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July 24, 2001

2CAN070102

U. S. Nuclear Regulatory Commission
Document Control Desk
Mail Station OP1-17
Washington, DC 20555

Subject: Arkansas Nuclear One - Unit 2
Docket No. 50-368
License No. NPF-6
ANO-2 Pressure/Temperature Curves

Gentlemen:

Entergy Operations, Inc. submitted a license application on December 19, 2000 (2CAN120001), to increase the authorized power level for Arkansas Nuclear One, Unit 2 (ANO-2) from 2815 megawatts thermal to 3026 megawatts thermal. On June 6, 2001, the NRC staff requested written responses to three questions posed by Reactor Systems Branch personnel regarding the December 19, 2000, application. Telephone discussions between Entergy and the NRC staff had previously been held on May 14 and 31, 2001. The attachment contains the written responses. This submittal contains no regulatory commitments.

I declare under penalty of perjury that the foregoing is true and correct.

Very truly yours,

Jimmy D Vandergrift

Jimmy D. Vandergrift
Director, Nuclear Safety Assurance

JDV/dwb
Attachment

A001

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Response to NRC RAI on Pressure/Temperature Curves

On May 31, 2001, the staff held a conference call with the licensee regarding the Pressure/Temperature (P/T) curves. The change of the applicability period (from 21 to 17 effective full power years (EFPYs)), the expected results of the latest surveillance capsule, and the implications of the 7.5% power uprate for the P/T curves were discussed. As discussed in the conference call, the staff needs the following information to continue the power uprate review:

NRC Question 1

Identify the change of the beltline controlling element, and the associated chemistry and fluence factors.

ANO Response

The ANO-2 reactor vessel is made up of six beltline plates and eight welds. These are identified as:

C8009-1, -2, -3	Intermediate Shell Plates
C8010-1, -2, -3	Lower Shell Plates
2-203-A, B, C	Intermediate Shell Longitudinal Welds
3-203-A, B, C	Lower Shell Longitudinal Welds
8-203	Upper / Intermediate Shell Girth Weld
9-203	Lower / Intermediate Shell Girth Weld

Provided below is a discussion of the limiting component and the changes in the chemistry factor and fluence factor for each of these components except weld 8-203. The fluence to this weld is significantly lower than what is seen by the other beltline components. As noted above this is the Upper Shell to Intermediate Shell Girth Weld. It is in the upper portion of the beltline region. For additional information concerning this weld, see letter to the NRC dated November 2, 1998 (2CAN119803), "Additional Information Regarding Reactor Pressure Vessel Integrity."

The limiting component is the one with the highest adjusted reference temperature (ART) value at the end of the period under consideration at the quarter and three-quarter vessel wall thickness (1/4t and 3/4t) locations. The calculational procedure for the ART values for each component in the beltline is given by the following expression:

$$\text{ART} = \text{Initial } RT_{NDT} + \Delta\, RT_{NDT} + \text{Margin}$$

Initial RT_{NDT} is the reference temperature for the unirradiated material.

Δ RT_{NDT} is the mean value of the adjustment in the reference temperature caused by irradiation and is given as the product of the chemistry factor and the fluence factor. The chemistry factor is a function of residual element content, i.e., weight percent copper and nickel. The fluence factor is the neutron fluence at any depth in the vessel from the inside surface of the vessel. It is dependent upon the calculated value of the neutron fluence (10^{19} n/cm^2) at the inner wetted surface of the vessel.

Margin is the quantity that is added to obtain a conservative upper bound value of ART.

Regulatory Guide 1.99, "Radiation Embrittlement of Reactor Vessel Materials," Revision 2 provides the values for the chemistry factors given the copper and nickel content. The equation to determine the fluence factor and the margin term is also included in the regulatory guide.

As part of the efforts to respond to Generic Letter 92-01, "Reactor Vessel Structural Integrity," Revision 1, Supplement 1, a vessel specific summary of the evaluated fabrication records was developed. Table 1 provides a comparison of the best estimate original and revised copper and nickel values for the beltline materials listed above.

TABLE 1: COMPARISON OF ORIGINAL TO REVISED BEST-ESTIMATE CU/NI CONTENT

COMPONENT	ORIGINAL Cu%	ORIGINAL Ni%	REVISED Cu%	REVISED Ni%
C8009-1	0.12	0.63	0.098	0.605
C8009-2	0.08	0.59	0.085	0.600
C8009-3	0.08	0.60	0.096	0.580
C8010-1	0.08	0.59	0.085	0.585
C8010-2	0.07	0.66	0.083	0.668
C8010-3	0.07	0.65	0.080	0.653
2-203-A, B, C	0.05	0.18	0.046	0.082
3-203-A, B, C	0.05	0.18	0.046	0.082
9-203	0.05	0.08	0.045	0.087

The term "original" is used to define the values used in the development of the current ANO-2 pressure/temperature limits. These values were from before the efforts associated with the response to Generic Letter 92-01. The "revised" data is as a result of the Generic Letter 92-01 work.

Using the best-estimate chemistry values in Table 1 above and Table 1 of Regulatory Guide 1.99, Revision 2 for the welds and Table 2 for the plates, a chemistry factor (CF) was obtained. Table 2 provides a comparison of the original and revised chemistry factors.

TABLE 2: COMPARISON OF ORIGINAL TO REVISED CHEMISTRY FACTORS

COMPONENT	ORIGINAL CF	REVISED CF
C8009-1	83	63.6
C8009-2	51	54.5
C8009-3	51	62.2
C8010-1	51	54.5
C8010-2	44	53.1
C8010-3	44	51.0
2-203-A, B, C	47	34
3-203-A, B, C	47	34
9-203	35	34.1

The peak inside surface fast neutron fluence was determined to be $3.74 * 10^{19}$ n/cm^2 at 21 EFPY from the surveillance capsule that was removed at 1.69 EFPY. This is based on the rate of $1.78 * 10^{18}$ n/cm^2 per EFPY for these locations.

The shell course minimum reference thickness is 7.875 inch for both the lower and intermediate shell.

Using the information above and the equation provided in Regulatory Guide 1.99, Revision 2, the fluence at the 1/4t and 3/4t locations are $2.33 * 10^{19}$ n/cm^2 and $9.06 * 10^{18}$ n/cm^2, respectively.

Based on the information above, the 1/4t fluence factor is 1.23 and the 3/4t fluence factor is 0.97 at 21 EFPY. The fluence factor did not change due to the Generic Letter 92-01 effort.

To assist in the review of the controlling component, Table 3 provides the initial RT_{NDT} and the margin term for each component. These terms were not impacted by the work associated with Generic Letter 92-01.

TABLE 3: INITIAL RT_{NDT} AND MARGIN TERM

COMPONENT	**INITIAL RT_{NDT}, °F**	**MARGIN**
C8009-1	-26	34
C8009-2	0	34
C8009-3	0	34
C8010-1	12	34
C8010-2	-28	34
C8010-3	-30	34
2-203-A, B, C	-56	66
3-203-A, B, C	-56	66
9-203	-10	56

Using the equation provided earlier, the ART values can be determined. Table 4 provides the original ART values for the 1/4t and 3/4t locations. These values were used to develop the current pressure/temperature limits listed in the ANO-2 Technical Specifications. They were based on the 21 EFPY fluence value.

TABLE 4: ORIGINAL 1/4T AND 3/4T ART VALUES

COMPONENT	**1/4T, °F**	**3/4T, °F**
C8009-1	111	89
C8009-2	97	84
C8009-3	97	84
C8010-1	109	96
C8010-2	60	49
C8010-3	58	47
2-203-A, B, C	67	46
3-203-A, B, C	67	46
9-203	76	58

In reviewing the information in Table 4 the controlling components are Plate C8009-1 and C8010-1 for the 1/4t and 3/4t locations, respectively.

Table 5 provides similar information (21 EFPY fluence value) for the plates except it uses the revised chemistry factors. The welds were not reevaluated since they were not the limiting components originally. In addition, the chemistry factor is the only term that changed in the ART determination and the revised chemistry factors for the welds are equal to or less than the original ones.

TABLE 5

REVISED 1/4T AND 3/4T ART VALUES

COMPONENT	1/4T	3/4T
C8009-1	86.2	69.9
C8009-2	101.0	87.0
C8009-3	110.4	94.5
C8010-1	**113.0**	**99.0**
C8010-2	71.2	57.6
C8010-3	66.7	53.6

It can be seen that Plate C8010-1 is the new limiting component for both the 1/4t and 3/4t locations due to the change in the best-estimate chemistry values.

The above information is a summary of the information that was also provided in response to Generic Letter 92-01, Revision 1, Supplement 1. This response was transmitted to the Nuclear Regulatory Commission in letter dated June 18, 1997, "Response to Generic Letter 92-01, Revision 1, Supplement 1, 'Reactor Vessel Structural Integrity,' for ANO-2" (letter 2CAN069709). The impact of the change in the chemistry values on the various reactor vessel evaluations is addressed in that submittal as well.

NRC Question 2

Describe the proposed time-line of events for the revision of the period of applicability for Technical Specification Figures 3.4-2A, 3.4-2B and 3.4-2C and the expected revisions to be made when the surveillance capsule results become available.

ANO Response

The new P/T curves for Arkansas Nuclear One, Unit 2 (ANO-2) will incorporate the surveillance capsule results and include the 7.5% power uprate fluence that is scheduled for Cycle 16 forward. Cycle 16 is expected to begin about May 18, 2002. Revised P/T curves for ANO-2 will be submitted to the NRC in sufficient time to allow six months for NRC review and approval. This schedule should provide sufficient time for NRC approval of the new P/T curves before expiration of the current operating P/T curves. The new P/T Curves are being developed for use up to current end of life (32 effective full power years).

NRC Question 3

Describe your calculation of the fluence (in terms of actual fluence and flux values for energies greater than 1.0 million electron volts (E>1.0 MeV)) for the controlling element and the conservatisms built into your calculation which justify operation to 17 EFPYs. This period of operation extends into the next cycle (Cycle 16) at your proposed elevated power operation; therefore, please define the expected period at elevated power operation and the expected flux to the controlling element.

ANO Response

To date ANO-2 has removed two (2) of the reactor vessel surveillance specimens. The first specimen was removed at the end of Cycle 2 (1.69 EFPY). A summary report of the analysis of this specimen was provided in letter dated February 8, 1985, "Reactor Vessel Surveillance Capsule Summary Report" (2CAN028503). The second specimen was removed after ~15.7 EFPYs of operation (end of Cycle 14). The report of the analysis of the second capsule has not yet been submitted to the NRC. The second specimen was removed on November 13, 2000. Consistent with the requirements of 10CFR50, Appendix H, IV.A, the summary report will be submitted within one year of capsule removal. The current fluence predictions are based upon the results of the first capsule.

The current fluence extrapolation is based on the 1.69 EFPY capsule work. Personnel from Battelle's Columbus Laboratory used the following methodology to analyze the 1.69 EFPY specimen for ANO-2. The energy and spatial distribution of neutron flux in the reactor were calculated using the DOT IV 4.3 computer program. This program solves the Boltzmann transport equation in two-dimensional geometry using the method of discrete ordinates. Both R-Θ and R-Z runs were made to effectively produce a 3-D model. The computer code FLUX was written to combine the DOT code runs and calculate fluxes at points of interest in the vessel. The reactor power history was then factored into the equation. The 47-group structure is that of the RSIC Data Library BUGLE-80, and neutron absorption, scattering, and fission cross sections used were those supplied by this library. Additional details on the methodology can be found in the summary report referenced above.

Based upon the Battelle methodology it was determined that the maximum fast neutron fluence at the 1/4t location was $1.4 * 10^{18}$ n/cm^2 over 1.69 EFPY. The vessel surface fluence was not explicitly cited in the Battelle summary report; therefore a conservative value was derived and used in the ANO-2 evaluation. Using a similar equation to determine the fluence at any point in the material as given in Regulatory Guide 1.99, Revision 2, it was determined that the inside reactor vessel surface fluence at 1.69 EFPY was $3.01 * 10^{18}$ n/cm^2 ($1.78 * 10^{18}$ n/cm^2 per EFPY). Based on this correlation, the projected fast neutron fluence at 21 EFPY is $3.74 * 10^{19}$ n/cm^2. This is the basis for the current ANO-2 pressure/temperature limits.

The difference between the two equations was the coefficient used in the exponential term. The Regulatory Guide uses a coefficient of 0.24. The coefficient used in the ANO-2 evaluation was 0.37. This value was derived using ANO-2 specific values.

In addition to the technical specification required in-vessel surveillance capsules, ex-vessel/cavity dosimetry was installed to provide an alternative method of assessing vessel exposure. Cavity monitors were installed from the initial startup physics testing until Cycle 7 of operation. They provided a continuous record of exposure with the exception of the first 39.8 effective full power days (EFPDs) of operation. This work is documented in EPRI Report NP-5733 Project 772-4, "Pressure Vessel Neutron Dosimetry at three PWRs," April 1988, and EPRI report NP-4238 Project 827-4, "Neutron Energy Spectra in the Core and Cavity of the ANO-2 PWR," September 1985. Using the information for this work, the surface fluence at 1.69 EFPY was determined to be $2.049 * 10^{18}$ n/cm^2. The EPRI report noted "that the geometry factors used account only for fluence rate variations in the radial direction and therefore can only be used to obtain exposure parameters for the same azimuthal locations and elevations as the experiments. These do not necessarily correspond with the maxima of the azimuthal fluence rate distribution or the critical longitudinal weld." Since this work does not result in a maximum fluence value, it was determined that the capsule work, performed by Battelle, was the appropriate value to base the 21 EFPY extrapolation.

In reviewing the cavity dosimetry work it was noted that through approximately 1500 EFPD (end of Cycle 5), the fluence increases at almost a constant linear rate. Beginning in Cycle 6, however, the rate decreases as expected due to a change in fuel management in Cycle 6. Cycle 6 was the first transition cycle to a low leakage core design. The exposure rate decreases further in Cycle 7 as the low leakage core design has a dramatic effect. ANO-2 has maintained a low leakage core design since that time.

The increase in fluence through the end of Cycle 2 when the surveillance capsule was removed is much greater than what will be realized with the incorporation of the low leakage core design. This trend was also noted in the draft report of the analysis of the second capsule. The use of a low leakage core design demonstrates that an extrapolation utilizing the 1.69 EFPY surveillance capsule work will be conservative with respect to actual fluence experienced by the vessel. As part of the close out of the Generic Letter 92-01 efforts, letter 2CNA079901 dated July 8, 1999, includes a discussion documenting the NRC's earlier review of the currently accepted fluence values.

Another indication of the conservatism in using this extrapolation can be found in the analysis of the second specimen. Based on the draft report, the maximum inside surface fluence at the end of Cycle 14 (15.7 EFPY) was determined to be $2.0006 * 10^{19}$. Using the extrapolation listed above, the fluence is determined to be $2.7946 * 10^{19}$ using the methodology of BAW 2241A, Revision 1.

As can be seen in the response to NRC question 1, the ART values for the limiting component at 21 EFPY is beyond those used in the development of the current pressure/temperature limits. If one shortens the exposure limit from 21 EFPY to 17.0 EFPY, the ART values used in the pressure/temperature limits bound the revised ones (111°F versus 110°F at the 1/4t and 96.0°F versus 95.8°F at the 3/4t location), utilizing the extrapolation listed above. It should be noted that the 0.2°F difference between the 3/4t ART values represents a conservatism of approximately 0.25 EFPY. Credit has not been taken for this conservatism.

These revised ART values are at a surface fluence value of $3.03 * 10^{19}$ n/cm^2. The total ANO-2 exposure at the beginning of Cycle 15 was 15.69 EFPY, with an approximate fluence of $3.019 * 10^{19}$ n/cm^2. The average neutron fluence accumulation rate of $4.876 * 10^{15}$ n/cm^2 per EFPD. Cycle 15 has a scheduled duration of 458 EFPD. At the end of Cycle 15, the total exposure is predicted to be 16.96 EFPY. If the neutron flux is raised by 7.5% (based on a power uprate of 7.5%), Cycle 16 could be operated for 21 EFPDs prior to reaching the fluence level of $3.03 * 10^{19}$ n/cm^2.

It has been noted that some non-conservatism may have been introduced by using the linear extrapolation outlined above for the power uprate (e.g., the rate may be slightly higher than $1.78 * 10^{18}$ / EFPY). Entergy believes that more than enough conservatism in this approach has been demonstrated to account for this concern. This is in addition to the relative short time of operation at uprated conditions.