Consumers Power

POWERING MICHIGAN'S PROGRESS

Palisades Nuclear Plant: 27780 Blue Star Memorial Highway, Covert, MI 49043

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U S Nuclear Regulatory Commission
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DOCKET 50-255 - LICENSE DPR-20 - PALISADES PLANT
PRELIMINARY THERMAL ANNEALING REPORT, SECTION 3, FRACTURE TOUGHNESS RECOVERY AND REEMBRITTLEMENT ASSURANCE PROGRAM - RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

On October 12, 1995, Consumers Power Company submitted Section 3 of our Preliminary Thermal Annealing Report (TAR), The Fracture Toughness Recovery and Reembrittlement Assurance Program, to permit initial NRC review. By letter dated November 16, 1995, the NRC requested additional information and clarification of information on that section of our preliminary TAR. Attachment 1 of this letter provides the requested additional information and clarifications.

SUMMARY OF COMMITMENTS

This letter contains no new commitments.

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Manager, Licensing

CC Administrator, Region III, USNRC
Project Manager, NRR, USNRC
NRC Resident Inspector - Palisades

Attachment

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ATTACHMENT 1

CONSUMERS POWER COMPANY
PALISADES PLANT
DOCKET 50-255

RESPONSE TO

NRC REQUEST FOR ADDITIONAL INFORMATION DATED 11/16/95

THERMAL ANNEALING REPORT, SECTION 3

FRACTURE TOUGHNESS RECOVERY AND REEMBRITTLEMENT ASSURANCE

PROGRAM

Request for Additional Information

1. *This section of the report should address the issue of the potential for temper embrittlement (TE) or other forms of non-hardening embrittlement of the Palisades beltline materials resulting from the annealing heat treatment. Particular emphasis should be placed on weld heat affected zone (HAZ) materials.*

   What research/analyses/procedures will be used to demonstrate that TE is not a concern?

CPCo believes that the proposed surveillance program will identify any temper embrittlement which may occur. We plan to fabricate a limited number of additional irradiated HAZ specimens to specifically address this issue. The specimens will be annealed at 850°F and then fractured. The fracture surfaces will be examined by scanning electron microscopy for intergranular fractures. If no intergranular fracture is found, no further testing will be performed. However, if evidence of intergranular fracture is found, broken plate and weld specimens from previously tested surveillance capsules will be examined. If intergranular fracture is found in the plate or weld material, the Section 3 surveillance program will adequately measure the effects of intergranular fracture on the fracture toughness of the material, therefore, no further testing of HAZ material is required. If no intergranular failure is found in the plate or weld material, the surveillance program will be revised to include HAZ material.

- *Chemistry considerations - particularly phosphorus levels. Compare/contrast Palisades beltline materials with existing studies.*

Temper embrittlement that is caused by heat treatments at approximately 850°F is not expected in materials with phosphorus concentrations less than 0.02%.[1] The average phosphorus concentrations of the Palisades reactor vessel beltline plates range from 0.009% to 0.016%. Best estimate phosphorus levels reported for the welds are 0.017% for the axial welds and 0.013% for the circumferential weld. Phosphorus levels for the steam generator welds ranged from 0.006% to 0.012% for the weld fabricated with weld wire heat number W5214 and from 0.007% to 0.016% for the weld fabricated with weld wire heat number 34B009. Phosphorus concentrations for the supplemental surveillance weld representing weld wire heat number 27204 has phosphorus concentrations ranging from 0.008% to 0.010%.

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[1]Pelli, R. and Törrönen, K., "State of the Art Review on Thermal Annealing", AMES Report No. 2, December 1994, p. 26.

- *Metallurgical considerations - grain size, width of coarse-grained HAZ region, welding parameters, plate fabrication parameters. Compare/contrast Palisades beltline materials with existing studies.*

The basis document for the ASME code case addressing the requirements for an in-place dry anneal of a PWR reactor vessel states the following about temper embrittlement:

> "Western RPV steels and weldments are potentially susceptible to temper embrittlement in the temperature range recommended for thermal annealing. Temper embrittlement involves segregation of impurity elements (e.g., P, Sn, Sb) to grain boundaries in the steel microstructure.[2] This causes a weakening of the grain boundaries which is manifested by an increased TT and reduced USE and ductility. Temper embrittlement will also cause a change in fracture mode from transgranular to intergranular which is readily discernible with scanning electron microscope observation of Charpy specimen fracture surfaces. Temper embrittlement has been observed in foreign RPV steel weldments[3] but is considered to be primarily a concern for the weld heat affected zone (HAZ). The foreign steels generally have higher P and alloy content (Cr, Mo, V) which is known to exacerbate temper embrittlement. Extensive annealing studies on U.S. materials in both industry and NRC sponsored programs[4] have thus far indicated that temper embrittlement should not be a serious concern for annealing treatments. This includes experimental evidence showing a lack of intergranular fracture on irradiated impact specimens that have received annealing treatments. The recovery of toughness in weld HAZs is the subject of significant ongoing research efforts. However, in western RPV weldments of low P content with small coarse grained HAZs, the effects on toughness will be less significant than what have been observed with foreign steels."

Temper embrittlement has become an issue as a result of research on thermally induced phosphorus migration to the grain boundaries of a simulated HAZ

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[2]American Society for Metals, The Metals Handbook 9th Edition Volume 1, Properties and Selection: Irons and Steels, pp. 468-469, 684-685, 701-704, 1987.

[3]Pelli, R. and Törrönen, K., "State of the Art Review on Thermal Annealing," European Commission, DG XII - Joint Research Centre, Institute for Advanced Materials, DG XI - Safety of Nuclear Installations, Aging Materials and Evaluation Studies (AMES) Report No. 2, December, 1994.

[4]NUREG/CR-6327, "Models for Embrittlement Recovery Due to Annealing of Reactor Pressure Vessel Steels," E. Eason, J. Wright, R. Odette, E. Mader, February 1995.

microstructure. In this study, a uniform coarse grain microstructure was created by heat treating material to 1200°C (2134°F) for 0.5 hours. A reactor vessel weld should have seen such high temperatures for very short time periods due to the heat sink effect of the heavy wall plate material. As a result, the coarse grain region of HAZ in the vessel should be very small and nonuniform. This is not expected to be an issue for the Palisades reactor vessel.

- *Have fracture surfaces from Palisades surveillance materials previously been examined for evidence of intergranular fracture? If so, what were the results?*

Two unirradiated steam generator weld material Charpy specimens were examined for intergranular fracture as part of Consumers Power Company's investigation into the cause of higher than expected values for initial RT_{NDT}. One specimen was from Heat W5214 and one from Heat 34B009. The fracture surfaces of these specimens were examined and concluded to be transgranular cleavage with no evidence of intergranular fractures.

In addition, one irradiated and annealed transverse plate Charpy specimen, Plate D-3803-1 (TL), from the surveillance program was recently tested and the fracture surface showed no signs of intergranular fracture.

- *Will there be an experimental program to examine HAZ impact toughness for the Palisades beltline materials? If such a program is planned, the program should include surveillance materials with plate materials and weld materials and process parameters similar to those used for the vessel weldments.*

See the above response to the first item for a description of the experimental program.

The examination will be performed on HAZ material from one of the intermediate shell plates of the Palisades reactor vessel surveillance program. The HAZ material was created by welding two Palisades plate materials using the same type procedure, weld wire and weld flux as the Palisades beltline axial welds. The weld wire heat number differs from that of the beltline welds.

- *How will the annealing heat treatment affect the fracture toughness of the Palisades HAZ beltline materials?*

Exposure to neutron fluence is known to reduce the fracture toughness of base metal and weld metal to a greater extent than has been observed in HAZ material. The annealing heat treatment is expected to recover approximately the same percentage of transition temperature and upper shelf energy in the HAZ material as is expected for the other beltline materials. Thus, it is expected that the HAZ material will continue to have greater fracture toughness than the base metal and weld metal.

2. *Section 3.1.4.2 states that reconstituted specimens will be tested in the same orientation as the original. What was the original orientation of the specimens in the weld metal? Please provide a drawing showing the orientation.*

The weld specimens were originally oriented parallel to the principal rolling direction of the plate and perpendicular to the direction of the weld. A figure showing the orientation is attached.

3. *Section 3.1.5.2.a states that CVN [Charpy V-notch] specimen halves with "extensive" evidence of plastic deformation will be eliminated from further consideration. How is "extensive" deformation defined?*

Charpy V-notch specimen halves will be examined as part of the selection process. ASTM E 1253-88 requires that the central test section have a minimum of 14 mm of base metal or weld metal with no plastic deformation from previous testing. A specimen that cannot meet this criteria will be classified as having extensive deformation.

4. *Section 3.2.2 states that the original surveillance capsules will be annealed and "If possible", reinserted prior to restart. Explain, what is meant by "If possible."*

We plan to remove the remaining original surveillance capsules from the reactor vessel during the core unloading and to anneal them in parallel with the reactor vessel anneal. We then plan to reinstall the capsules during core reload. Historically, installation of new surveillance capsules has proven to be a difficult task. The handling and annealing of the surveillance capsules may cause physical changes to the capsules that might impair their ability to be installed or properly secured. Modifications made to new capsules to aid in installation are not present in the original capsules. Because of their design and activity levels, capsule modifications may be difficult to complete within the refueling outage schedule requirements. It is anticipated that any modification required to successfully reinstall the surveillance capsules could be completed to support reinstallation during the next refueling outage after removal.

<u>Clarifications</u>

1. *The annealing temperature and uncertainty were specified in Section 3.1.5.2.b as 850°F+/-25°F. RG 1.162 requires that the recovery estimates (Table 3.1.6.1 and 3.1.6.3) would have been calculated using 825°F. Was this the case?*

No. The calculations in Tables 3.1.6.1 and 3.1.6.3 were calculated using 850°F. Calculations of recovery of the reactor vessel beltline materials have been performed at 850°F assuming the reactor vessel will be annealed at the planned 850°F. The annealing recovery program has been designed to address recovery at

850°F. Because the recovery program is intended to determine the expected behavior of the Palisades surveillance material relative to the NUREG/CR-6327 equations, the measured recovery will be compared with the predicted recovery at the actual specimen annealing temperature. Actual recovery results will be used in the calculations in the final version of the Thermal Annealing Report.

2. *The first note on Table 3.1.3-1 states that the W5214 welds used in the annealing verification program were taken from the highest copper or higher nickel chemistry region of the steam generator (SG) welds and "bound" the estimate for the reactor pressure vessel (RPV) welds. NRC interprets this statement to mean that the RPV welds are not expected to recover to as great a degree as the SG welds. Is this interpretation correct?*

No. The specimens were removed from the area of the steam generator W5214 weld which exhibited higher copper concentrations than other depths of the weld. The higher chemistry factor of this material is expected to cause the test results of irradiated specimens to demonstrate greater embrittlement than expected for the reactor vessel material. In addition, the higher copper content of this material is expected to cause the test results from the annealed material to demonstrate less percent recovery than would be expected for the reactor vessel. The RT_{NDT} for the steam generator W5214 weld is expected to be higher than RT_{NDT} for the reactor vessel W5214 welds whether pre-annealed or post-annealed, which is why we consider it to be bounding.

In a similar manner, the specimens were removed from the area of the steam generator 34B009 weld which exhibited higher nickel concentrations than other depths of the weld. The higher chemistry factor of this material is expected to cause the test results of irradiated specimens to demonstrate greater embrittlement than expected for the reactor vessel material. The similar copper content of this material is expected to cause the test results from the annealed material to demonstrate percent recovery similar to that which would be expected for the reactor vessel. Therefore, the RT_{NDT} for the steam generator 34B009 weld is expected to be higher than RT_{NDT} for the reactor vessel 34B009 welds whether pre-annealed or post-annealed.

The following table demonstrates why we consider the steam generator surveillance material bounding.

Material	Chemistry Factor[2]	Before Anneal ΔRT_{NDT}[5]	Before Anneal RT_{NDT}	% Recovery	After Anneal ΔRT_{NDT}	After Anneal RT_{NDT}
Vessel W5214	232	256[1]	265[3]	90[3]	26[3]	36[3]
Surveillance W5214	267	294	304	82[4]	53	63
Vessel 34B009	219	242[1]	252[3]	92[3]	19[3]	29[3]
Surveillance 34B009	227	250	260	92[4]	20	30

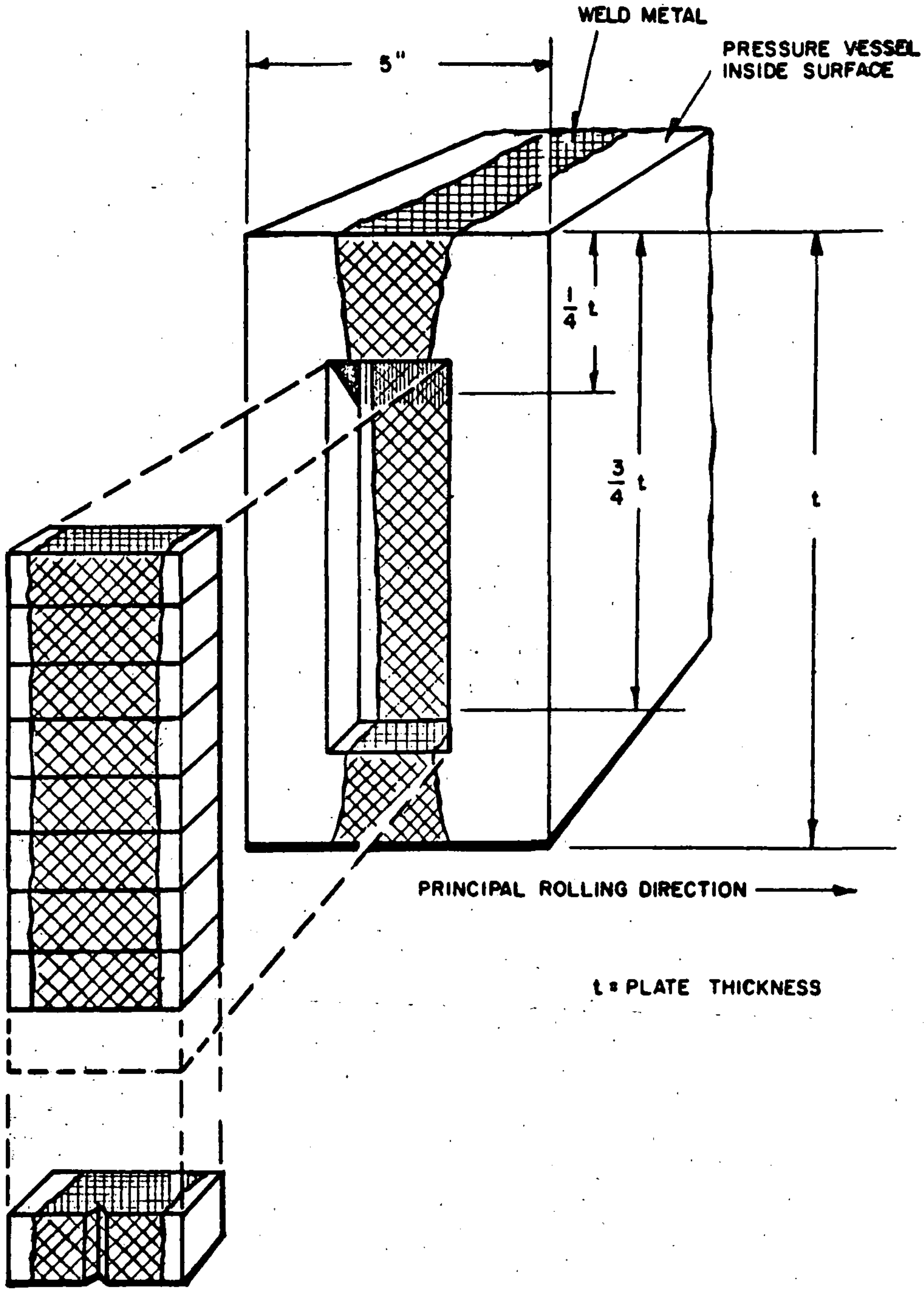
Notes:
1 TAR Section 1.1, Table 1.1.C-2
2 TAR Section 1.2, Table 1.2.C-1
3 TAR Section 1.1, Table 1.1.C-3
4 TAR Section 3.1, Table 3.1.6-1
5 Assumes fluence of 1.45 X 10^{19} at EOL

3. *Section 3.2.1.2 states that "application of the lateral shift method to the Charpy Upper Shelf Energy (USE) is more difficult because there is no generally accepted model of embrittlement. NRC expects that the trend curves from Figure 2 in RG 1.99, Rev. 2 will still apply to describe USE decline after annealing.*

We agree, predictions for reembrittlement have been calculated in accordance with the guidance of DG-1027, equation 15.

4. *Section 3.2.2 correctly assumes that the procedures of 10 CFR 50.61 will be used for the chemistry factor calculation. The licensee discussed in this section the calculation of a "new" post-anneal chemistry factor. The staff recognizes the potential for annealing to alter the sensitivity to radiation embrittlement. This may be a potential consideration for a future revision of RG 1.99, Rev. 2 and/or the annealing RG (1.162).*

We acknowledge the NRC statement.



Location of weld metal charpy specimens within test plate