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D. C. COOK UNIT 1 REACTOR VESSEL

RT_{PTS} EVALUATIONS

Attachment 15

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SUMMARY OF RESULTS

The Pressurized thermal shock evaluations were performed for D. C. Cook Unit 1 Reactor Vessel Belt line region materials and resulted the following conclusion:

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  - The limiting material is found to be the circumferential weld (Table 2-3). RT_{PTS} values are 200°F and 216°F for life up to 23 and 32 EFPY respectively. These values are below the screening criteria of 300°F for circumferential weld.

- o Using Regulatory Guide 1.99, Revision 2

  - The limiting material is found to be the circumferential weld (Table 2-4). RT_{PTS} values are 221°F and 238°F for life up to 23 and 32 EFPY respectively. These values are below the screening criteria of 300°F for circumferential weld.

SECTION 2
PRESSURIZED THERMAL SHOCK

2-1. THE PRESSURIZED THERMAL SHOCK RULE

The Pressurized Thermal Shock (PTS) Rule[1] was approved by the U.S. Nuclear Regulatory Commissioners on June 20, 1985, and appeared in the Federal Register on July 23, 1985. The date that the Rule was published in the Federal Register is the date that the Rule became a regulatory requirement.

The Rule outlines regulations to address the potential for PTS events on pressurized water reactor (PWR) vessels in nuclear power plants that are operated with a license from the United States Nuclear Regulatory Commission (USNRC). PTS events have been shown from operating experience to be transients that result in a rapid and severe cooldown in the primary system coincident with a high or increasing primary system pressure. The PTS concern arises if one of these transients acts on the beltline region of a reactor vessel where a reduced fracture resistance exists because of neutron irradiation. Such an event may produce the propagation of flaws postulated to exist near the inner wall surface, thereby potentially affecting the integrity of the vessel.

The Rule establishes the following requirements for all domestic, operating PWRs:

* The RT_{PTS} (measure of fracture resistance) Screening Criterion for the reactor vessel beltline region is

  270°F for plates, forgings, axial welds
  300°F for circumferential weld materials

* 6 Months From Date of Rule: All plants submitted their present RT_{PTS} values (per the prescribed methodology) and projected RT_{PTS} values at the expiration date of the operating license. The date that this submittal had to be received by the NRC for plants with operating licenses was January 23, 1986.

* 9 Months From Date of Rule: Plants projected to exceed the PTS Screening Criterion had to submit an analysis and a schedule for implementation of such flux reduction programs as are reasonably practicable to avoid reaching the Screening Criterion. The date for this submittal had to be received by the NRC for plants with operating licenses by April 23, 1986.

* Plant-specific PTS safety analyses are required before a plant is within 3 years of reaching the Screening Criterion, including analyses of alternatives to minimize the PTS concern.

* NRC approval for operation beyond the Screening Criterion is required.

For applicants of operating licenses, values of the projected RT_{PTS} are to be provided in the Final Safety Analysis Report. This requirement is added as part of 10CFR Part 50.34.

In the Rule, the NRC provides guidance regarding the calculation of the toughness state of the reactor vessel materials - the "reference temperature for nil-ductility transition" (RT_{NDT}). For purposes of the Rule, RT_{NDT} is now defined as "the reference temperature for pressurized thermal shock" (RT_{PTS}) and calculated as prescribed by 10 CFR 50.61(b) of the Rule. Each USNRC licensed PWR was required to submit a projection of RT_{PTS} values from the time of the submittal to the license expiration date. This assessment was required to be submitted within 6 months after the effective date of the Rule, on January 23, 1986, with updates whenever changes occur affecting projected values. The calculation must be made for each weld and plate, or forging, in the reactor vessel beltline.

Calculations were carried out using the latest plant specific material properties in accordance with both the current PTS rule[1] and Regulatory Guide 1.99-Revision 2[2], which was recently issued as the latest regulatory method for predicting irradiation embrittlement of reactor vessel materials. The NRC plans to incorporate Revision 2 of Regulatory Guide 1.99 into the PTS rule without changing the PTS screening criteria per NRC Generic Letter 88-11[3]. The RT_{PTS} results for all Cook Unit 1 reactor vessel beltline region materials are presented following a description of these two regulatory calculational methodologies.

2-2. METHODS FOR CALCULATION OF RT_{PTS}

2-2.1 PTS Rule Methodology

In the PTS Rule, the NRC Staff has selected a conservative and uniform method for determining plant-specific values of RT_{PTS} at a given time.

The prescribed equations in the PTS rule for calculating RT_{PTS} are actually one of several ways to calculate RT_{NDT}. For the purpose of comparison with the Screening Criterion, the value of RT_{PTS} for the reactor vessel must be calculated for each weld and plate, or forging in the beltline region as given below. For each material, RT_{PTS} is the lower of the results given by Equations 1 and 2.

Equation 1:

$$RT_{PTS} = I + M + [-10 + 470(Cu) + 350(Cu)(Ni)]\ f^{0.270} \qquad (1)$$

Equation 2:

$$RT_{PTS} = I + M + 283\ f^{0.194} \qquad (2)$$

where

I = the initial reference transition temperature of the unirradiated material measured as defined in the ASME Code, NB-331. If a measured value is not available, the following generic mean values must be used: 0°F for welds made with Linde 80 flux, and -56°F for welds made with Linde 0091, 1092 and 124 and ARCOS B-5 weld fluxes.

M = the margin to be added to cover uncertainties in the values of initial RT_{NDT}, copper and nickel content, fluence, and calculation procedures. In Equation 1, M=48°F if a measured value of I was used, and M=59°F if the generic mean value of I was used. In Equation 2, M=0°F if a measured value of I was used, and M=34°F if the generic mean value of I was used.

Cu and Ni = the best estimate weight percent of copper and nickel in the material.

f = the maximum neutron fluence, in units of 10^{19} n/cm^2 (E greater than or equal to 1 MeV), at the clad-base-metal interface on the inside surface of the vessel at the location where the material in question receives the highest fluence for the period of service in question.

Note that the chemistry values given in equations 1 and 2 are best estimate mean values. The margin, M, increases the RT_{PTS} values to be upper bound predictions. Thus, the mean material chemistry values are to be used when available so as not to compound conservatism.

2-2.2 Regulatory Guide 1.99 Revision 2 Methodology

Revision 2[2] to Regulatory Guide 1.99 was issued in May 1988. The Adjusted Reference Temperature (ART), based on the methods of Regulatory Guide 1.99 Revision 2, can be compactly described by the sequence of equations listed below:

$$ART = \text{Initial } RT_{NDT} + \Delta RT_{NDT} + \text{Margin} \quad (3)$$

$$\Delta RT_{NDT} = [CF]F^{(0.28 - 0.10 \text{ LOG } f)} \text{ where,} \quad (4)$$

f = Neutron fluence, n/cm^2 ($E > 1$ MeV), divided by 10^{19}

CF = Chemistry factor from tables for welds and for base metal (plates and forgings) (if no data use 0.35% Cu and 1.0% Ni)

$$\text{Margin} = 2\, [\sigma_I^{\,2} + \sigma_\Delta^{\,2}]^{0.5} \text{ where,} \quad (5)$$

σ_I = standard deviation of initial RT_{NDT}. If the initial RT_{NDT} is measured, σ_I is to be estimated from the precision of the test method; otherwise, σ_I is obtained from the same set of data that is used to get initial RT_{NDT}

σ_Δ = Standard deviation of ΔRT_{NDT}; 28°F for welds and 17°F for base metal

[σ_Δ need not exceed 1/2 times ΔRT_{NDT} surface]

The value of ART will be assumed to be the RT_{PTS} value for use with the PTS rule.

2-3. DETERMINATION OF RT_{PTS} VALUES FOR ALL BELTLINE REGION MATERIALS

For the RT_{PTS} calculation, the best estimate copper and nickel chemical composition of the reactor vessel beltline material is necessary.

The beltline region is defined by the Rule [2] to be "the region of the reactor vessel (shell material including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the active core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron irradiation damage to be considered in the selection of the most limiting material with regard to radiation damage." Figure 2-1 identifies the location of all beltline region materials for the reactor vessel.

A summary of the pertinent chemical and mechanical properties of the beltline region plate and weld materials and the initial RT_{NDT} values of the Cook Unit 1 reactor vessel are reproduced in Table 2-1 (Reference 4, Table A-1).

Also a summary of fluence (E > 1.0 MeV) values used for the evaluation of RT_{PTS} is provided in Table 2-2 (Reference 4, Table 6-14).

Using the methodology prescribed before and the material properties discussed in this section, the RT_{PTS} values for D. C. Cook Unit 1 can be determined.

2-4. STATUS OF REACTOR VESSEL INTEGRITY IN TERMS OF RT_{PTS} VERSUS FLUENCE RESULTS

Using the prescribed PTS Rule methodology, RT_{PTS} values were generated for all beltline region materials of the D. C. Cook Unit 1 reactor vessel as a function of pertinent vessel lifetimes. The tabulated results from this evaluation are presented in Table 2-3 and 2-4 for all beltline region materials.

Figures 2-2 and 2-3 present the RT_{PTS} versus fluence for the beltline material of the Cook Unit 1 vessel using PTS rule and Regulatory Guide 1.99, Revision 2, respectively. The curves in these figures can be used to provide guidance to evaluate fuel reload options in relation to the NRC RT_{PTS} Screening Criterion for PTS, if this would ever become necessary. That is, RT_{PTS} values can be readily projected for any options under consideration, provided that fluence is known.

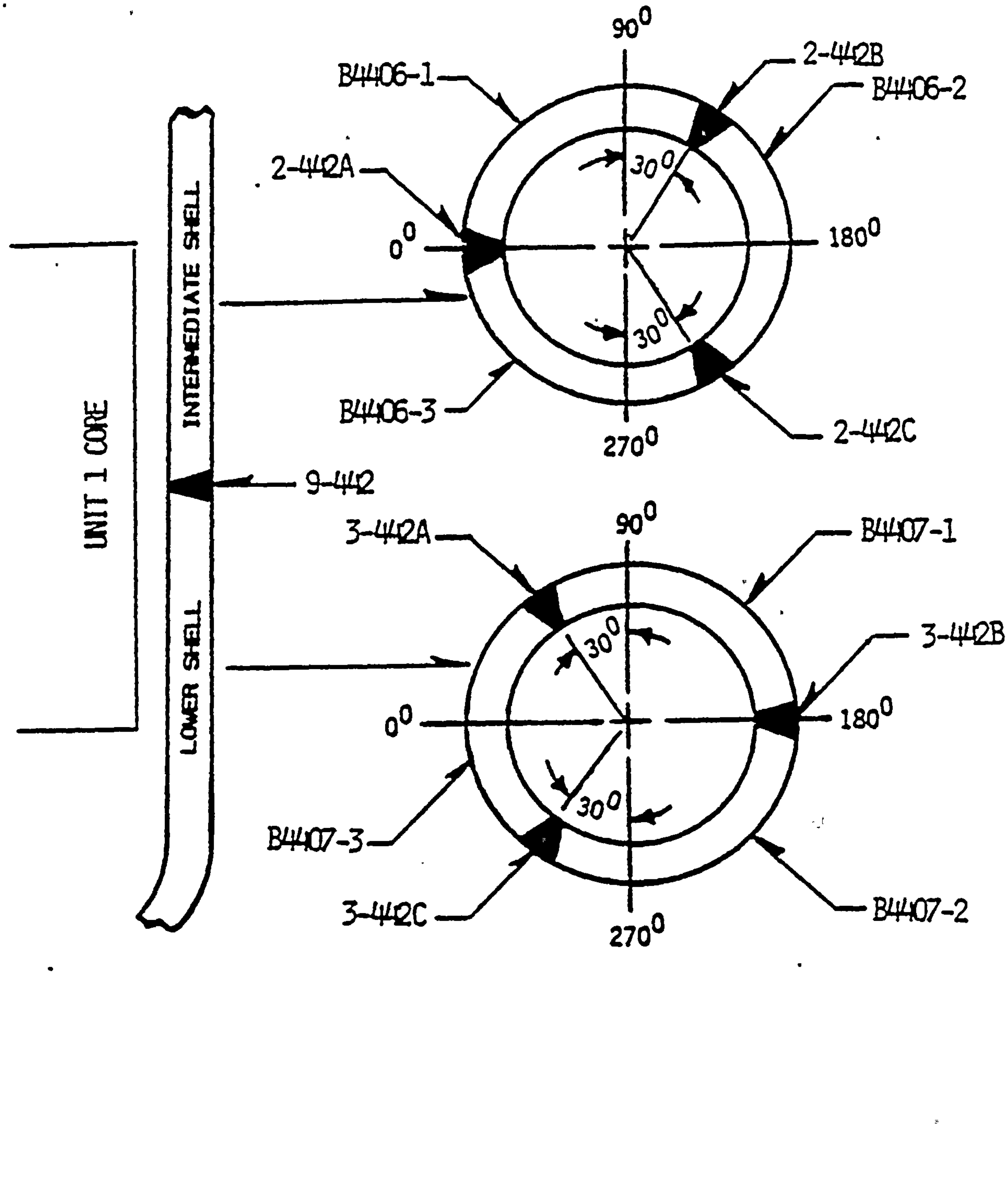

Figure 2-1. Identification and Location of Beltline Region Material for the D. C. Cook Unit 1 Reactor Vessel

TABLE 2-1[4]

D. C. UNIT 1 REACTOR VESSEL BELTLINE REGION MATERIAL PROPERTIES

Component	Plate No.	Cu (Wt/.)	Ni (Wt/.)	Initial RT_{NDT}(°F)
Intermediate Shell Plate	B4406-1	.12	.52	5
Intermediate Shell Plate	B4406-2	.15	.50	33
Intermediate Shell Plate	B4406-3	.15	.49	40
Lower Shell Plate	B4407-1	.14	.55	28
Lower Shell Plate	B4407-2	.12	.59	-12
Lower Shell Plate	B4407-3	.14	.50	38
Longitudinal Welds		.28	.74	-56
Circumferential Welds		.28	.74	-56

TABLE 2-2[4]

SUMMARY OF FLUENCE (E > 1.0 MeV) VALUES USED
FOR THE EVALUATION OF RT_{PTS}

Component	23 EFPY	32 EFPY
Intermediate Shell Plate, B4406-1	1.05	1.41
Intermediate Shell Plate, B4406-2	1.05	1.41
Intermediate Shell Plate, B4406-3	1.05	1.41
Lower Shell Plate, B4407-1	1.05	1.41
Lower Shell Plate, B4407-2	1.05	1.41
Lower Shell Plate, B4407-3	1.05	1.41
Longitudinal Weld	0.714	0.95
Circumferential Weld	1.05	1.41

Fluences are in $10^{19} n/cm^2$ (E > 1.0 MeV)

TABLE 2-3

RT_{PTS} VALUES PER PTS RULE FOR D. C. COOK UNIT 1

Location	Vessel Material	RT_{PTS} Values (°F) 23 EFPY	32 EFPY	SCREENING CRITERIA
1	Intermediate shell plate B4406-1	122	128	270
2	Intermediate shell plate B4406-2	169	176	270
3	Intermediate shell plate B4406-3	175	183	270
4	Lower shell plate B4407-1	160	167	270
5	Lower shell plate B4407-2	108	114	270
6	Lower shell plate B4407-3	167	174	270
7	Most Limiting Longitudinal weld	180	195	270
8	Circumferential weld	200	216	300

TABLE 2-4

RT_{PTS} VALUES PER REGULATORY GUIDE 1.99, REVISION 2

FOR D. C. COOK UNIT 1

Location	Vessel Material	RT_{PTS} Values (°F) 23 EFPY	32 EFPY	SCREENING CRITERIA
1	Intermediate shell plate B4406-1	121	128	270
2	Intermediate shell plate B4406-2	173	182	270
3	Intermediate shell plate B4406-3	179	188	270
4	Lower shell plate B4407-1	161	169	270
5	Lower shell plate B4407-2	106	113	270
6	Lower shell plate B4407-3	169	177	270
7	Most Limiting Longitudinal weld	199	215	270
8	Circumferential weld	221	238	300

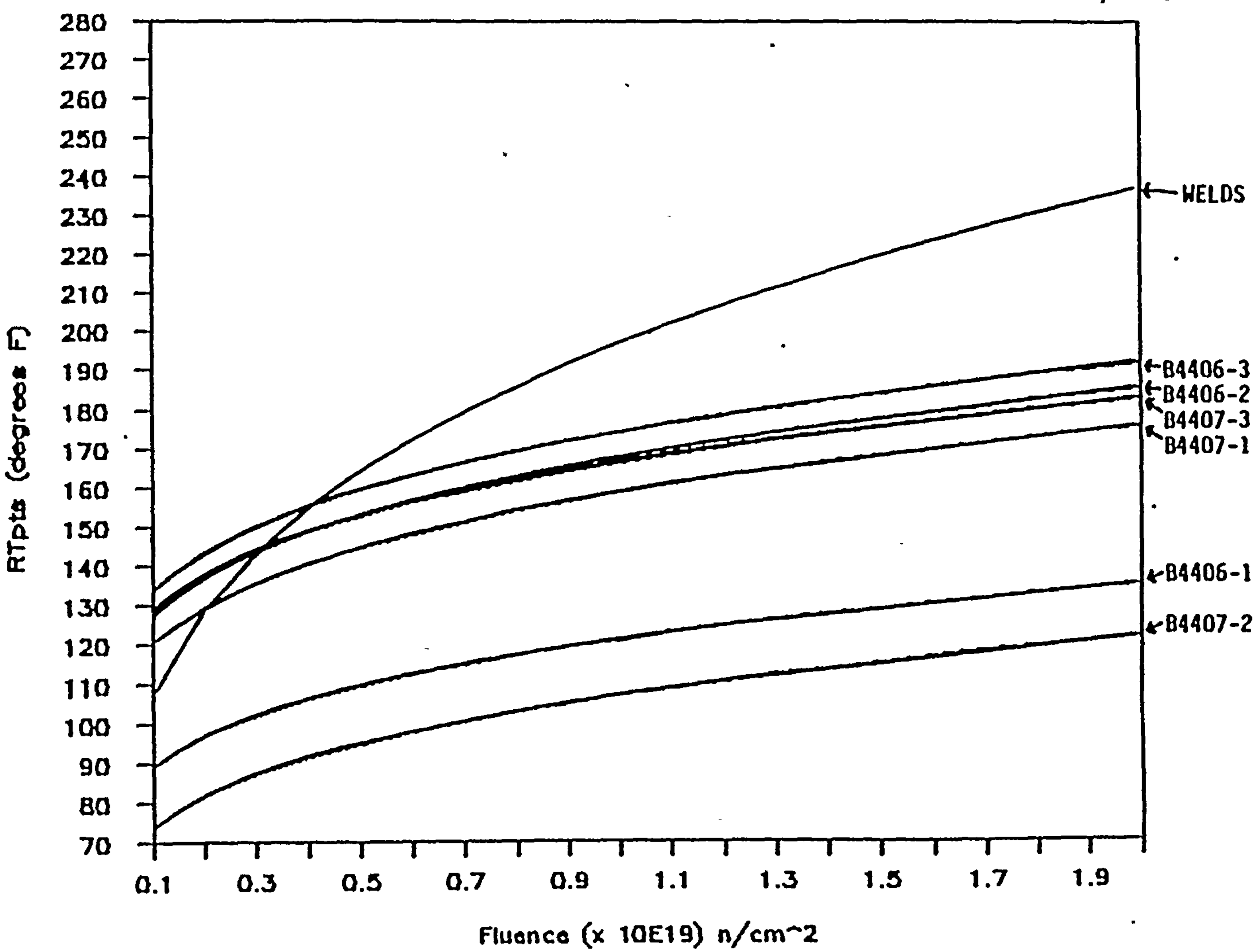

Figure 2-2. RT_{PTS} vs. Fluence per PTS Rule - Cook Unit 1

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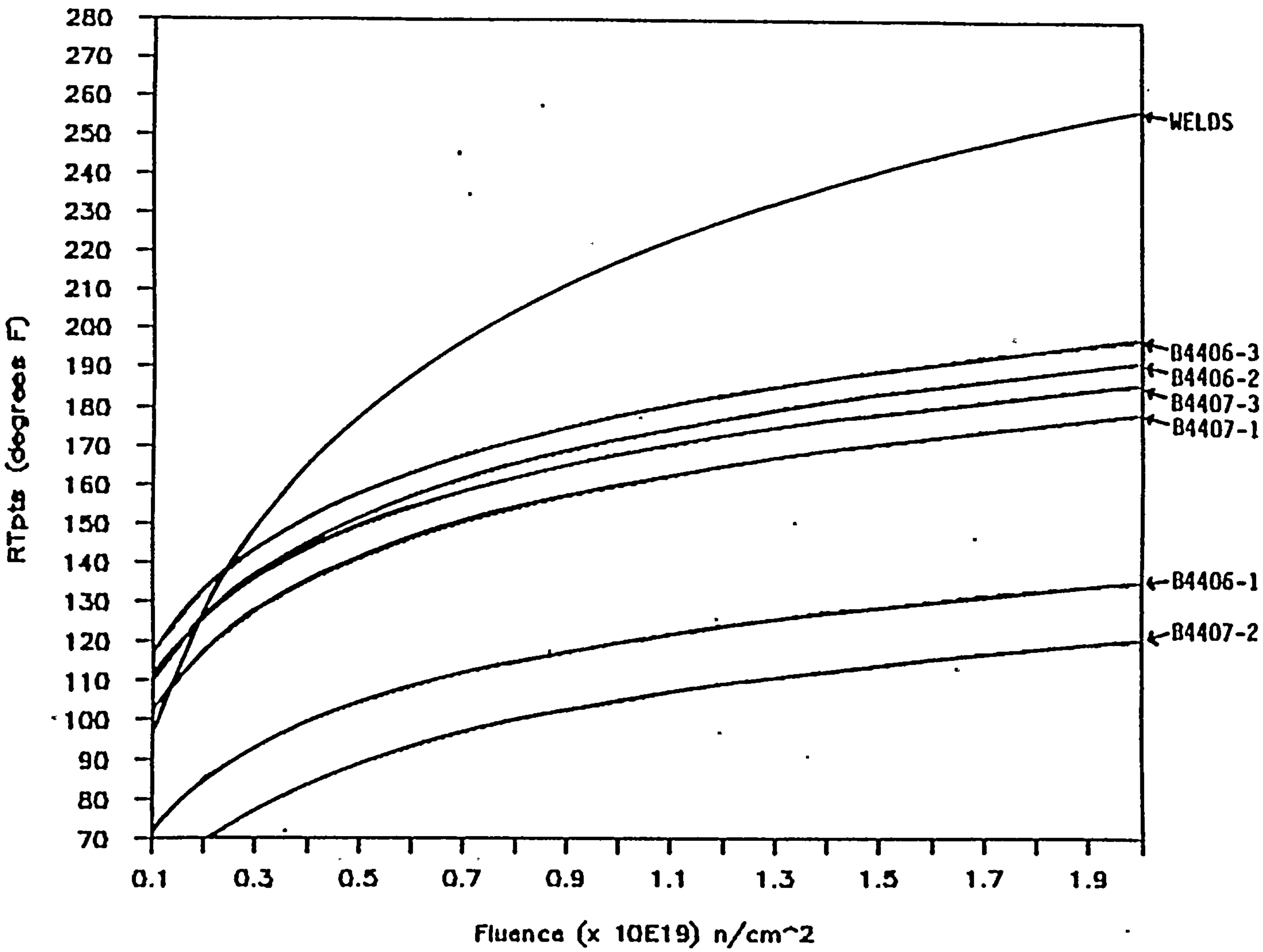

Figure 2-3. RT_{PTS} vs. Fluence per Regulatory Guide 1.99, Revision 2 - Cook Unit 1

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SECTION 3

REFERENCES

[1] "Analysis of Potential Pressurized Thermal Shock Events," 10 CFR part 50, Final Rule, July 23, 1985.

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

[3] NRC Generic letter 88-11, "NRC Position on Radiation Embrittlement of Reactor Vessel Materials and its Impact on Plant Operations", July 12, 1988.

[4] E. Terek, S. L. Anderson, L. Albertin, N. K. Ray, "Analysis of Capsule U from the American Electric Power Company D. C. Cook Unit 1 Reactor Vessel Radiation Surveillance Program."

SECTION 3

REFERENCES

[1] "Analysis of Potential Pressurized Thermal Shock Events," 10 CFR part 50, Final Rule, July 23, 1985.

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

[3] NRC Generic letter 88-11, "NRC Position on Radiation Embrittlement of Reactor Vessel Materials and its Impact on Plant Operations", July 12, 1988.

[4] E. Terek, S. L. Anderson, L. Albertin, N. K. Ray, "Analysis of Capsule U from the American Electric Power Company D. C. Cook Unit 1 Reactor Vessel Radiation Surveillance Program."