Consumers Power

POWERING MICHIGAN'S PROGRESS

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

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TEST RESULTS FROM THE SURVEILLANCE SPECIMEN ANNEALING RECOVERY PROGRAM

During the summer of 1995, Consumers Power Company performed annealing recovery testing to verify that annealing of surveillance program materials would regain sufficient toughness to warrant further commitment of resources for the thermal anneal of the Palisades reactor vessel. On November 16, 1995, we verbally notified your staff of the testing results and agreed to provide the written results after the report was finalized. This letter provides the written results of the testing performed.

Attachment 1 contains the Consumers Power Company analysis of the results. Attachment 2 contains the written report, "Consumers Power Company Palisades Surveillance Specimen Annealing Recovery Program", WCAP-14558.

SUMMARY OF COMMITMENTS

This letter contains no new commitments and no revisions to existing commitments.

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Manager, Licensing

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

Attachments

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ATTACHMENT 1

CONSUMERS POWER COMPANY
PALISADES PLANT
DOCKET 50-255

CONSUMERS POWER CO. ANALYSIS OF THE PALISADES ANNEALING RECOVERY TEST RESULTS

8 Pages

CONSUMERS POWER CO. ANALYSIS OF THE PALISADES ANNEALING RECOVERY TEST RESULTS

Palisades Annealing Recovery Test Program

During the summer of 1995, annealing recovery testing was performed on materials previously irradiated in the Palisades reactor vessel surveillance program. The testing was performed to verify that an 850°F heat treatment of the surveillance material would regain sufficient toughness to warrant further commitment of resources for the purpose of performing a thermal anneal on the Palisades reactor vessel. Testing was originally planned to be performed on plate and weld material from two wall (W-110 and W-290) and one accelerated (A-240) surveillance capsules. Capsules W-110 and W-290 were stored at the Westinghouse hot cell and were readily available for testing. Capsule A-240 was stored at the inactive hot cell at Battelle Columbus Laboratories. It was necessary for Battelle to reactivate equipment and procedures that had not been used for several years. As a result, the A-240 specimens were not available for testing in time to meet the schedule.

Section 3.1.6 of the Palisades Thermal Annealing Report (TAR) describes the proposed method for quantifying the post anneal material properties of the Palisades reactor vessel. As described in the text of the TAR, this method consists of computing the amount of annealing recovery using the predictive equations of NUREG CR-6327, supplemented by testing the Palisades reactor vessel surveillance program materials for the purpose of validating or adjusting the predictions. The methodology used in this report complies with Section 3.1.6 of the TAR and NUREG CR-6327 and is provided as an example of how the proposed TAR methodology will be applied once all of the annealing recovery data is obtained.

Broken Charpy specimens of weld metal and base metal from the reactor vessel surveillance program were annealed, reconstituted and tested for the purpose of quantifying the amount of recovery that might be expected for the reactor vessel beltline materials. Details of that testing is provided in the attached report "WCAP-14558, Revision 2, Consumers Power Company Palisades Surveillance Specimen Annealing Recovery Program". Figures 3-1 through 3-3 are particularly informative. The tests resulted in less recovery than projected in Table 3.1.6-1 and Table 3.1.6-3 of the TAR.

The results of the testing did not demonstrate as much recovery in the 30 ft-lb transition temperature and Charpy upper shelf energy as projected by the equations in NUREG CR-6327. A review of the results raised some concern that a bias was introduced by the reconstitution process. Consumers Power Co. plans to complete further testing to better understand the differences between actual and expected results.

Transition Temperature

The predicted 30 ft-lb transition temperature from an 850°F anneal (TT_{ia}) for the Palisades reactor vessel surveillance materials as calculated in Table 3.1.6-1 of the TAR is listed below.

Projected Transition Temperature Annealing Response @850°F for 168 hours

Material	Fluence $10^{19} n/cm^2$	Predicted Recovery	Predicted TT_{ia} (°F)	Lower 95% Confidence Limit (°F)	Upper 95% Confidence Limit (°F)
Weld 3277	1.09	88%	-53	-87	-19
Weld 3277	1.78	88%	-49	-83	-15
Plate D-3803-1 (T-L)	1.09	89%	35	1	69

The surveillance material annealing specification called for the specimen annealing temperature (T_a) to be:

$$T_a = 850°F \pm 25°F.$$

The annealing time, t_a, was specified as:

$$160 \text{ hours} < t_a \leq 168 \text{ hours}.$$

The actual annealing exceeded 825°F for 160.5 hours. The time weighted temperature is estimated to be 842°F. The projected response using this time and temperature follows.

Projected Transition Temperature Annealing Response @842°F for 160 hours

Material	Fluence 10^{19}n/cm²	Predicted Recovery	Predicted TT_{ia} (°F)	Lower 95% Confidence Limit (°F)	Upper 95% Confidence Limit (°F)
Weld 3277	1.09	87%	-50	-84	-16
Weld 3277	1.78	87%	-47	-81	-13
Plate D-3803-1 (T-L)	1.09	88%	36	2	70

Following the anneal, the specimens were reconstituted and then tested. The results of the testing are contained in Table 3-7 of WCAP-14558 and are summarized in the following table.

Measured Transition Temperature Annealing Response @842°F for 160 hours

Material	Fluence 10^{19}n/cm²	Measured Recovery	Measured TT_{ia} (°F)
Weld 3277	1.09	74%	-13
Weld 3277	1.78	77%	-18
Plate D-3803-1 (T-L)	1.09	82%	46

The average prediction error for the two weld measurements may be calculated using the equation:

$$\frac{\sum_n (TT_{mn} - TT_{pn})}{N} = \frac{[-13-(-50)]+[-18-(-47)]}{2} = 33$$

where TT_{mn} = measured transition temperature (°F) for data point n
TT_{pn} = predicted transition temperature (°F) for data point n
N = number of measurements.

This value (33°F) exceeds the 95% confidence interval of 23.8°F for two observations listed in the TAR Table 3.1.6-2. The guidance in TAR Section 3.1.6.a requires that a correction factor, or bias, be applied to the recovery projections for welds fabricated with weld wire heat number 3277. Using TAR equation 3.1-8, the correction factor for future recovery predictions would be:

$$K_{3277} = \frac{\sum_n \left[\frac{R_{mn}}{R_{pn}}\right]}{N} = \frac{\left[\frac{74}{87}\right] + \left[\frac{77}{87}\right]}{2} = 0.868$$

where R_{mn} = measured fractional recovery for data point n,
R_{pn} = predicted fractional recovery for data point n and
N = number of measurements.

This correction factor would be applied in the following manner:

If the next predicted recovery for TT_{ia} was 87% for the weld material, then

Corrected Predicted Recovery = Predicted Recovery x K_{3277}
= 87% x 0.868 = 75.5%

The measured TT_{ia} of 46°F for Plate D-3803-1 (T-L) falls within the 95% confidence interval (from 2°F to 70°F) for a single measurement and therefore no correction factor is needed.

The second test required for determining the need for a correction factor involves combining the data set of all materials which pass the material specific test as does Plate D-3803-1 (T-L). Because Plate D-3803-1 (T-L) is the only material to meet this criteria, the combined data set inclusive of this one material falls within the 95% confidence interval. Because this material meets both test criteria, no correction factor is required.

Upper Shelf Energy

The predicted Charpy upper shelf energy from an 850°F anneal (C_vUSE_{ia}) for the Palisades reactor vessel surveillance materials as calculated in Table 3.1.6-3 of the TAR is listed below.

Projected Upper Shelf Energy Annealing Response @850°F for 168 hours

Material	Fluence $10^{19}n/cm^2$	Predicted Recovery	Predicted C_vUSE_{ia} (ft-lbs)	Lower 95% Confidence Limit (ft-lbs)	Upper 95% Confidence Limit (ft-lbs)
Weld 3277	1.09	84%	109	99	118
Weld 3277	1.78	82%	107	97	117
Plate D-3803-1 (T-L)	1.09	100%	102	92	102

As mentioned above, the best estimate annealing conditions were 842°F for 160.5 hours. The projected response using this time and temperature follows.

Projected Upper Shelf Energy Annealing Response @842°F for 160 hours

Material	Fluence $10^{19}n/cm^2$	Predicted Recovery	Predicted C_vUSE_{ia} (ft-lbs)	Lower 95% Confidence Limit (ft-lbs)	Upper 95% Confidence Limit (ft-lbs)
Weld 3277	1.09	83%	109	99	118
Weld 3277	1.78	81%	107	97	117
Plate D-3803-1 (T-L)	1.09	100%	102	92	102

Following the anneal, the specimens were reconstituted and then tested. The results of the testing are contained in Table 3-7 of WCAP-14558 and are summarized in the following table.

Measured Upper Shelf Energy Annealing Response @842°F for 160 hours

Material	Fluence 10^{19}n/cm²	Measured Recovery	Measured C_vUSE_{ia} (ft-lbs)
Weld 3277	1.09	61%	97
Weld 3277	1.78	65%	97
Plate D-3803-1 (T-L)	1.09	11%	86

The average prediction error for the two weld measurements may be calculated using the equation:

$$\frac{\sum_n (C_vUSE_{mn} - C_vUSE_{pn})}{N} = \frac{(109-97)+(107-97)}{2} = 11$$

where C_vUSE_{mn} = measured upper shelf energy (ft-lbs) for data point n
C_vUSE_{pn} = predicted upper shelf energy (ft-lbs) for data point n
N = number of measurements.

This value (11 ft-lbs) exceeds the 95% confidence interval of 7.1 ft-lbs for two observations listed in TAR Table 3.1.6-4. The guidance in TAR Section 3.1.6.b requires that a correction factor, or bias, be applied to the recovery projections for welds fabricated with weld wire heat number 3277. Using TAR equation 3.1-8, the correction factor for future recovery predictions would be:

$$K_{3277} = \frac{\sum_n [\frac{R_{mn}}{R_{pn}}]}{N} = \frac{[\frac{61}{83}]+[\frac{65}{81}]}{2} = 0.769$$

where R_{mn} = measured fractional recovery for data point n,
R_{pn} = predicted fractional recovery for data point n and
N = number of measurements

This correction factor would be applied in the following manner:

If the next predicted recovery for C_vUSE was 83% for the weld material, then

Corrected Predicted Recovery = Predicted Recovery x K_{3277}
= 83% x 0.769 = 63.8%

The measured C_vUSE_{ia} of 86 ft-lbs for the plate material falls outside of the 95% confidence interval (from 92 to 102 ft-lbs) for a single observation. Since this criteria was not met, a correction factor, or bias, will be applied to future projections of base metal recovery. Using the TAR equation 3.1.8, the correction factor for future recovery predictions is:

$$K_{D-3803-1(T-L)} = \frac{\sum_n [\frac{R_{mn}}{R_{pn}}]}{N} = \frac{[\frac{11}{100}]}{1} = 0.11$$

This correction factor would be applied in the following manner:

If the next predicted recovery for C_vUSE was 100% for the plate material, then

Corrected Predicted Recovery = Predicted Recovery x $K_{D-3803-1\ (L-T)}$
= 100% x 0.11 = 11%

The second test required for determining the need for a correction factor could not be completed as none of the material data sets passed the material specific test criteria.

Plans for Additional Testing

Consumers Power Company (CPCo) is still reviewing the results of the W-110 and W-290 testing and plans to perform additional testing. Although Charpy Upper Shelf Energy (C_vUSE) is not an immediate concern for the Palisades reactor vessel, CPCo is concerned with the limited amount of recovery observed in the surveillance plate. The possibility that the reconstitution process may have biased the results has not been excluded.

In addition, there is the possibility that scatter which exists for the initial properties of the T-L plate material may become significant due to the small changes in C_vUSE which have been measured. This scatter results in the C_vUSE for the unirradiated specimens, the irradiated specimens and the annealed specimens being very close together. Figure 3-1 of WCAP-14558 shows the band between the C_vUSE values to be very small. This small band exaggerates any small errors that may have occurred due to processing, reconstitution or other material variability. Figure 3-1 of WCAP-14558 suggests that the unirradiated, the irradiated and the annealed C_vUSE values are indistinguishable.

The loss of upper shelf energy in this material was less than predicted by Regulatory Guide 1.99, Revision 2. For example, the calculated upper shelf energy for the plate material at this fluence level is 68 ft-lbs. Recovery to 86 ft-lbs from this projected USE level would be calculated as 53%. The observed results (initial, irradiated, and irradiated-annealed) may simply be due to scatter from a variable material or different test conditions.

It is planned to repeat the base metal testing, placing additional emphasis on monitoring the reconstitution and annealing process. Weld metal and base metal from accelerated surveillance capsule A-240, that was not available in time for the initial testing, will be annealed, reconstituted and tested. Standard reference material (HSST01) from wall capsule W-110 will also be included in the test program.

ATTACHMENT 2

CONSUMERS POWER COMPANY
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DOCKET 50-255

CONSUMERS POWER COMPANY PALISADES SURVEILLANCE SPECIMEN ANNEALING RECOVERY PROGRAM
WCAP-14558, REVISION 2

107 Pages