Entergy

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2CAN020202

February 5, 2002

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

SUBJECT:
Arkansas Nuclear One, Unit 2
Docket No. 50-368
License No. NPF-6

Response to NRC Request for Additional Information on ANO-2 Reactor Coolant Pump Flywheel Inspection Interval

REFERENCES:

1. Entergy Letter to NRC dated July 31, 2001, "Change to the ANO-2 Reactor Coolant Pump Flywheel Inspection Interval Surveillance Requirements" (2CAN070107)
2. W. Oldfield, et al., Nuclear Plant Irradiated Steel Handbook, EPRI NP-4797, September, 1986
3. Topical Report SIR-94-080-A, Revision 1, *"Relaxation of Reactor Coolant Pump Flywheel Inspection Requirements," (September 1999)*
4. NRC Letter from Brian Sheron to Dwight Mims dated May 21, 1997, "Acceptance for Referencing of Topical Report SIR-94-080, *Relaxation of Reactor Coolant Pump Flywheel Inspection Requirements"* (0CNA059718)
5. NRC Letter from Tom Alexion to Craig Anderson dated November 9, 2001, "Request For Additional Information On Reactor Coolant Pump Flywheel Inspection Interval Application - Arkansas Nuclear One, Unit 2" (2CNA110101)
6. ANO-2 Final Safety Analysis Report, Amendment No. 29, June 20, 1975, Section 5.2.6.1

Dear Sir or Madam:

Entergy Operations, Inc. submitted a license amendment request (Ref. 1), to modify the Arkansas Nuclear One, Unit 2 (ANO-2) Technical Specifications (TS) Surveillance Requirement (SR) 4.4.10.1. This SR requires performance of the reactor coolant pump (RCP) flywheel inspections in accordance with the recommendations of Regulatory Position C.4.b of Regulatory Guide (RG) 1.14, Revision 1, *Reactor Coolant Pump Flywheel Integrity* (August 1975). Paragraph (1) of Regulatory Position C.4.b requires an in-place ultrasonic volumetric examination of the areas of higher stress concentration at the bore and key way at

A047

approximately 3-year intervals. Entergy proposed to extend the flywheel inspection interval to once every 10 years. Structural Integrity Associates, Inc. prepared Topical Report SIR-94-080-A, Revision 1, (Ref. 3) which concluded that there is sufficient structural margin in the RCP flywheels evaluated that the integrity is assured between 10 year inspections. The NRC reviewed and approved the topical report as provided in Reference 4.

During a subsequent conference call, the NRC Staff questioned the adequacy of the documentation for the original ANO-2 flywheel to ensure the fracture toughness of the ASTM A-533, Grade B, Class 1 steel. As a result the NRC Staff issued a Request for Additional Information (RAI) dated November 9, 2001 (Ref. 5).

Since additional testing of the ANO-2 flywheels cannot be performed, Entergy with the support of Structural Integrity Associates has further evaluated the original test information of the ANO-2 flywheels and has prepared supplemental information in Attachment 1 justifying the adequacy of the ASTM, A-533 flywheel material to meet the minimum 100 ksi√in fracture toughness as concluded in Reference 3. The conclusions reached by Structural Integrity Associates in the attached response are similar to those reached in the current ANO-2 FSAR Section 5.2.6.1 as well as the original Operating License FSAR (Ref. 6) for compliance to Regulatory Guide 1.14. The FSAR concluded that the ANO-2 RCP flywheels have a minimum fracture toughness equivalent to a stress intensity factor of at least 100 ksi√in. Entergy believes that the attached supplemental information provides adequate basis for the NRC to reach the conclusion that the ANO-2 RCP flywheels have sufficient fracture toughness to defer their inspection to a once in 10-year frequency as requested by Entergy in Reference 1.

There are no new commitments being provided in this letter. If you require additional information, please contact Steve Bennett at 479-858-4626.

I declare under penalty of perjury that the foregoing is true and correct. Executed on February 5, 2002.

Sincerely,

Glenn R. Ashley

Glenn R. Ashley
Manager, Licensing

GRA/sab

Attachment 1: Response to NRC Request for Additional Information Regarding ANO-2 Flywheel Inspection Extension

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Response to NRC Request for Additional Information Regarding ANO-2 Flywheel Inspection Extension

NRC Request:

The licensee did not provide any basis for using the nil-ductility transition temperature (NDT) as the reference temperature (RT_{NDT}) for the RCP flywheel material. Based on the two Charpy test data of 63 ft-lbs. and 105 ft-lbs. performed at 150°F, the NRC staff used the American Society of Mechanical Engineers (ASME) Code procedure and determined that the RT_{NDT} value of the RCP flywheel material is 90°F instead of 10°F as stated in the submittal, and the fracture toughness (K_{IC}) is 50 ksi square-root-inch instead of 180 ksi square-root-inch as stated in the submittal. Provide additional information to support your RT_{NDT} value of 10°F. If you plan to propose an alternative methodology in determining the K_{IC} value to replace the use of the K_{IC} versus (T-RT_{NDT}) curve in the ASME Code, you need to submit a relief request.

ANO-2 Response:

In March 1995, Structural Integrity Associates completed a topical report (Ref. 3) for a group of CE plant owners that justified relaxation of the reactor coolant pump (RCP) flywheel inspection requirements currently specified in Regulatory Guide (RG) 1.14, Revision 1. Part of the justification for the relaxation of the inspection requirements was based on a stress analysis and fracture mechanics evaluation performed in Reference 3. In the fracture mechanics evaluation performed in Reference 3, a fracture toughness (K_{Ic}) value of 100 ksi $\sqrt{in}$ was used for the ASTM A-533, Grade B, Class1 flywheel material for ANO-2.

The fracture mechanics evaluation in Reference 3 was performed in accordance with ASME Code, Section XI, Subsection IWB-3600. The acceptance criteria in this case involved the use of the fracture toughness versus temperature curve in Appendix A of ASME Section XI which requires the operating temperature to be indexed to the reference nil-ductility temperature (RT_{NDT}). However, the purchase specification of ANO-2 flywheels did not require the determination of RT_{NDT} since the specification was designed to meet the requirements of RG 1.14, Rev. 1. The specific requirements in the purchase specification were that the material nil-ductility transition temperature (NDTT) be +10°F or lower and a Charpy upper shelf energy be greater than 50 ft-lbs.

In the material testing of original ANO-2 flywheels, the nil-ductility transition temperature (NDTT) was determined for the two melts (-20°F for Melt B5070 and 10°F for Melt B5083). Charpy values were also determined at a temperature of 150°F. Absorbed energies were greater than 100 ft-lbs for Melt B5070 and 63, 68, and 65 ft-lbs for Melt B5083 (contained in Ref. 5 of Ref. 3 of this letter). The reference nil-ductility temperature (RT_{NDT}) as defined in ASME Code Section III was not determined. RT_{NDT} is used together with Figure A-4200 of ASME Code Section XI to determine the fracture toughness (K_{Ic}) at the operating temperature of the flywheel. A very conservative method as described below is proposed to determine RT_{NDT} and hence K_{Ic} for the original ANO-2 flywheels.

Topical Report SIR-94-080-A, Revision 1 (Ref. 3) considers nominal operating containment air temperatures of 100°F to 110°F for consideration in determining the fracture toughness of the RCP flywheels at conditions where they will be typically operating. However, operating temperatures different from the reference temperature of the report can be justified based on plant specific information available to the licensee.

Entergy has two air temperature sensors located in each of the ANO-2 Steam Generator (SG) cavities which contain the RCPs. These sensors are located at approximately the 376' elevation. The bottom of the ANO-2 RCP motors are at a nominal 380' elevation and are approximately 15.5' high (approx. El. 395). The temperatures in the cavities at the 376' elevation averaged 95°F or less during an approximate 12-month period in 2001. However, at this elevation the air temperatures are primarily reflective of cooled air from the containment cooler supply fans since there is only moderate heatup as a result of thermal loads from the RCS. The RCPs are 6750 horsepower motors and generate significant heat under normal RCS operating conditions. At the higher cavity elevations the temperatures increase due to the more dominant heat loads from the RCPs, steam generators and RCS. During ANO-2 Cycle 14 operation (prior to containment cooler improvement in the fall of 2000) Entergy installed temporary air temperature data loggers in various locations in the SG cavities to collect temperature data for steam generator replacement. Various elevations were selected including both cavities in the vicinity of the RCPs. Two channels of temperature measuring devices were installed in each cavity at elevation 392' (A SG cavity) and 390' (B SG cavity) for approximately 18 months during cycle 14. The lowest daily maximum averages indicated that the temperatures during this period were 116°F and 114°F, respectively for the subject A and B cavity instruments. The permanently installed temperature indicators in the cavity at elevation 376' prior to and after cooler replacement showed an approximate 4 to 5°F reduction in temperature as a result of the new coolers. It is expected that the air temperatures at elevation 390'/392' would show a similar reduction but would still indicate increased temperatures at higher elevations around the RCPs.

As noted above, the RCPs run at substantially hotter temperatures than the surrounding air temperatures since they are a source of heat load to the cavity temperatures. As shown on Figure 1, the flywheels are located above the motor windings and below the anti-reverse device and the thrust and upper guide bearings. The RCP stator windings are cooled by drawing air from air inlet locations below the RCP flywheels and then discharging through the stator outlet ports below the RCP flywheels. The flywheel is separated from the stator compartment by a divider plate at the top of the air inlets. The flywheels receive a small amount of cooling air as it is drawn into the motor. The RCPs have installed temperature indicators at various locations throughout the motors. Table 1, with corresponding locations shown on Figure 1; provide a listing of various component temperatures in each of the four RCP motors. This data was collected for the period from January 2001 to January 2002. All components show an average temperature of no less than 122°F. The stator windings provide the greatest heat load from the RCPs, which have average temperatures of greater than 180°F. Even though the flywheel does not have temperature indication, the compartment containing the flywheel is immediately above the compartment containing the motor windings. It is expected that the flywheel compartment will receive significant heat load through conduction and convection from the adjacent compartment with the motor windings. This will provide additional warming of the flywheels.

Therefore, Entergy believes that the overall operation of the RCPs is well in excess of the ambient air temperature and that the flywheels operate at a temperature well in excess of

112°F. As provided below, Entergy has elected to perform the fracture toughness evaluation at a conservative nominal operating temperature of 112°F, as follows.

Industry experience with a large number of "full" Charpy curves for A-533, Grade B and related materials has shown that the inverse slope of the transition region is 2°F per ft-lb. General Electric Company has generated a procedure for estimating TT_{50} that uses that same correlation for the inverse slope of the transition region when full Charpy curves are not available [GE Specification Y1006A006, Methods for Establishing Initial Reference Temperatures for Vessel Steels for Certain Plants, 1979].

For this evaluation, an independent assessment of Charpy impact data from A533, Grade B and similar materials was conducted to confirm the 2°F per ft-lb inverse slope relationship. Data from unirradiated reactor vessel materials as reported in EPRI's Nuclear Plant Irradiated Steel Handbook (Reference 2) was reviewed and analyzed. That handbook has summarized that the Charpy curves for all of the unirradiated and irradiated heats tested has the form of a hyperbolic tangent, where

$$Y = A + B \cdot \tanh[(T-T_0)/C]$$

where Y = impact energy, lateral expansion or % Shear

T = Temperature , and
A, B, C, and T_0 = fitted constants
A+B = the upper shelf value
A-B = the lower shelf value
2C = the width of the transition region, and
T_0 = the temperature at the mid-point of the transition region.

As a result of these relationships, the slope of the transition region = B/C.

The constants for the hyperbolic tangent fits were tabulated from data from all of the unirradiated base metals (primarily A533, Grade B, A302B, and A508, Class 2) reported in Reference 2 and are presented in Table 2 (all base metals) and Table 3 (only A533, Grade B). The primary focus of that tabulation was a determination of the inverse slope of the transition region of the Charpy curves.

Tables 2 and 3 show that the mean inverse slope for the data is approximately 1.5°F per ft-lb with a standard deviation of 0.5°F per ft-lb. A more conservative estimate for the inverse slope is (Mean + Standard Deviation) = 2°F per ft-lb.

The fracture toughness for the ANO-2 flywheel material was determined exclusively from the 150°F Charpy impact results. This approach ignores the drop weight test results for Melt 5083 and also ignores the percent shear values from the Charpy results that demonstrate that at the 150°F test temperature that the material is on the upper shelf.

The 50 ft-lb transition temperature, TT_{50}, was estimated from the Charpy data at 150°F and the conservative slope of the transition region of the Charpy impact energy curve, 2°F per ft-lb, for A-533, Grade B, as discussed more completely above. This is illustrated by moving "down" the transition curve in Figure 2. Because of the conservative nature of this approach, the most favorable of the three Charpy values (68 ft-lbs) for Melt B5083 is used. This value is not that much different from the mean Charpy value of 65.3 ft-lbs.

Using,

$$TT_{50} = (150°F) - (68 \text{ ft-lbs} - 50 \text{ ft-lbs}) \bullet 2°F/\text{ft-lb}$$

Based on this, TT_{50} is 114°F.

RT_{NDT} is TT_{50} – 60°F, which provides an RT_{NDT} value of +54°F (i.e., 44°F higher than NDTT determined from the drop-weight testing).

Using the appropriate value of ($T\text{-}RT_{NDT}$), K_{Ic} at the temperature of interest (112°F) is determined from the expression given in ASME Code Section XI, Appendix A:

$$K_{Ic} = 33.2 + 20.734 \exp [0.02(T - RT_{NDT})]$$

$$K_{Ic} = 99.3 \text{ ksi } \sqrt{in}$$

Because of the conservative approach used to determine RT_{NDT} for the ANO-2 flywheels, it is concluded by Entergy that the K_{Ic} value of 100 ksi$\sqrt{in}$ reported in the fracture mechanics evaluation of the ANO-2 RCP flywheel in Topical Report SIR-94-080-A (Ref. 3) is met by this analysis. The proposed methodology is consistent with Topical Report SIR-94-080-A using the acceptance standards in Section XI of the ASME code. Therefore, a Code alternative is not required for the NRC staff to approve this evaluation approach.

Table 1
ANO-2 RCP Temperatures

Description		Data Pts	12 mo. Ave Temp
Anti Reverse Devise	RCP-A	T6049	158°F
	RCP-B	T6059	161°F
	RCP-C	T6069	169°F
	RCP-D	T6079	158°F
	Anti Reverse Devise Average Temp		**161°F**
Upper Guide Bearing	RCP-A	T6007	143°F
	RCP-B	T6017	156°F
	RCP-C	T6027	148°F
	RCP-D	T6037	151°F
	Upper Guide Bearing Average Temp		**149°F**
Upper Thrust Bearing	RCP-A	T6080	131°F
	RCP-B	T6090	133°F
	RCP-C	T6100	131°F
	RCP-D	T6110	131°F
	Upper Thrust Bearing Average Temp		**131°F**
Lower Thrust Bearing	RCP-A	T6043	122°F
	RCP-B	T6053	124°F
	RCP-C	T6063	120°F
	RCP-D	T6073	125°F
	Lower Thrust Bearing Average Temp		**122°F**
Stator Winding	RCP-A	T6040A	183°F
	RCP-B	T6050A	189°F
	RCP-C	T6060A	179°F
	RCP-D	T6070A	187°F
	Stator Winding Average Temp		**184°F**
Lower Guide Bearing	RCP-A	T6003	136°F
	RCP-B	T6013	123°F
	RCP-C	T6023	111°F
	RCP-D	T6033	124°F
	Lower Guide Bearing Average Temp		**123°F**

Table 2

Unirradiated Data from (Ref. 2). All base metals

ANO	SA-533B-1	HSST02/A1195	L-T	63	60.8	96.3	82.1	123.7	78	1.35
ANO	SA-533B-1	C5114-1	L-T	68.4	66.2	346	82.3	134.6	11	1.24
ANO	SA-533B-1	C5114-1	T-L	48.8	466	53.7	105.8	95.5	56	0.23
ANO	SA-533B-1	C5114-2	L-T	72.6	70.4	40.8	77.8	142.9	15	1.11
ANO	SA-533B-1	C5114-2	T-L	55.4	53.2	53.4	78.1	108.6	45	1.47
Beaver Valley	SA-533B-1	C6137-1	L-T	68.9	66.7	52.6	83.8	135.6	28	1.26
Beaver Valley	SA-533B-1	C6137-1	T-L	43.4	41.2	49.4	92.7	84.7	64	2.25
Big Rock Point	SA-302B	19246-2	T-L	45.8	43.6	39.4	92	89.4	48	2.11
Jose Cabrera	SA-533B-1	A8312	L-T	57.6	55.4	22	112.7	113	6	2.03
Jose Cabrera	SA-533B-1	B3170	L-T	63.6	61.4	3.3	50.6	124.9	-8	0.82
Jose Cabrera	SA-302B	CMM/A0421	L-T	87.7	85.5	137	120.8	173.2	80	1.41
Calvert Cliffs-1	SA-533B-1	HSST02/A1195	L-T	69	66.8	76.9	56.3	135.8	60	0.84
Calvert Cliffs-1	SA-533B-1	C4441-1	L-T	73.7	71.5	68.9	84.7	145.2	40	1.18
Connecticut Yankee	SA-302B	CMM/A0421	L-T	79.5	77.3	118.6	107.7	156.9	75	1.39
Connecticut Yankee	SA-302B	A5892	L-T	70.5	68.3	33.1	92.4	138.8	4	1.35
Connecticut Yankee	SA-302B	A5877	L-T	66.1	63.9	43.4	95.7	130	19	1.50
Connecticut Yankee	SA-302B	A5911	L-T	63.7	61.5	28.1	86.2	125.2	9	1.40
D.C. Cook-1	SA-533B-1	C3506	L-T	67	64.8	63.8	88.7	131.8	40	1.37
D.C. Cook-1	SA-533B-1	C3506	T-L	50.8	48.6	65.7	102.8	99.4	64	2.12
D.C. Cook-2	SA-533B-1	Unknown (8.8 thk)	L-T	66.4	64.2	67.7	67.9	130.6	50	1.06
D.C. Cook-2	SA-533B-1	Unknown (8.8 thk)	T-L	46.7	44.5	62.2	94	91.2	69	2.11
Diablo Canyon-1	SA-533B-1	C2884-1	L-T	69.1	66.9	49.9	69.1	136.1	30	1.03
Diablo Canyon-1	SA-533B-1	C2854-2	L-T	66.4	64.2	62.5	86.1	130.6	40	1.34
Diablo Canyon-1	SA-533B-1	C2793-1	L-T	62.2	60	58.8	89.7	122.1	40	1.50
Diablo Canyon-2	SA-533B-1	C5161-1	L-T	73.4	71.1	59.9	77.9	144.5	33	1.10
Diablo Canyon-2	SA-533B-1	C5161-1	T-L	48.5	46.3	70.9	95.4	94.8	74	2.06
Dresden-3	SA-302B	C5161-1	L-T	68.4	66.2	48	79.5	134.5	25	1.20
Farley-1	SA-533B-1	C6940	L-T	72.6	70.3	35.8	85.4	142.9	7	1.21
Farley-1	SA-533B-1	C6940	T-L	52.4	50.2	63.6	125.5	102.6	58	2.50
Farley-2	SA-533B-1	C7466	L-T	69.7	67.5	38.6	92.4	137.2	11	1.37
Farley-2	SA-533B-1	C7466	T-L	50.3	48.1	35.6	97.3	98.4	35	2.02
Ginna	SA-508-2	125P666-VA1	L-T	95.1	92.9	38.8	100.6	188	-15	1.08
Ginna	SA-508-2	125S255-VA1	L-T	85.8	83.6	57.5	116.6	169.4	4	1.39
Indian Point-2	SA-533B-1	B4688-2	L-T	65	62.8	72.3	101.8	127.8	47	1.62
Indian Point-2	SA-533B-1	B4701	L-T	61.7	59.5	66.6	83.3	121.2	50	1.40
Indian Point-2	SA-533B-1	B4922-1	L-T	61.9	59.7	76.2	100.6	121.7	56	1.69
Indian Point-2	SA-302B	CMM/A0421	L-T	61.1	58.9	-12.5	92	120	-30	1.56
Indian Point-3	SA-302B	B5394	L-T	68.7	66.5	44	75.6	135.1	22	1.14
Indian Point-3	SA-302B	A0516	L-T	65.2	63	0.4	88.1	128.1	-21	1.40
Indian Point-3	SA-302B	B5391	L-T	65.4	63.2	29.1	83.7	128.7	8	1.32
Indian Point-3	SA-302B	A0512	L-T	54	51.8	54	67.6	105.9	49	1.31
Indian Point-3	SA-302B	A0512	T-L	36.6	34.4	76	88.2	71	112	2.56
Kewaunee	SA-508-2	122X208-VA1	T-L	73.1	70.9	54	87.9	144	24	1.24
Kewaunee	SA-508-2	123X167-VA1	T-L	83	80.8	-1.9	80.5	163.7	-37	1.00
LaCrosse	SA-302B	A5848/NP1055	L-T	64.2	62	-39.6	61.8	126.3	-54	1.00
LaCrosse	SA-302B	A5852	L-T	31.3	29.1	23.4	63.1	60.4	72	2.17
LaCrosse	SA-302B	STD/N31438	L-T	48.7	46.5	-31.1	71	95.2	-61	1.53
Maine Yankee	SA-533B-1	B9755-1	L-T	79.8	77.6	53.3	79.4	157.4	21	1.02
Maine Yankee	SA-533B-1	B9755-1	T-L	58.8	56.6	47.9	79	115.3	36	1.40
Maine Yankee	SA-533B-1	HSST01	L-T	68.8	66.6	65.6	77.9	135.4	43	1.17
McGuire-1	SA-533B-1	B5012-1	L-T	74	71.8	60.7	74.7	145.7	35	1.04
McGuire-1	SA-533B-1	B5012-1	T-L	69.4	67.2	118.2	175	136.5	66	2.60
Millstone-2	SA-533B-1	C5667-1	L-T	70.3	68.1	81.7	58.9	138.4	42	0.86
Millstone-2	SA-533B-1	C5667-1	T-L	59.9	57.7	68.9	94.2	117.7	53	1.63
North Anna-1	SA-508-2	990400/29233	L-T	67.8	65.6	41.5	75.5	133.3	21	1.15
North Anna-1	SA-508-2	990400/29233	T-L	46.4	44.2	76.7	92.2	90.5	84	2.09
North Anna-2	SA-508-2	990496/29242	L-T	67	64.8	51.4	131	131.8	16	2.02
North Anna-2	SA-508-2	990496/29242	T-L	37.6	35.4	75.1	95.4	73.1	110	2.69

Table 2

Unirradiated Data from (Ref. 2). All base metals (Continued)

Oconee-1	SA-302B	C3265-1	L-T	72	69.8	46.8	84.3	141.8	19	1.21
Oconee-1	SA-302B	C3265-1	T-L	57.2	55	68.4	114.8	112.2	53	2.09
Oconee-1	SA-302B	C2800-1,2	L-T	60.9	58.7	58.7	101.8	119.6	40	1.73
Oconee-1	SA-302B	C2800-1,2	T-L	63.8	61.6	76.8	127.4	125.4	48	2.07
Oconee-2	SA-508-2	3P2359	L-T	74.1	71.9	21.5	73.8	145.9	-4	1.03
Oconee-2	SA-508-2	3P2359	T-L	64.4	62.2	9.7	66.1	126.6	-6	1.06
Oconee-3	SA-508-2	522194	L-T	88	85.8	60	78.7	173.9	23	0.92
Oconee-3	SA-508-2	522194	T-L	71.6	69.4	32.1	52.5	141	15	0.76
Oconee-3	SA-508-2	522314K	L-T	78.8	76.6	13.1	93.6	155.3	-24	1.22
Oconee-3	SA-508-2	522314K	T-L	56.3	54.1	39.8	78.4	110.3	31	1.45
Palisades	SA-302B	C1279-3	L-T	80.6	78.4	56.1	75.6	159	25	0.96
Palisades	SA-302B	C1279-3	T-L	52.3	50	52.4	71.5	102.3	49	1.43
Point Beach-1	SA-302B	C1423	L-T	61.5	59.3	15.2	73.5	120.9	1	1.24
Point Beach-1	SA-302B	A9811	L-T	55.6	53.4	-3	61.7	109	-9	1.16
Point Beach-2	SA-508-2	122W195-VA1	L-T	82.3	80.1	24.4	105	162.4	-20	1.31
Prairie Island-1	SA-508-3	38566	L-T	82.5	80.3	34.9	96	162.8	-6	1.20
Prairie Island-1	SA-508-3	38566	T-L	73.5	71.3	37.5	97.3	144.8	4	1.36
Prairie Island-2	SA-508-3	22642	L-T	74.5	72.3	13.5	57.8	146.7	-7	0.80
Prairie Island-2	SA-508-3	22642	T-L	54.7	52.5	42.6	86.1	107.2	35	1.64
Quad Cities-1	SA-302B	Unknown	L-T	54.2	51.9	8.2	68.8	106.1	3	1.33
Quad Cities-2	SA-302B	Unknown	L-T	70.1	67.9	39.3	74.3	137.9	17	1.09
Rancho Seco	SA-533B-1	C5062-1	T-L	46.7	44.4	37.8	81.7	91.1	44	1.84
Robinson	SA-302B	CMM/A0421	T-L	30	27.8	64.7	101.4	57.7	157	3.65
Robinson	SA-302B	A6604-1	L-T	49.8	47.6	17.5	82.2	97.5	18	1.73
Robinson	SA-302B	B1256-1	L-T	50.7	48.5	36	56.6	99.2	35	1.17
Robinson	SA-302B	B1250-1	L-T	57.4	55.2	64.8	68.4	112.5	56	2.04
Salem-1	SA-533B-1	C1354-1	L-T	66.3	64.1	62.7	127.3	130.4	30	1.99
Salem-1	SA-533B-1	C1354-2	L-T	72.1	69.9	63.2	119.5	142	24	1.71
Salem-1	SA-533B-1	C1354-2	L-T/T-L	72.4	70.2	-27.5	186.3	142.6	-89	2.65
Salem-1	SA-533B-1	C1397	L-T	69.7	67.5	13.8	86.9	137.1	-12	1.29
Salem-2	SA-533B-1	B4712-2	L-T	62.7	60.5	71.8	74.9	123.3	56	1.24
Salem-2	SA-533B-1	B4712-2	T-L	52.5	50.3	63.7	109.7	102.7	58	2.18
SONGS-1	SA-302B	19585	L-T	49.9	47.7	82	114.4	97.6	82	2.40
SONGS-1	SA-302B	19585	T-L	44.5	42.3	88.9	104	86.8	103	2.46
SONGS-1	SA-302B	A3099	L-T	56.6	54.4	79.9	121.6	111.1	65	2.24
SONGS-1	SA-302B	A3099	T-L	43	40.8	72.3	96	83.8	89	2.35
SONGS-1	SA-302B	A3119	L-T	53.8	51.6	79.7	104.5	105.3	72	2.03
SONGS-1	SA-302B	A3119	T-L	41.3	39.1	88.5	86.1	80.4	108	2.20
Sequoyah-1	SA-508-2	908919/281587	L-T	60.6	58.4	20.5	96.3	119.1	3	1.65
Sequoyah-1	SA-508-2	908919/281587	T-L	34.4	32.1	53.3	86.9	66.5	99	2.71
Sequoyah-2	SA-508-2	288587/981057	L-T	70.2	68	8.5	105.6	138.3	-24	1.55
Sequoyah-2	SA-508-2	288587/981057	T-L	49.4	47.2	44.1	134	96.7	46	2.84
St. Lucie-1	SA-533B-1	C5935-2	L-T	75.3	73	63.9	80.8	148.3	35	1.11
St. Lucie-1	SA-533B-1	C5935-2	T-L	52.4	50.2	49.6	70.1	102.6	46	1.40
Summer	SA-533B-1	A9154	L-T	68.7	66.5	29.6	79.2	135.1	7	1.19
Summer	SA-533B-1	A9154	T-L	39.9	37.7	46.7	82.4	77.6	69	2.19
Surry-1	SA-533B-1	C4415-1	L-T	65.1	62.9	44.1	82.2	127.9	24	1.31
Surry-1	SA-533B-1	C4415-1	T-L	54.2	52	55.5	96.2	106.2	48	1.85
Surry-1	SA-533B-1	C4326-1	L-T	76.3	74.1	39.2	103.2	150.3	1	1.39
Surry-1	SA-533B-1	C4326-1	T-L	60.7	58.4	46.5	104.8	119.1	27	1.79
Surry-2	SA-533B-1	C4339-1	L-T	67.9	65.7	61.1	96.8	133.7	34	1.47
Surry-2	SA-533B-1	C4339-1	T-L	57.4	55.2	68.7	106.9	112.5	54	1.94
TMI-1	SA-302B	C2789-2	L-T	65.5	63.3	47.3	94.4	128.8	24	1.49
TMI-1	SA-302B	C2789-2	T-L	50.2	48	63.1	84.4	98.2	63	1.76
Trojan	SA-533B-1	C5583	L-T	60.5	58.3	25.9	77.1	118.8	12	1.32
Trojan	SA-533B-1	C5583	T-L	44.4	42.2	29	94.7	86.6	42	2.24
Turkey Point 3	SA-508-2	123P461-VA1	L-T	74.7	72.5	5.5	73.7	147.2	-21	1.02
Turkey Point 3	SA-508-2	123S266-VA1	L-T	83.6	81.4	7.3	91.6	165	-33	1.13
Turkey Point 4	SA-508-2	123P481-VA1	L-T	72.6	70.3	64.8	112	142.9	28	1.59
Turkey Point 4	SA-508-2	123P481-VA1	L-T/T-L	91.5	89.3	-114.6	159.9	180.7	-195	1.79
Turkey Point 4	SA-508-2	122S180-VA1	L-T	66.2	64	7.1	55.9	130.1	-7	0.87
Watts Bar 1	SA-508-2	527536	L-T	69.4	67.2	19.3	116.6	136.6	-15	1.74
Watts Bar 1	SA-508-2	527536	T-L	32.8	30.6	54.3	94.9	63.4	115	3.10
Zion-1	SA-533B-1	B7835-1	L-T	71.1	68.9	46.5	76	140.1	22	1.10
Zion-1	SA-533B-1	B7835-1	T-L	59.8	57.5	70.1	85.1	117.3	56	1.48
Zion-2	SA-533B-1	C4007-1	L-T	64.2	62	71	62.2	126.1	57	1.00
Zion-2	SA-533B-1	C4007-1	T-L	48.7	46.5	78.6	72.7	95.1	81	1.56

Average	1.57
S.D	0.549
Min	0.23
Max	3.65

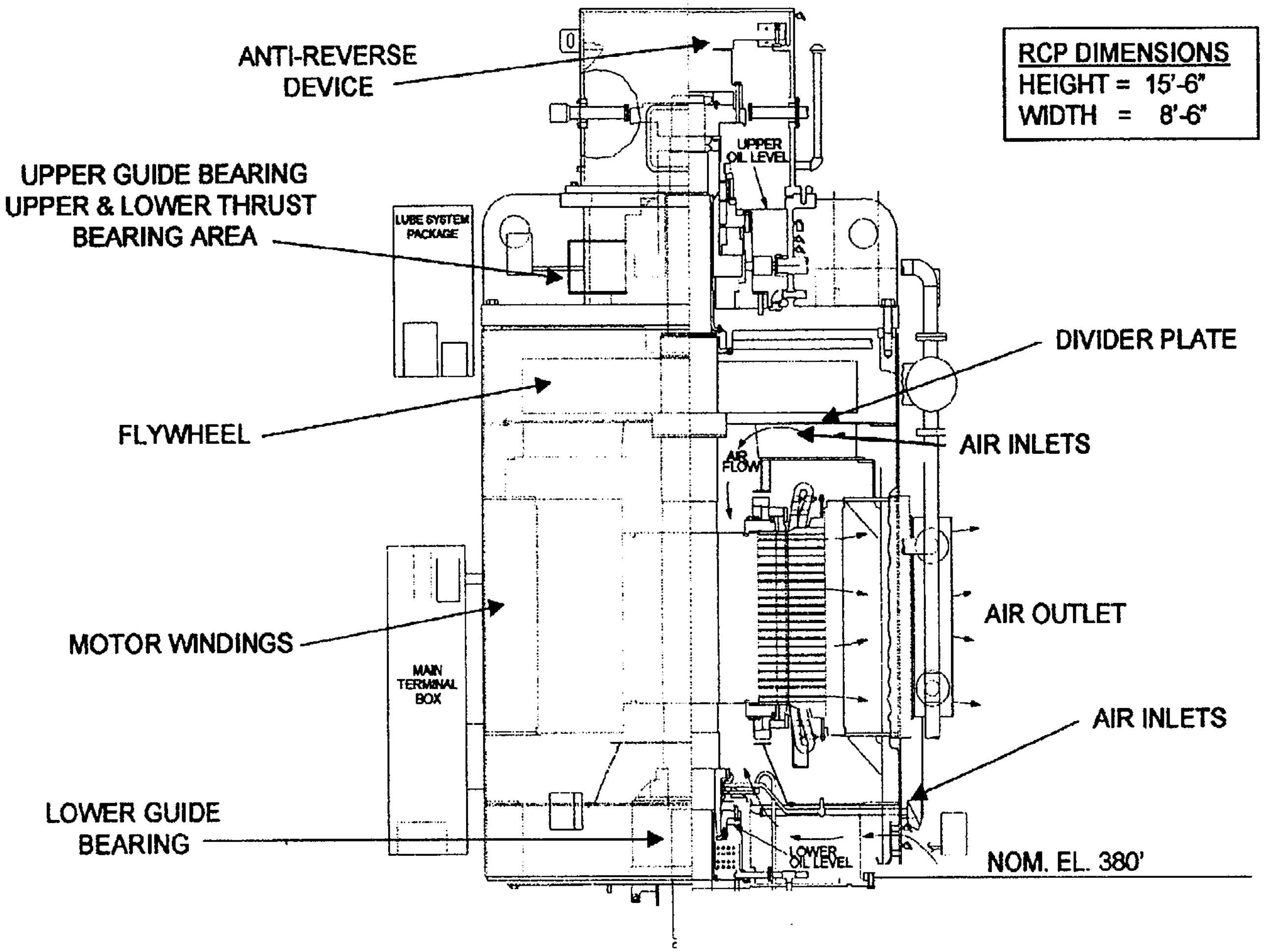
Table 3

Unirradiated Data from (Ref. 2). A533, Grade B Only

Description	Alloy	Heat	Orientation	A	B	T_o	C	USE	TT_{50}	1/Slope (F/ft-lbs)
ANO	SA-533B-1	HSST02/A1195	L-T	63	60.8	96.3	82.1	123.7	78	1.35
ANO	SA-533B-1	C5114-1	L-T	68.4	66.2	346	82.3	134.6	11	1.24
ANO	SA-533B-1	C5114-1	T-L	48.8	466	53.7	105.8	95.5	56	0.23
ANO	SA-533B-1	C5114-2	L-T	72.6	70.4	40.8	77.8	142.9	15	1.11
ANO	SA-533B-1	C5114-2	T-L	55.4	53.2	53.4	78.1	108.6	45	1.47
Beaver Valley	SA-533B-1	C6137-1	L-T	68.9	66.7	52.6	83.8	135.6	28	1.26
Beaver Valley	SA-533B-1	C6137-1	T-L	43.4	41.2	49.4	92.7	84.7	64	2.25
Jose Cabrera	SA-533B-1	A8312	L-T	57.6	55.4	22	112.7	113	6	2.03
Jose Cabrera	SA-533B-1	B3170	L-T	63.6	61.4	3.3	50.6	124.9	-8	0.82
Calvert Cliffs-1	SA-533B-1	HSST02/A1195	L-T	69	66.8	76.9	56.3	135.8	60	0.84
Calvert Cliffs-1	SA-533B-1	C4441-1	L-T	73.7	71.5	68.9	84.7	145.2	40	1.18
D.C. Cook-1	SA-533B-1	C3506	L-T	67	64.8	63.8	88.7	131.8	40	1.37
D.C. Cook-1	SA-533B-1	C3506	T-L	50.8	48.6	65.7	102.8	99.4	64	2.12
D.C. Cook-2	SA-533B-1	Unknown (8.8 thk)	L-T	66.4	64.2	67.7	67.9	130.6	50	1.06
D.C. Cook-2	SA-533B-1	Unknown (8.8 thk)	T-L	46.7	44.5	62.2	94	91.2	69	2.11
Diablo Canyon-1	SA-533B-1	C2884-1	L-T	69.1	66.9	49.9	69.1	136.1	30	1.03
Diablo Canyon-1	SA-533B-1	C2854-2	L-T	66.4	64.2	62.5	86.1	130.6	40	1.34
Diablo Canyon-1	SA-533B-1	C2793-1	L-T	62.2	60	58.8	89.7	122.1	40	1.50
Diablo Canyon-2	SA-533B-1	C5161-1	L-T	73.4	71.1	59.9	77.9	144.5	33	1.10
Diablo Canyon-2	SA-533B-1	C5161-1	T-L	48.5	46.3	70.9	95.4	94.8	74	2.06
Farley-1	SA-533B-1	C6940	L-T	72.6	70.3	35.8	85.4	142.9	7	1.21
Farley-1	SA-533B-1	C6940	T-L	52.4	50.2	63.6	125.5	102.6	58	2.50
Farley-2	SA-533B-1	C7466	L-T	69.7	67.5	38.6	92.4	137.2	11	1.37
Farley-2	SA-533B-1	C7466	T-L	50.3	48.1	35.6	97.3	98.4	35	2.02
Indian Point-2	SA-533B-1	B4688-2	L-T	65	62.8	72.3	101.8	127.8	47	1.62
Indian Point-2	SA-533B-1	B4701	L-T	61.7	59.5	66.6	83.3	121.2	50	1.40
Indian Point-2	SA-533B-1	B4922-1	L-T	61.9	59.7	76.2	100.6	121.7	56	1.69
Maine Yankee	SA-533B-1	B9755-1	L-T	79.8	77.6	53.3	79.4	157.4	21	1.02
Maine Yankee	SA-533B-1	B9755-1	T-L	58.8	56.6	47.9	79	115.3	36	1.40
Maine Yankee	SA-533B-1	HSST01	L-T	68.8	66.6	65.6	77.9	135.4	43	1.17
McGuire-1	SA-533B-1	B5012-1	L-T	74	71.8	60.7	74.7	145.7	35	1.04
McGuire-1	SA-533B-1	B5012-1	T-L	69.4	67.2	118.2	175	136.5	66	2.60
Millstone-2	SA-533B-1	C5667-1	L-T	70.3	68.1	81.7	58.9	138.4	42	0.86
Millstone-2	SA-533B-1	C5667-1	T-L	59.9	57.7	68.9	94.2	117.7	53	1.63
Rancho Seco	SA-533B-1	C5062-1	T-L	46.7	44.4	37.8	81.7	91.1	44	1.84
Salem-1	SA-533B-1	C1354-1	L-T	66.3	64.1	62.7	127.3	130.4	30	1.99
Salem-1	SA-533B-1	C1354-2	L-T	72.1	69.9	63.2	119.5	142	24	1.71
Salem-1	SA-533B-1	C1354-2	L-T/T-L	72.4	70.2	-27.5	186.3	142.6	-89	2.65
Salem-1	SA-533B-1	C1397	L-T	69.7	67.5	13.8	86.9	137.1	-12	1.29
Salem-2	SA-533B-1	B4712-2	L-T	62.7	60.5	71.8	74.9	123.3	56	1.24
Salem-2	SA-533B-1	B4712-2	T-L	52.5	50.3	63.7	109.7	102.7	58	2.18
St. Lucie-1	SA-533B-1	C5935-2	L-T	75.3	73	63.9	80.8	148.3	35	1.11
St. Lucie-1	SA-533B-1	C5935-2	T-L	52.4	50.2	49.6	70.1	102.6	46	1.40
Summer	SA-533B-1	A9154	L-T	68.7	66.5	29.6	79.2	135.1	7	1.19
Summer	SA-533B-1	A9154	T-L	39.9	37.7	46.7	82.4	77.6	69	2.19
Surry-1	SA-533B-1	C4415-1	L-T	65.1	62.9	44.1	82.2	127.9	24	1.31
Surry-1	SA-533B-1	C4415-1	T-L	54.2	52	55.5	96.2	106.2	48	1.85
Surry-1	SA-533B-1	C4326-1	L-T	76.3	74.1	39.2	103.2	150.3	1	1.39
Surry-1	SA-533B-1	C4326-1	T-L	60.7	58.4	46.5	104.8	119.1	27	1.79
Surry-2	SA-533B-1	C4339-1	L-T	67.9	65.7	61.1	96.8	133.7	34	1.47
Surry-2	SA-533B-1	C4339-1	T-L	57.4	55.2	68.7	106.9	112.5	54	1.94
Trojan	SA-533B-1	C5583	L-T	60.5	58.3	25.9	77.1	118.8	12	1.32
Trojan	SA-533B-1	C5583	T-L	44.4	42.2	29	94.7	86.6	42	2.24
Zion-1	SA-533B-1	B7835-1	L-T	71.1	68.9	46.5	76	140.1	22	1.10
Zion-1	SA-533B-1	B7835-1	T-L	59.8	57.5	70.1	85.1	117.3	56	1.48

Average	1.52
S.D.	0.495921
Min	0.23
Max	2.65

FIGURE 1



RCP MOTOR DETAILS

RCP DIMENSIONS
HEIGHT = 15'-6"
WIDTH = 8'-6"

Figure 2. Schematic of Charpy Impact Energy Curve where Lower Shelf and Upper Shelf Energies are Known