NUCLEAR POWER BUSINESS UNIT
CALCULATION REVIEW AND APPROVAL

Calculation #	96-0273
Number of Pages	15

Title of Calculation: Determination of PBNP LTOP Setpoint Using ASME Code Case N-514 (applicable through appx. Jan 2001)

☐ Original Calculation ☒ QA-Scope

☒ Revised Calculation. Revision # 1

☐ Superseding Calculation. Supersedes Calculation # ______

Modification #	Description:
N/A	N/A

Other References:
See Sheet 1 of Calculation.
Technical Specifications 15.3.15.

Prepared By:	Date:
[signature]	1/22/97

This Calculation has been reviewed in accordance with NP 7.2.4. The review was accomplished by one or a combination of the following (as checked):

✓ A review of a representative sample of repetitive calculations.

✓ A detailed review of the original calculation.

✓ A review of the calculation against a similar calculation previously performed.

____ A review by an alternate, simplified, or approximate method of calculation.

Comments:
Review and Verification of calculation determined methodology and arithmatic appropriate and correct. Change from Rev. Ø to Rev. 1 was due to NRC committment, which did not greatly affect final Results.

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Reviewed By:	Date:	Approved By:	Date:
G. P. Barrto	1/27/97	[signature]	1/27/97

CALCULATION SHEET

CALC. NO. 96-0273, Rev. 1

TITLE Determination of PBNP LTOP Setpoint Using ASME Code Case N-514 (applicable though appx. Jan. 2001) MADE BY J. R. Pfefferle DATE 1/22/97
REV'D. BY G. P. Baretta DATE 1/24/97

Purpose:

This calculation determines the maximum acceptable setpoint for the Low Temperature Overpressure Protection System applicable to both Point Beach units when implementing ASME Code Section XI, Code Case N-514. This calculation is bounding for the two units, in that it determines the maximum pressure allowed by Code Case N-514 for each unit at a reactor vessel inside surface fluence of 2.05×10^{19} n/cm^2 and utilizes the limiting pressure of the two units to determine the LTOP setpoint.

Revision 1 of this calculation is being issued to utilize neutron attenuation in accordance with Regulatory Guide 1.99, Rev. 2, in lieu of plant specific attenuation.

References:

1. BAW-2166, "B&W Owners Group Response to Generic Letter 92-01," June 1992.
2. ASME Boiler and Pressure Vessel Code, Sections III & XI, 1986 Edition.
3. Westinghouse WEP-96-562, "Pressure Bias for Low-Temperature, Overpressure Protection System," December 11, 1996
4. Instruction Manual 132-Inch I.D. Reactor Pressure Vessel, Babcock & Wilcox, September 1969.
5. Calculation N-94-05, Rev. 2, "Reactor Coolant System Heatup and Cooldown Curve Calculations - Effective Through January 2001," January 23, 1996.
6. Not used.
7. NRC Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," May 1988.
8. NRC Branch Technical Position - MTEB 5-2, Rev. 1, "Fracture Toughness Requirements," July 1981.
9. Westinghouse Report, "Pressure Mitigating Systems Transient Analysis Results," July 1977.
10. Westinghouse Report, "Supplement to the July 1977 Report, Pressure Mitigating Systems Transient Analysis Results," September, 1977.
11. ASME Code Case N-514, "Low Temperature Overpressure Protection," 1993.
12. Vectra letter to Wisconsin Electric, "Low Temperature Overpressure Protection (LTOP) Preliminary Instrument Loop Uncertainty," March 5, 1996.
13. Vectra letter to Wisconsin Electric, "Wide Range RCS Hot and Cold Leg Temperature Instrument Uncertainty Calculation," May 29, 1996.
14. WCAP-8743, "Heatup and Cooldown Limit Curves For Point Beach Nuclear Plant Unit No. 1," January, 1977.
15. WCAP-8738, "Heatup and Cooldown Limit Curves For Point Beach Nuclear Plant Unit No. 2," January, 1977.
16. 10 CFR 50, Appendix G, "Fracture Toughness Requirements," January 1, 1996 edition.
17. Framatome Technologies Fax, "Inputs for Enable Temperature for the Point Beach Units," November 11, 1996.
18. WCAP-8631, "Analysis of Capsule T from the Florida Power & Light Company Turkey Point Unit No. 3 Reactor Vessel Radiation Surveillance Program," December, 1975.

Methods and Assumptions:

The methodology of this calculation follows the steps listed below:

I. Determine the projected fluence at the limiting material at the reactor vessel inner radius on January 1, 2001.
II. Determine the corresponding fluence at the 1/4T reactor vessel location.
III. Determine the chemistry factor, initial properties, and margin term for the limiting PBNP reactor vessel materials.
IV. Determine the projected adjusted reference temperature at the 1/4T location for the limiting reactor vessel material on January 1, 2001.
V. Determine the reference stress intensity factor corresponding to the metal temperature of interest and adjusted reference temperature of the limiting materials.
VI. Determine the permissible stress intensity caused by membrane stress for an isothermal event at the temperature of interest.
VII. Determine the allowable pressure corresponding to the permissible membrane tension.
VIII. Correct for pressure instrument uncertainty and location bias in relation to the reactor vessel beltline.
IX. Correct for pressure overshoot due to PORV accumulation during the design basis mass input or heat input transient for the conditions of interest to determine the acceptable LTOP pressure setpoint.
X. Determine LTOP enable temperature.

Other methods and assumptions are listed below:

1. One setpoint applicable to Point Beach Units 1 and 2 will be determined based on the limiting Appendix G allowable pressure for the two units. The limiting material for Unit 1 is the intermediate-to-lower shell circumferential weld, SA-1101 (Ref. 1). The limiting material for Unit 2 is the intermediate-to-lower shell circumferential weld, SA-1484 (Ref. 1).
2. The reactor vessel is assumed to be in an isothermal condition for evaluation of LTOP setpoints.

Inputs:

Pressure Instrument Location Bias:

Unit 1
- 41.3 psig w/one RCP in operation (Ref. 3)
- 70.3 psig w/two RCPs in operation

Unit 2
- 44.6 psig w/one RCP in operation (Ref. 3)
- 74.4 psig w/two RCPs in operation

The instrument location bias values associated with the elevation difference of the wide range pressure transmitter and the mid-plane of the reactor vessel are plant specific values and include the affects of two RHR pumps operating.

Instrument Uncertainty: Pressure ± 13 psi (Ref. 12)
Temperature ± 17.8 °F (Ref. 13)

Yield Strength of SA-1101 Steel: 73 ksi (Ref. 18)
Yield strength of SA-1484 Steel: Not available. The yield strength of SA-1101 will be used as representative.

Reactor Vessel Thickness: 6.5 inches (Ref. 4)
One-Quarter Thickness: 1.625 inches
Reactor Vessel I.D.: 132.312 inches

Accumulated Reactor Vessel Fluence:

$IS = 2.05 \times 10^{19}$ n/cm^2 through 23.6 EFPY (Ref. 5)
$T/4 = IS * e^{(-0.24 * 1.625)}$ (Ref. 7)
$T/4 = 2.05 \times 10^{19} * 0.677 = 1.39 \times 10^{19}$ n/cm^2

Limiting Material Properties:

Unit 1

Pertinent material properties for SA-1101 weld material are (Ref. 1):

Cu = .26 wt. %
Ni = .60 wt. %
CF = 180°F
Initial RT_{NDT} = 0°F (measured)
Margin $= 2(\sigma_I^2 + \sigma_\Delta^2)^{1/2} = 2(0^2 + 28^2)^{1/2} = 56°F$

Flange Forging Properties (Ref. 14):
Head Flange RT_{NDT} = 50°F
Vessel Flange RT_{NDT} = 48°F

Unit 2

Pertinent material properties for SA-1484 weld material are (Ref. 1):

Cu = .24 wt. %
Ni = .60 wt. %
CF = 173°F
Initial RT_{NDT} = -5°F (best estimate for Linde 80)
Margin $= 2(\sigma_I^2 + \sigma_\Delta^2)^{1/2} = 2(17^2 + 28^2)^{1/2} = 66°F$

Flange Forging Properties (Ref. 15):
Head Flange RT_{NDT} = 48°F
Vessel Flange RT_{NDT} = 60°F

Calculations:

I. **Calculation of Adjusted Reference Temperature:**

UNIT 1

ART = Initial RT_{NDT} + ΔRT_{NDT} + Margin (Ref. 7, Section C.1.1):

ΔRT_{NDT} = (CF)(Fluence Factor)

Fluence Factor = $f^{(0.28 - .10\log f)}$
Where f = fluence at one-quarter thickness (10^{19} n/cm^2)

$$ART = 0^{\circ}F + (180 * (1.39^{(0.28 - .10\log(1.39))})) + 56^{\circ}F$$
$$= 262.4^{\circ}F$$

UNIT 2

ART = Initial RT_{NDT} + ΔRT_{NDT} + Margin (Ref. 7, Section C.1.1):

ΔRT_{NDT} = (CF)(Fluence Factor)

$$ART = -5^{\circ}F + (173 * (1.39^{(0.28 - .10\log(1.39))})) + 66^{\circ}F$$
$$= 249.7^{\circ}F$$

II. **Determination of Setpoint for Mass Input Transient**

A. Calculation of Reference Critical Stress Intensity Factor (K_{IR}):

$$K_{IR} = 26.78 + 1.223 \exp[0.0145 (T_{min} - ART_{NDT} + 160)]$$ (Ref. 2, Art. G-2110)

By inspection of calculation inputs, the limiting material in the closure flange region that is highly stressed by bolt preload has a reference temperature of 60°F. In accordance with the requirements of 10 CFR 50, App. G (Ref. 16), the material temperature in this region must be greater than this reference temperature in order to pressurize the reactor vessel to ≤ 20% of its preservice hydrostatic test pressure (≈625 psia) with the reactor core not critical. Therefore, this is the minimum temperature at which the RCS can be pressurized. Substituting, the minimum allowable temperature (T_{min}) = 60 °F

UNIT 1: K_{IR} = 27.44 ksi-in$^{1/2}$

UNIT 2: K_{IR} = 27.57 ksi-in$^{1/2}$

To account for temperature instrument uncertainty during plant operation a correction is made to determine the minimum allowable indicated temperature.

Minimum allowable indicated temperature ($T_{min\ ind}$) = 60 °F + 17.8 °F = 77.8 °F

B. Calculation of Maximum Allowable Pressure (Ref. 2, G-2215):

ASME Code Case N-514 permits the LTOP setpoint to be established such that the maximum pressure in the reactor vessel is limited to 110% of the pressure determined to satisfy ASME Section XI, Appendix G, Article G-2215.

UNIT 1

Maximum Allowable Membrane Tension (K_{Im}):

$2K_{Im} + K_{It} < K_{IR}$; where $K_{It} = 0$ for isothermal conditions (Ref. 2, Article G-2215)

$K_{Im} = K_{IR}/2 = 27.44/2 = 13.72$ ksi-in$^{1/2}$

Maximum Allowable Pressure:

$K_{Im} = M_m$ * membrane stress (Ref. 2, Article G-2214.1)

membrane stress = P*R/t = P*D/(2*t) (Ref. 8, Section 2.2.2)

where: P = ASME App. G pressure limit, psig
$P_{max} = 1.1 * P$ (Ref. 11)
D = inside diameter, inch
t = vessel thickness, inch

D = 132.312 inch, t = 6.5 inch (Ref. 4, Section 1.1.3)

Initially assume:

$M_m = 2.4$ (Ref. 2, Fig. G-2214-1, assuming $\sigma/\sigma_y = .1$)

$$P = \frac{K_{Im} * (2*t)}{M_m * D} = \frac{13.72 \text{ ksi-in}^{1/2} * 2 * 6.5 \text{ inch}}{2.4 * 132.312 \text{ inch}} = 561.7 \text{ psig}$$

$P_{max} = 1.1 * 561.7$ psig $= 617.9$ psig

Verifying selection of $M_m = 2.4$:

Membrane stress = (P*D) / (2*t) = (.618 ksi * 132 inch) / 2 * 6.5 inch
= 6.28 ksi

$\sigma/\sigma_y = 6.28/73 = 0.09$

From Fig. G-2214-1: $M_m = 2.4$ verifies assumption.

Maximum Allowable Indicated Pressure:

$P_{max\text{-}ind} = P_{max}$ - Location Bias - Instrument Uncertainty
= 617.9 psig - 70.3 psig - 13 psig = 534.6 psig

UNIT 2

Maximum Allowable Membrane Tension (K_{Im}):

$2K_{Im} + K_{It} < K_{IR}$; where $K_{It} = 0$ for isothermal conditions (Ref. 2, Article G-2215)

$K_{Im} = K_{IR}/2 = 27.57/2 = 13.79$ ksi-in$^{1/2}$

Maximum Allowable Pressure:

$K_{Im} = M_m$ * membrane stress (Ref. 2, Article G-2214.1)

membrane stress = P*R/t = P*D/(2*t) (Ref. 8, Section 2.2.2)

where: P = ASME App. G pressure limit, psig
$P_{max} = 1.1 * P$ (Ref. 11)
D = inside diameter, inch
t = vessel thickness, inch

D = 132.312 inch, t = 6.5 inch (Ref. 4, Section 1.1.3)

Initially assume:

$M_m = 2.4$ (Ref. 2, Fig. G-2214-1, assuming $\sigma/\sigma_y = .1$)

$$P = \frac{K_{Im} * (2*t)}{M_m * D} = \frac{13.79 \text{ ksi-in}^{1/2} * 2 * 6.5 \text{ inch}}{2.4 * 132.312 \text{ inch}} = 564.4 \text{ psig}$$

$P_{max} = 1.1 * 564.4$ psig = 620.9 psig

Verifying selection of $M_m = 2.4$:

Membrane stress = (P*D) / (2*t) = (.621 ksi * 132 inch) / 2 * 6.5 inch
= 6.28 ksi

$\sigma/\sigma_y = 6.28/73 = 0.09$

From Fig. G-2214-1: $M_m = 2.4$ verifies assumption.

Maximum Allowable Indicated Pressure:

$P_{max\text{-}ind} = P_{max}$ - Location Bias - Instrument Uncertainty

= 620.9 psig - 74.4 psig - 13 psig = 533.5 psig

Limiting Maximum Allowable Indicated Pressure

By inspection, the Unit 2 Appendix G allowable indicated pressure is most limiting, and the LTOP setpoint for the two units will be determined based on this value of 533.5 psig.

C. Determine Acceptable LTOP Setpoint:

By trial and error, an LTOP setpoint of 440 psig was determined to be the maximum acceptable setpoint for operation with a minimum reactor pressure vessel metal temperature of 60°F. Details of the determination of the acceptability of this setpoint are provided below for the mass input transient.

The mass input transient setpoint determination follows the methods described in Section 4 of Reference 9. The design basis mass input transient is one high pressure safety injection pump discharging to the reactor coolant system while the system is solid with pressure relieved by one power operated relief valve. The criteria for demonstrating that the 440 psig setpoint is acceptable is to determine the setpoint overshoot (ΔP) and add it to the setpoint. If this sum is less than the maximum allowable indicated pressure of 533.5 psig, the setpoint is considered to be acceptable.

The equation to use in the determination of setpoint overshoot for the mass input transient is as follows:

$$\Delta P\ (V, S, Z, X) = \Delta P_{REF}\ (X) * F_Y * F_S * F_Z * \text{Exp. Ratio}$$

where:

ΔP (V, S, Z, X)	=	setpoint overshoot, psig
V	=	total RCS & RHR volume, ft^3
S	=	relief valve setpoint, psig
Z	=	relief valve opening time, sec.
X	=	mass input rate, lb/sec
$\Delta P_{REF}(x)$	=	reference overshoot at mass input rate X, psi
F_Y	=	RCS volume factor
F_S	=	relief valve setpoint factor
F_Z	=	relief valve opening time factor
Exp. Ratio	=	ratio of maximum overshoot with metal expansion considered versus without its consideration

The method described in Reference 9 was developed from a reference set of parameters which are as follows:

X = mass input rate from the reference safety injection pump
V = 6000 cubic foot primary system volume
S = relief valve setpoint at 600 psig
Z = reference 3 second opening valve

From the reference parameters and results of the various transient analyses, the factors F_Y, F_S, and F_Z were developed as described in Section 4.3 of Reference 9. The report states that the development of these factors is conservative and plant specific analyses would result in peak values less than the peak values calculated using the algorithm outlined in the report.

The Point Beach plant specific parameters are the same for both units and have the following values:

X = mass input rate for Point Beach is identical to the reference SI pump used in the analyses (curve C of Figure 2.3.2). Therefore, the results of the analyses can be used directly for the Point Beach SI pump characteristic.
V = 7200 cubic feet for total RCS and RHR volume
S = 440 psig for relief valve setpoint
Z = 2 seconds for relief valve open time

The factors $\Delta P_{REF}(x)$ and F_S can be considered to determine the overshoot at a specific setpoint for the characteristics of a given mass input transient. Because the Point Beach pump characteristic was the one used in the analyses, the results of the analyses can be used directly. Therefore, the appropriate values for setpoint overshoot are:

Setpoint (psig)	Overshoot (psi)	Reference
600	155	Line 1, page A-2 of Ref. 9
400	192	Line 1, page A-3 of Ref. 9

Linear interpolation for a 440 psig setpoint results in:

Overshoot = $\Delta P_{REF}(x) * F_S$ = 184.6 psig.

From Figure 4.2.3 the F_Z for a 2 second valve is:

F_Z = 0.733 at 2 seconds.

From Figure 4.2.2 the F_V for a 7200 cubic foot RCS volume is:

F_V = 0.92 at 7200 ft^3

The effect of metal expansion is evaluated using the method of Section 5.2 of Ref. 9. The effect on overshoot is related to the ratio of the value in peak pressure when metal expansion is assumed in the analysis to the value without metal expansion. Using the maximum values from Figure 5.2, the ratio is:

$$\text{Exp. Ratio} = \frac{\text{Maximum overshoot with metal expansion}}{\text{Maximum overshoot without metal expansion}} = \frac{115}{155} = 0.74$$

The resulting overshoot is:

ΔP = 184.6 * 0.733 * 0.92 * 0.74 = 92.1 psi

Adding this to the setpoint results in:

P_{MAX} = 440 + 92.1 = 532.1 psig

This value is less than the maximum indicated allowable pressure of 533.5 psig for the mass input transient and is acceptable. Therefore, the proposed setpoint of 440 psig is acceptable for operation at reactor vessel metal temperatures greater than 60°F (RCS indicated water temperature of 78°F).

IV. Determination of Overshoot for Heat Input Transient

The design basis heat input transient assumes the starting of the first reactor coolant pump during water solid conditions with a temperature difference between the reactor coolant system and the steam generator of 50°F. Pressure is relieved by a single power operated relief valve. The information provided in the Supplement to the July 1977 Report (Ref. 10, "the supplement") is used to determine the setpoint overshoot for the heat input transient.

The following parameters are applicable to Point Beach:

Steam generator heat transfer area	=	44,000 ft^2 - Unit 1*
	=	47,500 ft^2 - Unit 2*
RCS volume	=	6,259 ft^3
RCS/SG ΔT	=	50 °F
Initial RCS pressure	=	300 psig
Relief valve setpoint	=	440 psig
Relief valve opening time	=	2 seconds

* Although the Unit 2 replacement steam generators have a larger heat transfer area than the Unit 1 steam generators, because of material differences, the heat transfer capabilities of each steam generator design is equivalent. As a conservatism in this analysis, it is assumed that the heat transfer capability for each unit is proportional to the heat transfer area of the larger Point Beach Unit 2 steam generators.

A bounding assessment based on the overshoot with a 6000 ft^3 RCS, 500 psig setpoint, and 3 second relief valve opening time for the Point Beach LTOP setpoint will be made, after making a correction for steam generator heat transfer area. This assessment is bounding because:

1. A smaller system volume results in a larger overshoot pressure;
2. A higher relief valve setting results in a larger overshoot pressure; and
3. A longer relief valve opening time results in a larger pressure accumulation.

Therefore, the actual pressure overshoot will be smaller than that estimated in this bounding assessment.

As a conservatism, the evaluation of the heat input transient includes a correction for the limiting Unit 2 steady state pressure bias due to two RCPs operating. This is done by reducing the maximum allowable pressure at the pressure instrument by the pressure bias due to two RCPs operating. This pressure bias correction is conservative because the maximum location pressure bias is not achieved until two reactor coolant pumps reach steady state flow conditions, whereas the limiting energy input transient occurs following the start of the first RCP. The adjusted reference temperature for the Unit 1 limiting material is used to conservatively bound the level of embrittlement for each unit.

Calculations of the bounding cases of pressure overshoot for initial RCS temp::atures of 100°F, 140°F, 180°F, and 250°F with bias correction for two reactor coolant pumps operating are provided below. These four temperatures represent all the temperatures analyzed in the supplement (Ref. 10).

A. Pressure Overshoot for Heat Input Transient at 100°F

1. Calculation of Reference Critical Stress Intensity Factor (K_{IR}):

Minimum temperature (T_{min}) = 100°F - 17.8°F = 82.2°F

$K_{IR} = 26.78 + 1.223\exp[0.0145(T_{min} - ART_{NDT} + 160)] = 27.69$ ksi-in$^{1/2}$

2. Calculation of Maximum Allowable Pressure (Ref. 2, G-2215):

Maximum Allowable Membrane Tension (K_{Im}):

$2K_{Im} < K_{IR}$

$K_{Im} = K_{IR}/2 = 27.69/2 = 13.85$ ksi-in$^{1/2}$

Maximum Allowable Pressure:

$K_{Im} = M_m$ * membrane stress (Ref. 2, Article G-2214.1)

membrane stress = [P*D/(2*t)] (Ref. 8, Section 2.2.2)

Initially assume:

$M_m = 2.4$ (Ref. 2, Fig. G-2214-1, assuming $\sigma/\sigma_y = .1$)

$$P = \frac{K_{Im} * (2*t)}{M_m * D} = \frac{13.85 \text{ ksi-in}^{1/2} * 2 * 6.5 \text{ inch}}{2.4 * 132.312 \text{ inch}} = 566.8 \text{ psig}$$

$P_{max} = 1.1 * 566.8$ psig = 623.5 psig

Verifying selection of $M_m = 2.4$:

Membrane stress = (P*D) / (2*t) = (.624 ksi * 132 inch) / 2 * 6.5 inch
= 6.34 ksi

$\sigma/\sigma_y = 6.34/73 = 0.09$

From Fig. G-2214-1: $M_m = 2.4$ verifies assumption.

Maximum Allowable Indicated Pressure:

$P_{max\text{-}ind} = P_{max}$ - Location Bias - Instrument Uncertainty

= 623.5 psig - 74.4 psig - 13 psig = 536.1 psig

3. **Calculation of Overshoot Pressure**

From Figure 16 of the supplement, the Reference UA for an RCS volume of 6000 at 100°F is read as 0.083. This reference value is normalized to Point Beach by applying the ratio of steam generator heat transfer areas:

$$\text{Normalized UA @ 6000 ft}^3 = 0.083 * 47{,}500/58{,}000 = 0.068$$

Entering Figure 16 with UA = 0.068 we find:

$$P_{MAX} - P_{SETPOINT} = \Delta P_{6K} = 24 \text{ psi.}$$

The maximum pressure that can be reached with this bounding overshoot value is:

$$P_{MAX} = P_{SETPOINT} + \Delta P_{6K} = 440 \text{ psig} + 24 \text{ psi} = 464 \text{ psig.}$$

This value is less than the maximum indicated allowable pressure of 536.1 psig at an indicated RCS cold leg temperature of 100°F. Therefore, a setpoint of 440 psig is acceptable for the heat input transient at 100°F.

B. **Pressure Overshoot for Heat Input Transient at 140°F**

1. **Calculation of Reference Critical Stress Intensity Factor (K_{IR}):**

$$\text{Minimum temperature } (T_{min}) = 140°F - 17.8°F = 122.2°F$$

$$K_{IR} = 26.78 + 1.223\exp[0.0145(T_{min} - ART_{NDT} + 160)] = 28.41 \text{ ksi-in}^{1/2}$$

2. **Calculation of Maximum Allowable Pressure (Ref. 2, G-2215):**

Maximum Allowable Membrane Tension (K_{Im}):

$$2K_{Im} < K_{IR}$$
$$K_{Im} = K_{IR}/2 = 28.41/2 = 14.21 \text{ ksi-in}^{1/2}$$

Maximum Allowable Pressure:

$K_{Im} = M_m$ * membrane stress (Ref. 2, Article G-2214.1)

membrane stress = [P*D/(2*t)] (Ref. 8, Section 2.2.2)

Initially assume:

$M_m = 2.4$ (Ref. 2, Fig. G-2214-1, assuming $\sigma/\sigma_y = .1$)

$$P = \frac{K_{Im} * (2*t)}{M_m * D} = \frac{14.21 \text{ ksi-in}^{1/2} * 2 * 6.5 \text{ inch}}{2.4 * 132.312 \text{ inch}} = 581.5 \text{ psig}$$

$$P_{max} = 1.1 * 581.5 \text{ psig} = 639.7 \text{ psig}$$

Verifying selection of $M_m = 2.4$:

Membrane stress = (P*D) / (2*t) = (.640 ksi * 132 inch) / 2 * 6.5 inch
= 6.51 ksi

$\sigma/\sigma_y = 6.51/73 = 0.09$

From Fig. G-2214-1: $M_m = 2.4$ verifies assumption.

Maximum Allowable Indicated Pressure:

$P_{max\text{-}ind} = P_{max}$ - Location Bias - Instrument Uncertainty
= 639.7 psig - 74.4 psig - 13 psig = 552.3 psig

3. Calculation of Overshoot Pressure

From Figure 16 of the supplement, the Reference UA for an RCS volume of 6000 at 140°F is read as 0.097. This reference value is normalized to Point Beach by applying the ratio of steam generator heat transfer areas:

Normalized UA @ 6000 ft^3 = 0.097 * 47,500/58,000 = 0.079

Entering Figure 16 with UA = 0.063 we find:

$P_{MAX} - P_{SETPOINT} = \Delta P_{6K} = 48$ psi.

The maximum pressure that can be reached with this bounding overshoot value is:

$P_{MAX} = P_{SETPOINT} + \Delta P_{6K}$ = 440 psig + 48 psi = 488 psig.

This value is less than the maximum indicated allowable pressure of 552.3 psig at an indicated RCS cold leg temperature of 140°F. Therefore, a setpoint of 440 psig is acceptable for the heat input transient at 140°F.

C. Pressure Overshoot for Heat Input Transient at 180°F

1. Calculation of Reference Critical Stress Intensity Factor (K_{IR}):

Minimum temperature (T_{min}) = 180°F - 17.8°F = 162.2°F

$K_{IR} = 26.78 + 1.223\exp[0.0145(T_{min} - ART_{NDT} + 160)] = 29.69$ ksi-in$^{1/2}$

2. Calculation of Maximum Allowable Pressure (Ref. 2, G-2215):

Maximum Allowable Membrane Tension (K_{Im}):

$2K_{Im} < K_{IR}$
$K_{Im} = K_{IR}/2 = 29.69/2 = 14.85$ ksi-in$^{1/2}$

Maximum Allowable Pressure:

$K_{Im} = M_m$ * membrane stress (Ref. 2, Article G-2214.1)

membrane stress = [P*D/(2*t)] (Ref. 8, Section 2.2.2)

Initially assume:

$M_m = 2.4$ (Ref. 2, Fig. G-2214-1, assuming $\sigma/\sigma_y = .1$)

$$P = \frac{K_{Im} * (2*t)}{M_m * D} = \frac{14.85 \text{ ksi-in}^{1/2} * 2 * 6.5 \text{ inch}}{2.4 * 132.312 \text{ inch}} = 607.7 \text{ psig}$$

P_{max} = 1.1 * 607.7 psig = 668.5 psig

Verifying selection of $M_m = 2.4$:

Membrane stress = (P*D) / (2*t) = (.669 ksi * 132 inch) / 2 * 6.5 inch = 6.81 ksi

σ/σ_y = 6.81/73 = 0.09

From Fig. G-2214-1: $M_m = 2.4$ verifies assumption.

Maximum Allowable Indicated Pressure:

$P_{max\text{-}ind} = P_{max}$ - Location Bias - Instrument Uncertainty

= 668.5 psig - 74.4 psig - 13 psig = 581.1 psig

3. Calculation of Overshoot Pressure

From Figure 16 of the supplement, the Reference UA for an RCS volume of 6000 at 180°F is read as 0.114. This reference value is normalized to Point Beach by applying the ratio of steam generator heat transfer areas:

Normalized UA @ 6000 ft^3 = 0.114 * 47,500/58,000 = 0.093

Entering Figure 16 with UA = 0.093 we find:

$P_{MAX} - P_{SETPOINT} = \Delta P_{6K}$ = 78 psi.

The maximum pressure that can be reached with this bounding overshoot value is:

$P_{MAX} = P_{SETPOINT} + \Delta P_{6K}$ = 440 psig + 78 psi = 518 psig.

This value is less than the maximum indicated allowable pressure of 581.1 psig at an indicated RCS cold leg temperature of 180°F. Therefore, a setpoint of 440 psig is acceptable for the heat input transient at 180°F.

D. Pressure Overshoot for Heat Input Transient at 250°F

1. Calculation of Reference Critical Stress Intensity Factor (K_{IR}):

Minimum temperature (T_{min}) = 250°F - 17.8°F = 232.2°F

K_{IR} = 26.78 + 1.223exp [0.0145 (T_{min} - ART_{NDT} + 160)] = 34.81 ksi-in$^{1/2}$

2. Calculation of Maximum Allowable Pressure (Ref. 2, G-2215):

Maximum Allowable Membrane Tension (K_{Im}):

$2K_{Im} < K_{IR}$

$K_{Im} = K_{IR}/2$ = 34.81/2 = 17.41 ksi-in$^{1/2}$

Maximum Allowable Pressure:

$K_{Im} = M_m$ * membrane stress (Ref. 2, Article G-2214.1)

membrane stress = [P*D/(2*t)] (Ref. 8, Section 2.2.2)

Initially assume:

M_m = 2.4 (Ref. 2, Fig. G-2214-1, assuming σ/σ_y = .1)

$$P = \frac{K_{Im} * (2*t)}{M_m * D} = \frac{17.41 \text{ ksi-in}^{1/2} * 2 * 6.5 \text{ inch}}{2.4 * 132.312 \text{ inch}} = 712.6 \text{ psig}$$

P_{max} = 1.1 * 712.6 psig = 783.9 psig

Verifying selection of M_m = 2.4:

Membrane stress = (P*D) / (2*t) = (.784 ksi * 132 inch) / 2 * 6.5 inch = 8.02 ksi

σ/σ_y = 8.02/73 = 0.11

From Fig. G-2214-1: M_m = 2.4 verifies assumption.

Maximum Allowable Indicated Pressure:

$P_{max-ind} = P_{max}$ - Location Bias - Instrument Uncertainty

= 783.9 psig - 74.4 psig - 13 psig = 696.5 psig

3. Calculation of Overshoot Pressure

From Figure 16 of the supplement, the Reference UA for an RCS volume of 6000 at 250°F is read as 0.138. This reference value is normalized to Point Beach by applying the ratio of steam generator heat transfer areas:

$$\text{Normalized UA @ } 6000\ ft^3 = 0.138 * 47{,}500/58{,}000 = 0.113$$

Entering Figure 16 with UA = 0.113 we find:

$$P_{MAX} - P_{SETPOINT} = \Delta P_{6K} = 127 \text{ psi.}$$

The maximum pressure that can be reached with this bounding overshoot value is:

$$P_{MAX} = P_{SETPOINT} + \Delta P_{6K} = 440 \text{ psig} + 127 \text{ psi} = 567 \text{ psig.}$$

This value is less than the maximum indicated allowable pressure of 696.5 psig at an indicated RCS cold leg temperature of 250°F. Therefore, a setpoint of 440 psig is acceptable for the heat input transient at 250°F.

V. Determination of LTOP Enable Temperature

The LTOP enable temperature will be determined based on the limiting RT_{NDT} for the two units (i.e., RT_{NDT} = 262.4 for Unit 1). In accordance with Code Case N-514, the LTOP enable temperature may be determined as the RCS water temperature corresponding to a metal temperature of at least RT_{NDT} + 50°F + Instrument Uncertainty at the beltline location (1/4t). The 1/4t metal temperature lags the fluid temperature by 23.5°F at a 100°F/hr heatup rate (Ref. 17).

Hence: $T_{enable} = 262.4°F + 50°F + 17.8°F + 23.5°F$

$= 353.7°F$

Conclusions:

This calculation demonstrates that an LTOP setpoint of 440 psig provides acceptable protection of the reactor vessel from overpressure events at low temperatures through the expiration of the Technical Specification pressure-temperature limit curves in January 2001. An enable temperature of greater than or equal to 353.7°F will be established in the Point Beach Technical Specifications.