Letter Report MT/SMART-

BEAVER VALLEY UNIT 1

REACTOR VESSEL HEATUP AND COOLDOWN LIMIT CURVES FOR NORMAL OPERATION

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

HEATUP AND COOLDOWN LIMIT CURVES FOR NORMAL OPERATION

1.0 INTRODUCTION

Heatup and cooldown limit curves are calculated using the most limiting value of RT_{NDT} (reference nil-ductility temperature) for the reactor vessel. The most limiting RT_{NDT} of the material in the core region of the reactor vessel is determined by using the preservice reactor vessel material fracture toughness properties and estimating the radiation-induced ΔRT_{NDT}. RT_{NDT} is designated as the higher of either the drop weight nil-ductility transition temperature (NDTT) or the temperature at which the material exhibits at least 50 ft-lb of impact energy and 35-mil lateral expansion (normal to the major working direction) minus 60°F.

RT_{NDT} increases as the material is exposed to fast-neutron radiation. Therefore, to find the most limiting RT_{NDT} at any time period in the reactor's life, ΔRT_{NDT} due to the radiation exposure associated with that time period must be added to the original unirradiated RT_{NDT}. The extent of the shift in RT_{NDT} is enhanced by certain chemical elements (such as copper and nickel) present in reactor vessel steels. The Nuclear Regulatory Commission (NRC) has published a method for predicting radiation embrittlement in Regulatory Guide 1.99 Rev. 2 (Radiation Embrittlement of Reactor Vessel Materials)[1].

2.0 FRACTURE TOUGHNESS PROPERTIES

The fracture-toughness properties of the ferritic material in the reactor coolant pressure boundary are determined in accordance with the NRC Regulatory Standard Review Plan[3]. The pre-irradiation fracture-toughness properties for the materials in the Beaver Valley Unit 1 reactor vessel are presented in table 1.

3.0 ADJUSTED REFERENCE TEMPERATURE

From Regulatory Guide 1.99 Rev. 2 [1] the adjusted reference temperature (ART) for each material in the beltline is given by the following expression:

$$ART = \text{Initial } RT_{NDT} + \Delta RT_{NDT} + \text{Margin} \quad (1)$$

Initial RT_{NDT} is the reference temperature for the unirradiated material as defined in paragraph NB-2331 of Section III of the ASME Boiler and Pressure Vessel Code. If measured values of initial RT_{NDT} for the material in question are not available, generic mean values for that class of material may be used if there are sufficient test results to establish a mean and standard deviation for the class.

ΔRT_{NDT} is the mean value of the adjustment in reference temperature caused by irradiation and should be calculated as follows:

$$\Delta RT_{NDT} = [CF] f^{(0.28-0.10 \log f)} = [CF]\,[ff] \quad (2)$$

The value, "f", used in equation (2) is the calculated value of the neutron fluence at the location in the vessel at the location of the postulated defect, n/cm^2 ($E > 1$ MeV) divided by 10^{19}. The fluence factor, "ff" is shown in figure 1.

To calculate ΔRT_{NDT} at any depth (e.g., at 1/4T or 3/4T), the following formula must first be used to attenuate the fluence at the specific depth.

$$f_{(\text{depth } X)} = f_{surface}^{(e^{-.24x})} \quad (3)$$

where x (in inches) is the depth into the vessel wall measured from the vessel inner (wetted) surface. The attenuated fluence is then used in equation (2) to calculate ΔRT_{NDT} at the specific depth.

CF (°F) is the chemistry factor, obtained from reference 1 for the beltline region materials of the Beaver Valley Unit 1 reactor pressure vessel. The

limiting material was found to be the intermediate shell plate B6607-2 for Beaver Valley Unit 1 for 9.5 EFPY. The calculation of ART for this limiting material is shown in table 2. The ART values at 1/4T and 3/4T locations will be used to develop the reactor pressure vessel heatup and cooldown curves as described in the following sections.

4.0 CRITERIA FOR ALLOWABLE PRESSURE-TEMPERATURE RELATIONSHIPS

The ASME approach for calculating the allowable limit curves for various heatup and cooldown rates specifies that the total stress intensity factor, K_I, for the combined thermal and pressure stresses at any time during heatup or cooldown cannot be greater than the reference stress intensity factor, K_{IR}, for the metal temperature at that time. K_{IR} is obtained from the reference fracture toughness curve, defined in Appendix G to the ASME Code[4]. The K_{IR} curve is given by the following equation:

$$K_{IR} = 26.78 + 1.223 \exp [0.0145 (T-RT_{NDT}^* + 160)] \quad (4)$$

where

K_{IR} = reference stress intensity factor as a function of the metal temperature T and the metal reference nil-ductility temperature RT_{NDT}^*

Therefore, the governing equation for the heatup-cooldown analysis is defined in Appendix G of the ASME Code[4] as follows:

$$C K_{IM} + K_{IT} \leq K_{IR} \quad (5)$$

*NOTE: RT_{NDT} as used in the ASME Code [4] is in fact the adjusted reference temperature (ART) as defined in NRC Regulatory Guide 1.99, Rev. 2 [1] and calculated in section 3.0.

where

K_{IM} = stress intensity factor caused by membrane (pressure) stress

K_{IT} = stress intensity factor caused by the thermal gradients

K_{IR} = function of temperature relative to the RT_{NDT} of the mater l

C = 2.0 for Level A and Level B service limits

C = 1.5 for hydrostatic and leak test conditions during which the reactor core is not critical

At any time during the heatup or cooldown transient, K_{IR} is determined by the metal temperature at the tip of the postulated flaw, the appropriate value for RT_{NDT}, and the reference fracture toughness curve. The thermal stresses resulting from the temperature gradients through the vessel wall are calculated and then the corresponding (thermal) stress intensity factors, K_{IT}, for the reference flaw are computed. From equation (5), the pressure stress intensity factors are obtained and, from these, the allowable pressures are calculated.

For the calculation of the allowable pressure versus coolant temperature during cooldown, the reference flaw of Appendix G to the ASME Code [4] is assumed to exist at the inside of the vessel wall. During cooldown, the controlling location of the flaw is always at the inside of the wall because the thermal gradients produce tensile stresses at the inside, which increase with increasing cooldown rates. Allowable pressure-temperature relations are generated for both steady-state and finite cooldown rate situations. From these relations, composite limit curves are constructed for each cooldown rate of interest.

The use of the composite curve in the cooldown analysis is necessary because control of the cooldown procedure is based on the measurement of reactor coolant temperature, whereas the limiting pressure is actually dependent on the material temperature at the tip of the assumed flaw.

During cooldown, the 1/4 T vessel location is at a higher temperature than the fluid adjacent to the vessel inside surface. This condition, of course, is not true for the steady-state situation. It follows that, at any given reactor coolant temperature, the ΔT developed during cooldown results in a higher value of K_{IR} at the 1/4 T location for finite cooldown rates than for steady-state operation. Furthermore, if conditions exist so that the increase in K_{IR} exceeds K_{IT}, the calculated allowable pressure during cooldown will be greater than the steady-state value.

The above procedures are needed because there is no direct control on temperature at the 1/4 T location and, therefore, allowable pressures may unknowingly be violated if the rate of cooling is decreased at various intervals along a cooldown ramp. The use of the composite curve eliminates this problem and ensures conservative operation of the system for the entire cooldown period.

Three separate calculations are required to determine the limit curves for finite heatup rates. As is done in the cooldown analysis, allowable pressure-temperature relationships are developed for steady-state conditions as well as finite heatup rate conditions assuming the presence of a 1/4 T defect at the inside of the wall that alleviate the tensile stresses produced by internal pressure. The metal temperature at the crack tip lags the coolant temperature; therefore, the K_{IR} for the 1/4 T crack during heatup is lower than the K_{IR} for the 1/4 T crack during steady-state conditions at the same coolant temperature. During heatup, especially at the end of the transient, conditions may exist so that the effects of compressive thermal stresses and lower K_{IR}'s do not offset each other, and the pressure-temperature curve based on steady-state conditions no longer represents a lower bound of all similar curves for finite heatup rates when the 1/4 T flaw is considered. Therefore, both cases have to be analyzed in order to ensure that at any coolant temperature the lower value of the allowable pressure calculated for steady-state and finite heatup rates is obtained.

The second portion of the heatup analysis concerns the calculation of the pressure-temperature limitations for the case in which a 1/4 T deep outside

surface flaw is assumed. Unlike the situation at the vessel inside surface, the thermal gradients established at the outside surface during heatup produce stresses which are tensile in nature and therefore tend to reinforce any pressure stresses present. These thermal stresses are dependent on both the rate of heatup and the time (or coolant temperature) along the heatup ramp. Since the thermal stresses at the outside are tensile and increase with increasing heatup rates, each heatup rate must be analyzed on an individual basis.

Following the generation of pressure-temperature curves for both the steady-state and finite heatup rate situations, the final limit curves are produced by constructing a composite curve based on a point-by-point comparison of the steady-state and finite heatup rate data. At any given temperature, the allowable pressure is taken to be the lesser of the three values taken from the curves under consideration. The use of the composite curve is necessary to set conservative heatup limitations because it is possible for conditions to exist wherein, over the course of the heatup ramp, the controlling condition switches from the inside to the outside, and the pressure limit must at all times be based on analysis of the most critical criterion.

Finally, the 1983 Amendment to 10CFR50[5] has a rule which addresses the metal temperature of the closure head flange and vessel flange regions. This rule states that the metal temperature of the closure flange regions must exceed the material RT_{NDT} by at least 120°F for normal operation when the pressure exceeds 20 percent of the preservice hydrostatic test pressure.

5.0 HEATUP AND COOLDOWN LIMIT CURVES

Limit curves for normal heatup and cooldown of the primary Reactor Coolant System have been calculated using the methods described in section 4.0, and the Westinghouse procedure of reference 6.

Allowable combinations of temperature and pressure for specific temperature change rates are below and to the right of the limit lines shown in figures 2

and 3 for 9.5 EFPY. This is in addition to other criteria which must be met before the reactor is made critical.

The leak limit curve shown in figure 2 represents the minimum temperature requirements at the leak test pressure specified by applicable codes[3,4]. The leak test limit curves were determined by the methods of references 3 and 5.

Finally, table 1 indicates that the limiting flange RT_{NDT} of 60°F occurs in the closure head and vessel flange so the minimum allowable temperature of this region is 180°F per reference 5. These limits are shown in figure 3.

Figures 2 and 3 define the limits for ensuring prevention of nonductile failure for the Beaver Valley Unit 1 Primary Reactor Coolant System.

6.0 REFERENCES

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

2. Response to U. S. Nuclear Regulatory Commission Generic Letter 88-11 for the Beaver Valley Unit 1, MT-SMART-209(88), November 1988.

3. "Fracture Toughness Requirements," Branch Technical Position MTEB 5-2, Chapter 5.3.2 in Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition, NUREG-0800, 1981.

4. ASME Boiler and Pressure Vessel Code, Section III, Division 1 - Appendixes, "Rules for Construction of Nuclear Power Plant Components, Appendix G, Protection Against Nonductile Failure," pp. 558-563, 1986 Edition, American Society of Mechanical Engineers, New York, 1986.

5. Code of Federal Regulations, 10CFR50, Appendix G, "Fracture Toughness Requirements," U.S. Nuclear Regulatory Commission, Washington, D.C., Federal Register, Vol. 48 No. 104, May 27, 1983.

6. "Procedure for Developing Heatup and Cooldown Curves," Westinghouse Electric Corporation, Generation Technology Systems Division Procedure GTSD-A-1.12 (Rev. 0), July 13, 1988.

7. "Beaver Valley Unit 1 Reactor Vessel Fluence and RT_{PTS} evaluations" WCAP-10829, Revision 1.

TABLE 1

BEAVER VALLEY UNIT 1 REACTOR VESSEL TOUGHNESS PROPERTIES (UNIRRADIATED)

Component	Heat No.	Code No.	Material Type	Cu (%)	Ni (%)	T_{NDT} (°F)	R_{TNDT} (°F)	Upper Shelf Energy (Ft-lb) MWD	Upper Shelf Energy (Ft-lb) NMWD
Closure Head Dome	C6213-1B	B6610	A533B Cl. 1	.15	.54	-40	0*	121	-
Closure Head Seg.	A5518-2	B6611	A533B Cl. 1	.14	.60	-20	-20*	131	-
Closure Head Flange	ZV3758	B6601-1	A508 Cl. 2	.08	.65	60*	60*	>100	-
Vessel Flange	ZV3661	B6603	A508 Cl. 2	.12	.71	60*	60*	166	-
Inlet Nozzle	9-5443	B6608-1	A508 Cl. 2	.10	.84	60*	60*	82.5	-
Inlet Nozzle	9-5460	B6608-2	A508 Cl. 2	.10	.83	60*	60*	94	-
Inlet Nozzle	9-5712	B6608-3	A508 Cl. 2	.08	.80	60*	60*	97	-
Outlet Nozzle	9-5415	B6603-1	A508 Cl. 2	-	.79	60*	60*	97	-
Outlet Nozzle	9-5415	B6603-2	A508 Cl. 2	-	.79	60*	60*	112.5	-
Outlet Nozzle	9-5444	B6603-3	A508 Cl. 2	.09	.78	60*	60*	103	-
Upper Shell	123V339	B6604	A508 Cl. 2	-	.67	40	40*	155	-
Inter. Shell	C4381-2	B6607-2	A533B Cl. 1	.14	.62	-10	73	123	82.5
Inter. Shell	C4381-1	B6607-1	A533B Cl. 1	.14	.62	-10	43	128.5	90
Lower Shell	C6317-1	B6903-1	A533B Cl. 1	.20	.54	-50	27	134	80
Lower Shell	C6293-2	B7203-2	A533B Cl. 1	.14	.57	-20	20	129.5	83.5
Trans. Ring	123V223	B6602	A508 Cl. 2	-	-	30	30*	143	-
Bottom Head Seg.	C4423-3	B6618	A533B Cl. 1	.13	.55	-30	-29*	124	-
Bottom Head Dome	C4482-1	B6619	A533B Cl. 1	.13	.55	-50	-33*	125.5	-
Inter. Shell Long. Weld	(Wire 305424 and Linde 1092 Flux)		SAW	.28***	.63	-	-56**	-	-

3675s-032189:10

TABLE 1 (cont.)

BEAVER VALLEY UNIT 1 REACTOR VESSEL TOUGHNESS DATA (UNIRRADIATED)

Component	Heat No.	Code No.	Material Type	Cu (%)	Ni (%)	T_{NDT} (°F)	R_{TNDT} (°F)	Upper Shelf Energy (Ft-lb) MWD	Upper Shelf Energy (Ft-lb) NMWD
Inter. to Lower Shell Girth	(Wire 90136 and Linde 0091 Flux)		SAW	.29***	.07	-	-56**	-	-
Lower Shell Weld	(Wire 305414 and (Linde 1092 Flux)		SAW	.34***	.61	-	-56**	-	-
Weld HAZ				-	-	-40	-40	-	136.5

* Estimated per NUREG-0800 NRC Standard Review Plan Branch Technical Position MTEB 5-2

** Generic Mean Value Estimated per 10 CFR 50.61 PTS Rule

MWD - Major Working Direction

NMWD - Normal to Major Working Direction

*** From Reference 7.

TABLE 2

CALCULATION OF ADJUSTED REFERENCE TEMPERATURES FOR LIMITING BEAVER VALLEY UNIT 1 REACTOR VESSEL MATERIAL - INTERMEDIATE SHELL PLATE B6607-2[2]

Parameter	Regulatory Guide 1.99 - Revision 2 9.5 EFPY 1/4 T	3/4 T
Chemistry Factor, CF (°F)	100.5	100.5
Fluence, f (10^{19} n/cm^2)(a)	0.81	0.32
Fluence Factor, ff	0.94	0.69
ΔRT_{NDT} = CF x ff (°F)	95	69
Initial RT_{NDT}, I (°F)	73	73
Margin, M (°F)	34	34
Revision 2 to Regulatory Guide 1.99		
Adjusted Reference Temperature, ART = Initial RT_{NDT} + ΔRT_{NDT} + Margin	202	176

(a) Fluence, f, is based upon f_{surf} (10^{19} n/cm^2, E>1 Mev) = 1.30 at 9.5 EFPY at inner surface. The Beaver Valley Unit 1 reactor vessel wall thickness is 7.875 inches at the beltline region.

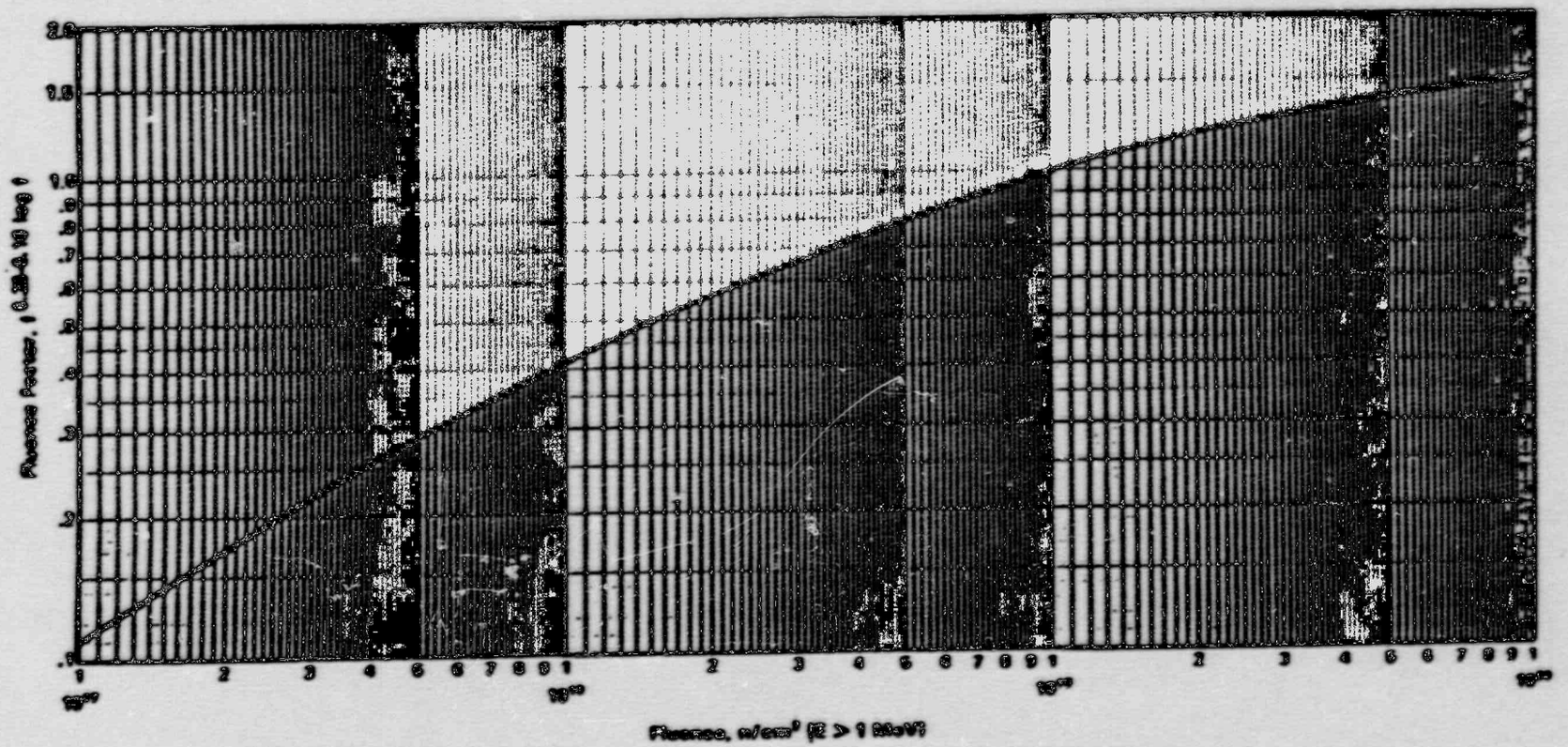

Figure 1. Fluence Factor for Use in the Expression for ΔRT_{NDT}

MATERIAL PROPERTY BASIS

CONTROLLING MATERIAL: INTERMEDIATE SHELL PLATE B6607-2

RT_{NDT} AFTER 9.5 EFPY: 1/4T, 202°F

3/4T, 176°F

CURVES APPLICABLE FOR HEATUP RATES UP TO 60°F/HR FOR THE SERVICE PERIOD UP TO 9.5 EFPY. DOES NOT CONTAIN MARGIN FOR POSSIBLE INSTRUMENT ERRORS.

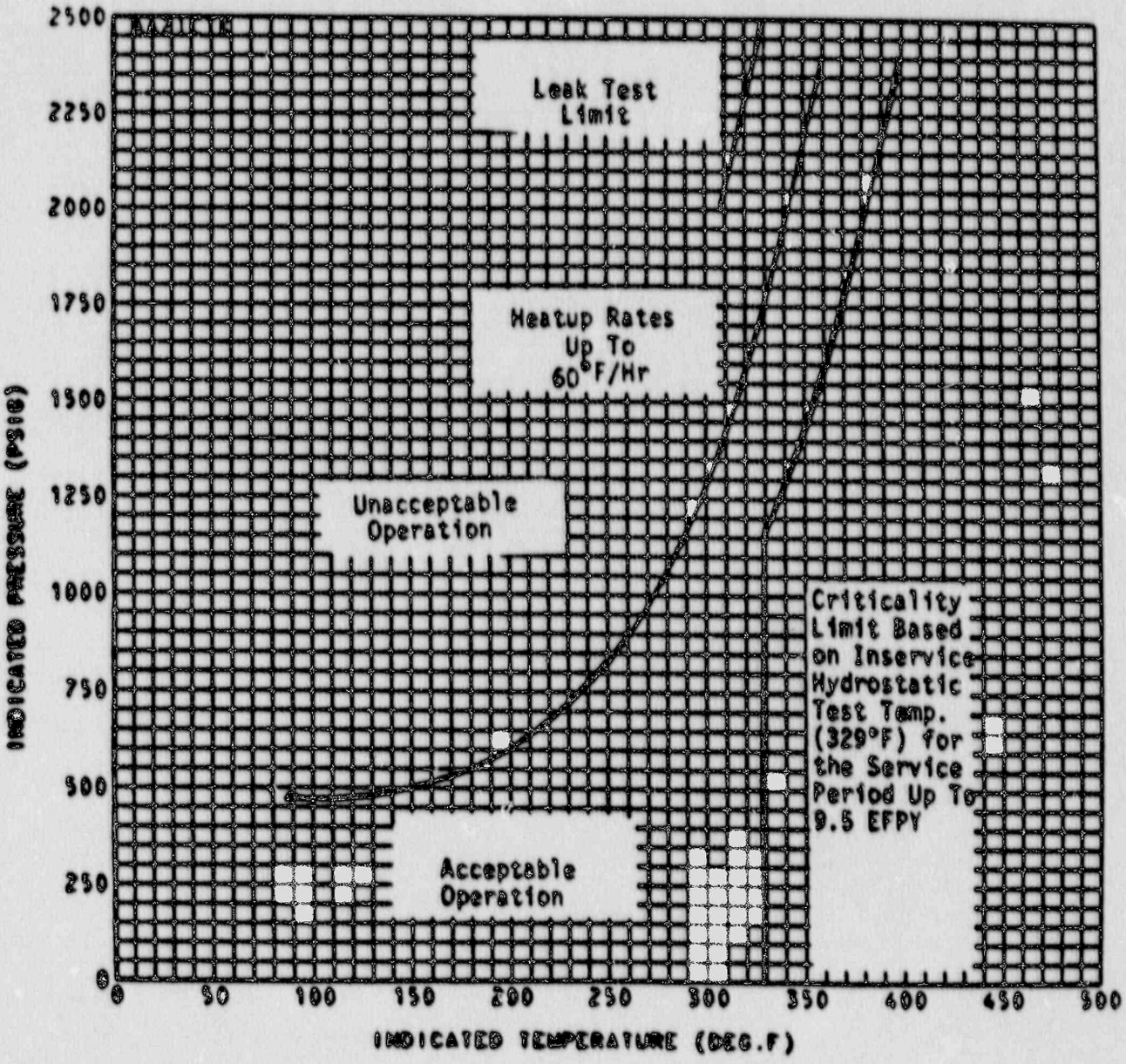

Figure 2. Beaver Valley Unit 1 Reactor Coolant System Heatup Limitations Applicable for the First 9.5 EFPY

MATERIAL PROPERTY BASIS

CONTROLLING MATERIAL: INTERMEDIATE SHELL PLATE B 6607-2

RT_{NDT} AFTER 9.5 EFPY: 1/4T, 202°F

3/4T, 176°F

CURVES APPLICABLE FOR COOLDOWN RATES UP TO 100 °F/HR FOR THE SERVICE PERIOD UP TO 9.5 EFPY. DOES NOT CONTAIN MARGIN FOR POSSIBLE INSTRUMENT ERRORS.

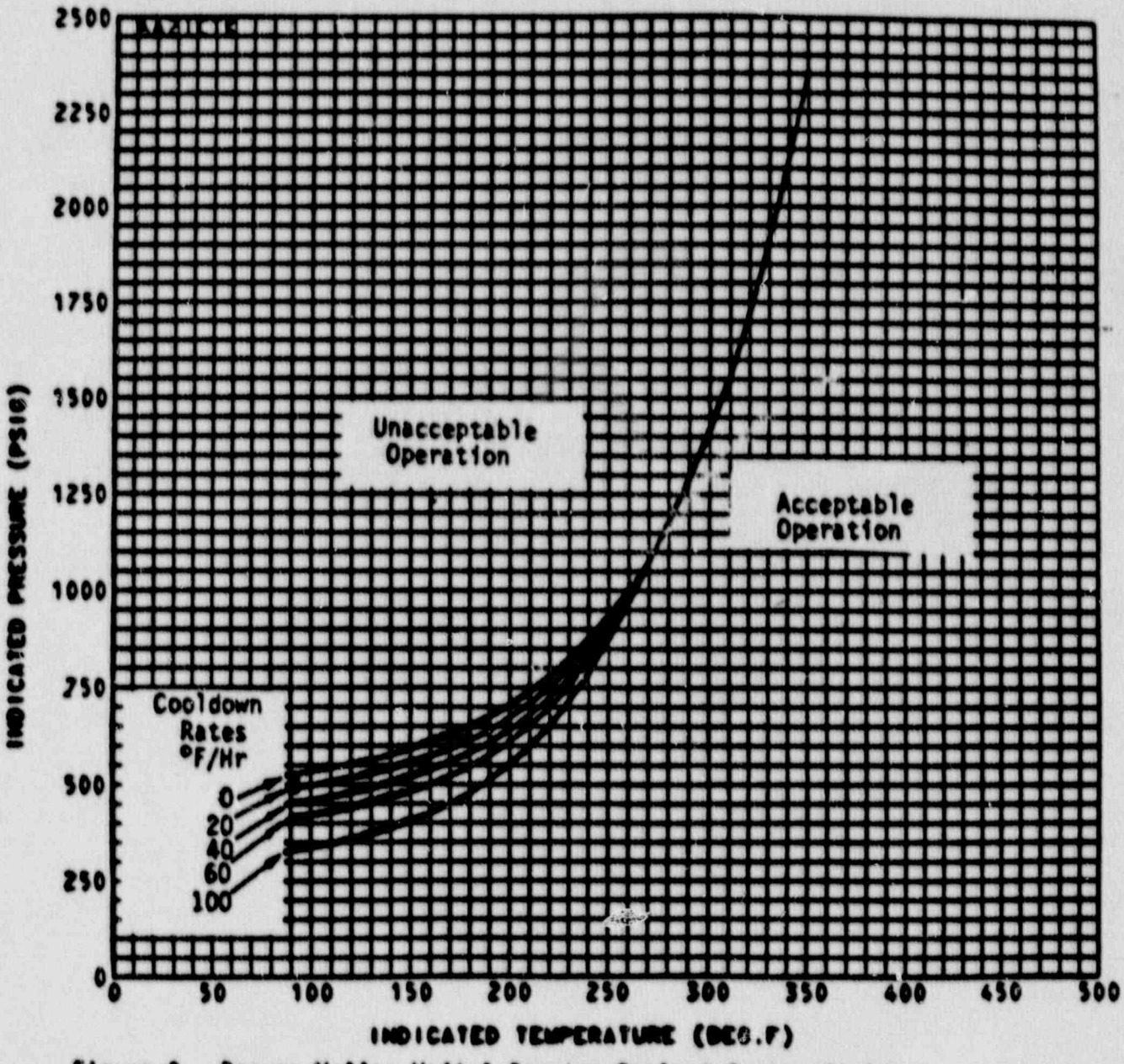

Figure 3. Beaver Valley Unit 1 Reactor Coolant System Cooldown Limitations Applicable for the First 9.5 EFPY

APPENDIX A
HEATUP AND COOLDOWN DATA

DLW 60F/HR HEATUP CURVE REG. GUIDE 1.99,REV.2 FOR PLATE B6607-2 10/20/88

THE FOLLOWING DATA WERE CALCULATEDFOR THE INSERVICE HYDROSTATIC LEAK TEST.

MINIMUM INSERVICE LEAK TEST TEMPERATURE (9.500 EFPY)

PRESSURE (PSI)	TEMPERATURE (DEG.F)
2000	307
2485	329

PRESSURE (PSI)	PRESSURE STRESS (PSI)	1.5 KIA (PSI SQ.RT.IN.)
2000	20984	84471
2485	26073	105852

DLW 607/M2 HEATUP CURVE REG. GUIDE 1.99,REV.2 FOR PLATE BG607-2 10/20/88

COMPOSITE CURVE PLOTTED FOR HEATUP PROFILE 2 HEATUP RATE(S) (DEG.F/HR) = 60.0

IRRADIATION PERIOD = 0.900 EFP YEARS
FLAW DEPTH = (1-AOWIN)T

	INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)			INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)
1	86.000	469.15		20	180.000	550.28	39	278.000	1041.04
2	90.000			21	185.000	561.86	40	280.000	1057.09
3	95.000			22	190.000	574.36	41	285.000	1109.92
4	100.000			23	195.000	587.86	42	290.000	1159.55
5	105.000			24	200.000	602.25	43	295.000	1210.45
6	110.000	468.15		25	205.000	617.93	44	300.000	1277.21
7	115.000	469.71		26	210.000	634.79	45	305.000	1342.86
8	120.000	471.24		27	215.000	652.81	46	310.000	1412.97
9	125.000	473.79		28	220.000	672.34	47	315.000	1486.12
10	130.000	477.10		29	225.000	693.32	48	320.000	1568.40
11	135.000	481.26		30	230.000	715.78	49	325.000	1664.93
12	140.000	486.08		31	235.000	740.05	50	330.000	1747.07
13	145.000	491.68		32	240.000	766.01	51	335.000	1869.01
14	150.000	497.88		33	245.000	793.87	52	340.000	1951.23
15	155.000	504.74		34	250.000	824.09	53	345.000	2034.90
16	160.000	512.39		35	255.000	856.24	54	350.000	2168.68
17	165.000	520.71		36	260.000	890.80	55	355.000	2280.28
18	170.000	529.80		37	265.000	928.20	56	360.000	2399.49
19	175.000	539.68		38	270.000	968.14			

A2

DLW COOLDOWN CURVES REG. GUIDE 1.99,REV.2 FOR PLATE 86807-2 10/20/88

THE FOLLOWING DATA WERE PLOTTED FOR COOLDOWN PROFILE 1 (STEADY-STATE COOLDOWN)

IRRADIATION PERIOD = 8.900 EFP YEARS
FLAW DEPTH = ADVIN T

	INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)
1	80.000	523.85	19	179.000	834.80 621*	37	269.000	1060.64
2	90.000	526.76	20	180.000	843.80	38	270.000	1082.28
3	95.000	530.10	21	189.000	697.98	39	278.000	1127.03
4	100.000	533.65	22	190.000	671.20	40	280.000	1173.10
5	105.000	537.98	23	199.000	685.42	41	289.000	1228.79
6	110.000	541.70	24	200.000	700.53	42	290.000	1282.09
7	115.000	548.16	25	209.000	716.97	43	295.000	1341.78
8	120.000	550.65	26	210.000	734.61	44	300.000	1405.87
9	125.000	558.01	27	219.000	753.49	45	308.000	1473.66
10	130.000	561.53	28	220.000	773.84	46	310.000	1547.63
11	135.000	567.52	29	229.000	795.97	47	315.000	1620.30
12	140.000	573.93	30	230.000	819.17	48	320.000	1710.60
13	145.000	580.82	31	239.000	844.28	49	325.000	1801.30
14	150.000	588.23	32	240.000	871.55	50	330.000	1898.26
15	155.000	593.10	33	249.000	900.97	51	335.000	2001.82
16	160.000	604.63	34	250.000	931.99	52	340.000	2112.92
17	165.000	613.84 621*	35	259.000	965.64	53	345.000	2231.69
18	170.000	621*	36	260.000	1001.69	54	350.000	2358.28

* SEE THE COOLDOWN CURVE (FLANGE REQUIREMENT)

DLW COOLDOWN CURVES REG. GUIDE 1.99,REV.2 FOR PLATE B6807-2 10/20/88

THE FOLLOWING DATA WERE PLOTTED FOR COOLDOWN PROFILE 2 (20 DEG-F / HR COOLDOWN)

IRRADIATION PERIOD = 0.500 EFP YEARS
FLAW DEPTH = ADVIN T

	INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)
1	85.000	480.34	15	155.000	550.82	28	220.000	747.12
2	90.000	468.45	16	160.000	568.86	29	225.000	770.39
3	95.000	491.83	17	165.000	578.50	30	230.000	795.19
4	100.000	495.45	18	170.000	588.85	31	235.000	822.12
5	105.000	499.40	19	175.000	599.90	32	240.000	850.82
6	110.000	503.53	20	180.000	611.91	33	245.000	881.93
7	115.000	508.10	21	185.000	624.85	34	250.000	915.20
8	120.000	513.02	22	190.000	638.77	35	255.000	950.94
9	125.000	518.33	23	195.000	653.81	36	260.000	989.38
10	130.000	524.04	24	200.000	669.73	37	265.000	1030.88
11	135.000	530.22	25	205.000	687.08	38	270.000	[illegible]
12	140.000	536.85	26	210.000	705.59	39	275.000	1123.1[illegible]
13	145.000	544.02	27	215.000	725.70	40	280.000	1174.40
14	150.000	551.61						

DLW COOLDOWN CURVES REG. GUIDE 1.99,REV.2 FOR PLATE B0607-2 10/20/88

THE FOLLOWING DATA WERE PLOTTED FOR COOLDOWN PROFILE 3 (40 DEG-F / HR COOLDOWN)

IRRADIATION PERIOD = 0.300 EFF YEARS
FLAW DEPTH = AOWIN T

	INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)
1	88.000	446.26	14	150.000	514.61	27	218.000	688.10
2	90.000	449.31	15	155.000	523.30	28	220.000	721.09
3	98.000	462.74	16	160.000	532.69	29	228.000	748.61
4	100.000	466.42	17	165.000	542.76	30	230.000	772.19
5	108.000	480.44	18	170.000	553.53	31	238.000	800.82
6	110.000	484.76	19	175.000	565.28	32	240.000	831.37
7	118.000	469.48	20	180.000	577.91	33	248.000	864.38
8	120.000	474.51	21	185.000	591.57	34	250.000	899.76
9	128.000	480.00	22	190.000	606.12	35	258.000	938.05
10	130.000	485.91	23	195.000	621.96	36	260.000	979.11
11	138.000	492.32	24	200.000	639.00	37	268.000	1023.20
12	140.000	499.21	25	205.000	657.24	38	270.000	1070.71
13	148.000	506.58	26	210.000	677.01	39	278.000	1121.80

BLW COOLDOWN CURVES REG. GUIDE 1.99,REV.2 FOR PLATE BGGO7-2 10/20/98

THE FOLLOWING DATA WERE PLOTTED FOR COOLDOWN PROFILE 4 (60 DEG-F / HR COOLDOWN ^)

IRRADIATION PERIOD = 0.900 EFP YEARS
FLAW DEPTH = AOWIN T

	INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)
1	85.000	408.34	14	190.000	479.60	27	215.000	671.26
2	90.000	409.51	15	155.000	486.19	28	220.000	695.99
3	95.000	412.00	16	160.000	496.01	29	225.000	721.75
4	100.000	416.59	17	165.000	506.55	30	230.000	749.06
5	105.000	420.90	18	170.000	517.98	31	235.000	780.38
6	110.000	425.24	19	175.000	530.38	32	240.000	812.99
7	115.000	430.08	20	180.000	543.71	33	245.000	848.19
8	120.000	435.30	21	185.000	558.02	34	250.000	886.15
9	125.000	440.98	22	190.000	573.35	35	255.000	926.84
10	130.000	447.11	23	195.000	590.32	36	260.000	970.81
11	135.000	453.70	24	200.000	608.25	37	265.000	1018.03
12	140.000	460.89	25	205.000	627.75	38	270.000	1068.77
13	145.000	468.68	26	210.000	648.99	39	275.000	1123.37

DLW COOLDOWN CURVES REG. GUIDE 1.99,REV.2 FOR PLATE 86607-2 10/20/88

THE FOLLOWING DATA WERE PLOTTED FOR COOLDOWN PROFILE 9 (100 DEG-F/HR COOLDOWN)

IRRADIATION PERIOD = 0.500 EFP YEARS
FLAW DEPTH = AOWIN ?

	INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)		INDICATED TEMPERATURE (DEG.F)	INDICATED PRESSURE (PSI)
1	86.000	323.86	14	190.000	400.38	27	218.000	819.68
2	90.000	327.14	15	195.000	410.48	28	220.000	846.78
3	95.000	330.74	16	200.000	421.32	29	225.000	878.98
4	100.000	334.68	17	199.000	433.16	30	230.000	709.69
5	105.000	339.04	18	170.000	445.94	31	235.000	742.45
6	110.000	343.76	19	175.000	459.74	32	240.000	780.29
7	115.000	348.84	20	180.000	474.70	33	245.000	821.15
8	120.000	354.38	21	185.000	490.92	34	250.000	864.52
9	125.000	360.74	22	190.000	508.32	35	255.000	911.38
10	130.000	367.41	23	195.000	527.25	36	260.000	961.62
11	135.000	374.68	24	200.000	547.87	37	265.000	1015.88
12	140.000	382.52	25	205.000	569.64	38	270.000	1074.16
13	145.000	391.11	26	210.000	593.49			