisture absorbing GTAW weld process/procedures and maintaining the post-weld soak temperature at 300 degrees F for four hours will eliminate the possibility of hydrogen induced cracking."

2.4.3 Licensee's Bases for Requesting Relief (as stated)

"IWA-4634 of ASME Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1995 edition through 1996 Addenda specifies that the weld region shall undergo volumetric examination after the weld repair area has been at ambient temperature for a minimum of 48 hours. The 48-hour hold is specified to assure that no delayed cold cracking in the ferritic steel HAZ has occurred. The weld consumables to be used in the new pressure boundary weld consist of bare wire with no flux. The welding will be performed at 300 degrees F minimum preheat temperature using the GTAW process, as required by IWA-4610(a).

The preheat temperature of 300 degrees F and the PSHT requirement of IWA-4633.2(d) is to assure that no delayed cold cracking in the ferritic steel HAZ occurs. Elevated preheat is intended to eliminate moisture and contaminants (hydrocarbons) that could be introduced into the molten metal during welding. The PSHT requirement, initiated immediately after welding is completed, allows the hydrogen potentially trapped in the HAZ and weld metal an extended time period to diffuse out of the HAZ and weld metal. The weld consumables to be used will consist of bare wire with no flux. The preheat temperature of 300 degree F will be maintained during the post-weld soak for four hours in accordance with IWA-4633.2(d) of ASME Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1995 edition through 1996 Addenda. The combination of the low moisture absorbing GTAW weld process and maintaining the post-weld soak temperature at 300 degrees F for four hours will eliminate the possibility of hydrogen induced cracking.

The anticipated ambient temperature for the reactor vessel head will be in the 70 degree F to 80 degree F range by the time a CRDM location would be designated for a repair. Varying plant conditions can affect the temperature of the head. The ambient temperature range for a typical repair is determined by taking an actual measurement and applying a +50 degree F tolerance.

Given a nominal ambient temperature of 75 degree F, a single repair location on the head would take approximately 8 hours to reach the upper end of the 125 degree F ambient temperature range from the 300 degree F minimum PSHT temperature. The time between the end of the welding operations and the beginning of the UT and PT examinations may vary, however, the elapsed time between the end of the welding operation and the beginning of the examinations is estimated to be approximately 12 hours with an ambient temperature no greater than 125 degrees F. This estimate includes the PSHT period and the cool-down period.

The PSHT period will not have any significant effect on the microstructure of the base metal, weld metal or HAZ. Its only purpose is to enhance hydrogen evolution through the matrix.

The reactor vessel base material SA-533 Grade B, Class 1 is a low alloy steel material. This ASME P3 material requires preheat and post weld heat treatment for most applications due to its higher carbon equivalence. The formation of untempered martensite can be expected in the HAZ of this material for welds performed using standard (non temper-bead) welding techniques. The untempered martensite formation in the HAZ will result in reduced mechanical properties in the HAZ. The [ASME] Code required 1150 degree F stress relief that is typically applied after welding reduces the localized residual stresses form the weld. This required stress relief has little effect on the microstructure and restoration of the mechanical properties of the HAZ but removes the high-localized residual stresses that are one of the components responsible for hydrogen cracking. The temper-bead welding technique through the use of controlled heat input and specified bead placement produces tempered martensite in the HAZ. The tempered martensite will not adversely affect mechanical properties in the ferritic based metal HAZ. This is verified with the required impact testing comparison of the HAZ and unaffected base material in the welding procedure qualification. Attachment 1 to this relief request provides PQR-7109 (Reference 3) [included in the licensee's September 12, 2001, submittal], which contains the impact data in the mechanical testing section.

The Inconel 690 weld metal will display superior impact properties and a dendritic microstructure typical of GTAW deposits.

PQR-7001(Reference 5) is provided as Attachment 3 [included in the licensee's September 12, 2001, submittal]. This PQR was one of the first full size temper-bead PQRs utilizing SA-533 Grade B, Class 1 material that Framatome performed using the machine GTAW process. The base material had received 60 hours of stress relief prior to welding. A considerable amount of microhardness testing and metallographic examinations were performed to characterize the HAZ. Microhardness traverses, using a Knoop indenter with a 500g load (HK_{500}) were performed to evaluate the HAZ for potential locations of untempered martensite. Microhardness traverses were performed on three (3) PQR-7001 metallographic specimens from the weld metal to the unaffected base metal at three locations. The results of this testing are summarized in Table 1 of PQR-7001.

Metallographic examination was performed on the same three specimen cross sections that were subjected to microhardness evaluation to determine if any untempered martensitic structure or cracking existed. Metallographic examinations were conducted throughout the entire cross section, but primarily at the HAZs, with emphasis on the locations were microhardness testing was performed. For this class of steels, the microhardness of a bainitic structure is expected to be approximately the same as tempered martensite, therefore, microhardness alone cannot be used to judge the existence of tempered martensite.

The microstructure of tempered martensite is expected to generally consist of carbide precipitation and (in some cases) ferrite formation in the matrix martensite. In general, the degree of carbide and ferrite formation is time and temperature dependent. The criterion to consider a martensitic microstructure to be "tempered" was any evidence of carbide precipitation or ferrite formation. For comparison, an untempered martensitic base metal specimen was also prepared from each weld assembly base material by heat treatment.

The specimen HAZs were carefully examined up to 500X magnification in the optical microscope. Metallographic examination revealed no evidence of untempered martensitic structure or microcracking in the HAZ of any of the samples, especially in the areas where microhardness readings were questionable. HAZ regions of all cross sections exhibited a fine grained structure comprised of a complex conglomerate of microstructure typically found in the HAZs of multiple-pass welds....

Moisture contaminated shielding gas or high humidity environments may introduce hydrogen into GTAW welds. The Electric Power Research Institute (EPRI) performed tests (Reference 1) [included in the licensee's September 12, 2001, submittal] where argon shielding gase was bubbled through a cylinder of water and then mixed with welding grade argon having a dew point of -70 degrees F to produce gas mixtures with dew points from -60 degrees F to +60 degrees F. At +60 degrees F dew point (an unrealistically high dew point), the measured hydrogen concentration in test welds was 4.6 ml/100g of as deposited weld metal. This value falls in the extra low hydrogen range specified by American Welding Society (AWS). The EPRI study also measured the hydrogen content of bare filler material and found it to be less than 1 ml/100g of as deposited weld metal.

The EPRI work further showed that 450 degrees F PSHT would reduce the already low hydrogen content to infinitesimally small values. Work by Coe and Moreton, as documented in table 2-6 of Reference 1 determined that it takes only 0.3 hours at 450 degrees F to remove 95% of any hydrogen present. At 300 degrees F, the diffusivity rate measurements showed that only 0.7 hours is required to remove 95% of any hydrogen that is present...."

2.4.4 Evaluation

The 48-hour hold time after welding at ambient temperature before performing PT examinations required by the ASME Code is to provide time for cold cracks and other latent cracking mechanisms to grow if conditions for cracking existed in the weldment. Cold cracks are hydrogen-induced cracks associated with multiple-pass welding that is applied with insufficient preheating of the base material or weldment. Cold cracks are located in the HAZ of the weld bead layers and the base material. The cracks occur from the effects of hydrogen embrittlement in predominantly martensitic, coarse-grain material that is subjected to internal stresses. They are short, shallow cracks positioned perpendicular to the weld bead direction and embedded below the weld/base metal surface. As residual hydrogen from the welding process diffuses into the cracks, they may grow and open to the surface. Since the cracks are both subsurface and surface breaking, the combination of UT and PT would increase the likelihood of detecting the cracks, rather than just PT.

The licensee's proposed alternative to the 48-hour hold time is to perform the ASME Code-required post-weld heat treatment of the repaired area for 4 hours at 300 °F, after which the repaired area would air cool to ambient temperatures not to exceed 125 °F (Code maximum temperature for normal PT examinations). In the Electric Power Research Institute (EPRI) document EPRI TR-103354, "Temperbead Welding Repair of Low Alloy Pressure Vessel Steels: Guidelines," dated December 1993 (page 2-27), the hydrogen remaining in low alloy carbon steel after a 300 °F, 4-hour, post-weld heat treatment was less than 0.01 parts per million. The elevated temperatures associate with post heat treatment and cool down to NDE temperatures provide sufficient time (approximately 12 hours) for most of the hydrogen above solubility to diffuse from the carbon steel. The small amount of hydrogen left (1 ml/100g weld metal) is not known to produce cold cracking.

Therefore, based on the UT and PT examinations and the post-weld heat treatment followed by the cooldown to ambient temperatures as discussed above, the NRC staff has determined that the proposed alternative will provide an acceptable level of quality and safety.

2.4.5 Conclusion

Based on the discussion above for Relief Request RR 01-16, the NRC staff has concluded that the proposed alternative, to perform a post-weld heat treatment at 300 °F for a minimum of 4 hours followed by an 8-hour cooldown to ambient temperatures less than 125 °F, will provide sufficient time for hydrogen to diffuse from the repaired area. Therefore, the time between finished welding and nondestructive examinations of the repaired and surrounding areas will provide an acceptable level of quality and safety. Pursuant to 10 CFR 50.55a(a)(3)(i), the licensee's proposed alternative described in Relief Request RR 01-16 is authorized for the third 10-year ISI interval.

2.5.0 RR 01-17, Monitoring Interpass Temperature

The components affected by RR 01-17 are the CRDM nozzle-to-RPV pressure boundary welds.

2.5.1 ASME Code Requirements for which Relief is Requested

The ASME Code requirement for the repairs is the ASME Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 1995 Edition through 1996 Addenda.

Paragraph IWA-4610(a) of ASME Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," states, "The area to be welded plus a band around the area of at least 1-1/2 times the component thickness or 5 in., whichever is less shall be preheated to and maintained at a minium temperature of 350 degrees F for the SMAW process and 300 degrees for the GTAW process during welding. The maximum interpass temperature shall be 450 degrees F. Thermocouples and recording instruments shall be used to monitor the process temperatures. Their attachment and removal shall be in accordance with Section III."

2.5.2 Licensee's Proposed Alternative to the ASMECode

Pursuant to 10 CFR 50.55a(a)(3)(ii), compliance with the requirement of IWA-4610(a) of ASME Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 1995 Edition through 1996 Addenda would result in hardship without a compensating increase in the level of quality and safety. It is physically impossible to directly monitor interpass temperature. It is proposed that the requirement for monitoring of the welding interpass temperature be eliminated.

2.5.3 Licensee's Bases for Requesting Relief

Due to the difficulty in placing thermocouples adjacent to the new pressure boundary welds, direct monitoring of the interpass temperature is a hardship and is physically impossible. In lieu of monitoring the interpass temperature via adjacent thermocouples, a calculation has been performed justifying the actual interpass temperature at the weld location based on a maximum allowable welding heat input; weld bead placement, travel speed, and conservative preheat temperature assumptions. The calculation supports the conclusion that using the maximum heat input through the third layer of the weld, the interpass temperature returns to the preheat temperature. Heat input beyond the third layer will not have a metallurgical affect on the low alloy steel HAZ.

The calculation is based on a typical inter-bead time interval of 5 minutes. The 5-minute inter-bead interval is based on the time required: 1) to explore the previous weld deposit with the two remote cameras housed in the weld head, 2) to shift the starting location of the next weld bead circumferentially away from the end of the previous weld bead, and 3) to shift the starting location of the next bead axially to insure a 50-percent weld-bead overlap required to properly execute the temper-bead technique.

A welding mockup on the full size Midland RV closure head was used to demonstrate the welding technique described herein. During the mockup, thermocouples were placed to monitor the resistance heating of the head. These locations will be retained for the actual repairs. During the mockup, thermocouples were placed on the outside diameter of the RV head within a 5-inch band surrounding the CRDM nozzle. Three other thermocouples were placed on the RV head inner diameter. One of the three thermocouples was placed 1-1/2 inches from the CRDM penetration, on the lower hillside. The other inner diameter thermocouples were placed at the edge of the 5-inch band surrounding the CRDM nozzle, one on the lower hillside, the second on the upper hillside. During the mockup, all thermocouples fluctuated less than 15 °F throughout the 18-hour welding cycle. Based on past experience, it is believed that the temperature fluctuation was due more to the resistance heating variations than the low heat input from the welding process.

2.5.4 Evaluation

The NRC staff has evaluated the licensee's request and supporting information on the proposal to eliminate the requirement for direct measurement of the 450 °F maximum welding interpass temperature as required by Section IWA-4500(e)(2) of ASME Code, Section XI. The NRC staff has concluded that the proposed alternative to direct weld interpass temperature measurement is acceptable based on the fact that:

1) placing of thermocouples in direct proximity to the welds for monitoring of the interpass temperature is a hardship and is physically impossible;
2) calculation of the temperature rise has been performed to show that the maximum interpass temperature will not be exceeded;
3) thermocouples will be placed at locations near the area of repair welding; and
4) a full size mockup of the closure head was used to demonstrate that the welding technique would assure that the maximum interpass temperature will not be exceeded.

2.5.5 Conclusion

The NRC staff concludes that the licensee's proposed alternative to Section IWA-4610(a) of ASME Code, Section XI, which requires the direct measurement of the preheat and maximum interpass temperature, provides an acceptable means of ensuring that the maximum interpass temperature will not be exceeded. The licensee has demonstrated that compliance with the requirement of direct measurement of the preheat and interpass temperature as required by Section IWA-4610(a) in ASME Code, Section XI, would result in an unusual difficulty in performing the repair weld to the CRDM nozzles without a compensating increase in the level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(ii), the licensee’s alternative is authorized for the third 10-year ISI interval.

3.0 <u>CONCLUSION</u>

The NRC staff concludes that the licensee’s proposed alternatives in Relief Requests 01-14 and 01-16 are authorized pursuant to 10 CFR 50.55a(a)(3)(i) on the basis that they would provide an acceptable level of quality and safety. The licensee’s proposed alternatives in Relief Requests 01-15 and 01-17 are authorized pursuant to 10 CFR 50.55a(a)(3)(ii) because compliance with the specified requirements would result in hardship and unusual difficulty respectively without a compensating increase in the level of quality and safety.

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