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REACTOR VESSEL MATERIAL SURVEILLANCE PROGRAM FOR INDIAN POINT UNIT NO. 2 ANALYSIS OF CAPSULE Z

by
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ABSTRACT

Capsule Z, the third vessel material surveillance capsule removed from the Indian Point Unit No. 2 nuclear power plant has been tested, and the results have been evaluated. The analysis of the data confirms the previous fluence rate results and indicates that the pressure vessel plate material will retain adequate shelf toughness throughout the 32 EFPY design lifetime.

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I. SUMMARY OF RESULTS AND CONCLUSIONS

The analysis of the third material surveillance capsule removed from the Indian Point Unit No. 2 reactor pressure vessel led to the following conclusions:

(1) Based on a calculated neutron spectral distribution, Capsule Z received a fast fluence of 1.1×10^{19} neutrons/cm^2 (E > 1 MeV) at its radial center line.

(2) The surveillance specimens of the core beltline plate materials experienced shifts in RT_{NDT} over the range of 120°F (Plate B2002-2) to 185°F (Plate B2002-3) as a result of exposure up to the 1982 refueling outage.

(3) The core beltline plate B2002-3 exhibited the largest shift in RT_{NDT} and is projected to control the heatup and cooldown limitations throughout the design lifetime of the pressure vessel.

(4) The estimated maximum neutron fluence of 3.07×10^{18} neutrons/cm^2 (E > 1 MeV) received by the vessel wall accrued in 5.17 effective full power years (EFPY), which is equal to a fluence rate of 5.94×10^{17} per EFPY. The use of a low leakage core loading pattern beginning with Cycle 6 will significantly reduce the future fluence rate.

(5) The Indian Point Unit No. 2 vessel shell plates located in the core beltline region are projected to retain sufficient toughness to meet the current 50 ft-lb Charpy upper shelf requirements of 10CFR50 Appendix G throughout the design life of the pressure vessel.

(6) Based on Regulatory Guide 1.99 trend curves, the projected maximum RT_{NDT} for the Indian Point Unit No. 2 vessel core beltline materials at the 1/4T and 3/4T positions after 32 EFPY of operation are 229°F and 132°F, respectively. These values were used as the bases for computing heatup and cooldown limit curves to be used for up to 32 EFPY of operation.

II. BACKGROUND

The allowable loadings on nuclear pressure vessels are determined by applying the rules in Appendix G, "Fracture Toughness Requirements," of 10CFR50 [1]. In the case of pressure-retaining components made of ferritic materials, the allowable loadings depend on the reference stress intensity factor (K_{IR}) curve indexed to the reference nil ductility temperature (RT_{NDT}) presented in Appendix G, "Protection Against Non-Ductile Failure," of Section III of the ASME Code [2]. Further, the materials in the beltline region of the reactor vessel must be monitored for radiation-induced changes in RT_{NDT} per the requirements of Appendix H, "Reactor Vessel Material Surveillance Program Requirements," of 10CFR50.

The RT_{NDT} is defined in paragraph NB-2331 of Section III of the ASME Code as the highest of the following temperatures:

(1) Drop-weight Nil Ductility Temperature (DW-NDT) per ASTM E 208 [3];

(2) 60 deg F below the 50 ft-lb Charpy V-notch (C_v) temperature;

(3) 60 deg F below the 35 mil C_v temperature.

The RT_{NDT} must be established for all materials, including weld metal and heat-affected zone (HAZ) material as well as base plates and forgings, which comprise the reactor coolant pressure boundary.

It is well established that ferritic materials undergo an increase in strength and hardness and a decrease in ductility and toughness when exposed to neutron fluences in excess of 10^{17} neutrons per cm^2 ($E > 1$ MeV) [4]. Also, it has been established that tramp elements, particularly copper and

phosphorus, affect the radiation embrittlement response of ferritic materials [5-7]. The relationship between increase in RT_{NDT} and copper content is defined in Regulatory Guide 1.99. Estimates of shifts in RT_{NDT} in this report are based on the current Revision 1 of Regulatory Guide 1.99 [8].

In general, the only ferritic pressure boundary materials in a nuclear plant which are expected to receive a fluence sufficient to affect RT_{NDT} are those materials which are located in the core beltline region of the reactor pressure vessel. Therefore, material surveillance programs include specimens machined from the plate or forging material and weldments which are located in the core beltline region of high neutron flux density to provide the data required to assess the degree of neutron embrittlement. ASTM E 185 [9] describes the recommended practice for monitoring and evaluating the radiation-induced changes occurring in the mechanical properties of pressure vessel beltline materials.

Westinghouse has provided such a surveillance program for the Indian Point Unit No. 2 nuclear power plant [10]. The encapsulated C_v specimens are located on the O.D. surface of the thermal shield where the fast neutron flux density is about three times that at the adjacent vessel wall surface. Therefore, the increases (shifts) in transition temperatures of the materials in the pressure vessel are generally less than the corresponding shifts observed in the surveillance specimens. However, because of azimuthal variations in neutron flux density, capsule fluences may lead or lag the maximum vessel fluence in a corresponding exposure period. The capsules also contain several dosimeter materials for experimentally determining the average neutron flux density at each capsule location during the exposure period.

The Indian Point Unit No. 2 material surveillance capsules also include tensile specimens as recommended by ASTM E 185. At the present time, irradiated tensile properties are used only to indicate that the materials tested continue to meet the requirements of the appropriate material specification. In addition, the material surveillance capsules contain wedge opening loading (WOL) fracture mechanics specimens. Current technology limits the testing of these specimens at temperatures well below the minimum service temperature to obtain valid fracture mechanics data per ASTM E 399 [11], "Standard Method of Test for Plane-Strain Fracture Toughness of Metallic Materials." Currently, the NRC suggests storing these specimens until an acceptable testing procedure has been defined for determing the J_{Ic} fracture toughness [12].

This report describes the results obtained from testing the contents of Capsule Z. These data and those obtained previously from Capsules T and Y [13-15] are analyzed to estimate the radiation-induced changes in the mechanical properties of the pressure vessel at the time of the Cycle 5/6 refueling outage as well as predicting the changes expected to occur at selected times in the future operation of the Indian Point Unit No. 2 power plant. The future projections are based on the continued use of a low leakage core loading pattern, put in service during the Cycle 5/6 refueling outage, which involves placing burnt assemblies at the perifery and fresh assemblies in the interior of the core so that the peak vessel wall neutron flux is reduced by about 45 percent [16].

III. DESCRIPTION OF MATERIAL SURVEILLANCE PROGRAM

The Indian Point Unit No. 2 material surveillance program is described in detail in WCAP 7323 [10], dated May 1969. Eight materials surveillance capsules (five Type I and three Type II) were placed in the reactor vessel between the thermal shield and the vessel wall before startup, see Figure 1. The vertical center of each capsule is opposite the vertical center of the core. The neutron flux density at each 40° capsule location exceeds three times the maximum flux density on the vessel I.D. [17]. However, the peak vessel exposure rate has been significantly reduced since the introduction of a low leakage core loading pattern in Core Cycle 6.

Capsule Z, a Type I capsule, was removed during the 1982 refueling outage. The Type I capsules each contain Charpy V-notch, tensile, and WOL specimens machined from the three SA533 Gr B, Cl 1 beltline shell plates plus Charpy V-notch specimens machined from a correlation monitor heat of steel. The chemistries and heat treatments of the vessel surveillance materials are summarized in Table I. All test specimens were machined from the test materials at the quarter-thickness (1/4 T) location. The longitudinal base metal C_v specimens were oriented with their long axis parallel to the primary rolling direction and with V-notches perpendicular to the major plate surfaces. Tensile specimens were machined with the longitudinal axis parallel to the plate primary rolling direction. The WOL specimens were machined with the simulated crack perpendicular to the primary rolling direction and to the major plate surfaces. All mechanical test specimens, see Figure 2, were taken at least one plate thickness from the quenched edges of the plate material.

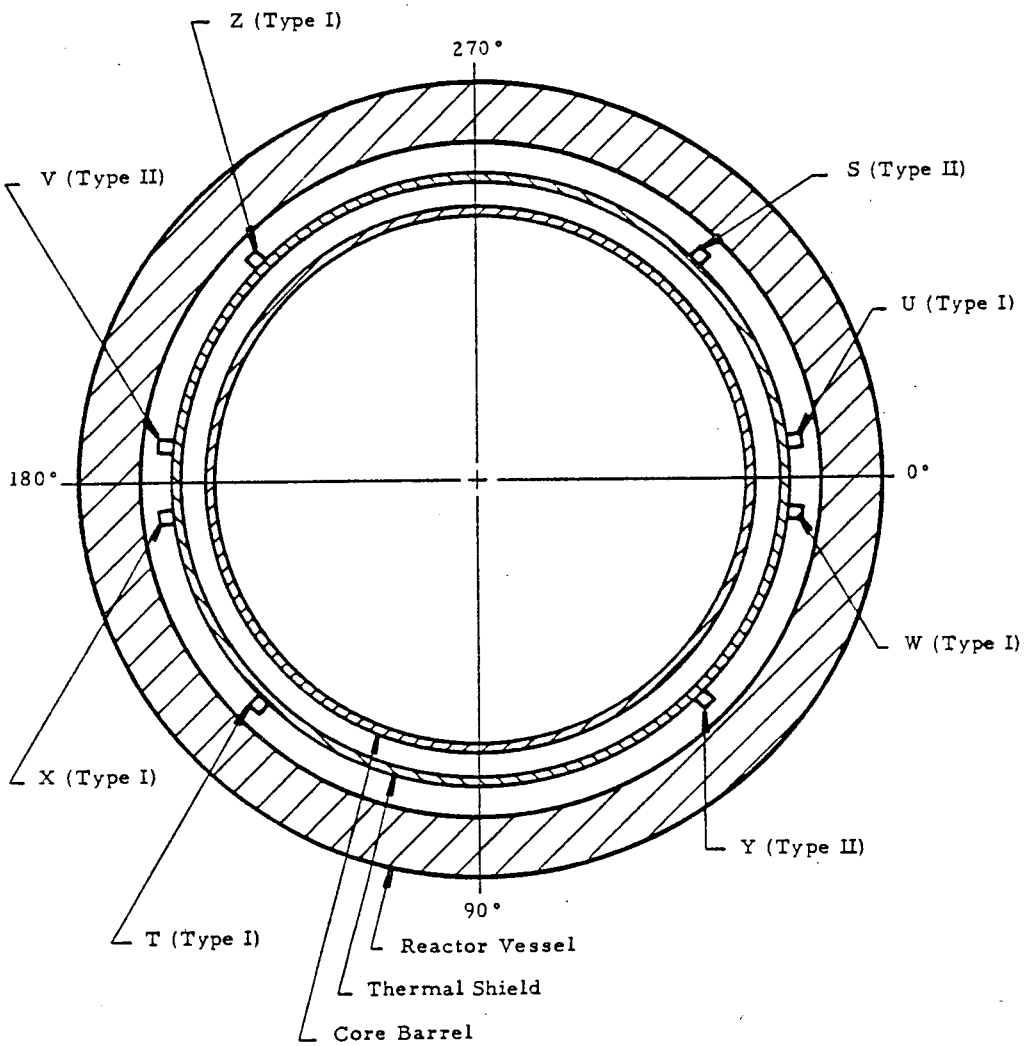


FIGURE 1. ARRANGEMENT OF SURVEILLANCE CAPSULES IN THE PRESSURE VESSEL

TABLE I

INDIAN POINT UNIT NO. 2 REACTOR VESSEL SURVEILLANCE MATERIALS [10]

Heat Treatment History

Shell Plate Material:

Heated to 1550-1600 F for 4 hours, water quenched.

Tempered at 1225 F for 4 hours, air cooled.

Stress relieved at 1150 F for 40 hours, furnace cooled to 600 F

Weldment:

Stress relieved at 1150 F for 19.75 hours, furnace cooled to 600 F

Correlation Monitor:

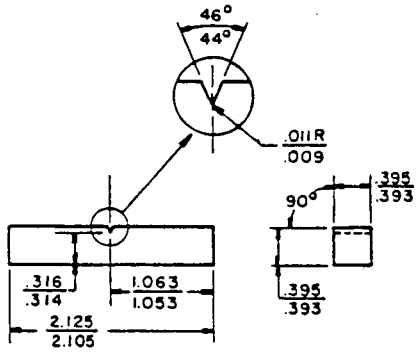
1650 F, 4 hours, water quenched to 300 F

1200 F, 6 hours, air cooled.

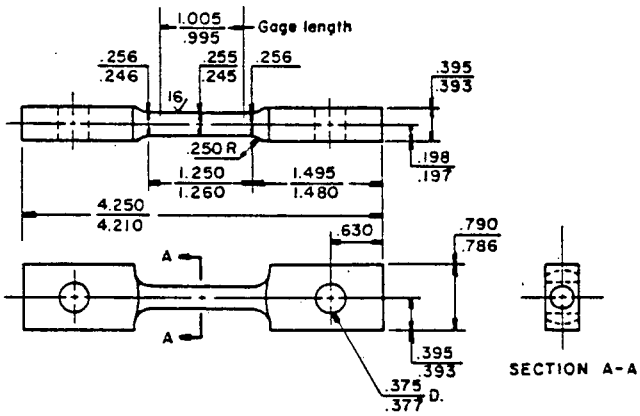
Chemical Composition (Percent)

Material	C	Mn	P	S	Si	Ni	Mo	Cu
Plate B2002-1	0.20	1.28	0.010	0.019	0.25	0.58	0.46	0.25
Plate B2002-2	0.22	1.30	0.014	0.018	0.22	0.46	0.50	0.14
Plate B2002-3	0.22	1.29	0.011	0.020	0.25	0.57	0.46	0.14
Correlation Monitor	0.24	1.34	0.011	0.023	0.23	(a)	0.51	(a)
Weld Metal	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)

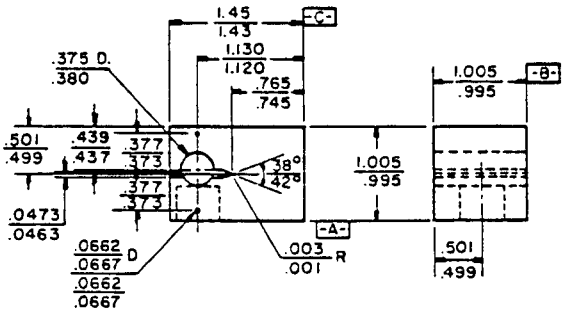
(a) Not reported in WCAP 7323 [10].



(a) Charpy V-notch Impact Specimen



(b) Tensile Specimen



(c) Wedge Opening Loading Specimen

FIGURE 2. VESSEL MATERIAL SURVEILLANCE SPECIMENS

Capsule Z contained 32 Charpy V-notched specimens (8 longitudinal from each plate material, plus 8 each from the correlation monitor material); 3 tensile specimens (1 from each plated); and 6 base plate WOL specimens (2 from each plate.) The specimen numbering system and location within Capsule Z is shown in Figure 3.

Capsule Z also contained the following dosimeters for determining the neutron flux density:

Target Element	Form	Quantity
Copper	Bare wire	2
Nickel	Bare wire	1
Cobalt (in aluminum)	Bare wire	3
Cobalt (in aluminum)	Cd shielded wire	3

In addition, ends were cut from 10 tested Charpy specimens to serve as iron dosimeters.

Three eutectic alloy thermal monitors had been inserted in holes in the steel spacers in Capsule Z. Two (located at the top and bottom) were 2.5% Ag and 97.5% Pb with a melting point of 579°F. The other (located at the center of the capsule) was 1.75% Ag, 0.75% Sn, and 97.5% Pb having a melting point of 590°F.

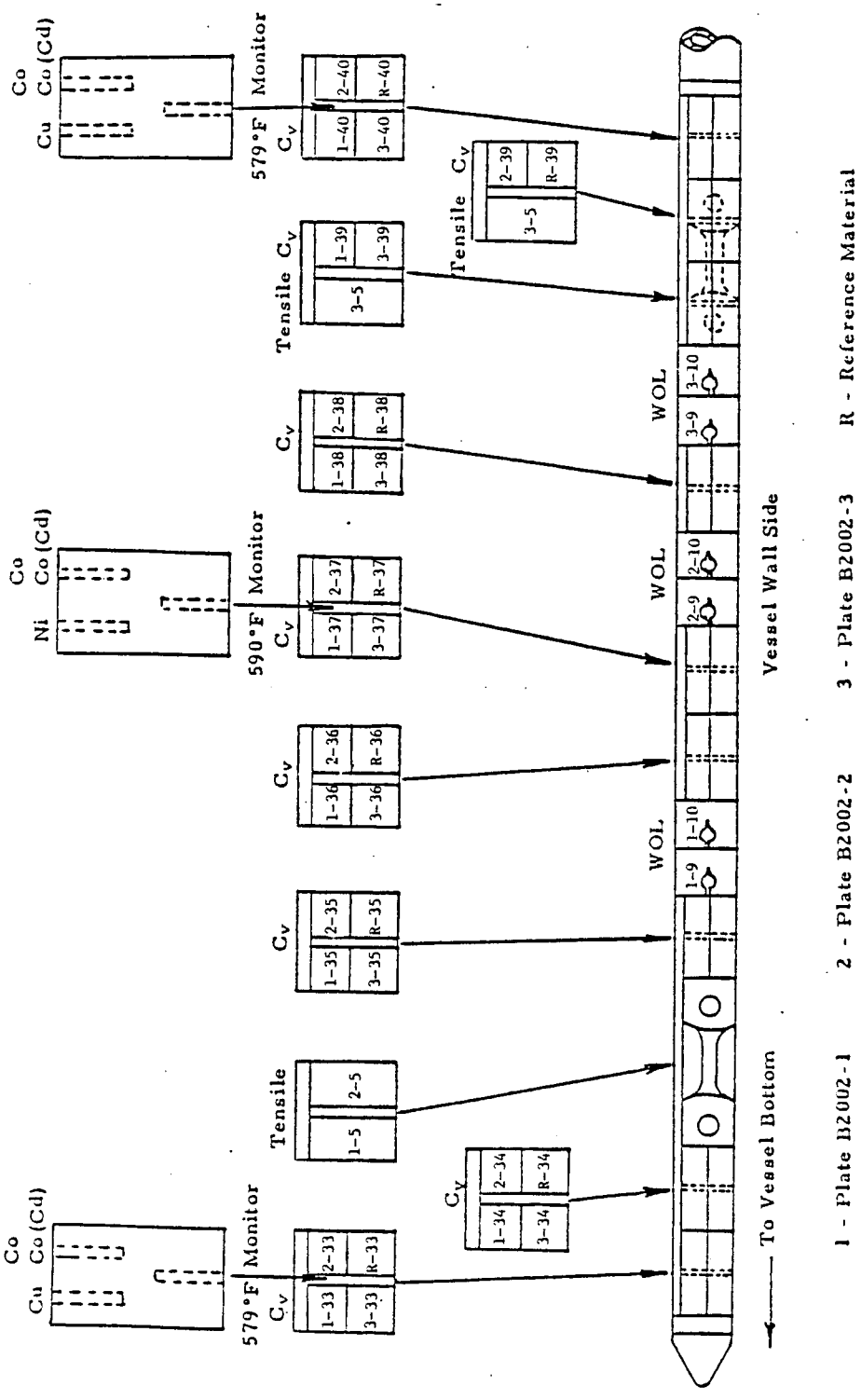


FIGURE 3. ARRANGEMENT OF SPECIMENS IN CAPSULE Z

IV. TESTING OF SPECIMENS FROM CAPSULE Z

The capsule shipment, capsule opening, specimen testing, and reporting of results were carried out in accordance with the Project Plan for Indian Point Unit No. 2 Reactor Vessel Irradiation Surveillance Program. The SwRI Nuclear Projects Operating Procedures called out in this plan include:

(1) XIII-MS-104-1, "Shipment of Westinghouse PWR Vessel Material Surveillance Capsule Using SwRI Cask and Equipment"

(2) XI-MS-101-1, "Determination of Specific Activity and Analysis of Radiation Detector Specimens"

(3) XI-MS-103-1, "Conducting Tension Tests on Metallic Specimens"

(4) XI-MS-104-1, "Charpy Impact Tests on Metallic Specimens"

(5) XIII-MS-103-1, "Opening Radiation Surveillance Capsules and Handling and Storing Specimens"

Copies of the above documents are on file at SwRI.

A. Shipment, Opening, and Inspection of Capsule

Southwest Research Institute utilized Nuclear Projects Operating Procedure XIII-MS-104-1, as incorporated in approved Con Edison procedures, for the shipment of Capsule Z to the SwRI laboratories. SwRI personnel severed the capsule from its extension tube, sectioned the extension tube into several lengths, supervised the loading of the capsule and extension tube materials into the shipping cask, and transported the cask to San Antonio, Texas.

The capsule was opened and the contents identified and stored in accordance with Procedure XIII-MS-103-1. The long seam welds were milled off using a Bridgeport vertical milling machine. Before milling the long seam weld beads, transverse saw cuts were made to remove the capsule ends. After the long seam welds had been milled off, the top half of the capsule shell

was removed. The specimens and spacer blocks were carefully removed and placed in indexed receptacles identifying each capsule location. After the disassembly had been completed, each specimen was carefully checked to insure agreement with the identification and location as listed in WCAP 7323 [10]. No discrepancies were found.

The thermal monitors and neutron dosimeter wires were removed from the holes in the spacers. The thermal monitors, contained in quartz vials, were examined. No evidence of melting was observed, thus indicating that the maximum temperature during exposure of Capsule Z did not exceed 579°F. All neutron dosimeters were in the positions called out in WCAP 7323 and were correctly accounted for.

B. Neutron Dosimetry

The dosimeters wires were weighed on a Mettler microbalance, and the Charpy slices were weighed on a Mettler digital balance. The gamma activities of the dosimeters were determined in accordance with Procedure XI-MS-101-1 using an IT-5400 multichannel analyzer and a Ge(Li) coaxial detector system. The calibration of the equipment was accomplished with ^{54}Mn, ^{60}Co, and ^{137}Cs radioactivity standards obtained from the U.S. Department of Commerce National Bureau of Standards. All activities were corrected to the time-of-removal (TOR) at reactor shutdown.

Infinitely dilute saturated activities (A_{SAT}) were calculated for each of the dosimeters because A_{SAT} is directly related to the product of the energy-dependent microscopic activation cross section and the neutron flux density. The relationship between A_{TOR} and A_{SAT} is given by:

$$\frac{A_{TOR}}{A_{SAT}} = \sum_{m-1}^{m=n} P_m(1-e^{-\lambda T_m})(e^{-\lambda t_m})$$

where:

λ = decay constant for the activation product, day^{-1};

t_m = decay time after operating period m, days;

T_m = operating days;

P_m = average fraction of full power during operating period.

The values of t_m, T_m, and P_m up to the 1982 refueling shutdown for Indian Point Unit No. 2 are presented in Table II. The calculation of the neutronic factors is described below.

Westinghouse performed a two-dimensional discrete ordinates transport calculation with a 21-group neutron cross section library, a P1 expansion of the scattering matrix, and an S_8 order of angular quadrature. A one-eighth segment of a plane through the vertical axis was used to model the core, core barrel, thermal shield, surveillance capsules and holders, pressure vessel, and three water regions using R-θ coordinates. The resulting axial, radial, and azimuthal dependence of the fast neutron (E > 1.0 MeV) flux density and energy spectrum within the reactor vessel and surveillance capsules were used to calculate the spectrum-averaged cross sections for the threshold and the fission detectors as well as the lead factors for use in relating neutron exposure of the pressure vessel to that of the surveillance capsule. The pertinent factors obtained from these transport calculations are summarized in Table III.

The primary result desired from the dosimeter analysis is the total neutron fluence (E > 1 MeV) which the surveillance specimens and pressure vessel have received. The average flux density at full power is given by:

$$\phi = A_{SAT}/N_o\bar{\sigma}$$

TABLE II

SUMMARY OF REACTOR OPERATIONS
INDIAN POINT UNIT NO. 2

Operating Period	Dates Start	Dates Stop	Operating Days (T_m)	Shutdown Days	Fraction of Full Power (P_m)	Decay Time After Period, Days (t_m)
1	08/15/73	08/24/73	10	-	0.4377	3311
	08/25/73	08/25/73	-	1	-	-
2	08/26/73	09/07/73	13	-	0.4532	3297
	09/08/73	09/20/73	-	13	-	-
3	09/21/73	09/28/73	8	-	0.3161	3276
	09/29/73	09/30/73	-	2	-	-
4	10/01/73	10/12/73	12	-	0.3088	3262
	10/13/73	01/25/74	-	105	-	-
5	01/26/74	01/29/74	4	-	0.2412	3153
	01/30/74	03/21/74	-	51	-	-
6	03/22/74	04/18/74	28	-	0.5438	3074
	04/19/74	04/28/74	-	10	-	-
7	04/29/74	05/03/74	5	-	0.4962	3059
	05/04/74	05/04/74	-	1	-	-
8	05/05/74	05/10/74	6	-	0.4743	3052
	05/11/74	05/12/74	-	2	-	-
9	05/13/74	05/13/74	1	-	0.0730	3049
	05/14/74	05/20/74	-	7	-	-
10	05/21/74	06/14/74	25	-	0.6653	3017
	06/15/74	06/16/74	-	2	-	-
11	06/17/74	07/22/74	36	-	0.7691	2979
	07/23/74	07/23/74	-	1	-	-
12	07/24/74	07/26/74	3	-	0.7593	2975
	07/27/74	08/05/74	-	10	-	-
13	08/06/74	09/06/74	32	-	0.6653	2933
	09/07/74	09/09/74	-	3	-	-
14	09/10/74	09/30/74	21	-	0.7429	2909
	10/01/74	10/11/74	-	11	-	-
15	10/12/74	11/09/74	29	-	0.8637	2869
	11/10/74	11/10/74	-	1	-	-
16	11/11/74	12/06/74	26	-	0.8306	2842
	12/07/74	12/07/74	-	1	-	-
17	12/08/74	01/01/75	25	-	0.8495	2816
	01/02/75	01/04/75	-	3	-	-
18	01/05/75	01/05/75	1	-	0.5450	2812
	01/06/75	01/06/75	-	1	-	-
19	01/07/75	01/31/75	25	-	0.8810	2786
	02/01/75	02/02/75	-	2	-	-
20	02/03/75	02/28/75	26	-	0.9408	2758
	03/01/75	04/03/75	-	34	-	-
21	04/04/75	05/02/75	29	-	0.7632	2695
	05/03/75	05/03/75	-	1	-	-
22	05/04/75	07/28/75	86	-	0.9114	2608
	07/29/75	08/10/75	-	13	-	-
23	08/11/75	09/12/75	33	-	0.7108	2562
	09/13/75	09/13/75	-	1	-	-
24	09/14/75	10/16/75	33	-	0.7962	2528
	10/17/75	10/29/75	-	13	-	-
25	10/30/75	11/14/75	16	-	0.7467	2499
	11/15/75	11/15/75	-	1	-	-
26	11/16/75	01/04/76	50	-	0.8427	2448
	01/05/76	01/05/76	-	1	-	-
27	01/06/76	01/29/76	24	-	0.8703	2423
	01/30/76	02/04/76	-	6	-	-
28	02/05/76	03/30/76	55	-	0.9122	2362
	03/31/76	09/26/76	-	180	-	-
29	09/27/76	09/27/76	1	-	0.0680	2181
	09/28/76	09/28/76	-	1	-	-

TABLE II (CONTINUED)

SUMMARY OF REACTOR OPERATIONS
INDIAN POINT UNIT NO. 2

Operating Period	Dates Start	Dates Stop	Operating Days (T_m)	Shutdown Days	Fraction of Full Power (P_m)	Decay Time After Period, Days (t_m)
30	09/29/76	10/29/76	31	-	0.8423	2149
	10/30/76	12/10/76	-	42	-	-
31	12/11/76	01/27/77	48	-	0.8396	2059
	01/28/77	01/29/77	-	2	-	-
32	01/30/77	02/01/77	3	-	0.7250	2054
	02/02/77	02/05/77	-	4	-	-
33	02/06/77	03/11/77	34	-	0.8825	2016
	03/12/77	03/14/77	-	3	-	-
34	03/15/77	04/10/77	27	-	0.9242	1986
	04/11/77	05/13/77	-	33	-	-
35	05/14/77	07/02/77	50	-	0.8936	1903
	07/03/77	08/05/77	-	34	-	-
36	08/06/77	08/19/77	14	-	0.6372	1855
	08/20/77	08/21/77	-	2	-	-
37	08/22/77	02/13/78	176	-	0.9022	1677
	02/14/78	05/24/78	-	100	-	-
38	05/25/78	07/28/78	65	-	0.8960	1512
	07/29/78	07/30/78	-	2	-	-
39	07/31/78	09/15/78	47	-	0.9820	1463
	09/16/78	10/05/78	-	20	-	-
40	10/06/78	11/23/78	49	-	0.9360	1394
	11/24/78	12/02/78	-	9	-	-
41	12/03/78	06/15/79	195	-	0.9690	1190
	06/16/79	09/14/79	-	91	-	-
42	09/15/79	11/27/79	74	-	0.8120	1025
	11/28/79	11/29/79	-	2	-	-
43	11/30/79	12/02/79	3	-	0.1840	1020
	12/03/79	12/07/79	-	5	-	-
44	12/08/79	01/11/80	35	-	0.8710	980
	01/12/80	02/09/80	-	29	-	-
45	02/10/80	02/14/80	5	-	0.4200	946
	02/15/80	02/18/80	-	4	-	-
46	02/19/80	06/03/80	106	-	0.9310	836
	06/04/80	06/11/80	-	8	-	-
47	06/12/80	08/10/80	60	-	0.9310	768
	08/11/80	08/13/80	-	3	-	-
48	08/14/80	10/17/80	65	-	0.9400	700
	10/18/80	05/21/81	-	216	-	-
49	05/22/81	07/10/81	50	-	0.7120	434
	07/11/81	07/11/81	-	1	-	-
50	07/12/81	08/21/81	41	-	0.9640	392
	08/22/81	09/15/81	-	25	-	-
51	09/16/81	10/05/81	20	-	0.9040	347
	10/06/81	10/15/81	-	10	-	-
52	10/16/81	11/11/81	27	-	0.9710	310
	11/12/81	11/22/81	-	11	-	-
53	11/23/81	04/02/82	131	-	0.9590	168
	04/03/82	04/03/82	-	1	-	-
54	04/04/82	05/17/82	44	-	0.9230	123
	05/18/82	05/23/82	-	6	-	-
55	05/24/82	08/12/82	81	-	0.9520	36
	08/13/82	08/14/82	-	2	-	-
56	08/15/82	09/02/82	19	-	0.7890	15
	09/03/82	09/07/82	-	5	-	-
57	09/08/82	09/17/82	10	-	0.7980	0

TABLE III

RESULTS OF DISCRETE ORDINATES Sn TRANSPORT ANALYSIS [17]
INDIAN POINT UNIT NO. 2
40° CAPSULES

A. Calculated Reaction Cross Sections for Analysis of Fast Neutron Monitors (E > 1.0 Mev)

Reaction	(barns)
$^{54}Fe(n,p)^{54}Mn$	.067
$^{58}Ni(n,p)^{58}Co$	.0899
$^{63}Cu(n,\alpha)^{60}Co$	.000490

B. Calculated Capsule Lead Factors

Position[a]	Location within Capsule	Lead Factor[b]
211.10 cm	Center of core-side Charpy layer	3.90
211.33 cm	Center of capsule	3.72
211.60 cm	Center of two specimen layers	3.52
212.10 cm	Center of vessel-side Charpy layer	3.14

(a) Distance from center of core

(b) $\frac{\text{Capsule neutron flux density, } E > 1.0 \text{ MeV}}{\text{Maximum neutron flux density at vessel I.D., } E > 1.0 \text{ MeV}}$

where ϕ = energy dependent neutron flux density, n/cm^2 sec;

$\bar{\sigma}$ = spectrum-averaged activation cross section, cm^2; and

N_o = number of target atoms per mg.

The total neutron flux fluence is then equal to the product of the average neutron flux density and the equivalent reactor operating time at full power.

In Capsule Z, the correlation monitor and B2002-3 shell plate Charpy specimens were located in the specimen layer nearest to the vessel wall and the B2002-1 and B2002-2 shell plate Charpy specimens were located in the specimen layer nearest to the core. Since there is a radial dependence of the fast neutron flux in the vessel, the neutron exposure received by the correlation monitor and B2002-3 shell plate Charpy specimens is expected to be lower than that received by the B2002-1 and B2002-2 shell plate Charpy specimens. The dosimetry program is capable of providing information on the radial dependence of the fast flux because the Charpy ends used for iron dosimetry were taken from both of the Charpy specimen layers (nearest to and farthest from the core).

The activities of dosimeters and resulting flux values obtained from Capsule Z are presented in Table IV. A summary of the capsule Z and vessel I.D. fluxes calculated for full-power operation up to the 1982 refueling outage is as follows:

Radial Position	Measured Capsule Flux $cm^{-2}.sec^{-1}$, E > 1 MeV	Lead Factor	Peak Vessel Flux at I.D. $cm^{-2}.sec^{-1}$, E > 1 MeV
211.1 cm	7.64×10^{10}	3.90	1.96×10^{10}
212.1 cm	5.63×10^{10}	3.14	1.79×10^{10}

TABLE IV

SUMMARY OF NEUTRON DOSIMETRY RESULTS
INDIAN POINT UNIT NO. 2, CAPSULE Z

Dosimeter Position[a]	Dosimeter Identification[b]	Activation Reaction	ATOR (dps/mg)	ASAT (dpo/mg)	Capsule Flux ($cm^{-2}.sec^{-1}$, E > 1 MeV)[c]
211.1 cm	Cu (Top)	$^{63}Cu(n,\alpha)^{60}Co$	1.43×10^{2}	3.45×10^{2}	1.07×10^{11}
	Cu (Bottom)		1.26×10^{2}	3.03×10^{2}	9.44×10^{10}
	Ni (Middle)	$^{58}Ni(n,p)^{58}Co$	3.51×10^{4}	4.30×10^{4}	6.84×10^{10}
	2-40 (Top)	$^{54}Fe(n,p)^{54}Mn$	2.02×10^{3}	2.94×10^{3}	7.02×10^{10}
	1-38		1.97×10^{3}	2.88×10^{3}	6.87×10^{10}
	2-36		1.99×10^{3}	2.90×10^{3}	6.93×10^{10}
	2-53		1.94×10^{3}	2.82×10^{3}	6.74×10^{10}
	1-33 (Bottom)		1.89×10^{3}	2.75×10^{3}	6.56×10^{10}
				Average =	7.64×10^{10}
212.1 cm	R-40 (Top)	$^{54}Fe(n,p)^{54}Mn$	1.66×10^{3}	2.42×10^{3}	5.79×10^{10}
	R-36		1.64×10^{3}	2.39×10^{3}	5.71×10^{10}
	3-38		1.64×10^{3}	2.39×10^{3}	5.71×10^{10}
	R-33		1.61×10^{3}	2.34×10^{3}	5.59×10^{10}
	3-33 (Bottom)		1.55×10^{3}	2.25×10^{3}	5.38×10^{10}
				Average =	5.63×10^{10}
					Thermal Flux[d]
212.7 cm	Co (Top)	$^{59}Co(n,\gamma)^{60}Co$	1.21×10^{7}	2.92×10^{7}	-
	Co (Mid)		1.38×10^{7}	3.35×10^{7}	-
	Co (Bottom)		1.29×10^{7}	3.11×10^{7}	-
	Co(Cd) (Top)		6.12×10^{6}	1.48×10^{7}	3.78×10^{10}
	Co (Cd) (Mid)		6.04×10^{6}	1.46×10^{7}	4.96×10^{10}
	Co(Cd) (Bottom)		5.98×10^{6}	1.44×10^{7}	4.39×10^{10}
				Average =	4.38×10^{10}

(a) Distance from center of core.
(b) For iron dosimeters, identification refers to Charpy specimens.
(c) Calculated flux values subject to ± 16.5% uncertainty (1σ).
(d) Calculated per ASTM Method E262 using a 37.2 barn 2200 m/sec cross section.

The discrepancies in the peak vessel flux values determined from the several dosimeter materials are attributed primarily to the uncertainties in the calculated spectra and in the reaction cross sections. Other neutronic factors contributing to the estimated $\pm$ 16.5% uncertainty (1σ) in a calculated flux value are the determination of disintegration rates, the calculation of reaction rates (A_{SAT}/N_0), and reactor vessel dimensional tolerances.

Averaging the results obtained from the Capsule Z iron, copper and nickel neutron dosimeters, the peak neutron flux incident on the I.D. surface of the pressure vessel to the 1982 refueling outage is calculated to be 1.88×10^{10} $cm^{-2}.sec^{-1}$, E > 1 MeV. This is within 9% of the value determined from the analysis of Capsule Y [13] and within 7% of the revised value of 1.75×10^{10} obtained when the Table III constants are applied to the Capsule T dosimeter activities [14]. The calculated full power neutron flux for the correlation monitor and B2002-3 shell plate Charpy specimen layer is given by:

$$1.88 \times 10^{10} \times 3.14 = 5.90 \times 10^{10}$$

Similarly, the calculated full power neutron flux for the B2002-1 and B2002-2 shell plate Charpy specimens, the tensile specimens, and the WOL specimens are given by:

$1.88 \times 10^{10} \times 3.90 = 7.33 \times 10^{10}$ (B2002-1 and B2002-2 C_v)

$1.88 \times 10^{10} \times 3.52 = 6.62 \times 10^{10}$ (Tensile Specimens)

$1.88 \times 10^{10} \times 3.72 = 6.99 \times 10^{10}$ (WOL Specimens)

Since Indian Point Unit No. 2 operated for 1887.5 effective full power days (EFPD) up to the 1982 refueling outage, the calculated fluences for Capsule Z and the vessel up to the 1982 refueling outage are as follows:

- Correlation Monitor and B2002-3 - 9.62×10^{18} n/cm^2
- B2002-1 and B2002-2 C_v Specimens - 1.20×10^{19} n/cm^2
- Tensile Specimens - 1.08×10^{19} n/cm^2
- WOL Specimens - 1.14×10^{19} n/cm^2
- Pressure Vessel ID Surface - 3.07×10^{18} n/cm^2

C. Mechanical Property Tests

The irradiated Charpy V-notch specimens were tested on a calibrated* SATEC Model SI-1K 240 ft-lb, 16 ft/sec impact machine in accordance with Procedure XI-MS-104-1. The test temperatures, selected to develop the ductile-brittle transition and upper shelf regions, were obtained using a liquid conditioning bath monitored with a Fluke Model 2168A digital thermometer. The Charpy V-notch impact data obtained by SwRI on the specimens contained in Capsule Z are presented in Tables V through VIII. The shifts in the Charpy V-notch transition temperatures determined for the three vessel plates and the correlation monitor are shown in Figures 4 through 7. The Capsule T [15] and Capsule Y [13] results, included for comparison, show that longer exposures result in increasing embrittlement, as expected.

A summary of the shifts in RT_{NDT} determined at the 46 ft-lb level as specified in NUREG-0800 [18] and Appendix G to 10 CFR 50 [1], and the reduction in C_v upper shelf energies for each material, is presented in Table IX.

* Inspected and calibrated using specimens and procedures obtained from the Army Materials and Mechanics Research Center.

TABLE V
CHARPY IMPACT PROPERTIES OF LONGITUDINAL PLATE B2002-1
INDIAN POINT UNIT NO. 2
CAPSULE Z

Specimen No.	Temperature (°F)	Fracture Energy (ft-lb)	Lateral Expansion (mils)	Fracture Appearance (% shear)
1-33	75	17.5	15	5
1-36	110	30.5	28	5
1-37	140	33.5	29	20
1-38	180	48.0	44	35
1-34	210	79.0	69	80
1-39	250	84.5	73	100
1-35	300	99.0	71	100
1-40	300	92.0	78	100

TABLE VI

CHARPY IMPACT PROPERTIES OF LONGITUDINAL PLATE B2002-2
INDIAN POINT UNIT NO. 2
CAPSULE Z

Specimen No.	Temperature (°F)	Fracture Energy (ft-lb)	Lateral Expansion (mils)	Fracture Appearance (% shear)
2-33	75	13.0	12	5
2-36	110	24.0	24	10
2-37	140	34.5	32	15
2-38	180	71.5	61	35
2-34	210	81.5	69	80
2-39	250	83.5	71	100
2-35	300	92.5	78	100
2-40	300	92.0	73	100

TABLE VII

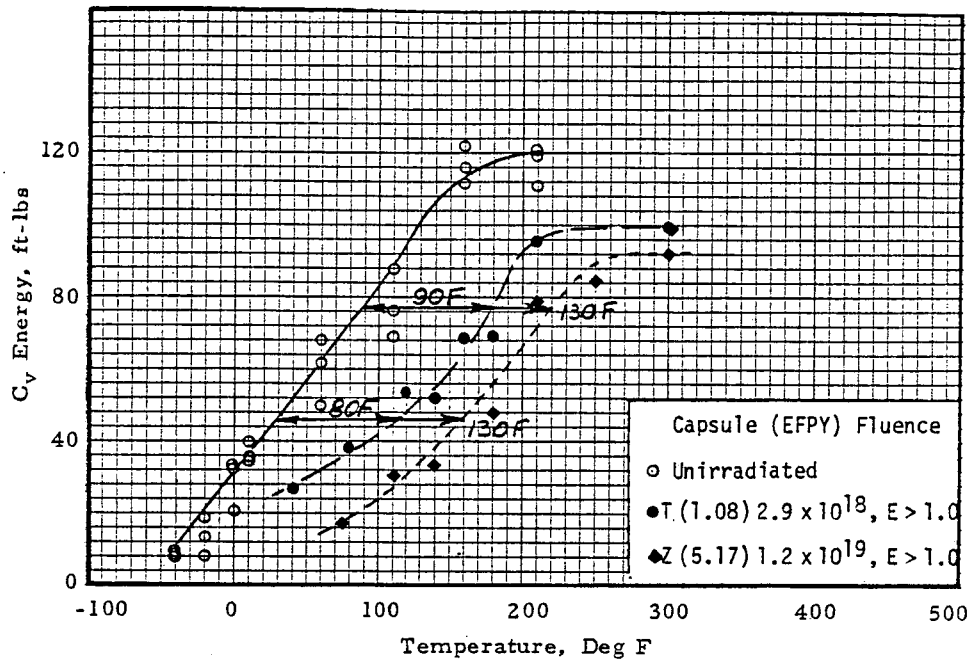
CHARPY IMPACT PROPERTIES OF LONGITUDINAL PLATE B2002-3
INDIAN POINT UNIT 2

Specimen No.	Temperature (°F)	Fracture Energy (ft-lb)	Lateral Expansion (mils)	Fracture Appearance (% shear)
3-33	75	6.5	4	0
3-36	160	17.0	17	10
3-38	180	27.0	24	10
3-34	210	34.5	32	20
3-37	250	46.0	42	45
3-35	300	78.0	56	100
3-39	350	82.5	71	100
3-40	350	82.0	58	100

TABLE VIII

CHARPY IMPACT PROPERTIES OF CORRELATION MONITOR MATERIAL
INDIAN POINT UNIT 2
CAPSULE Z

Specimen No.	Temperature (°F)	Fracture Energy (ft-lb)	Lateral Expansion (mils)	Fracture Appearance (% shear)
R-33	75	17.5	16	10
R-36	110	18.5	16	5
R-40	125	38.5	35	25
R-37	140	41.0	39	50
R-38	180	32.5	34	20
R-34	210	52.0	49	100
R-39	250	58.0	57	100
R-35	300	64.0	55	100



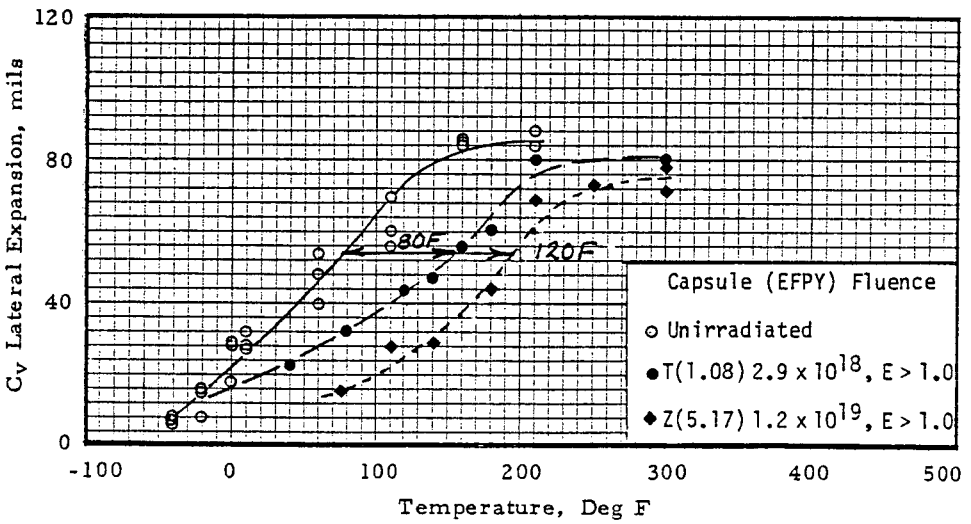
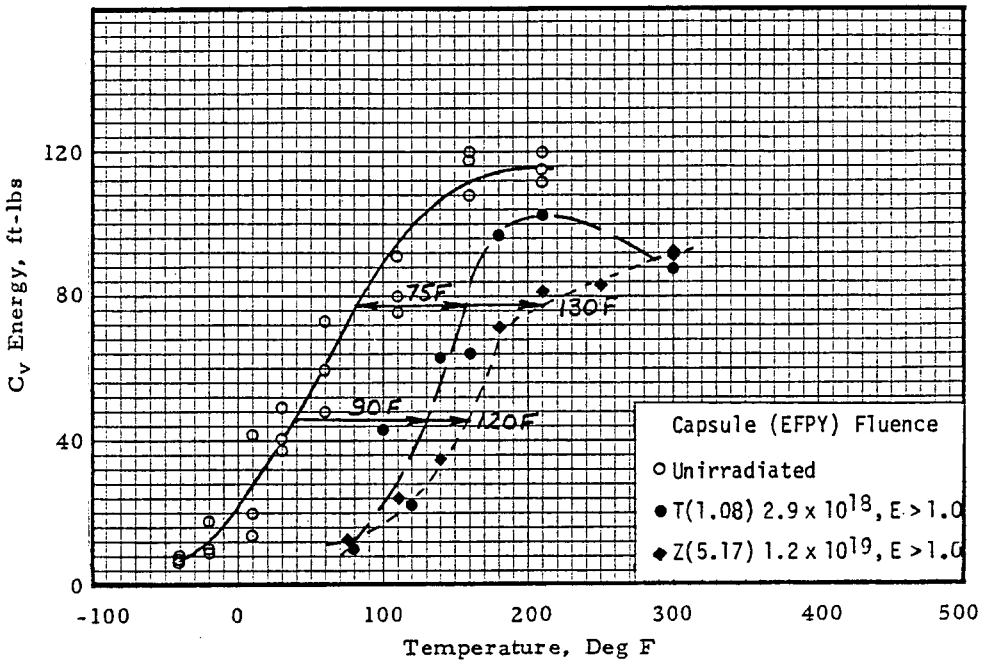


FIGURE 4. RADIATION RESPONSE OF INDIAN POINT UNIT NO. 2 VESSEL SHELL PLATE B2002-1 (LONGITUDINAL ORIENTATION)



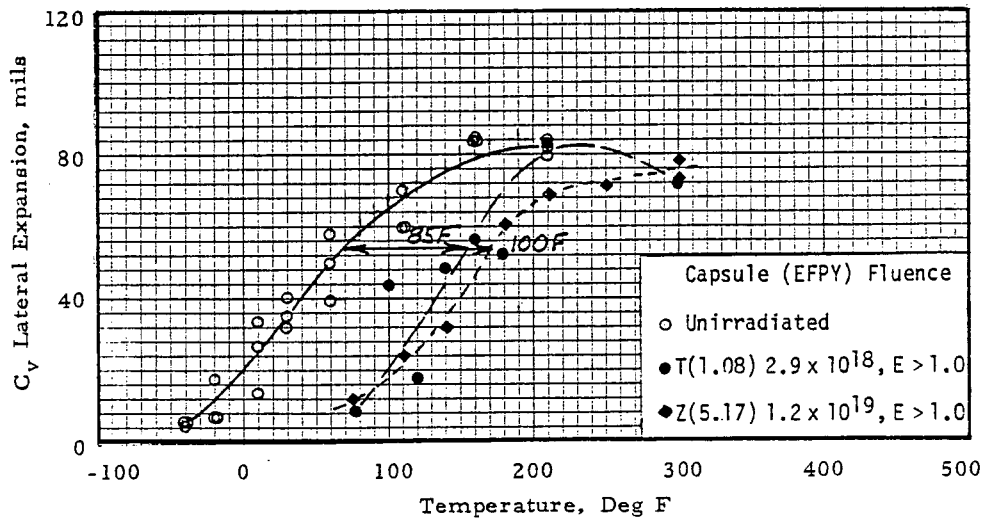
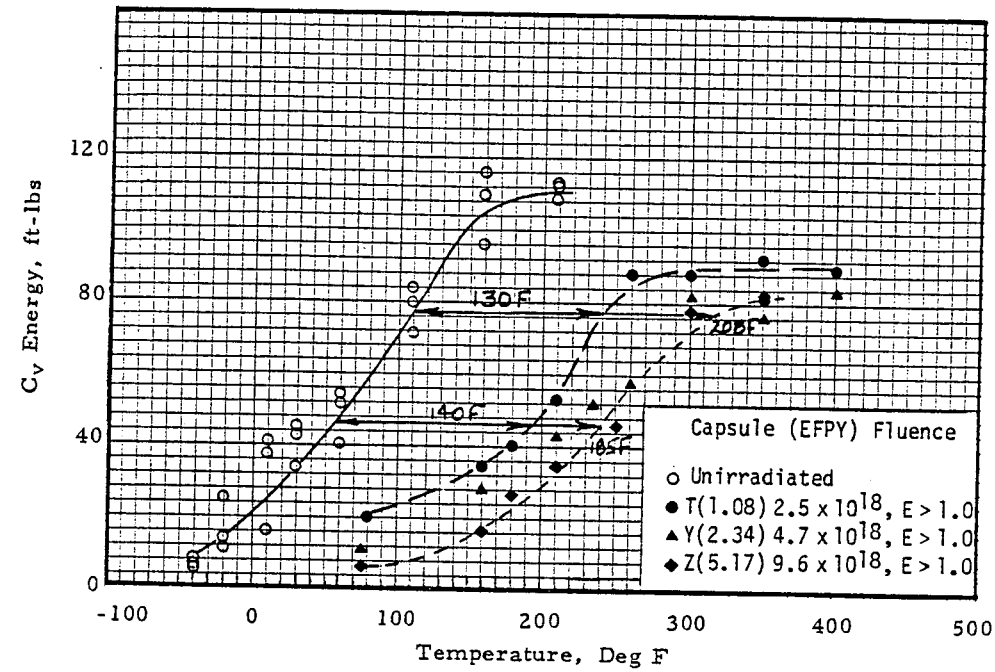


FIGURE 5. RADIATION RESPONSE OF INDIAN POINT UNIT NO. 2 VESSEL SHELL PLATE B2002-2 (LONGITUDINAL ORIENTATION)



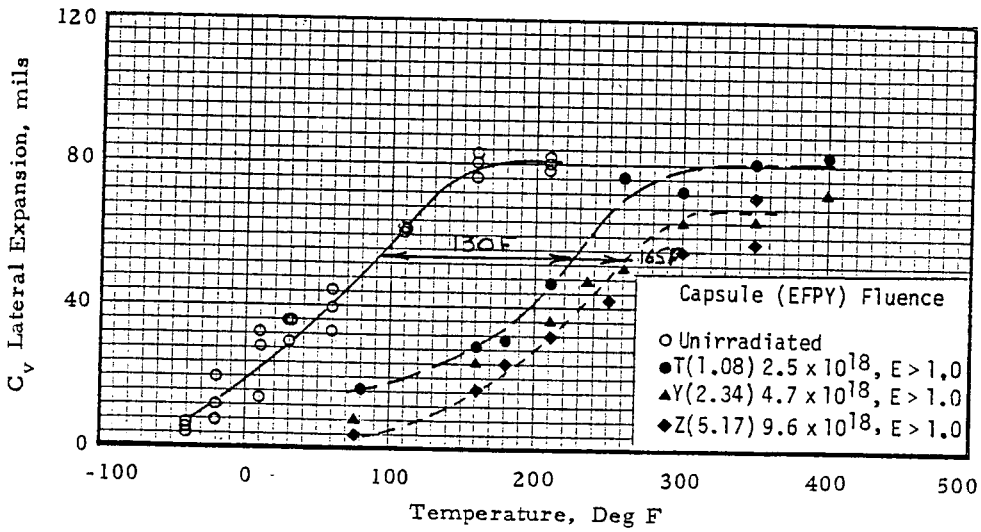


FIGURE 6. RADIATION RESPONSE OF INDIAN POINT UNIT NO. 2 VESSEL SHELL PLATE B2002-3 (LONGITUDINAL ORIENTATION)

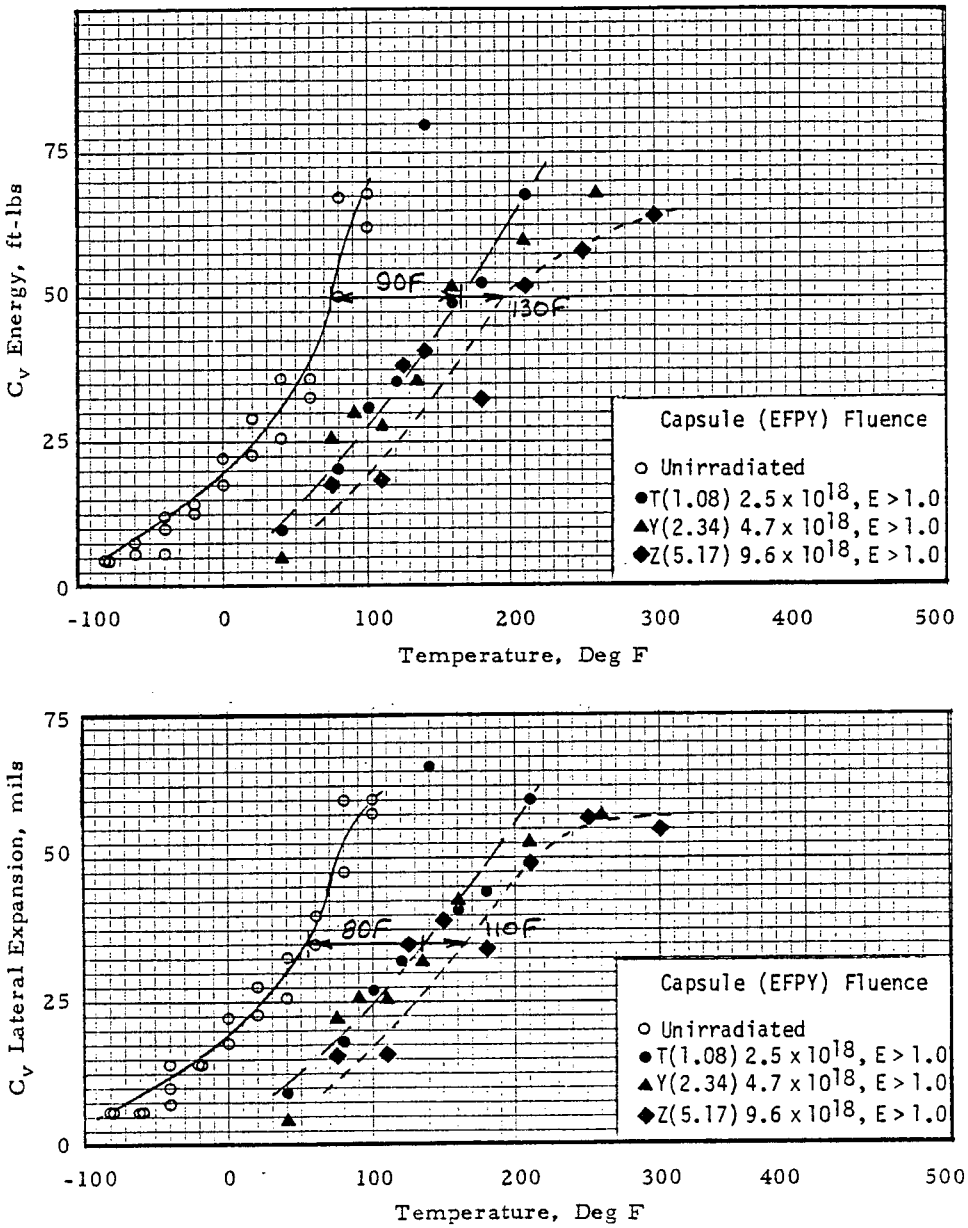


FIGURE 7. RADIATION RESPONSE OF INDIAN POINT UNIT NO. 2 CORRELATION MONITOR MATERIAL

TABLE IX

EFFECT OF IRRADIATION ON CAPSULE Z SURVEILLANCE MATERIALS
INDIAN POINT UNIT NO. 2

Criterion(1)	Correlation Monitor(2)	Long. Plate B2002-3(2)	Long. Plate B2002-2(3)	Long. Plate B2002-1(3)
Transition Temperature Shift				
@ 77 ft-lb	(4)	208°F	130°F	130°F
@ 46 ft-lb	130°F	185°F	120°F	130°F
@ 54 mil	110°F	165°F	100°F	120°F
ΔRT_{NDT} (5)	130°F	185°F	120°F	130°F
C_v Upper Shelf Drop	60 ft-lb (51%)	32 ft-lb (28%)	27 ft-lb (23%)	25 ft-lb (21%)

(1) Refer to Figures 4-7.
(2) Fluence = 9.62×10^{18} n/cm^2, E > 1 MeV.
(3) Fluence = 1.20×10^{19} n/cm^2, E > 1 MeV.
(4) Indeterminant.
(5) Transition temperatures at 46 ft-lb [1].

Tensile tests were carried out in accordance with Procedure XI-MS-103-1 using a 22-kip capacity MTS Model 810 Material Test System equipped with an Instron Catalogue No. G-51-13A 2-in. strain gage extensometer and Hewlett Packard Model 7004B X-Y autographic recording equipment. Tensile tests on the plate material and the weld metal were run at room temperature at a strain rate of 0.005 in/in/min. through the 0.2% offset yield strength using servo-control and ramp generator. The results, along with the room temperature tensile data reported by Westinghouse on the unirradiated materials [10], are presented in Table X. The load-strain records are included in Appendix A.

Testing of the WOL specimens was deferred at the request of Consolidated Edison Company. The specimens are in storage at the SwRI radiation laboratory.

D. Check Chemical Analysis Results

Check analyses for copper and nickel content of the ten broken Charpy V-notch specimens used for iron dosimetry and the three tested tensile specimens were run using ASTM Method E 322 [19]. The following results were obtained:

Material Identification	Specimen No.	% Copper	% Nickel
B2002-1	1-33 (C_V)	0.22	0.62
B2002-1	1-38 (C_V)	0.19	0.71
B2002-1	1-5 (Tensile)	0.29	0.61
B2002-2	2-33 (C_V)	0.19	0.47
B2002-2	2-36 (C_V)	0.17	0.46
B2002-2	2-40 (C_V)	0.20	0.50
B2002-2	2-5 (Tensile)	0.15	0.52
B2002-3	3-33 (C_V)	0.30	0.64
B2002-3	3-38 (C_V)	0.27	0.59
B2002-3	3-5 (Tensile)	0.23	0.58
Corr. Mon.	R-33 (C_V)	0.35	0.28
Corr. Mon.	R-36 (C_V)	0.31	0.27
Corr. Mon.	R-40 (C_V)	0.21	0.21

TABLE X

TENSILE PROPERTIES OF SURVEILLANCE MATERIALS
INDIAN POINT UNIT NO. 2
CAPSULE Z

Condition	Test Material	Spec. No.	Temp. (°F)	0.2% YS (ksi)	UTS (ksi)	Fracture Load (lb)	Fracture Stress (ksi)	Uniform Elongation (%)	Total Elongation (%)	Red. in Area (%)
Capsule Z[a]	Plate B2002-1	1-5	Room	81.6	104.6	3803	182.2	14.3	20.9	57.5
	Plate B2002-2	2-5	Room	69.9	91.5	3047	167.9	14.6	22.7	62.7
	Plate B2002-3	3-5	Room	74.3	96.2	3227	177.8	14.7	22.6	63.0
(b)	Plate B2002-1	-	Room	68.5	89.0	(c)	(c)	(c)	25.1	67.8
		-	Room	65.8	87.8	(c)	(c)	(c)	25.3	67.4
	Plate B2002-2	-	Room	62.4	83.8	(c)	(c)	(c)	27.1	70.0
		-	Room	66.8	90.5	(c)	(c)	(c)	28.2	69.6
	Plate B2002-3	-	Room	65.6	87.3	(c)	(c)	(c)	27.6	67.3
		-	Room	65.0	87.4	(c)	(c)	(c)	24.8	66.7

(a) Fluence = 1.08×10^{19} m/cm^2, E > 1 MeV.
(b) Unirradiated [10].
(c) Data not reported [10].

The copper results average about 0.05 higher than those reported from Capsule T [15] and Capsule Y [13], approximately equal to the estimated 1σ confidence level for the X-ray flourescence determination of copper in irradiated steels.

V. ANALYSIS OF RESULTS

The analysis of data obtained from surveillance program specimens has the following goals:

(1) Estimate the period of time over which the properties of the vessel beltline materials will meet the fracture toughness requirements of Appendix G of 10CFR50. This requires a projection of the measured reduction in C_v upper shelf energy to the vessel wall using knowledge of the energy and spatial distribution of the neutron flux and the dependence of C_v upper shelf energy on the neutron fluence.

(2) Develop heatup and cooldown curves to describe the operational limitations for selected periods of time. This requires a projection of the measured shift in RT_{NDT} to the vessel wall using knowledge of the dependence of the shift in RT_{NDT} on the neutron fluence and the energy and spatial distribution of the neutron flux.

The energy and spatial distribution of the neutron flux for Indian Point Unit No. 2 was calculated for Capsule Z with a discrete ordinates transport code [17]. This analysis, also applicable to Capsules T and Y, predicted that the lead factor (ratio of fast flux at the capsule location to the maximum pressure vessel flux) was 3.72 at the capsule centerline, 3.90 for the core-side Charpy layer, and 3.14 for the vessel-side Charpy layer (see Table III). This analysis also predicted that the fast flux at the 1/4T and 3/4T positions in the 8.5-in. pressure vessel wall would be 56% and 12%, respectively, of that at the vessel I.D. However, in this report the projection of Capsule Z results to the pressure vessel wall utilizes the more conservative attenuation figures of 60% and 15% for the 1/4T and 3/4T

positions to allow for the increased fraction of neutrons which might accrue in the 0.1 to 1.0 MeV range in deep penetration situations.

A method for estimating the increase in RT_{NDT} as a function of neutron fluence and chemistry is given in Regulatory Guide 1.99, Revision 1 [8]. However, the Guide also permits interpolation between credible surveillance data and extrapolation by extending the response curves parallel to the Guide trend curves. The slopes of the response curves for the shell plate materials constructed in Figure 8 are less than the square root of fluence utilized in Regulatory Guide 1.99. However, the projected responses of the Indian Point Unit No. 2 vessel beltline materials are based on the trend curves of Figure 8 which were constructed in accordance with Regulatory Guide 1.99 procedures. These surveillance capsule results agree well with the Regulatory Guide 1.99, Revision 1, trend curves, see Figure 8.

The Indian Point Unit No. 2 vessel plate B2002-3 is more sensitive than the plates B2002-1 and B2002-2 to irradiation embrittlement. Since the unirradiated values of RT_{NDT} for the three intermediate shell plates are higher than those of the weld and HAZ materials [20], the beltline region plate material is projected to control the adjusted value of RT_{NDT} through the 32 EFPY design life of Indian Point Unit No. 2. A long-term projection of the vessel RT_{NDT} has been made from Cycle 6 and beyond using a low leakage core loading pattern, which significantly reduces the pressure vessel fluence rate from that produced by the Design Basis core [16]; see Table XI.

A method for estimating the reduction in C_v upper shelf energy as a function of neutron fluence is also given in Regulatory Guide 1.99, Revision 1 [8]. The results from Capsules T, Y and Z are compared to a portion of Figure 2 of the Regulatory Guide 1.99, Revision 1, in Figure 9. The shelf energy responses of the pressure vessel surveillance materials from all

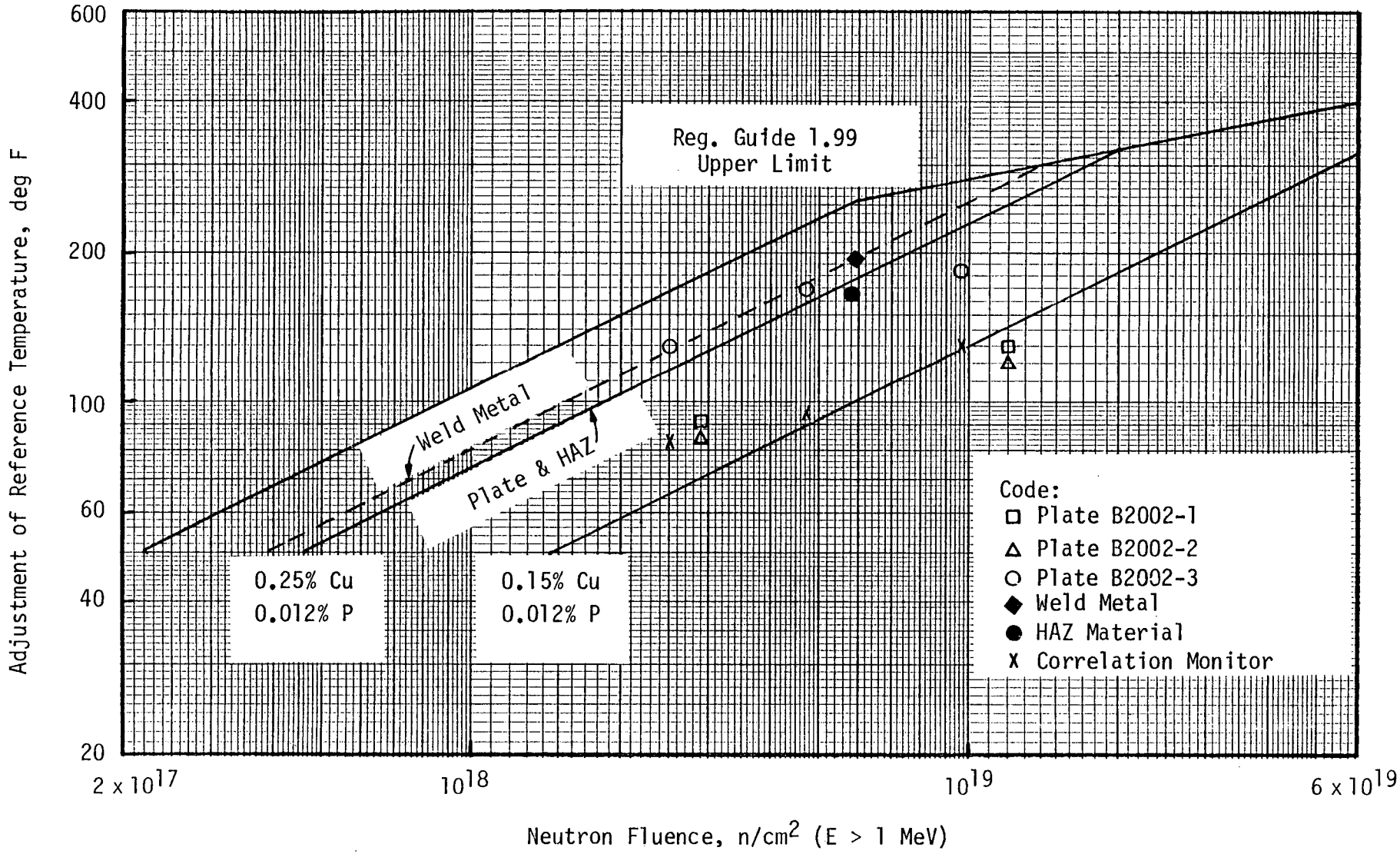


FIGURE 8. EFFECT OF NEUTRON FLUENCE ON RT_{NDT} SHIFT, INDIAN POINT UNIT NO. 2

TABLE XI

ADJUSTED VALUES OF RT_{NDT} FOR INDIAN POINT UNIT NO. 2

EFPY[a]	P.V. Material	Location	Initial RT_{NDT}	Fluence[b]	ΔRT_{NDT}	Adjusted RT_{NDT} Reg. Guide 1.99	Adjusted RT_{NDT} PTS
10	Plate B2002-3	I.D.	34°F	4.7×10^{18}	158	192	-
		1/4T	34°F	2.8×10^{18}	122	156	-
		3/4T	34°F	7.0×10^{17}	61	95	-
10	HAZ Material	I.D.	0°F	4.7×10^{18}	158	158	-
		1/4T	0°F	2.8×10^{18}	122	122	-
		3/4T	0°F	7.0×10^{17}	61	61	-
10	Weld Metal	I.D.	0°F	4.7×10^{18}	175	175	-
		1/4T	0°F	2.8×10^{18}	133	133	-
		3/4	0°F	7.0×10^{17}	67	67	-
15	Plate B2002-3	I.D.	34°F	6.3×10^{18}	182	216	-
		1/4T	34°F	3.8×10^{18}	142	176	-
		3/4T	34°F	9.5×10^{17}	71	105	-
15	HAZ Material	I.D.	0°F	6.3×10^{18}	182	182	-
		1/4T	0°F	3.8×10^{18}	142	142	-
		3/4T	0°F	9.5×10^{17}	71	71	-
15	Weld Metal	I.D.	0°F	6.3×10^{18}	200	200	-
		1/4T	0°F	3.8×10^{18}	155	155	-
		3/4T	0°F	9.5×10^{17}	103	103	-
32	Plate B2002-3	I.D.	34°F	1.2×10^{19}	250	284	248
		1/4T	34°F	7.2×10^{18}	195	229	227
		3/4T	34°F	1.8×10^{18}	98	132	182
32	HAZ Material	I.D.	0°F	1.2×10^{19}	250	250	-
		1/4T	0°F	7.2×10^{18}	195	195	-
		3/4T	0°F	1.8×10^{18}	98	98	-
32	Weld Metal	I.D.	0°F	1.2×10^{19}	280	280	271[c]
		1/4T	0°F	7.2×10^{18}	215	215	244[c]
		3/4T	0°F	1.8×10^{18}	108	108	177[c]

(a) 1 EFPY = 1,006,700 MWDt.
(b) Neutrons/cm^2, E > 1 MeV.
(c) The generic value for initial RT_{NDT} of -56°F for pressurized thermal shock (PTS), 1% Ni and 0.35% Cu were used to calculate this per 49/FR 4498-4502 for the circumferential weld.

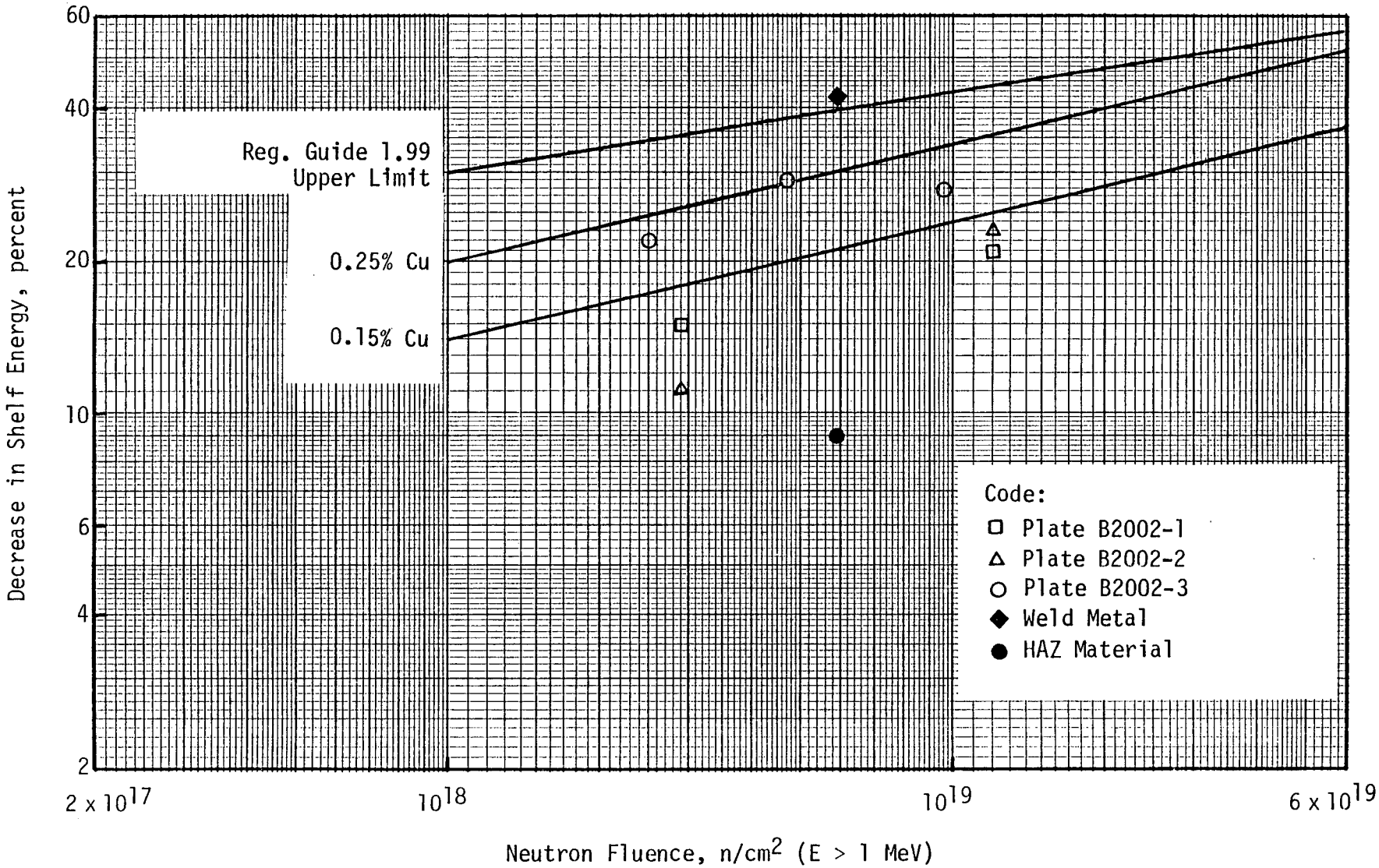


FIGURE 9. DEPENDENCE OF C_V SHELF ENERGY ON NEUTRON FLUENCE, INDIAN POINT UNIT NO. 2

three capsules are reasonably consistent and fall below the predictive trend curves of Regulatory Guide 1.99, Revision 1, for nominal plate chemistries of 0.15% Cu and 0.25% Cu. A long-term projection of the degradation in upper shelf energy has been made using the end-of-life fluences given In Table XI. Since the projected 32 EFPY 1/4T fluence is less than that received by Capsule Z and the shelf energies of the Capsule Z vessel plate specimens were all in excess of 77 ft-lb, it can be concluded that more than 32 EFPY of operation will be required before the Charpy shelf energy of the shell plate material reaches 77 ft-lb.

The current Indian Point Unit No. 2 reactor vessel surveillance program removal schedule, revised to conform to ASTM E 185-79 [9], is summarized in Table XII. There are five capsules remaining in the vessel, of which three are standbys.

TABLE XII

REACTOR VESSEL SURVEILLANCE CAPSULE REMOVAL SCHEDULE [21]
INDIAN POINT UNIT NO. 2

Capsule Ident. No.	Code	WOL Material	Removal Time	Equivalent Vessel Fluence
1	T	Three Plates	1.08 EFPY[a]	3.4 EFPY at I.D.
2	Y	Weld & B2002-3	2.34 EFPY[b]	11 EFPY at I.D.
3	Z	Three Plates	5.17 EFPY[c]	29 EFPY at I.D.
4	S	Weld & B2002-1	9 EFPY	43 EFPY at I.D.
5	U	Three Plates	32 EFPY	39 EFPY at I.D.
6	V	Weld & B2002-2	Standby	-
7	W	Three Plates	Standby	-
8	X	Three Plates	Standby	-

(a) Removed after core cycle 1.
(b) Removed after core cycle 3.
(c) Removed after core cycle 5.

VI. HEATUP AND COOLDOWN LIMIT CURVES FOR NORMAL OPERATION OF INDIAN POINT UNIT NO. 2

Indian Point Unit No. 2 is a 2758 Mw_t pressurized water reactor operated by Consolidated Edison Company. The unit has been provided with a reactor vessel material surveillance program as required by 10CFR50, Appendix H.

The third surveillance capsule (Capsule Z) was removed during the 1982 refuelling outage. This capsule was tested by Southwest Research Institute, the results being described in the earlier sections of this report. In summary, these results correlate well with those obtained from the first two capsules (Capsules T and Y) and indicate that plate B2002-3 will control the value of RTNDT over the plant design lifetime. Since there is a difference between surveillance capsule copper content and that reported for the reactor vessel plates, bounding values of copper content (0.25%) and initial RT_{NDT} (34°F) have been used for generating the heatup and cooldown curves.

The maximum RT_{NDT} after 32 effective full power years (EFPY) of operation was predicted to be 229°F at the 1/4T and 132°F at the 3/4T vessel wall locations, as controlled by plate B2002-3. The Unit No. 2 heatup and cooldown limit curves for up to 32 EFPY of operation have been computed on the basis of the above values of RT_{NDT} using Code procedures [2] and the following pressure vessel constants:

Vessel Inner Radius, r_i	=	86.50 in.
Vessel Outer Radius, r_o	=	95.28 in.
Operating Pressure, P_o	=	2235 psig
Initial Temperature, T_o	=	70°F
Final Temperature, T_f	=	550°F
Effective Coolant Flow Rate, Q	=	136.3 x 106 lb_m/hr
Effective Flow Area, A	=	26.719 ft2
Effective Hydraulic Diameter, D	=	15.051 in.

Heatup curves were computed for heatup rates of 60°F/hr and 100°F/hr. Since lower rates tend to raise the curve in the central region, the 60°F/hr

heatup curve applies to all heating rates up to 60°F/hr. The 100°F/hr heat-up curve applied to heatup rates between 60°F/hr and 100°F/hr. Cooldown curves were computed for cooldown rates of 0°F/hr (steady state), 20°F/hr, 60°F/hr, and 100°F/hr. The 20°F/hr curve would apply to cooldown rates up to 20°F/hr; the 60°F/hr curve would apply to rates from 20°F to 60°F/hr; the 100°F/hr curve would apply to rates from 60°F/hr to 100°F/hr.

The Unit No. 2 heatup, cooldown and leak test curves for up to 32 EFPY are given in Figures 10, 11, and 12.

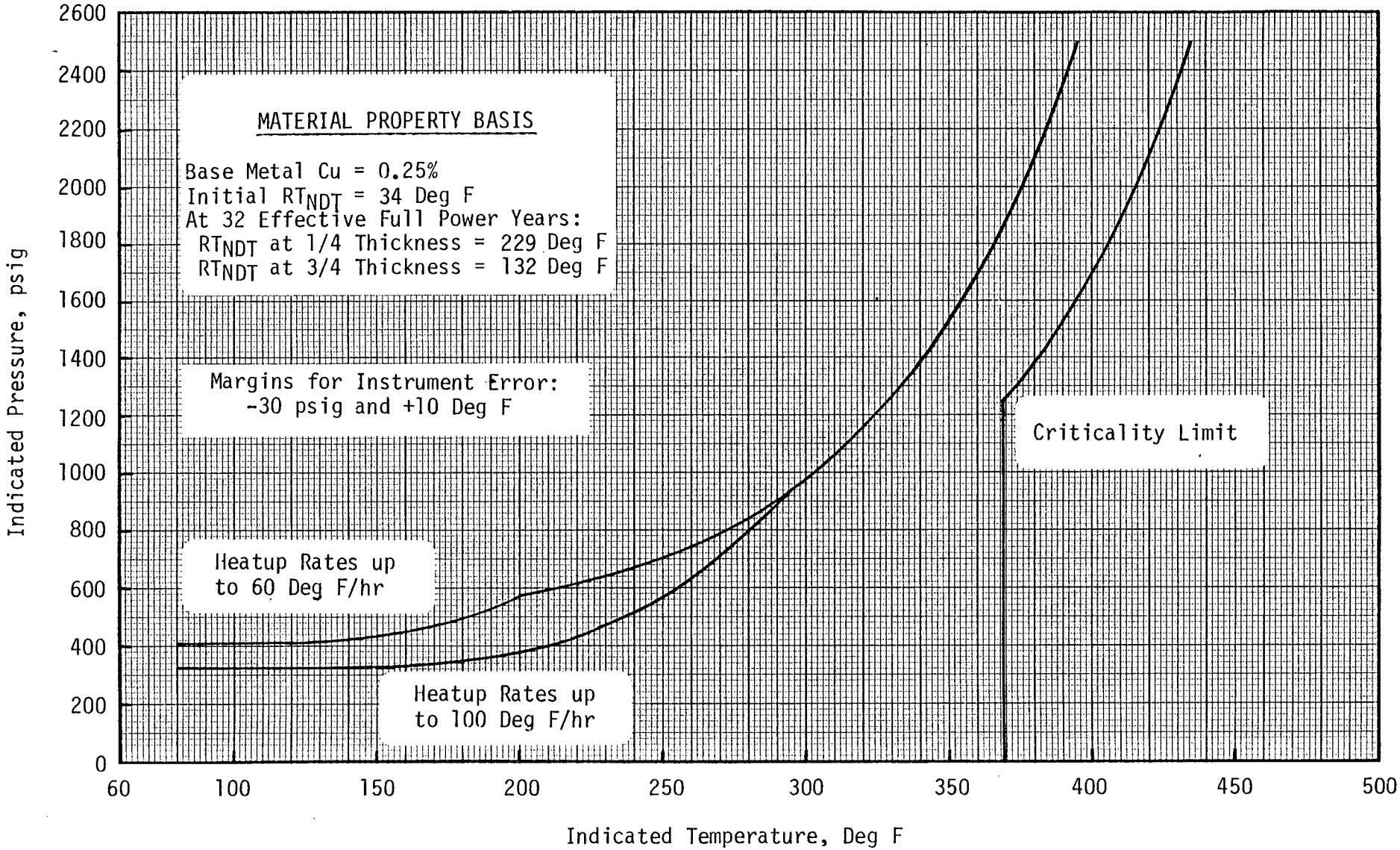


FIGURE 10. INDIAN POINT UNIT NO. 2 REACTOR COOLANT HEATUP LIMITATIONS APPLICABLE FOR PERIODS UP TO 32 EFFECTIVE FULL POWER YEARS

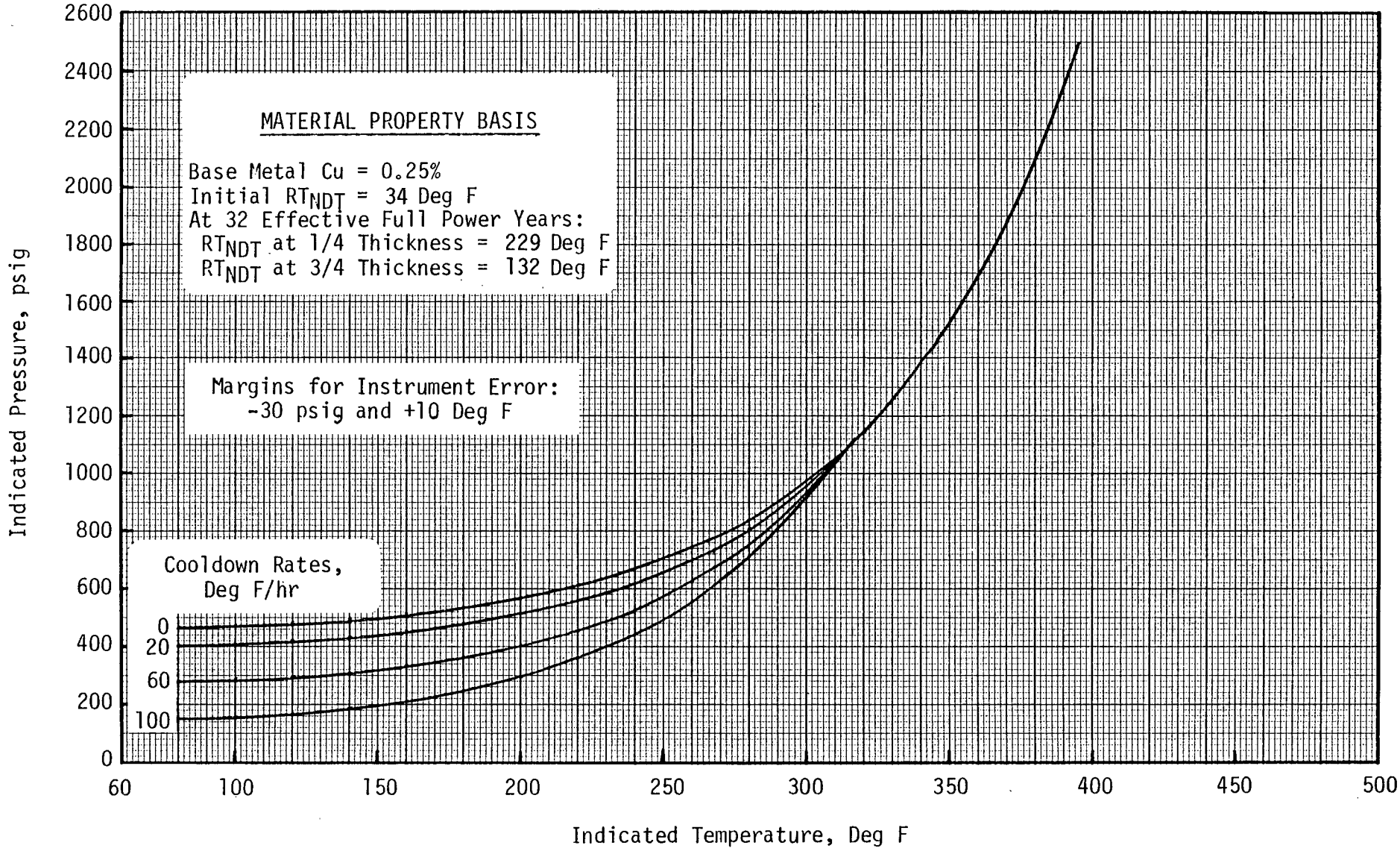


FIGURE 11. INDIAN POINT UNIT NO. 2 COOLANT COOLDOWN LIMITATIONS APPLICABLE FOR PERIODS UP TO 32 EFFECTIVE FULL POWER YEARS

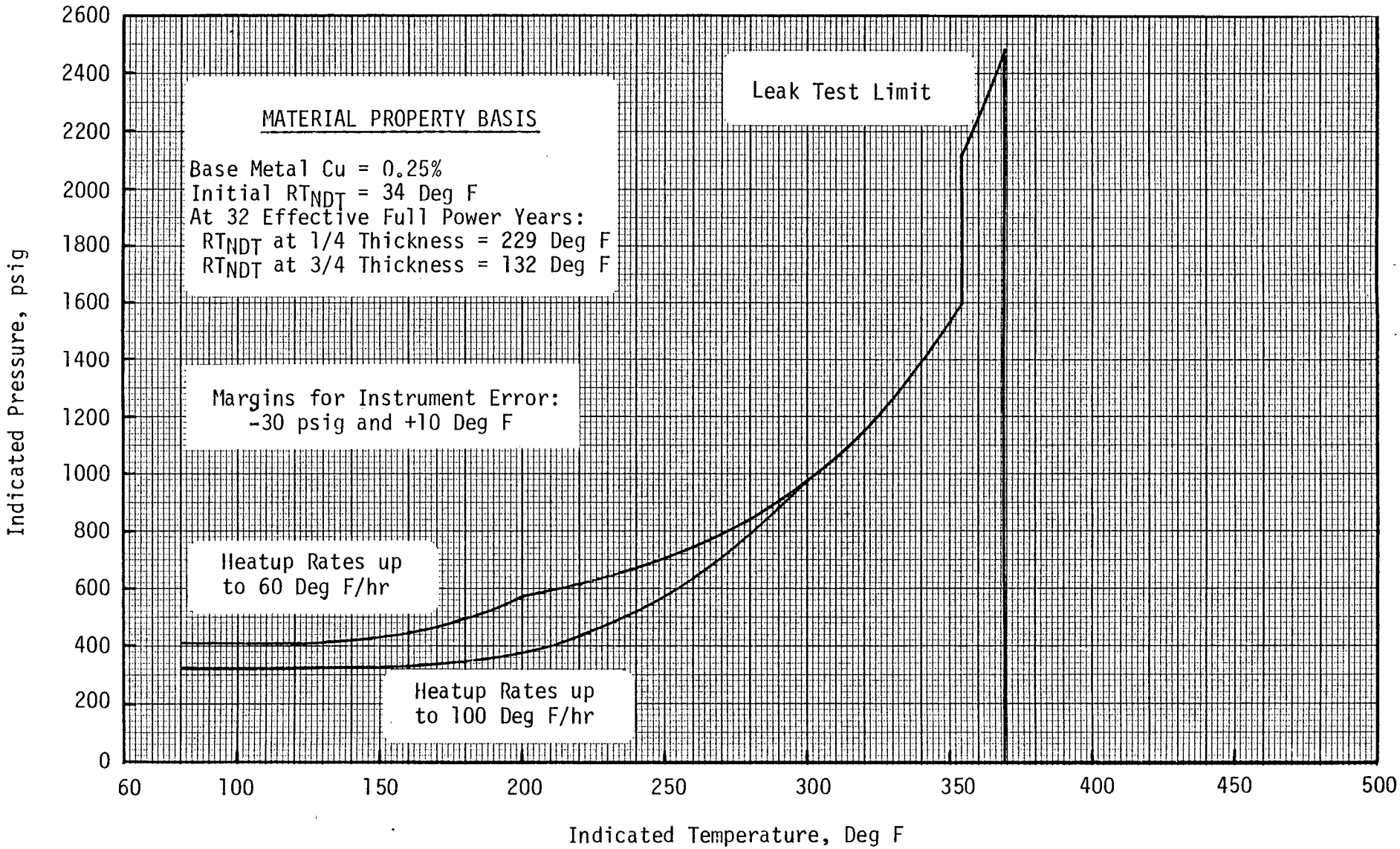


FIGURE 12. INDIAN POINT UNIT NO. 2 LEAK TEST LIMITATIONS APPLICABLE FOR PERIODS UP TO 32 EFFECTIVE FULL POWER YEARS

VII. REFERENCES

1. Title 10, Code of Federal Regulations, Part 50, "Licensing of Production and Utilization Facilities."

2. ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components."

3. ASTM E 208-81, "Standard Method for Conducting Drop-Weight Test to Determine Ni-Ductility Transition Temperture of Ferritic Steels," 1982 Annual Book of ASTM Standards.

4. Steele, L. E., and Serpan, C. Z., Jr., "Analysis of Reactor Vessel Radiation Effects Surveillance Programs," ASTM STP 481, December 1970.

5. Steele, L. E., "Neutron Irradiation Embrittlement of Reactor Pressure Vessel Steels," International Atomic Energy Agency, Technical Reports Series No. 163, 1975.

6. ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 1974 Edition.

7. Randall, P. N., "NRC Perspective of Safety and Licensing Issues Regarding Reactor Vessel Steel Embrittlement - Criteria for Trend Curve Development," presented at the American Nuclear Society Annual Meeting, Detroit, Michigan, June 14, 1983.

8. Regulatory Guide 1.99, Revision 1, Office of Standards Development, U.S. Nuclear Regulatory Commission, April 1977.

9. ASTM E 185-79, "Standard Recommended Practice for Surveillance Tests for Nuclear Reactor Vessels," 1981 Annual Book of ASTM Standards.

10. "Indian Point Unit No. 2 Reactor Vessel Radiation Surveillance Program," WCAP-7323, May 1969.

11. ASTM E 399-81, "Standard Method of Test for Plane-Strain Fracture Toughness of Metallic Materials," 1982 Annual Book of ASTM Standards.

12. ASTM E 813-81, "Standard Test Method for J_{Ic}, a Measure of Fracture Toughness," 1982 Annual Book of ASTM Standards."

13. Norris, E. B., "Reactor Vessel Material Surveillance Program for Indian Point Unit No. 2; Analysis of Capsule Y," SwRI Report 02-5212, November 16, 1980.

14. Norris, E. B., "Reactor Vessel Material Surveillance Program for Indian Point Unit No. 2; Analysis of Capsule T," Supplement to Final Report 02-4531, December 1980.

15. Norris, E. B. "Reactor Vessel Material Surveillance Program for Indian Point Unit No. 2; Analysis of Capsule T," SwRI Report 02-4531, June 30, 1977.

16. Anderson, S. L., "Analysis of Neutron Flux Levels and Surveillance Capsule Lead Factors for the Indian Point Unit No. 2 Reactor Using a Low Leakage Core," July 1982.

17. Anderson, S. L., "Analysis of Neutron Flux Levels and Surveillance Lead Factors for the Indian Point Unit 1 Reactor," July 1979.

18. US NRC Standard Review Plan, NUREG-0800, Section 5.3.2, Pressure-Temperature Limits, Revision 1, July 1981.

19. ASTM E 322,"Standard Method for Spectrochemical Analysis of Low Alloy Steels and Cast Irons Using an X-ray Flourescence Spectrometer."

20. Letter dated March 29, 1978 from W. J. Cahill, Jr. (Consolidated Edison) to R. W. Reid (NRC), "Indian Point Unit No. 2 Reactor Vessel Material Surveillance Program."

21. Indian Point Unit No. 2 Technical Specifications.

APPENDIX A

TENSILE TEST RECORDS

Cal = .01913" Y-e 6.2v

2.001 X 10^-3 / inch

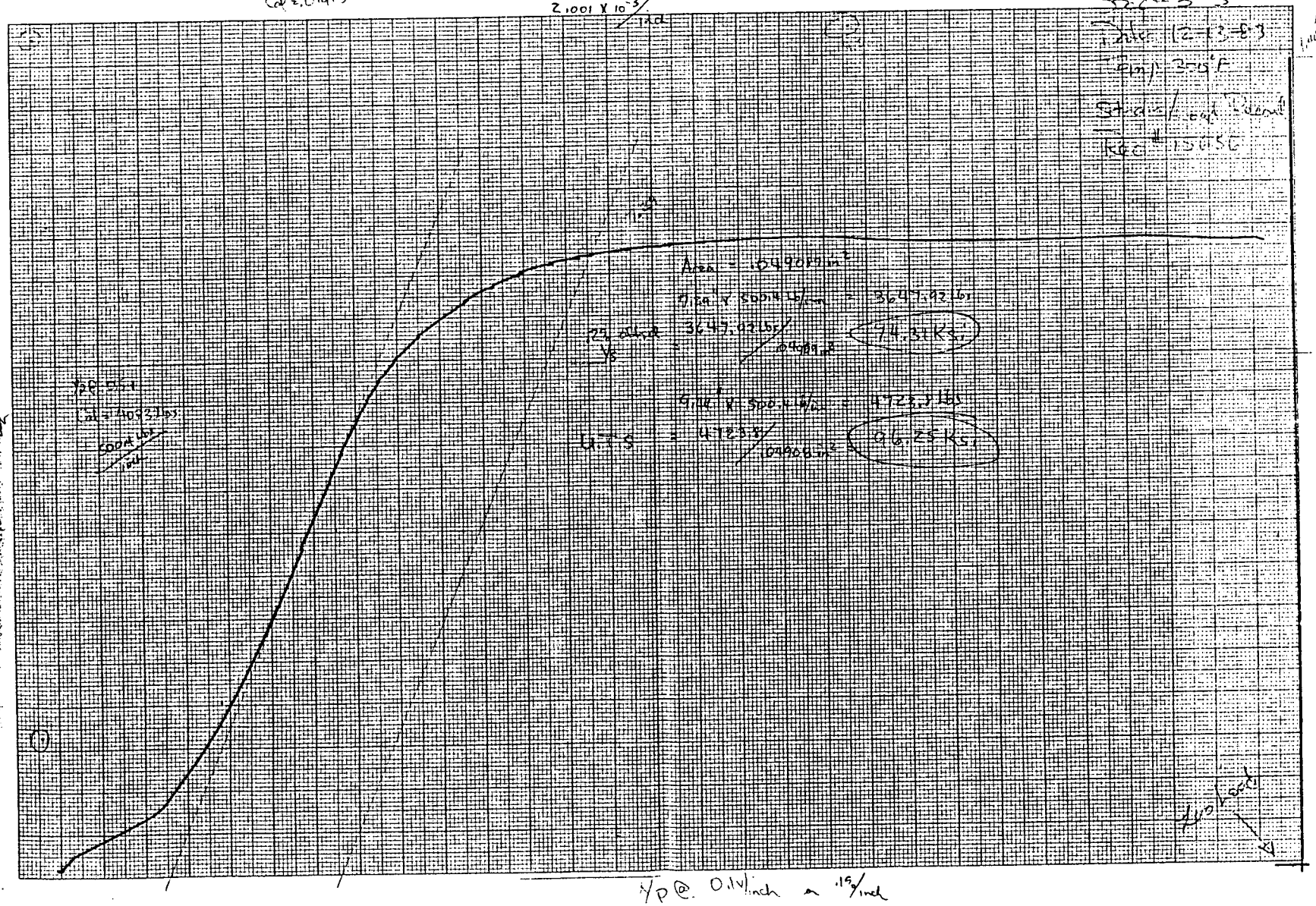
Spec #3-5

Date 12-13-83

Final 3-9 F

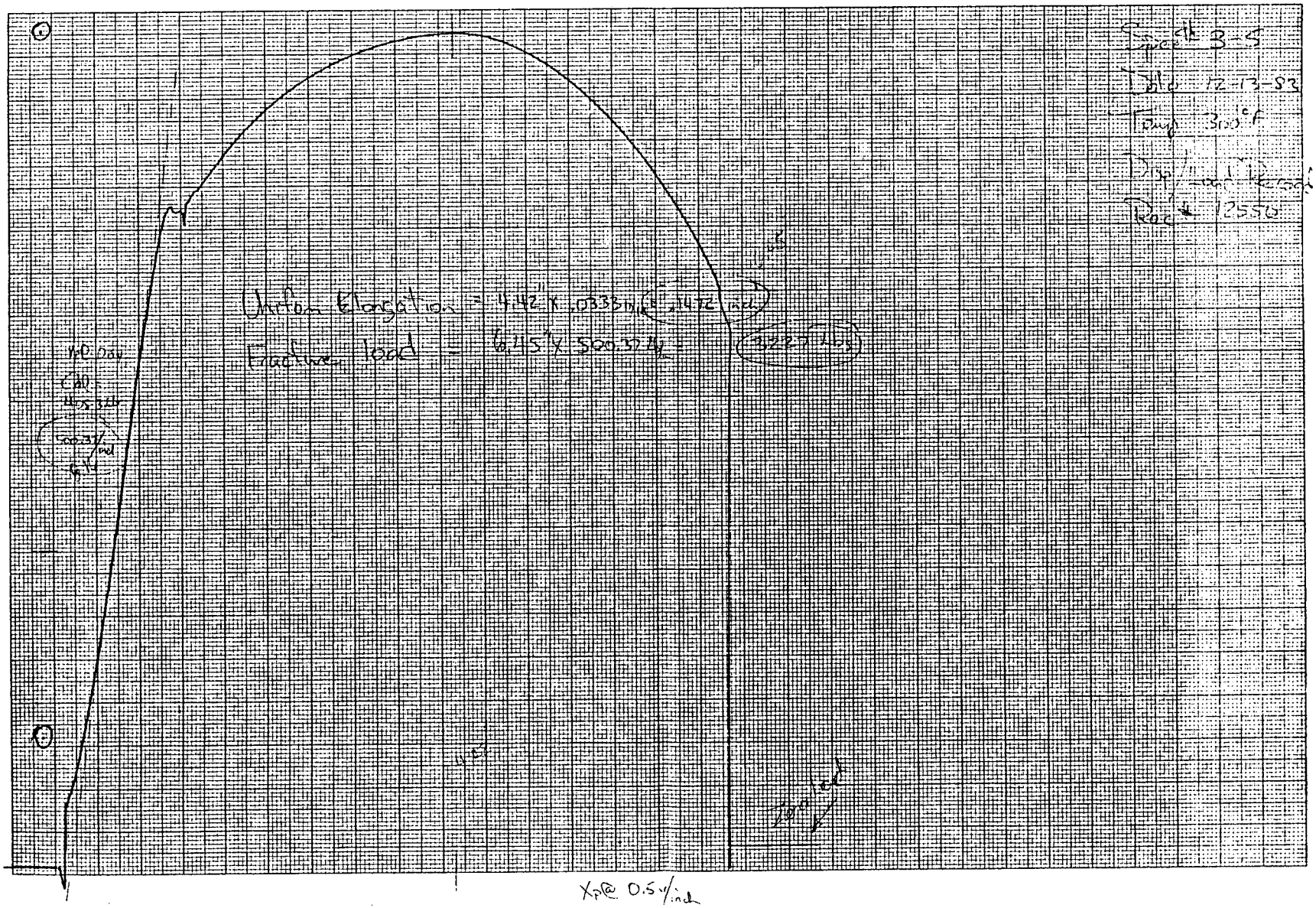
Strain / Load Curve

Rec # 15456



47 1323

K+E 10 X 10 TO ½ INCH • 10 X 15 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.



K+E 10 X 10 TO 14 INCH • 10 X 15 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.
47 1323

Spec # 2-5

Date 12-13-83

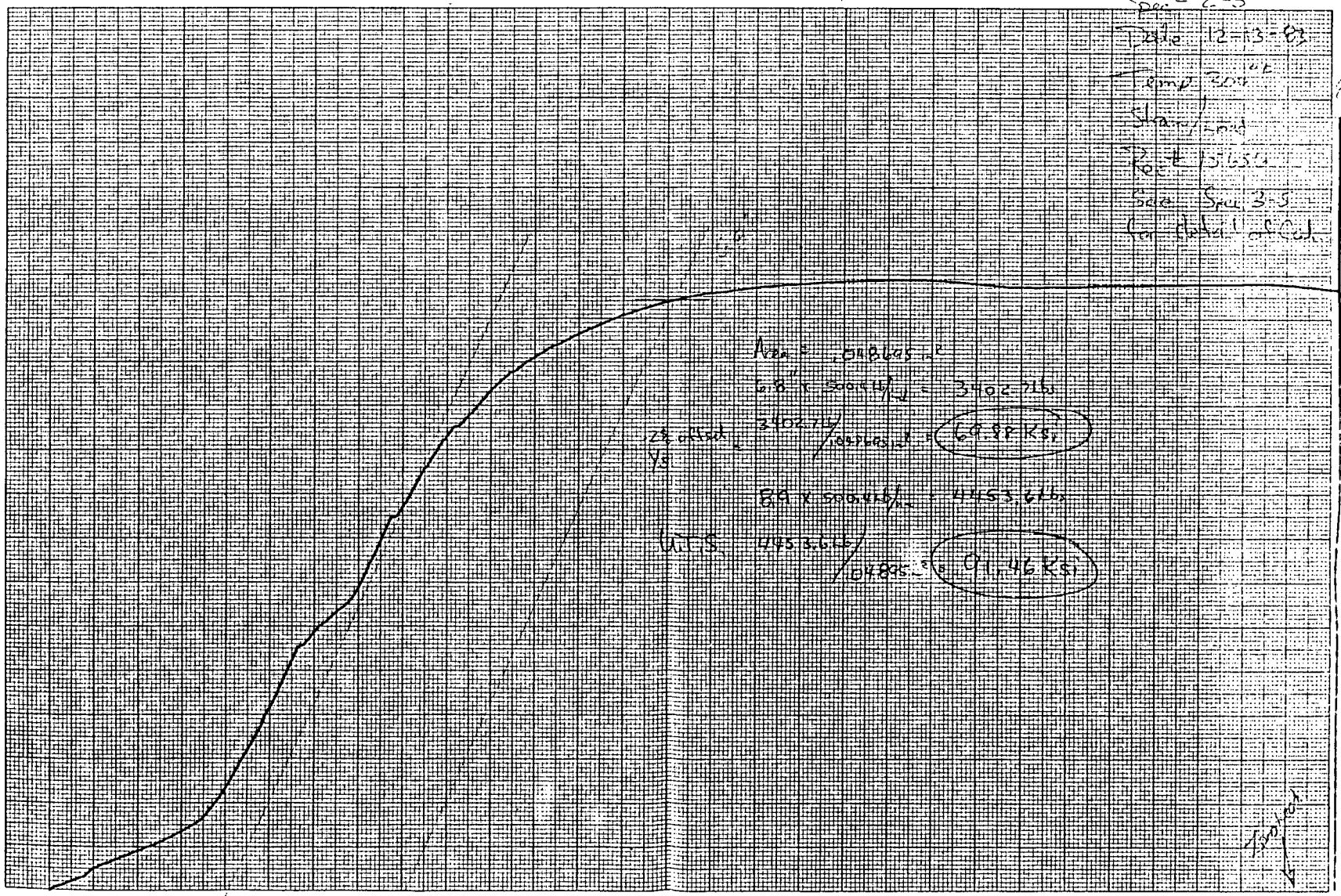
Temp 500°F

Specimen

Rc # 15654

Spec Spec 3-5

Cor Metal Sol.



Area = .048695 in²

6.8" x 500 lb/in² = 3402.7 lb

Ys offset = 3402.7 lb / .048695 in² = 69.88 Ksi

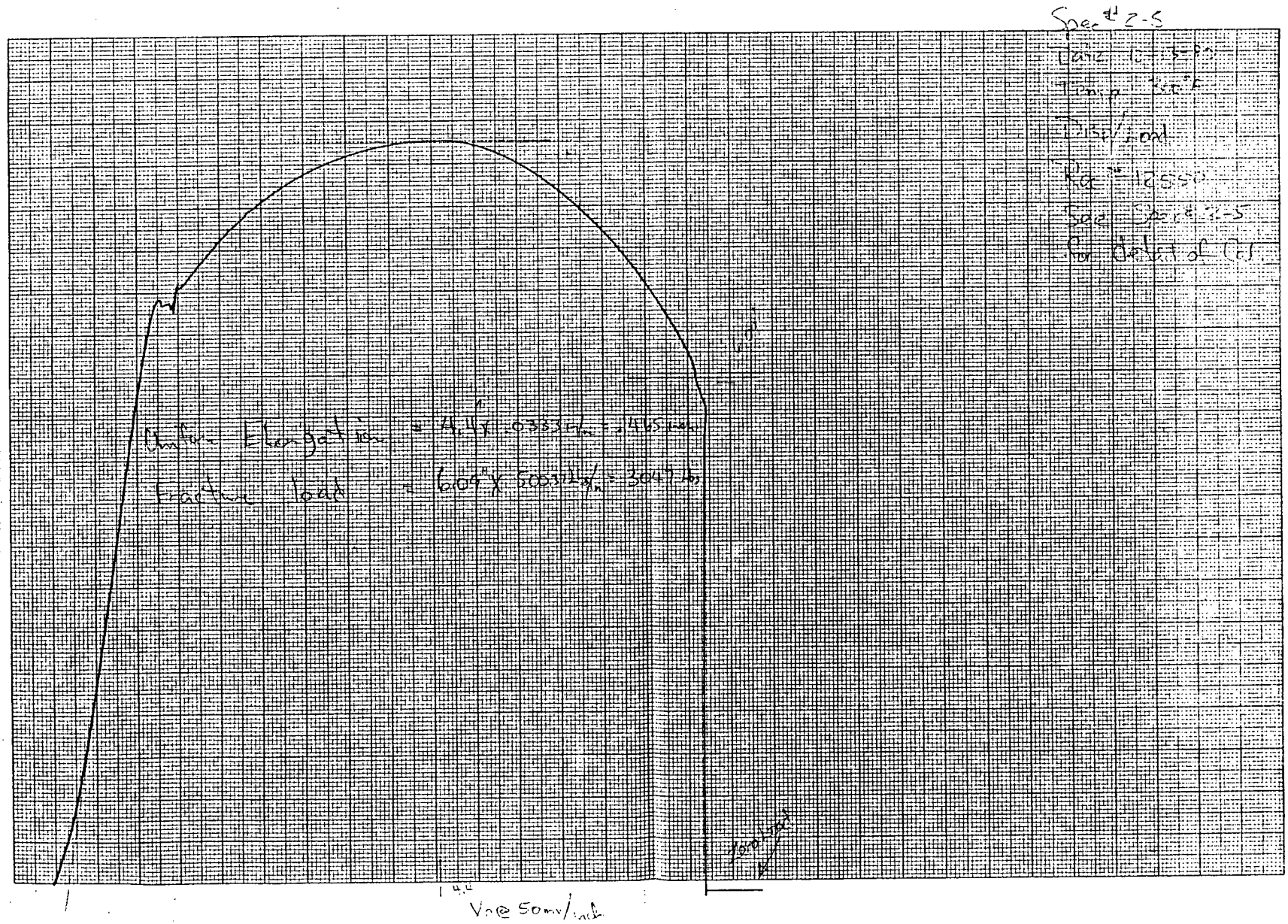
89 x 500 lb/in² = 4453.6 lb

Ult S = 4453.6 lb / .048695 in² = 91.46 Ksi

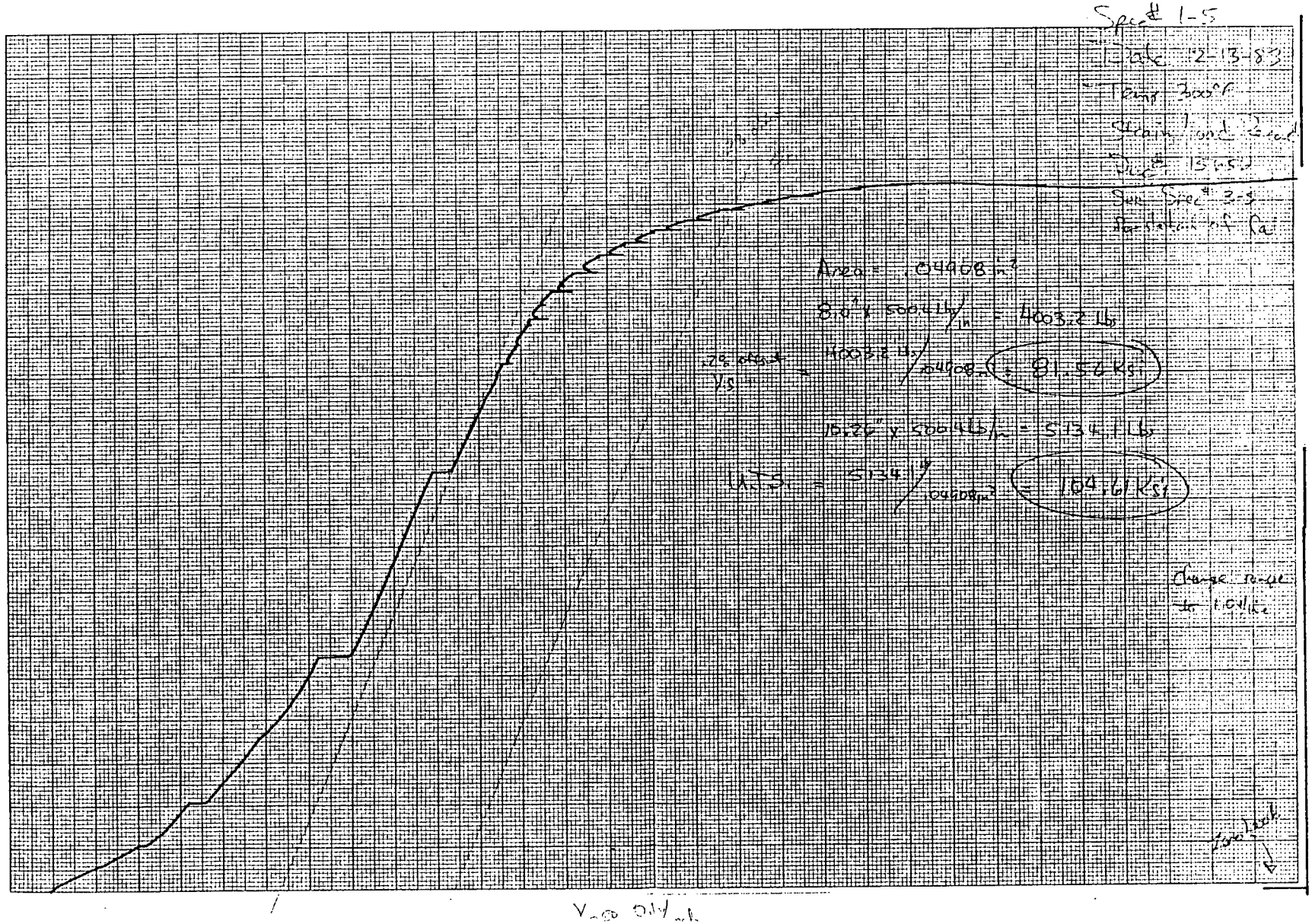
Ys @ offset

47 1323

K+E 10 X 10 TO 1/2 INCH 18 X 25 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.



K+E 10 X 10 TO 14 INCH • 10 X 15 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 47 1323



47 1323

K+E 10 X 10 TO 14 INCHES • 10 X 15 INCHES KEUFFEL & ESSER CO.

Yoder O. Sylvae

Spec # 1-5

Test Date 12-13-83

Temp. 300°F

15 sp/Feed Rate

Test # 2-50

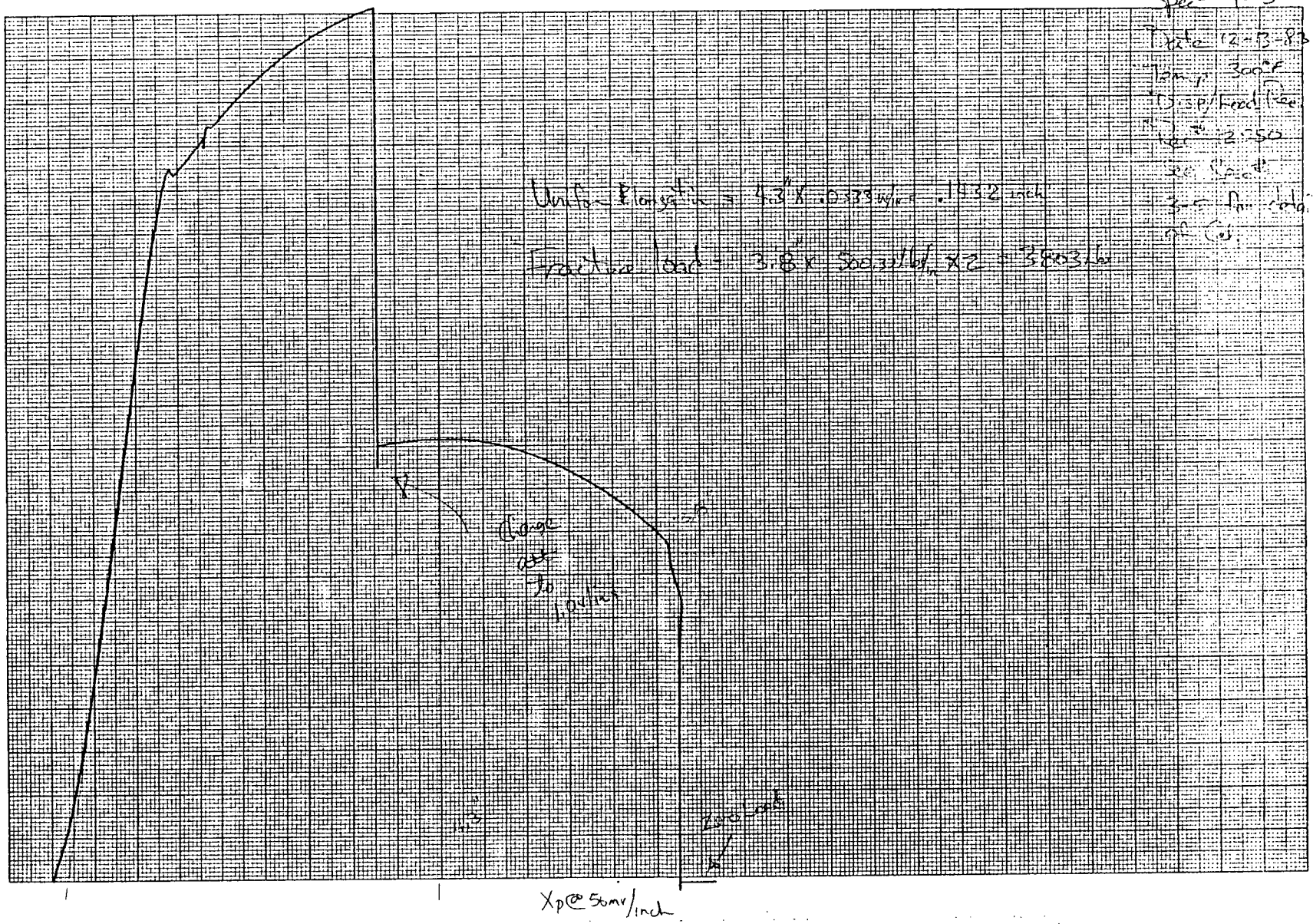
See Sheet #

3-5 Pin Model

on Col.

Uniform Elongation = 4.3" X .0333 in/in = .1432 inch

Fracture load = 3.8" X 500 33 lbf/in X 2 = 5803 lbs



K+E 10 X 10 TO ½ INCH • 10 X 15 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 47 1323

10.6.5 Align tabular entries as follows:

1 Horizontally by related entries.

2 Vertically by decimal point for numerical entries.

3 Vertically by first letter for word entries; however, indent run-over lines three spaces.

10.6.6 Double space between horizontal entries sufficently to segregate such entries, although horizontal lines may also be used if desired. If used, double horizontal lines should be above and below the column headings.

10.6.7 Do not leave vacant cells in the table. Enter "N.A." if no entry is necessary to indicate not applicable.

10.6.8 See Section 6.3 for table numbering requirements.

10.7 Figures

Include as figures all graphs, drawings, diagrams, and illustrations. The following rules apply:

1 Place the figure number and its title two line spaces below the figure field.

2 The figure number and title should be the same type style and size as used in the text of the procedure.

3 Maintain the figure field within the page margins.

4 Make the figure field of sufficient size to offer good readability.

5 Make the figure as clear and simple as possible.

6 Use grid lines for graphs that are at least 1/8 inch apart; making numbered grid lines bolder than unnumbered grid lines.

7 Accompany labeling within the figure by arrows pointing to the item.

8 Orient the items within the figure as naturally as possible. For example, height on a graph should be along the vertical axis.

5 Subsequent lines of text begin under the first character of the first line of text.

Example:

NOTE: The switch to disable the circuit is located behind the XX panel.

10.4 Breaking of Words

Avoid breaking of words to increase procedure readability and allow word processing. If necessary, break words between syllables.

10.5 Rotation of Pages

Rotate pages only if it is not possible to otherwise fit figures or tables on a page. Rotate pages using the following guidelines:

1 Place the top of the rotated page at the left-hand edge.

2 Do not rotate page margins. That is, the top of the rotated page has the margin of the left-hand edge of the standard page, the right-hand edge of the rotated page has the margin of the top of the standard page, etc.

3 Rotate page identification and numbering to allow word processing.

10.6 Tables

Type tables using the following rules:

10.6.1 Use the same type style and size as that used in the text of the procedure.

10.6.2 Locate the table number and title above the table field and three line spaces below preceding text.

10.6.3 Provide a heading for each column and center it within the column; capitalize the first letter of words in headings.

10.6.4 Place horizontal lines above and below the column headings; vertical lines, while desirable, are not necessary or required.

3 Move the right margin in (left) approximately ten characters.

4 Type line of alternating asterisks and blank spaces to the new right margin.

5 For each subsequent line of the caution provide an asterisk under the first and last asterisk of this line.

6 Center, capitalize and underline 'caution' on the next line.

7 Provide one line without text under the caution heading. Provide the necessary asterisk at the left and right border.

8 Provide three blank spaces after the fourth asterisk down and begin the text.

9 Provide one line without text at the end. Provide the necessary asterisk at the left and right border.

10 Close the box with a line of alternating asterisks and blank spaces. Provide two carriage returns and begin the next paragraph.

Example:

```
* * * * * * * * * * * * * * * * * * * * * * * *
*                  CAUTION                    *
*                                             *
*   RPV high water level (+ 54 in.) will trip *
*   FW pumps, RCIC, and HPCI.                 *
*                                             *
* * * * * * * * * * * * * * * * * * * * * * * *
```

10.3.5 NOTES

Type notes as follows:

1 Provide two carriage returns after the previous text.

2 Indent to the previous text location.

3 Type 'NOTE:' in capitals and underlined.

4 Provide three spaces and begin the text.

3 Capitalize every first letter of each word of a third level heading.

4 Capitalize the first letter of each word of a fourth level heading.

10.3.3 INDENTING OF PARAGRAPH NUMBERS AND HEADINGS

The indenting instructions below apply for procedures where the first level paragraph number is a single digit (1-9) and all other paragraph numbers are a single or double digit (1-99). When the instructions are followed there will always be at least one space between a step number and its heading or text; and list numbers will align under the first character of the preceeding heading or step.

For instructions below count the character on the left margin as character number 0.

1 At character 0, i.e. the left margin, begin all first and second level paragraph or step numbers.

2 At character 3 begin third level paragraph numbers when the number is of the form 1.1.1. This does not apply to a third level list.

3 At character 5 begin all first and second level headings, steps or text.

4 At character 5 begin third level list numbers.

5 At character 6 begin fourth level paragraph numbers when the number is of the form 1.1.1.1. This form rarely occurs and therefore it may not warrant setting a tab for it.

6 At character 11 begin all third level headings, steps or test.

7 At character 11 begin fourth level list numbers.

8 At character 17 begin all fourth level headings, steps or test.

10.3.4 CAUTIONS

Enclose cautions in an asterisked box as follows:

1 Provide two carriage returns after the preceding text.

2 Indent to the previous text location.

10 TYPING FORMAT AND REPRODUCTION

10.1 General Typing Instructions

Follow these general requirements for typing procedures.

1 Prepare procedures using a word processor, if possible.

2 Use a Courier typewriter element with the pitch set at 10.

3 On pages of procedure steps, use only white, 8-1/2 x 11 inch paper suitable for reproduction. Foldout diagrams may be on 11x17 inch paper.

10.2 Page Arrangement

1 Use page margins of 1-1/4 inch minimum on binding edge and 1/2 inch minimum margin on all other sides.

2 Center page numbering (refer to paragraph 5.2) one line space above the bottom page margin.

3 Orient pages so that the 8-1/2 inch edges are at the top and bottom. Text, tables and figures shall be readable with the page so arranged. Avoid rotation of printed matter for procedures. If absolutely necessary, refer to paragraph 10.5.

10.3 Heading and Text Arrangement

10.3.1 GENERAL

1 Use block style as illustrated in Figures 4 and 5, and by this OAD.

2 Provide two carriage returns after each heading and begin text directly under the first character of the heading.

3 Provide three carriage returns before a first level heading.

4 Provide two carriage returns before a second or higher level paragraph or step.

10.3.2 CAPITALIZATION AND UNDERLINING PARAGRAPH HEADINGS

1 Capitalize and underline all of a first level paragraph heading.

2 Capitalize the first letter of each word except conjunctions and prepositions and underline all of a second level paragraph heading.

system are used and reference to that system is not intended.

Examples: Residual Heat Removal system
Direct flow from the tank to Liquid Radwaste
Verify adequate lube oil flow to .....

9.8.5 HEADINGS AND SUBHEADINGS

Capitalize headings and subheadings in accordance with Section 10.3.

9.8.6 ENGRAVINGS AND LEGENDS

Use full capitalization for nameplate engravings, alarm window engravings, switch or circuit breaker positions, controller modes of operation, and the wording on status lights. For switch names, capitalize the first letter of each word.

9.8.7 SYSTEM, COMPONENT, AND DEVICE IDENTIFIERS

Use capitalization for all letters of component identification codes including device designations, Master Parts List references, and system acronyms.

Examples: PS-B21-N004A
B33-F023A

Exceptions to this guideline are:

Examples: delta P or dP - designator for differential pressure
pH - chemical symbol for hydronium ion concentration

9.8.8 TABLES AND FIGURES

Use initial letter capitalization for references to tables and figures, titles of tables and figures within text material, and column headings within a table.

Examples: Refer to Figure 201 for ...
... as shown in Table 201, Equipment Power Sources

9.8.9 Modes of Operation

Modes of operation should be capitalized as they apply to a specific configuration of the plant or of a system.

Examples: Cold Shutdown
Hot Shutdown
Refueling Shutdown

Avoid overuse of abbreviations, symbols, and acronyms. Use them to save reading time, to ensure clarity when space is limited, and to communicate mathematic ideas.

9.8 Capitalization

Use capitalization consistently per modern English usage rules and the following guidance.

9.8.1 ORGANIZATIONS, INSTITUTIONS, COMPANIES, AND ASSOCIATIONS

Capitalize full titles of organizations, institutions, companies, and associations and their departments. Words such as "school" or "company" are lower-cased when used alone. Examples: Indian Point Simulator, Indian Point Nuclear Power Station, Consolidated Edison, the company, the station.

9.8.2 TITLES OF WORKS AND PUBLICATIONS

Capitalize the first letter of all nouns, pronouns, adjectives, verbs, adverbs, and subordinate conjunctions. Articles, coordinate conjunctions, and prepositions, regardless of length, unless they are the first or last words of the title or subtitle, are lower case.

Examples: Code of Federal Regulations
Procedure OP-E51-1
Indian Point Station Technical Specifications

9.8.3 PERSONNEL TITLES

Capitalize staff positions and titles, when they refer to an individual with specific authority, duties, and responsibilities. General categories or groups of people identified within the organizational structure are not capitalized.

Examples: Operations Superintendent
Senior Watch Supervisor
Senior Reactor Operator
electrician
mechanic

9.8.4 SYSTEMS AND COMPONENTS

Capitalize the name of plant system titles. When the word "system" is deleted from the title because of brevity and is understood because of the context, the title is capitalized. Words are not capitalized when words from the title of a

3 Use a number of significant digits equal to that contained in the acceptance tolerance for the measurement and available from the display.

4 Do not specify acceptance values such that addition and subtraction by the user is necessary. State acceptance values as a range of value, for example: 510F to 530F instead of 520+/-10F. For calibration points, state the midpoint and its lower and upper limits. Example: 10 milliamperes (9.5 to 10.5).

9.6 Units of Measure

Use units of measure consistent with the United States National Bureau of Standards (NBS) definitions.

Provide the units of measurement for numerical values which represent measurement data or calculational results in procedural text, figures, tables, and attachments.

9.7 Abbreviations, Letter Symbols, and Acronyms

Minimize the use of unfamiliar abbreviations because they may be confusing to those who are not thoroughly familiar with them. Use abbreviations where necessary to save time and space and where their meaning is unquestionably clear to the intended reader, as in formulas, tables, and other compressed presentations. Write their full meaning before the first use of an abbreviation. Maintain consistency throughout the procedure.

When reference is made to automatic, manual, overpower, overtemperature, etc., as functions (as opposed to proper switch names) these terms should not be abbreviated. This construction readily differentiates the functional use of these terms from their use as proper switch names.

Capitalize abbreviations uniformly. If the abbreviation is comprised of lowercase letters and is to appear in a title or heading, continue to use lowercase letters. Omit the period in abbreviations except in cases where the omission would result in confusion.

Use letter symbols to represent operations, quantities, elements, relations, and qualities. Define a symbol when first used within the procedure or other standard source. Avoid use of symbols not readily available on the word processing system used for the procedure, thus minimizing handwork of final procedure pages.

Acronyms are a type of symbol that are formed by the initial letter or letters of each of the successive parts or major parts of a compound term. Use acronyms if they are defined or commonly used.

3 Available: This word means that a system, subsystem, train, component, or device is capable of being operated and can be used as desired. It need not, however, be operating and it need not be capable of automatic initiation.

9.4.9 Component status will be denoted as follows:

1 In Service/Out of Service: This means that the component is or is not functioning within the planned mode of operation. For example, a demineralizer may be Out of Service although it is Operable.

2 Running/Shutdown: This refers to the condition of rotating equipment.

3 On Line/Off Line: This means that a generating unit is or is not tied into the power grid.

4 On/Off: This is used for simple equipment such as recorders and lights. It means that the equipment is or is not powered.

5 Racked In/Racked Out: This is used for physical status of switchgear. It means that the switchgear is available or not available to equipment supplied.

6 Energized/De-energized: This should be used to indicate status of electrical circuits, such as logic circuits and electrical buses. It means that the circuit is or is not powered.

9.4.10 Avoid blanket words unless the absolute meaning is actually desired. All-inclusive words include never, all, always, every, and none.

9.4.11 State acceptance criteria in specific terms. Avoid stating such criteria merely as satisfactory, normal, or adequate. Where acceptance criteria must be based on subjective evaluation, state the criteria in descriptive phrases which convey specific meaning.

9.5 Numerical Values

Use numerical values in accordance with the following rules:

1 Use Arabic numerals.

2 For numbers less than unity, precede the decimal point by a zero.

2 Use "T AVG" to refer to average reactor coolant temperature.

3 Use "T REF" to refer to reference reactor coolant temperature.

4 Use "Delta-T" to refer to hot leg to cold leg temperature difference.

5 Do NOT use "trip unit" when "trip reactor" or "trip turbine" is intended. If both trips are intended state each separately.

9.4.6 Use "shall", "will", "should", and "may" as follows:

1 Shall. Mandatory requirement
2 Will. Description of the result of an action. Where used as a requirement, consider the requirement mandatory.
3 Should. Non-mandatory, preferred, or desired method
4 May. Acceptable or suggested method

9.4.7 Use verbs with specific meaning. Examples are listed in Table 1.

9.4.8 Equipment status will be denoted as follows:

1 Operable/operability: These words mean that a system, subsystem, train, component, or device is capable of performing its intended function(s) within the required range (definition from Technical Specification 1.3). This definition assumes that all necessary instrumentation, controls, normal and emergency electrical power sources, cooling or seal water, lubrication or other auxiliary equipment that are required for the system, subsystem, train, component, or device to perform its function(s) are also capable of performing their related support function(s). For devices or equipment initiated automatically, operable means that the automatic initiation function will perform automatically.

2 Operating: This word means that a system, subsystem, train, component, or device is in operation and is performing its specified function(s), and that a "holdoff" or other conditions do not prevent it from maintaining that service.

9.3.7 BRACKETS

Avoid using brackets if possible. Use brackets only when necessary for clarity and to enclose statements containing parenthesis.

9.3.8 APOSTROPHE

Use an apostrophe to indicate possessive forms of nouns. For example, The Senior Watch Supervisor's office ... Do not use an apostrophe to indicate plural of acronyms. For example, SOPs, ARPs.

9.3.9 QUOTATION MARKS

Avoid using quotation marks. Where common usage or figurative language must be used, enclose the first use only in quotation marks.

9.3.10 SLANT LINE

Use a slant line as a substitute for "per" in units of measure. Example: ft/sec, lbs/hr.

9.3.11 DEGREE SIGN

Do not use a degree sign between a temperature and the scale.

Example: Use 525F instead of 525°F.

9.4 Vocabulary

Use words readily understandable to the trained person. Use the following guidelines:

9.4.1 Use simple, common words of few syllables.

9.4.2 Use the most common usage of words.

9.4.3 Use words which are concrete rather than vague, specific rather than general, familiar rather than formal, precise rather than blanket.

9.4.4 Define key words that may be understood in more than one sense.

9.4.5 The following common termonology should be used when refering to plant parameters or conditions.

1 Use "High" or "Low" instead of "Up-Scale" or "Down-Scale" when referring to channel failure position. This allows for partial channel failures.

9 Where multiplication of units is indicated. Example: ft-lbs

9.3 Punctuation

Use punctuation only as necessary to aid reading and to prevent misunderstanding. Select the word order to require a minimum of punctuation. When extensive punctuation is necessary for clarity, make several sentences instead. Use punctuation in accordance with the following guidance:

9.3.1 PERIOD

Use a period at the end of complete sentences and for indicating the decimal place in numbers.

9.3.2 COMMA

Use commas for the following:

1 To separate four or more digits. Examples: 14,500; 1,600,000.

2 After introductory phrases or conditional clauses for clarity or ease of reading. Example: When level decreases to 60 inches, start pump . . .

9.3.3 SEMICOLON

Favor periods and commas over semicolons. Do not use semicolons where common usage calls for colons. Use semicolons to set off independent clauses and a run-on listing when such clauses or listings are internally punctuated with commas.

9.3.4 COLON

Use a colon to indicate that something is to follow. For example: Restore cooling flow as follows:

9.3.5 DASH

Do not use dashes except within component numbers.

9.3.6 PARENTHESES

Minimize the use of parenthetical statements. Do not use parentheses for indicating alternative items in a procedure step. Use parentheses when including equipment numbers in a procedural step for separation.

3 For frequently used controls in routine applications, it may be acceptable to state only the functional requirement.

Examples: Place rod control in manual.
Place charging pump speed contol in automatic.

8.13 Graphs, Charts, Tables and Figures

When information is presented using graphs, charts, tables, and figures, ensure these aids are self-explanatory, legible, and readable under the expected conditions of use. See Sections 10.6 and 10.7.

9 MECHANICS OF STYLE

9.1 Spelling

Use spelling consistent with modern usage. When a choice of spelling is offered by a dictionary, use the first spelling.

9.2 Hyphenation

Use hyphens between elements of a compound word when common usage calls for it. Use hyphens in the following circumstances:

1 In compound numerals from twenty-one to ninety-nine. Example: one hundred thirty-four.

2 In fractions. Examples: one-half, two-thirds.

3 In compounds with self. Examples: self-contained, self-lubricated.

4 Where the first member of the compound word ends in the same vowel that the second member begins with. As an alternative, two words may be used. Example: fire-escape or fire escape.

5 Where misleading or awkward consonants would result by joining the words. Example: bell-like.

6 To avoid confusion with another word. Examples: re-cover to prevent confusion with recover, pre-position to avoid confusion with preposition.

7 Where a letter is linked with a noun. Examples: X-ray, O-ring, U-bolt, I-beam.

8 To separate chemical elements and their atomic weight. Examples: Uranium-235, U-235.

3 Give the noun name of the component in operator language (common usage) terms. These terms may not always match engraved names on panels.

4 Where the engraved names and numbers on panel placards are specifically the item of concern in the procedure, quote the engraving verbatim in all capitals (refer to Paragraph 9.8.6).

5 Give location information if the component is seldom used or if it is felt it would be useful.

8.12 Directing the Operation of Controls

8.12.1 To properly direct the operation of controls, the following factors should be considered:

1 The required level of detail. See Section 8.2.1.

2 The features of the controllers must be known. Controllers may be toggle, rotary switches, push button, etc. Controllers may maintain positional placement or they may be spring return. Associated circuitry may lock in or the controller may need to be held in position until the function is obtained.

8.12.2 Use the following guidelines to direct the operation of controls.

1 For controls which require the greatest degree of detail provide the control name as engraved on the placard, the desired position as engraved on the placard and the necessary instructions for the manipulation of the control. This level of detail should be used for SOPs describing the use of a control, when requiring the operation of seldom used controls, or where operation error is possible because of multiple controls in a bank arrangement.

Example: Place T AVG Defeat Switch (T412A OR T412B) to DEFEAT LOOP # for affected loop.

2 For a control switch which, through its circuitry, executes an entire function upon actuation of the control switch, the action verb appropriate to the component suffices without further amplification of how to manipulate the control device.

Example: "Close Pressurizer Spray Valve (PCV-455A)" rather than "Shut pressurizer spray valve PCV-455A by turning its control switch to CLOSE."

Contingency actions may be stated in any procedure as appropriate. They are only required, however, in emergency procedures.

Specify contingency actions for each circumstance where the expected results or actions might not be achieved. Identify, as appropriate, how to override automatic controls and how to manually initiate what is normally automatically initiated.

8.8 Calculations

Avoid mathematical calculations in operating procedures. Use a chart or graph, where feasible, when a value has to be determined. If calculations must be made, include all conversion factors and constants in the procedure. Allow sufficient space for the calculations.

8.9 Use of Underlining

Use underlining when necessary for emphasis of important key words and logic terms.

8.10 Listing of References

Minimize listing of references within the text of procedures. When necessary, indicate references within text of procedures as follows:

1 When the item required by a procedure is wholly governed by another procedure, reference the other procedure by title, number and section, rather than repeating its steps.

2 Reference only the procedure number and title when the entire referenced procedure must be used to accomplish an item.

3 Do not reference a procedure when only a few steps apply from the procedure to be referenced. Include such steps directly in the procedure.

8.11 Component Identification

Components should be identified using the following rules:

1 Identify the component by noun name followed by the system identifier and component number in parentheses, at the point of the first use within procedural text.

Example: Water Leg Pump (E51-C003)

2 Common components do not need to be identified by their system identifier and component number when the common usage name is unambigious.

Use a note if additional information, other than that in cautions is necessary to support an action instruction. Locate the note as close to the applicable instruction as possible. Keep the use of notes, however, to a minimum to increase the readability of procedures.

Make all cautions and notes stand out from the text by using the guidelines of section 10.3.4, and 10.3.5.

8.6 System Response

Make the content of procedures consistent with plant system and instrument response to the actions prescribed by the procedures. Describe expected system response when considered beneficial to the user's understanding and application of the instructions. The following guidelines are recommended:

1 Expected results of routine actions need not be identified.

2 Avoid describing standard practices for observation of abnormal results within procedural steps. For example, observation of noise, vibration, erratic flow or discharge pressure need not be specified by steps that start pumps.

3 List the alarm setpoint for ease of verification, when actions are required based upon receipt of an annunciated alarm.

4 List the expected results immediately following the task statement that resets or restores the plant system, when requiring resetting or restoration of an alarm or trip.

5 Describe the system response time associated with performance of the instruction, when considered beneficial to the user for proper understanding and performance.

6 Prescribe the time frame within which an instruction must be accomplished, when system response dictates a time frame.

7 Describe the conditions that will likely introduce instrument error, and the means of determining the occurrence of instrument error, when anticipated system response may adversely affect instrument indications.

8 Prescribe the backup readings when additional confirmation of system response is considered necessary.

8.7 Contingency Action

Contingency action refers to the actions that should be taken in the event a stated condition, event, or task does not represent or achieve the expected result. The need for contingency action occurs in conjunction with task involving verification, observation, confirmation, and monitoring.

3 Do not use "then" at the end of an action step to instruct the operator to perform the next step, because it runs actions together. Actions which are imbedded in this way (1) may be overlooked and not be performed, (2) make it difficult to verify the performance of each action step when a check-off or sign-off is used, and (3) can be confused with a logic statement.

4 When attention needs to be called to combinations of conditions, place the word "and" between the description of each condition. Do not use the word "and" to join more than three conditions. IF more than three conditions need to be joined, use a list format.

Examples: 1 "IF alarm is valid AND steam generator level is greater than 30%, transfer steam generator level control to manual. _____"

2 "IF all following conditions are met:

1 Condition 1 _____
2 Condition 2 _____
3 Condition 3 _____
4 Condition 4 _____

THEN perform... _____"

5 Use the word "or" when calling attention to alternative combinations of conditions. Use the word "or" in the inclusive sense. To specify the exclusive "or", use the following: "either A OR B but NOT both".

Example: "IF operable channels OR degree of redundency is less than that required by..."

6 The use of "and" and "or" within the same action will be avoided. When "and" and "or" are used together, the logic statement is ambiguous.

8.5 Use of Cautions and Notes

Place cautions immediately before the procedural content to which they apply. Place notes before or after the procedural content to which they apply. This helps to ensure that the user of the procedure is informed before performing the step. Do not use a caution in lieu of an instructional step.

Use cautions where loss of life, significant personnel injury (e.g. due to electrical shock, hot piping, toxic or caustic chemicals, and suffocation), or significant radiological hazard may occur if an instruction step is not followed verbatim. Also use cautions where equipment damage or significant maloperation may occur if an instruction step is not followed verbatim.

8.2.14 Complete sentences are neither necessary nor desirable.

8.3 Instruction Tense and Voice

1 Instructions are directive by nature and, thus, need to be explicit. To be so, care is needed in selection of tense and voice of verbs.

2 Tense of verbs generally indicates time. The selection of verb tense should ensure that the indicated time is consistent with the desired meaning. The writer should also ensure that the remainder of the instruction reflects the time meaning that is intended. Adverbs in particular can easily modify the tense of verbs.

3 Voice refers to the classification of verbs as active or passive. The passive voice is made with the past participle and some form of the verb "be". All other verb forms are active.

4 Use the active voice whenever the instruction is directing the user to perform an action. In the active voice, a person-action-goal pattern is expressed. The instruction is directive to the person. The passive voice is recommended whenever the object, or goal, is considered more important than the doer. In the passive voice, the emphasis is on the act or the object rather than the person. Because passive voice tends to be more wordy than active, it should not be used for providing direction to a person.

8.4 Use of Logic Terms

Logic terms should be highlighted so that all the contingencies are clear to the operator. Highlighting and emphasis is achieved by capitalizing and underlining each letter of a logic term. Avoid excessive use of highlighted logic terms. Provide highlighting only when a term is used as a logic term, as opposed to a conjunction or a preposition, and the use of highlighting adds clarity to the procedure.

Use logic terms as follows:

1 Use the words "if", "if not" or "when" in action steps that are contingent upon certain conditions or combinations of conditions. Begin the step with the words "if", "if not", or "when", followed by a description of the condition or conditions (the antecedent), a comma, followed by the action to be taken (the consequent). Use the word "then" between the antecedent and the consequent when doing so adds clarity to the procedure.

2 Limit use of "if not" to those cases where the operator must respond to the second of two possible conditions. Use "if" to specify the first condition.