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SUBJECT: Submits response to NRC 940422 ltr,supplying sets of summary tables containing pressurized thermal shock & upper shelf energy info for plant,per GL 92-01.

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AEP:NRC:1173C

Donald C. Cook Nuclear Plant Units 1 and 2
Docket Nos. 50-315 and 50-316
License Nos. DPR-58 and DPR-74
RESPONSE TO REQUEST FOR VERIFICATION OF INFORMATION SUPPLIED FOR GENERIC LETTER 92-01, REVISION 1 (TAC NOS. M83453 and M83454)

U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, D. C. 20555

Attn: W. T. Russell

May 20, 1994

Dear Mr. Russell:

References:

1) NRC letter from John B. Hickman to Mr. E. E. Fitzpatrick dated, April 22, 1994.

2) Letter No. AEP:NRC:1173 from Mr. E. E. Fitzpatrick to T. E. Murley (NRC) dated, July 13, 1992.

3) Letter No. AEP:NRC:1173A from Mr. E. E. Fitzpatrick to T. E. Murley (NRC) dated, November 29, 1993.

4) Letter No. AEP:NRC:1173B from Mr. E. E. Fitzpatrick to T. E. Murley (NRC) dated, January 24, 1994.

This letter is submitted in response to your April 22, 1994, letter which supplied two sets of summary tables containing pressurized thermal shock (PTS) and upper shelf energy (USE) information for each of the Donald C. Cook Nuclear Plant Units. Those summary tables were developed by your Staff based on our responses to Generic Letter (GL) 92-01, Revision 1, "Reactor Vessel Structural Integrity", and on previously docketed information. Specifically, in your April 22, 1994 letter, you requested that we verify that the information we supplied in response to GL 92-01, Revision 1, has been accurately entered in the subject summary tables.

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A028 1/1

As requested, we have reviewed and verified, with the exceptions noted in Enclosure 1 to this letter, the accuracy of the PTS and USE summary tables. For clarity, a copy of the PTS and USE tables, annotated with our comments, is included as Enclosure 2 to this letter.

Sincerely,

W. G. Smith Jr.

for E. E. Fitzpatrick
Vice President

dr

Enclosures

cc: A. A. Blind
G. Charnoff
J. B. Martin - Region III
NFEM Section Chief
NRC Resident Inspector
J. R. Padgett

ENCLOSURE 1 TO AEP:NRC:1173C

COMMENTS ON PRESSURIZED THERMAL SHOCK AND UPPER SHELF ENERGY SUMMARY TABLES

Donald C. Cook Unit 1

Summary File for Pressurized Thermal Shock

1. The 32 EFPY/EOL ID neutron fluence of 1.41 x E19 n/cm^2 is high for nozzle shell plates B4405-1, -2, and -3, and the nozzle/intermediate shell axial and circumferential welds 1-442 A/C, and 8-442 respectively since the plates and welds are located above the core affected height. The Donald C. Cook Unit 1 ID neutron fluence at 32 EFPY/EOL for the above mentioned plates and welds has been estimated by Westinghouse at 1.10 x E18 n/cm^2. Westinghouse used the 1.1 x E18 n/cm^2 fluence value in developing the Donald C. Cook Unit 1 USEs presented in WCAP-13587 "Reactor Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors." WCAP-13587 has been reviewed by the NRC Office of Nuclear Reactor Regulation, and is the subject of their safety assessment, dated April 21, 1994 (see Attachment 1 to Enclosure 1). For the above plates and welds, the value of 1.41 x E19 should be replaced with 1.10 x E18.

2. As identified on page 2-9 of the Donald C. Cook Unit 1 PTS evaluation, dated March 1990 (see Attachment 2 to Enclosure 1), the 32 EFPY/EOL ID neutron fluence for the longitudinal welds 2-442A/C and 3-442A/C is 0.95 x E19 n/cm^2. The Unit 1 PTS report was included as Attachment 15 to the Generic Letter 92-01 response, AEP letter No. AEP:NRC:1173 dated July 13, 1992.

3. As identified on page 2-8 of the Donald C. Cook Unit 1 PTS evaluation, dated March 1990 (see Attachment 2 to Enclosure 1), the percent Cu for axial welds 1-442A/C, 2-442A/C, and 3-442A/C and circumferential weld 9-442 is estimated at 0.28 percent. Again, the Unit 1 PTS report was also included as Attachment 15 to the Generic Letter 92-01 response, AEP letter No. AEP:NRC:1173 dated July 13, 1992. The 0.28 percent Cu value may change as additional information becomes available; however, the percent Cu value of .27 should be replaced with .28 for the above welds.

4. The Unirradiated Upper Shelf Energy values are not included in the PTS Table, and as such, the footnote should be removed.

Donald C. Cook Unit 2

Summary File for Pressurized Thermal Shock

5. As identified on page 8 of the Donald C. Cook Unit 2 PTS evaluation dated February 1993 (see Attachment 3 to Enclosure 1), the 32 EFPY/EOL ID neutron fluence for the lower shell plates C5540-2 and C5592-1 is 1.71 x E19 n/cm^2. For the above plates, the value of 1.71 x E18 should be replaced with 1.71 x E19. The Unit 2 PTS evaluation was not included with the Generic Letter 92-01 response; however, it was submitted per AEP letter No. AEP:NRC:0561F dated April 12, 1993.

6. As identified on page 7 of the Donald C. Cook Unit 2 PTS evaluation dated February 1993 (Attachment 3 to Enclosure 1), the percent Ni value for intermediate shell plate C5556-2 is 0.57, the percent Cu value for intermediate shell plate C5521-2 is 0.125, and the percent Ni content for lower shell plate C5592-1 is 0.59. The respective percent Cu and Ni values for these plates should be replaced with the values specified in this paragraph.

D.C. Cook Unit 1

Summary File for Upper Shelf Energy

7. The change in the percent Cu content of the axial and longitudinal welds, identified in Comment No. 3, results in the need for the NRC to re-calculate 1/4T USE at EOL. Using either the 0.27 or 0.28 percent Cu value, the revised 1/4T USE exceeds the minimum USE Energy criteria of 50 FT-Lbs.

8. The percent Cu values do not appear in the USE Tables, and as such the footnote should be removed.

9. It should be noted that, with the correction of the ID neutron fluence values for the nozzle shell plates and the nozzle/intermediate shell axial and circumferential welds as indicated in comment No.1 above, the 1/4T neutron fluence at EOL should also be re-calculated by the NRC. Westinghouse has determined that the 1/4T neutron fluences at EOL for the nozzle shell plates and the nozzle/intermediate shell axial and circumferential welds are 5.77 x E17 n/cm^2.

Attachment 1

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

APR 21 1994

Mr. William H. Rasin
Vice President and Director
Technical Division
Nuclear Management and Resources Council
1776 Eye Street, N.W., Suite 300
Washington, DC 20006-3706

SUBJECT: SAFETY ASSESSMENT OF REPORT WCAP-13587, REVISION 1, "Reactor Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors," September 1993

Dear Mr. Rasin,

By letter dated March 16, 1993, the Nuclear Management and Resources Council (NUMARC) submitted a report prepared by the Westinghouse Electric Corporation for the Westinghouse Owners' Group (WOG) entitled, "Reactor Pressure Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors," WCAP-13587, Revision 0.

The report was provided to NRC as supplemental information in response to Generic Letter (GL) 92-01. No review and approval was requested. The report is intended to demonstrate through fracture mechanics analyses that there exist margins of safety against fracture equivalent to those required by Appendix G of ASME Code Section III for beltline materials having upper shelf energy (USE) values below the screening criteria of 50 ft-lb.

By letter dated July 1, 1993, the NRC issued a request for additional information (RAI) concerning the report. The reply to the RAI was received by NRC on August 20, 1993 and the NRC was notified that the report would be revised based on the RAI. WCAP-13587, Revision 1, was subsequently submitted to NRC through NUMARC by letter dated September 30, 1993.

The Materials and Chemical Engineering Branch has completed a safety assessment of Revision 1 of the report. The enclosure contains the safety assessment. The staff finds the methodology employed and the analysis performed for the WOG to be acceptable except as noted in the enclosure. The report did not contain an equivalent margins analysis based on weldment properties because the WOG concluded that all of the beltline welds would be above 50 ft-lb at end of license (EOL). As part of the GL 92-01 review, the staff will be evaluating each beltline weld for the WOG plants to determine if the screening criterion will be met at EOL. Individual licensees desiring to reference WCAP 13587, Revision 1, as the basis for addressing the USE requirements of 10 CFR 50, Appendix G must confirm the specific plant applicability by either demonstrating that all beltline welds will have EOL

CONTACT: E. Hackett, 301-504-2751

USE above 50 ft-lb or that the bounding plate used in the report has a lower J-R curve than any other beltline material in the vessel. Further, individual licensees must request approval in accordance with 10 CFR 50, Appendix G. The staff also concluded that comparison of applied fracture driving force with material fracture resistance was overly conservative for some of the cases analyzed. This issue was addressed for a limiting plant specific case by letter dated December 21, 1993, and the WOG is preparing a revision to the report which addresses all of the cases considered.

If you have any questions, please contact Ed Hackett of my staff at 301-504-2751.

Sincerely,

Jack Strosnider

for M. Wayne Hodges, Acting Director
Division of Engineering
Office of Nuclear Reactor Regulation

Enclosure:
As stated

ENCLOSURE

SAFETY ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REACTOR VESSEL UPPER SHELF BOUNDING EVALUATION

FOR WESTINGHOUSE PRESSURIZED WATER REACTORS

WCAP-13587, REVISION 1

1.0 REVIEW SUMMARY

The staff has evaluated the equivalent margins analysis presented in report WCAP-13587, Revision 1, submitted by the Westinghouse Electric Corporation for the Westinghouse Owners' Group (WOG). The staff finds the methodology employed and the analysis performed for the WOG to be acceptable except as noted herein. The report did not contain an equivalent margins analysis based on weldment properties because the WOG concluded that all of the beltline welds would be above 50 ft-lb at end of license (EOL). As part of the GL 92-01 review, the staff will be evaluating each beltline weld for the WOG plants to determine if the screening criterion will be met at EOL. Individual licensees desiring to reference WCAP 13587, Revision 1, as the basis for addressing the USE requirements of 10 CFR 50, Appendix G must confirm the specific plant applicability by either demonstrating that all beltline welds will have EOL USE above 50 ft-lb or that the bounding plate used in the topical report has a lower J-R curve than any other beltline material in the vessel. Further, individual licensees must request approval in accordance with 10 CFR 50, Appendix G. The staff also concluded that comparison of applied fracture driving force with material fracture resistance was overly conservative for some of the cases analyzed. This issue was addressed for a limiting plant specific case by letter dated December 21, 1993 [17], and the WOG is preparing a revision to the report which addresses all of the cases considered.

2.0 INTRODUCTION

By letter dated March 16, 1993, the Nuclear Management and Resources Council (NUMARC) submitted a report prepared by the Westinghouse Electric Corporation for the WOG entitled, "Reactor Pressure Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors," WCAP-13587, Revision 0 [1]. The report was provided to NRC as supplemental information in response to GL 92-01 [2]. No review and approval was requested. The report is intended to demonstrate through fracture mechanics analyses that there exist margins of safety against fracture equivalent to those required by Appendix G of ASME Code Section III for beltline materials having USE values below the NRC screening criteria of 50 ft-lb in 10 CFR 50, Appendix G. By letter dated July 1, 1993, the NRC issued a request for additional information (RAI) on the report [3]. The reply to the RAI was received by the NRC on August 20, 1993 and the NRC was notified that the report would be revised based on the RAI.

WCAP-13587, Revision 1 [4], incorporating the responses to the RAI, was subsequently submitted to the NRC through NUMARC by letter dated September 30, 1993.

3.0 APPLICABLE REGULATORY REQUIREMENTS AND GUIDELINES

Regulatory requirements for upper shelf safety margins are contained in Appendix G of The Code of Federal Regulations, Title 10, Part 50 (10CFR50). Appendix G requires that the initial unirradiated Charpy V- Notch (CVN) upper shelf energy at the start of vessel life be no less than 75 ft-lb and that the vessel maintain an upper shelf energy level of no less than 50 ft-lb throughout the service life. If it is anticipated that a vessel might fall below 50 ft-lb before EOL, an analysis must be submitted which demonstrates "margins of safety against fracture equivalent to those required by Appendix G of the ASME Code." This analysis is subject to the approval of the Director, Office of Nuclear Reactor Regulation.

Guidelines that the staff finds acceptable for conducting equivalent margins analyses are contained in ASME Code Case N-512 [5] and draft Regulatory Guide DG-1023, "Evaluation of Reactor Vessels with Charpy Upper Shelf Energy less than 50 ft-lb"[6]. DG-1023 incorporates the criteria of Code Case N-512 and provides additional guidance on material properties and transient selection. DG-1023 was released by NRC for public comment on October 1, 1993. NUREG/CR-6023 [7] presents the results of generic bounding equivalent margins analyses conducted according to Code Case N-512 guidelines for both PWRs and BWRs.

As the majority of licensees do not have fracture toughness information for their limiting vessel materials, CVN data is typically used to estimate the fracture toughness. Regulatory Guide 1.99, Revision 2 [8] provides a procedure for estimating the decrease in CVN upper shelf energy as a function of copper content and fluence. NUREG/CR-5729 [9] provides empirically derived models for predicting material fracture toughness (J-R curves) from CVN data or chemical content and fluence. The NUREG/CR-5729 models are applicable to the majority of RPV materials.

NRC Branch technical position MTEB 5-2 [10] provides criteria for estimating the CVN toughness for the transverse orientation from longitudinal data for plate materials. The 50 ft-lb criterion in 10CFR50, Appendix G is for CVN data from transversely oriented specimens in plate or for welds. The transverse orientation in plate material has lower impact properties than the longitudinal orientation. The impact properties of the weld metal are not differentiated based on orientation.

4.0 EVALUATION

The WOG employed the procedures and criteria of ASME Code Case N-512 [5] to perform the equivalent margins analysis. For service levels A and B, the WOG performed an analysis for the limiting normal operation cooldown rate (100°F/hr). The analysis is consistent with the guidelines provided in Code Case N-512 [5] and DG-1023 [6]. In accordance with both the Code Case and Draft Regulatory Guide, the WOG assumed a quarter thickness depth flaw for Levels A and B and a flaw depth of up to 1/10 of the base metal wall thickness

plus cladding for Levels C and D. The flaw geometry considered for all service conditions was a semi-elliptical surface flaw with a 6:1 aspect ratio. A question raised in the RAI [3] concerned the issue of whether both axial and circumferential flaws had been addressed as required by the Code Case. The response to the RAI [3] cited that both cases were considered and the applied fracture driving force for the axial flaws was in all cases greater than those for the circumferential flaws. Consequently, the axial flaw cases were considered limiting. The RPV beltline base materials covered by the WOG included:

(1) A302 Grade A (Plate)
(2) A302 Grade B (Plate)
(3) A533 Grade B, Class 1 (Plate)
(4) A508 Class 2 (Forging)
(5) A508 Class 3 (Forging)

The RPV beltline welds covered by the WOG include those produced using the following fluxes:

(1) Linde 1092
(2) Linde 1091
(3) Linde 0091
(4) Linde 124
(5) UM89
(6) ARCOS B5
(7) Grau Lo
(8) SMIT 89

Linde 80 weldments were not included in the WOG report. The WOG maintains that "weldments fabricated with fluxes other than Linde 80 will not exhibit less than 50 ft-lb during service." Weldments will be discussed further in Section 4.2. Table 1 provides the WOG overall minimum acceptable USE values by plant type (2, 3 or 4 loop) from the equivalent margins analysis. The values in Table 1 are based on fracture properties for plate and forging materials. No analysis was performed based on weldment properties since the WOG maintains that all of their weldments will exceed 50 ft-lb at EOL.

The equivalent margins analysis compared the EOL USE value for each plant with the minimum acceptable USE values shown in Table 1:

TABLE 1 Minimum Acceptable USE Values From WCAP 13587, Revision 1

CASE	LOWEST USE (ft-lb)
2 Loop	29
3 Loop	42
4 Loop	43

The EOL USE values for each plant were determined in accordance with the methodology provided in Regulatory Guide 1.99, Revision 2 [8]. The adequacy of the equivalent margins analysis can be determined from the following considerations: (1) selection of mechanical properties, (2) the determination of predicted EOL USE value, (3) selection of the model for generating the fracture toughness data (J-R curves), (4) selection of the limiting transients, (5) the calculation for applied fracture driving force ($J_{applied}$) and, (6) the bounding nature of the analysis.

4.1 Mechanical Properties

Plant specific values of tensile mechanical properties for all of the WOG vessel materials were requested in the RAI [3]. The WOG instead chose to bound the mechanical properties for all of the plants by using the ASME Code minimum allowable mechanical properties at 600°F. The stress-strain curve used in the equivalent margins analysis was generated using typical data for carbon steel and then adjusting the curve to match the ASME Code minimum values. The staff finds this methodology to be acceptable.

4.2 Predicted EOL USE Values

Initial upper shelf energy values were determined from material certification and surveillance test reports. GL 92-01 responses were also used to obtain supplemental CVN data. The EOL USE values were estimated using the Regulatory Guide 1.99, Revision 2 methodology [8]. Using this approach three plants were found to have EOL USE values below 50 ft-lb as shown in Table 2:

TABLE 2 WOG PLants with USE Less Than 50 ft-lb at EOL and Comparison with Minimum Acceptable USE Values From The Equivalent Margins Analysis

PLANT I.D. No.	CASE	SHELL COURSE	MATERIAL	PREDICTED EOL USE (ft-lb)	MINIMUM ACCEPTABLE USE (ft-lb)
7	3 Loop	Intermed.	A302 Gr A	46	42
7	3 Loop	Lower	A302 Gr B	42	42
37	4 Loop	Upper	A508 Cl 2	49	43
41	4 Loop	Intermed.	A508 Cl 3	44	43

The limiting material for all three plants was either plate (A302, A533) or forging (A508). A comparison of the predicted EOL USE values with the WOG minimum acceptable USE values in Table 1, shows that the predicted plant data is equal to or bounded by the minimum acceptable values for all three plants. The subject report also noted an additional case (Plant 16) where EOL USE above 50 ft-lb was not demonstrated for an A533 B plate. It was noted by the WOG that the USE values for the upper shell course of Plant 16 were based on data from unirradiated longitudinal specimens with less than 100% shear

fracture indicating that the tests did not represent full upper shelf behavior. The licensee for Plant 16 has submitted an additional analysis of the Charpy data for their beltline plates [18]. This submittal shows that the upper shell course plates will achieve an EOL fluence of only 4.85 E+17 n/cm^2 and therefore the percent drop in USE with irradiation is low (approximately 10%). With the small predicted drop in USE an initial value of only 56 ft-lbs is required for the upper shell course plates to remain above 50 ft-lb to EOL. The submittal demonstrates that, although full shear performance was not achieved in the CVN tests for two of the upper shell course plates, the extrapolation to an EOL USE greater than 56 ft-lbs for full shelf performance is reasonable. The staff finds this analysis to be acceptable.

As the WOG did not provide a listing which identified the WOG plants and their corresponding USE data by name, confirmation of the input data (chemistry and fluence) and calculations on a plant-by-plant basis was not possible.

As stated previously in Section 4.0, the WOG maintains that "weldments fabricated with fluxes other than Linde 80 will not exhibit less than 50 ft-lb during service." Table 2-2 in the subject report confirms this statement by showing a listing with initial USE and projected EOL USE values for each plant. The lowest EOL USE value reported was 50 ft-lb for Plant 17 with ARCOS B5 flux. As was the case with the base materials, the WOG did not provide a listing which identified the WOG plants and their corresponding USE data by name. Therefore, confirmation of the input data (chemistry and fluence) and calculations on a plant-by-plant basis was not possible. Further, since the minimum acceptable USE values from the equivalent margins analysis were based on fracture toughness data for plate or forging materials, these values will not apply to weldments. However, calculations performed for NUREG/CR-6023 [7] with the Linde 80 weld model have shown a minimum acceptable USE of 41 ft-lb for a PWR. The staff considers that, while weldments for the WOG plants are not likely to be limiting for USE, the subject report does not provide sufficient information to make this determination conclusively. As part of the GL 92-01 review, the staff will be evaluating each beltline weld for the WOG plants to determine if the screening criterion will be met at EOL.

4.3 Selection of the Fracture Toughness (J-R Curve) Model

The J-R curve information required for the equivalent margins analysis was generated from the bounding EOL USE values calculated for each plant category (2 loop, 3 loop and 4 loop). The J-R curves for RPV base materials were obtained from CVN data using the Charpy model of NUREG/CR-5729 [9]. As stated previously, the WOG maintains that all of the WOG welds will be above 50 ft-lb at EOL and therefore did not develop J-R data for welds. For levels A and B the J-R curves for a temperature of 390.5°F were used. This value represents the greatest temperature at the crack tip during the 100°F/Hr. cooldown for a 1/4T flaw based on peak stress results from a 2-D finite element analysis. For Levels C and D the temperatures used for the J-R curves were from the appropriate transients (in the range of 400°F - 500°F). The staff finds the approach to developing the J-R curve data for all of the WOG base materials to be acceptable with the exception of the method used for A302 B. For A302 B plate, the WOG considers the 6T C(T) J-R curve data of NUREG CR/5265 [11] to be a lower bound for a 50 ft-lb A302 B plate. The WOG adjusted the 6T data

for lower USE values by decreasing $J_{material}$ by 3% per ft-lb of CVN energy. This rate of decrease corresponds to the rate determined from the Charpy model of NUREG/CR-5729 [9]. The staff also consider the 6T A302 B data of NUREG/CR-5265 to be a lower bound for A302 B. However, the staff finds the overall J-R Curve adjustment procedure for A302 B to be unacceptable for the following reasons:

(1) The percent decrease in $J_{material}$ calculated to EOL for the limiting A302 B material assumed that the material in NUREG/CR-5265 [11] had a USE of 50 ft-lb. However, the actual USE for the A302 B material in NUREG/CR-5265 [11] is 53 ft-lb. Therefore the % decrease in $J_{material}$ cited for A302 B in the subject report should be approximately 33% as opposed to 24%.

(2) The resulting $J_{material}$ data were not temperature corrected. The data from NUREG/CR-5265 [11] were generated at a temperature of 180°F. The staff maintains that a temperature correction is necessary. One method that has been proposed for determining the decrease in $J_{material}$ with temperature for NUREG/CR-5265 [11] material is contained in reference [12]. Using the equation provided in this reference, the decrease in $J_{material}$ with temperature from 180°F to 390°F is approximately 34%.

Adjusting the analysis to account for the above yields a $J_{material}$ value at 0.1 inches of crack extension ($J_{0.1}$) which is significantly less than that obtained by the WOG. A methodology for adjusting A302 B J-R curve data which is similar to that in reference [12] and has been found acceptable by the staff is contained in the BWR Owners Group Topical Report NEDO-32205 [13]. It should be noted that the A302 B plate tested for NUREG/CR-5265 [11] was a high sulphur plate which received a minimal amount of cross rolling. The resultant fracture properties were severely degraded by the presence of large manganese-sulfide (MnS) inclusions. For these reasons, it is questionable whether the plate can be considered representative of A302 B which would have been used in RPV construction. However, until recently, NUREG/CR-5265 represented the only large scale fracture data that were available for A302 B. Hence, the staff have considered these data to be a lower bound for A302 B plate. Recent preliminary fracture test results from the Oak Ridge National Laboratory (ORNL) on a potentially more representative A302 B plate indicate vastly superior properties to those obtained in NUREG/CR-5265 [11]. The staff will consider the ORNL data and other available fracture data in establishing future positions for A302 B plate fracture resistance.

4.4 Selection of Limiting Transients

The subject report used the 100°F/hr heatup/cooldown case as bounding for Levels A and B. This is consistent with the evaluation performed in NUREG/CR-6023 [7]. For Levels C and D the WOG used both peak stress and the overall magnitude of the through-wall stress as the criteria to determine the bounding transients. The resulting temperatures at the crack tip (10% of wall thickness + cladding) were 511°F for Plant 17 and 487°F for the remaining plants. Using these criteria, it was judged that a small steam line break (SLB) was the limiting Level C transient and large loss of coolant accident

(LOCA) and large SLB were the limiting Level D transients. For Level D, the large SLB was ultimately selected as the limiting Level D transient as a stress analysis conducted by the WOG showed that the large SLB produced slightly larger stresses at the crack tip for a 1 inch deep flaw. In response to the RAI, the WOG provided the pressure and temperature histories for all of the transients considered in their assessment. Based on an examination of all of the transients the staff concludes that the limiting C and D transients selected by the WOG are acceptable.

4.5 Calculation of Applied Fracture Driving Force ($J_{applied}$)

The WOG employed the procedures of Code Case N-512 [5] and DG-1023 [6] in the determination of the fracture driving force ($J_{applied}$) for Levels A and B. The staff performed an independent evaluation of the $J_{applied}$ calculations for the limiting Plant 7 case and were able to verify the WOG calculations. For levels C and D the pressure and temperature histories for all of the transients considered were input to a 2-D finite element model of the nuclear steam supply system (NSSS) using the WECAN [14] computer code. The resulting stress distributions for the limiting transients, which included the contributions of the cladding to the thermal stress, were used to calculate $J_{applied}$ using the PCFAD [15] computer code. Consistent with the results of the bounding analyses performed for NUREG/CR-6023, the WOG $J_{applied}$ values for Levels A and B were found to be controlling. The staff finds the methodology employed by the WOG for calculation of the fracture driving force to be acceptable. However, the staff discovered that the final analysis for equivalent margins was overly conservative when comparing the fracture driving force ($J_{applied}$) with the material fracture resistance ($J_{material}$). This will be discussed in the next section.

4.6 Bounding Nature of the Analysis

The results of the WOG equivalent margins analysis are presented in Tables 3, 4 and 5 for Levels A, B, C and D. These Tables show a comparison between the applied driving force and material resistance values for the three generic cases (2, 3, and 4 loop) and two plant-specific cases. The WOG concluded that in all cases the criteria of Code Case N-512 were met ($J_{material} > J_{applied}$). However, in examining the Plant 7 case (A302B plate) in detail, the staff concluded that the material value for $J_{0.1}$ determined by the WOG was not acceptable (see Section 4.3). The material value that the staff estimated for $J_{0.1}$ for Plant 7 was well below the applied value calculated by the WOG. Further examination of this case revealed that the actual reason for exceeding the Code Case N-512 criteria was that the WOG had conservatively compared the applied driving force for the axial flaw with the material resistance for the weak orientation which corresponds to the circumferential flaw (i.e., meeting the criteria under these conditions assures that the criteria will also be met when the values are compared as suggested by the Code Case.) A conference call [16] with the Westinghouse Electric Corporation and the licensee for Plant 7 confirmed that this conservative analysis was performed for all of the cases evaluated. The staff considers this analysis to be overly conservative. In a revision letter dated December 21, 1993 [17] which specifically addresses the Plant 7 case, the WOG demonstrated that the appropriate comparison of the applied and material values shows that the Code Case N-512 [5] criteria were

met. The letter [17] also addressed the USE adjustment and temperature correction concerns for A302 B plate that were discussed previously in Section 4.3. The WOG is preparing a more comprehensive revision to the report which will address all of the cases considered. The staff concludes that, in the interim, the subject report and the alternative evaluation provided in the revision letter of December 21, 1993, demonstrate equivalent margins of safety as per Code Case N-512 [5] for WOG plate and forging materials.

For the case of welds, as stated previously, the WOG maintains that "weldments fabricated with fluxes other than Linde 80 will not exhibit less than 50 ft-lb during service." However, the WOG did not provide a listing which identified the WOG plants and their corresponding USE data by name. Therefore, confirmation of the input data (chemistry and fluence) and calculations on a plant-by-plant basis was not possible. Further, since the minimum acceptable USE values from the equivalent margins analysis were based on fracture toughness data for plate or forging materials, these values will not apply to weldments. Calculations performed for NUREG/CR-6023 [7] with the Linde 80 weld model have shown a minimum acceptable USE of 41 ft-lb for a PWR. Therefore the staff considers that, while weldments for the WOG plants are not likely to be limiting for USE, the subject report does not provide sufficient information to make this determination conclusively. As part of the GL 92-0I review, the staff will be evaluating each beltline weld for the WOG plants to determine if the screening criterion will be met at EOL.

In the subject report, the WOG cited a minimum acceptable USE value of 29 ft-lb for plates and forgings in 2 loop plants. While numbers this low can result from the calculations and have been cited elsewhere [6], [7], their significance is not clear at this time and they represent an extrapolation of the data used to develop the correlations in NUREG/CR-5729 [9]. There is not at present a technical consensus on the CVN energy lower limit for equivalent margins analyses. However, values below 30 ft-lb for reactor pressure vessel steels are highly suspect as such low energies are likely to be associated with ductile tearing in combination with other fracture modes (e.g., intergranular, incipient cleavage) not considered in the development of the low upper shelf criteria.

5.0 CONCLUSIONS

The staff has evaluated the equivalent margins analysis presented in report WCAP-13587, Revision 1, submitted by the Westinghouse Electric Corporation for the WOG. The staff evaluation supports the following conclusions:

(1) The methodology employed for the WOG report was consistent with the guidelines in Code Case N-512 [5] and DG-1023 [6] and is therefore acceptable to the staff.

(2) The subject report demonstrates margins of safety equivalent to those of the ASME Code for WOG beltline plate and forging materials.

(3) An equivalent margins analysis based on weldment properties was not performed because the WOG concluded that all of the WOG beltline welds would be above 50 ft-lb at EOL. As part of the GL 92-01 review, the

staff will be evaluating each beltline weld for the WOG plants to determine if the screening criterion will be met at EOL.

(4) Individual licensees desiring to reference WCAP 13587, Revision 1, as the basis for addressing the USE requirements of 10 CFR 50, Appendix G must confirm the specific plant applicability by either demonstrating that all beltline welds will have EOL USE above 50 ft-lb or that the bounding plate used in the report has a lower J-R curve than any other beltline material in the vessel. Further, individual licensees must request approval in accordance with 10 CFR 50, Appendix G.

(5) The staff finds the WOG approach for modeling the J-R curve behavior of the A302 B plate in WCAP-13587, Rev. 1, to be unacceptable (see Section 4.3). However, the A302 B J-R curve methodology employed in the plant specific revision letter of December 21, 1993 [17] includes appropriate adjustments for USE and temperature corrections and is acceptable to the staff.

(6) The staff finds that the final comparison of applied fracture driving force with material fracture resistance was overly conservative for all cases analyzed. This issue was adequately addressed for a limiting plant specific case by letter dated December 21, 1993 [17], and the WOG is preparing a revision to the report which addresses all of the cases considered.

(7) Calculated minimum acceptable USE values below 30 ft-lb for reactor pressure vessel steels are highly suspect as such low energies are likely to be associated with ductile tearing in combination with other fracture modes (e.g., intergranular, incipient cleavage) not considered in the development of the low upper shelf criteria.

6.0 REFERENCES

[1] WCAP-13587, Revision 0, "Reactor Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors", S. Tandon and T.R. Mager, Westinghouse Electric Corporation, February, 1993.

[2] Generic Letter 92-01, Revision 1, Reactor Vessel Structural Integrity, 10 CFR 50.54(f), U.S. Nuclear Regulatory Commission, March 6, 1992.

[3] Request for Additional Information on WCAP-13587, "Reactor Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors," U.S. Nuclear Regulatory Commission, July 1, 1993.

[4] WCAP-13587, Revision 1, "Reactor Vessel Upper Shelf Energy Bounding Evaluation for Westinghouse Pressurized Water Reactors", S. Tandon M.J. Malone and T.R. Mager, Westinghouse Electric Corporation, September, 1993.

[5] Code Case N-512, "Assessment of Reactor Vessels with Low Upper Shelf Charpy Impact Energy Levels," Section XI, Division 1, ASME Boiler and Pressure Vessel Code, February 12, 1993.

[6] Draft Regulatory Guide DG-1023, "Evaluation of Reactor Pressure Vessels with Charpy Upper Shelf Energy Less than 50 ft-lb," U.S. Nuclear Regulatory Commission, August, 1993.

[7] NUREG/CR-6023, "Generic Analyses for Evaluation of Low Charpy Upper Shelf Energy Effects on Safety Margins Against Fracture of Reactor Pressure Vessel Materials," T.L. Dickson, USNRC, Washington, DC, July 1993.

[8] Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," U.S. Nuclear Regulatory Commission, May, 1988.

[9] NUREG/CR-5729, "Multivariable Modeling of Pressure Vessel and Piping J-R Data," E.D. Eason, J.E. Wright and E.E. Nelson, USNRC, Washington, DC, 1991.

[10] NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition," Branch Technical Position - MTEB 5-2, Fracture Toughness Requirements, Section 5.3.2, USNRC, Washington, DC, 1981.

[11] NUREG/CR-5265, "Size Effects on J-R Curves for A302-B Plate," A.L. Hiser and J.B. Terrell, USNRC, Washington, DC, 1989.

[12] Memorandum, A.L. Hiser and S.N.M. Malik of USNRC to K.R. Wichman, USNRC, "J-R Curves for Low Toughness A302 B Plate," USNRC, September 9, 1993.

[13] NEDO-32205, "10CFR50 Appendix G Equivalent Margin Analysis for Low Upper Shelf Energy in BWR/2 Through BWR/6 Vessels," Licensing Topical Report for the BWR Owners' Group, GE Nuclear Energy, April, 1993.

[14] Westinghouse Electric Computer Analysis (WECAN) Code, File 87-1J7-WESAD-R1, dated December 1987.

[15] Bloom, J.M. and D.R. Lee, "Users Guide for the Failure Assessment Diagram Computer Code FAD," Babcock and Wilcox, Rev. 4, April 1990.

[16] Conference Call, NRC, Carolina Power & Light and Westinghouse, December 13, 1993.

[17] Letter from D.B. Waters, Carolina Power & Light Company to USNRC, of December 21, 1993, "Carolina Power & Light Company, H.B. Robinson Steam Electric Plant - Unit No. 2, Docket No. 50-261/License No. DPR-23, Reactor Vessel Upper Shelf Energy For Reactor Vessel Core Region Plate Materials."

[18] Letter from E.E. Fitzpatrick, Indiana Michigan Power to T.E. Murley, USNRC, AEP:NRC:1173B, with Attachment entitled, "American Electric Power Service Corporation, Donald C. Cook Nuclear Plant Unit 2, Upper Shelf Charpy Values," January 24, 1994.

TABLE 3 $J_{applied}$ vs. $J_{material}$ for Levels A & B from WCAP 13587, Revision 1, (Units on J are in-lbs/in^2)

CASE	APPLIED		MATERIAL		MET CRITERIA?
	$J_{0.1}$	dJ/da	$J_{0.1}$	dJ/da	
2 Loop	384	318	702	2925	Yes
3 Loop	500	321	585 (527)	2140 (599)	Yes
4 Loop	590	345	614	2330	Yes
Plant 7	525	222	527	599	Yes
Plant 17	548	197	614	2330	Yes

( ) - Calculations based on J-R Curves from Reference 11

TABLE 4 $J_{applied}$ vs. $J_{material}$ for Level C from WCAP 13587, Revision 1 (Units on J are in-lbs/in^2)

CASE	APPLIED		MATERIAL		MET CRITERIA?
	$J_{0.1}$	dJ/da	$J_{0.1}$	dJ/da	
2 Loop	311	225	702	2925	Yes
3 Loop	310	252	585 (527)	2140 (599)	Yes
4 Loop	311	225	614	2330	Yes
Plant 7	308	250	527	599	Yes
Plant 17	319	240	614	2330	Yes

( ) - Calculations based on J-R Curves from Reference 11

TABLE 5 $J_{applied}$ vs. $J_{material}$ for Level D from WCAP 13587, Revision 1 (Units on J are in-lbs/in^2)

CASE	APPLIED dJ/da	MATERIAL dJ/da	MET CRITERIA ?
2 Loop	447	2925	Yes
3 Loop	447	2140 (599)	Yes
4 Loop	447	2330	Yes
Plant 7	443	599	Yes
Plant 17	468	2330	Yes

( ) - Calculations based on J-R Curves from Reference 11