Dominion Nuclear Connecticut, Inc.
Millstone Power Station
Rope Ferry Road
Waterford, CT 06385

Dominion

JUN 2 5 2001

Docket No. 50-423
B18428

RE: 10 CFR 50.90

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Millstone Nuclear Power Station, Unit No. 3
First Response to a Request for Additional Information
Technical Specifications Change Request 3-11-00
Reactor Coolant System Heatup and Cooldown Curves

In a letter dated April 23, 2001,(1) Dominion Nuclear Connecticut, Inc. (DNC), requested a change to the Millstone Unit No. 3 Technical Specifications. The proposed changes were primarily associated with revised Reactor Coolant System pressure/temperature limit curves and cold overpressure protection limit curves. In a facsimile received on June 7, 2001,(2) the Nuclear Regulatory Commission provided questions for discussion during a conference call conducted on June 14, 2001. The purpose of this letter is to transmit the responses to those questions, correct information contained in the original submittal, and provide additional information supporting the license amendment request. Attachment 1 contains this information. Attachment 2 contains requested calculations supporting the proposed changes to the Reactor Coolant System pressure/temperature limit curves and cold overpressure protection limit curves.

There are no regulatory commitments contained within this letter.

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(1) E. S. Grecheck letter to U.S. Nuclear Regulatory Commission, "Millstone Nuclear Power Station, Unit No. 3, Technical Specifications Change Request 3-11-00, Reactor Coolant System Heatup and Cooldown Curves," dated April 23, 2001.

(2) U.S. Nuclear Regulatory Commission letter to Dominion Nuclear Connecticut, Inc., "Millstone Nuclear Power Station, Unit 3, Facsimile Transmission, Draft Request for Additional Information (RAI) to be Discussed in an Upcoming Conference Call (TAC No. MA1785)," dated June 7, 2001.

A001

If you should have any questions on the above, please contact Mr. Ravi Joshi at (860) 440-2080.

Very truly yours,

DOMINION NUCLEAR CONNECTICUT, INC.

J. Alan Price, Vice President
Nuclear Technical Services - Millstone

Sworn to and subscribed before me

this 25th day of June, 2001

Sandra J Anton
Notary Public

My Commission expires

SANDRA J. ANTON
NOTARY PUBLIC
COMMISSION EXPIRES
MAY 31, 2005

Attachments (2)

cc: H. J. Miller, Region I Administrator
V. Nerses, NRC Senior Project Manager, Millstone Unit No. 3
A. C. Cerne, Senior Resident Inspector, Millstone Unit No. 3

Director
Bureau of Air Management
Monitoring and Radiation Division
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127

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Attachment 1

Millstone Nuclear Power Station, Unit No. 3

First Response to a Request for Additional Information
Technical Specifications Change Request 3-11-00
Reactor Coolant System Heatup and Cooldown Curves
Supplemental Information

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Technical Specifications Change Request 3-11-00
Reactor Coolant System Heatup and Cooldown Curves
Supplemental Information

In a letter dated April 23, 2001,(1) Dominion Nuclear Connecticut, Inc. (DNC), requested a change to the Millstone Unit No. 3 Technical Specifications. The proposed changes were primarily associated with revised Reactor Coolant System pressure/temperature limit curves and cold overpressure protection limit curves. In a letter dated June 7, 2001,(2) the Nuclear Regulatory Commission provided questions for discussion during a conference call conducted on June 14, 2001. The questions and associated responses are presented below. In addition, this letter will also correct information contained in the original submittal.

Question 1

In addition to the fluence values, did you also use other information from the surveillance report for capsule X (such as the chemistry factor of 25.1 and a reduced margin of 17°F for the limiting material) in your proposed pressure-temperature (P-T) limits calculations?

Response

The Westinghouse analysis of Capsule X (WCAP-15405, Rev. 0,(3)) was reviewed to evaluate the potential use of additional information beyond the fluence values. To date, the data provided by the surveillance capsule results show that the Regulatory Guide methods are over predicting the mean shift in RT_{NDT}. Therefore, DNC has chosen to use the more conservative Regulatory Guide 1.99, Rev. 2, Position 1.1 method to calculate the chemistry factor instead of deriving a plant specific chemistry factor.

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(1) E. S. Grecheck letter to U.S. Nuclear Regulatory Commission, "Millstone Nuclear Power Station, Unit No. 3, Technical Specifications Change Request 3-11-00, Reactor Coolant System Heatup and Cooldown Curves," dated April 23, 2001.

(2) U.S. Nuclear Regulatory Commission letter to Dominion Nuclear Connecticut, Inc., "Millstone Nuclear Power Station, Unit 3, Facsimile Transmission, Draft Request for Additional Information (RAI) to be Discussed in an Upcoming Conference Call (TAC No. MA1785)," dated June 7, 2001.

(3) WCAP-15405, Rev. 0, "Analysis of Capsule X from the Northeast Nuclear Energy Company Millstone Unit 3 Reactor Vessel Radiation Surveillance Program," May 2000.

Question 2

In the current P-T limit curves, you considered (1) indicator uncertainties, 22°F for temperature and 129 psia for pressure, (2) a pressure drop of 28.3 psi between the pressure transmitter and the reactor vessel beltline for one pump operation and a pressure drop of 74 psi for four pump operation, (3) the conservative portions of the P-T limits at a cooldown rate of 0°F/hr and the P-T limits at a cooldown rate of 80°F/hr to 160°F and 40°F/hr to 60°F, and (4) pressure in "psia", with a value of 10 added to the gage pressure to account for the primary containment pressure. Point out any deviations in the proposed P-T curves from the previous approach.

Response

The general methodology used to calculate the P-T curves is unchanged from the previous approach with the exception of using K_{IC} in place of K_{IR}. An administrative change has been made to allow a maximum of one reactor coolant pump (RCP) operation during cooldown from 160°F down to the minimum bolt up temperature. The previous cooldown curve was based on a maximum of one RCP in operation from 160°F to 120°F, and no RCPs in operation below 120°F.

The proposed P-T limit curves include the following adjustments, with the specific values clarified to indicate any changes.

1. The instrument uncertainty value for pressure has been revised from 129 psi to 115.5 psi. The instrument uncertainty value for temperature has been revised from 22°F to 25.3°F.

2. The pressure drop of 28.3 psi between the pressure transmitter and the reactor vessel beltline for one RCP operation and the pressure drop of 74 psi for four RCP operation remain unchanged from previous approach.

3. The curves shown are composite curves derived from the most restrictive pressure value considering the specified rates and isothermal conditions. This method remains unchanged from the previous approach.

4. The adjustment from gage pressure to an absolute containment pressure remains unchanged at 10 psi.

The development of the P-T curves is documented in DNC Calculation M3-LOE-284-EM, Rev. 4, which is contained in Attachment 2.

Question 3

Provide detailed explanation and calculations for the indented portion of the P-T limit curves between 160°F and 186°F.

Response

The "indent" or reduction in allowable pressure between 160°F and 186°F is due to different dynamic pressure correction factors for one and four RCP operation when applied to the calculation of the 20 percent preservice hydrostatic test pressure defined by ASME Code NB-6221. With one RCP in operation at or below 160°F, a dynamic correction of 28.3 psi is applied. Above 160°F, a factor of 74.0 psi is applied. These calculations are also included in DNC Calculation M3-LOE-284-EM, Rev. 4 (Attachment 2). The current Technical Specification P-T curves were administratively smoothed to hide this step.

Correction to Original Submittal

The following two corrections to the information contained in the original submittal should be made.

1. Attachment 1 Page 3 and Attachment 5 Page 2

   The following sentence should be replaced on the two identified pages.

   Original: The proposed COPPS setpoint curves have been established to protect the 32 EFPY isothermal reactor vessel beltline P/T curve and the power operated relief valve (PORV) discharge piping design pressure of 800 psia.

   Revised: The proposed COPPS setpoint curves have been established to protect the 32 EFPY isothermal reactor vessel beltline P/T curve and limit pressurizer pressure to 800 psia consistent with the current design analysis associated with the PORV discharge piping.

2. Attachment 1 Page 21

   The reference to the criteria contained in 10 CFR 50.36 for items required to be in Technical Specifications should be 10 CFR 50.36(c)(2)(ii). The parenthesis around the letter c were inadvertently omitted.

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Attachment 2

Millstone Nuclear Power Station, Unit No. 3

First Response to a Request for Additional Information
Technical Specifications Change Request 3-11-00
Reactor Coolant System Heatup and Cooldown Curves
Calculations

First Response to a Request for Additional Information Technical Specifications Change Request 3-11-00 Reactor Coolant System Heatup and Cooldown Curves

Calculations

The following calculations are included as requested:

1.	Calculation	M3-LOE-284-EM Rev. 4 Millstone 3: Pressure/Temperature Limits for 32 EFPY
2.	Calculation	94-ENG-1018E3 Rev. 2 Millstone Unit 3 COPPS/PORV Loop Uncertainty
3.	Calculation	94-ENG-01042C3 Rev. 4 Millstone 3: PORV Setpoint Curves for the Cold Overpressure System for 32 EFPY

Approved 9-28-99 Effective 10-5-99

CALCULATION TITLE PAGE

Total Number of Pages: 64

Millstone 3: Pressure/Temperature Limits for ~~10~~ 32 CSS EFPY

TITLE

M3-LOE-284-EM	4	RCS
CALCULATION No.	**Revision No.**	**System Name**

N/A	CS	3301	RXV
VENDOR CALCULATION No.	**Structure**	**System Number**	**Component**

N/A
VENDOR NAME

①

NUCLEAR INDICATOR:	Safety Evaluation or Screen Attached	**Calc. Supports DCR/MMOD?**	**Calc. Supports Other Process?**
☒CAT1 ☐RWQA ☐SBOQA ☐FPQA ☐ATWSQA ☐NON-QA	☐YES ☒NO	☐YES ☒NO	☒YES ☐NO
		↓	↓
		N/A	PTSCR
		DCR/MMOD No.	**Reference**
			TSCR 3-11-00

INCORPORATES:

CCN NO:	AGAINST REV.
N/A	

Executive Summary

The results of this calculation provide revised RCS Pressure/Temperature limits for Unit 3 Technical Specifications and new cold overpressure protection (COPS) enable temperatures. This change incorporates revised ART values through 32 EFPY and uses Code Case N-640 to develop beltline Pressure/Temperature limits. This method requires specific NRC approval prior to use. The enable temperatures for COPS are based on the ASME Section XI Appendix G recommendations. Note, revised instrument inaccuracies have been incorporated.

The same RCP pump operation has been used as well as the same heatup and cooldown rates.

In addition, this revision also provides a proposed reactor vessel surveillance capsule withdrawal schedule which satisfies ASTM E 185-82.

This information will be used to prepare a Technical Specification Change package and an exemption request.

Approvals (Print & Sign Name)

Preparer:Craig D. Stewart Craig D. Stewart		Date: 8/9/00
Interdiscipline Reviewer:	Discipline:	Date:
Interdiscipline Reviewer :	Discipline:	Date:
Independent Reviewer:Thomas A. Steahr Thomas A		Date: 8/9/00
Supervisor: N.P. SACCO		Date: 4/10/01

Installation Verification

☐ Calculation represents the installed configuration and approved licensing condition (Calculation of Record)

☐ N/A does not affect plant configuration (e.g., study, hypothetical analysis, etc.)

Preparer/Designer Engineer: (Print and Sign) Craig D. Stewart Date:

FOR INFORMATION ONLY

RECD 4-16-01
ON HOLD kt 4.10.01
CDS
CDS CC
NRP

DCM Form 5-1A
Rev. 7 Ch. 1
Page 1 of 1

Approved 9-28-99 Effective 10-5-99

PassPort DATABASE INPUTs

Page 2

Calculation Number: M3-LOE-284-EM Revision: 4

Vendor Calculation Number/Other: N/A Revision: N/A

CCN # N/A QA ☒ Yes ☐ No Calc Voided: ☐ Yes ☒ No

Superseded By: N/A Supersedes Calc: N/A

Discipline (Up to 10) L

Unit (M1, M2, M3)	Project Reference (EWA, DCR or MMOD)	Component Id	Computer Code	Rev. No./ Level No.
M3	N/A	3RCS*REV1	ABAQUS (1)	VER

①

PMMS CODES*					
Structure	System	Component	Reference Calculation	Rev No.	CCN
CS	RCS	RXV	95-SDS-1008MG	4	N/A
			94-ENG-1018-E3	2	1
			97SDE-01535-M3	0	N/A
			95-SDS-1007MG	4	N/A

*The codes required must be alpha codes designed for structure, system and component.

Reference Drawing	Sheet	Rev. No.
N/A	N/A	N/A

Comments:
These comment are transferred form Rev. 2. (1)ABAQUS is not maintained as a Q/A code. However, ABAQUS results were validated earlier using "VISA" and more recently (1/97) using PC Ver 5.2 of ANSYS. The results from ANSYS were within ±2°F of ABAQUS results. ANSYS is in the process of being QA'ed.

NOTE: Avoid multiple item references on a line, e.g., LT 1210 A-D requires four separate lines. ①

Table of Contents

1.0 OBJECTIVE

The purpose of this calculation is to develop revised pressure/temperature (P/T) limits for the Millstone Unit 3 reactor coolant pressure boundary ferritic materials through 32 effective full power years (EFPY) of operation.

The P/T curves will be developed for incorporation in to the Technical Specifications and address normal heatup, cooldown and hydrostatic test conditions. These curves will be adjusted to reflect indicated pressurizer pressure and indicated cold leg temperature which will include elevation and flow induced pressure differences and instrumentation uncertainties. The permissible heatup and cooldown rates (used to develop the curves) will be maintained consistent with the previous revision of this calculation.

This calculation will also develop cold overpressure protection system (COPS) enable temperature using the guidance provided by ASME Boiler and Pressure Vessel Code Section XI, Appendix G.

The Unit 3 surveillance capsule withdrawal schedule will be developed based upon the guidance of ASTM E 185-82 for the purpose of updating the Technical Specifications in accordance with 10 CFR 50 Appendix H. Consideration will be given to commercial issues and timing of the recommended withdrawal dates within the ASTM guidance.

Note, this revision is major and therefore revision bars have not been incorporated.

2.0 ASSUMPTIONS

2.1 Reactor coolant pump (RCP) operation will be assumed based upon the indicated cold leg temperature (T_C):

> During heatup, one RCP will be permitted to operate with $T_C \leq 160°F$.
> When $T_C > 160°F$, up to four RCP's may be operated.
>
> During cooldown, up to four RCP's can be operated while $T_C > 160°F$,
> and one RCP may be operated while $T_C \leq 160°F$.

Note: these pump restrictions affect the dynamic pressure losses between the vessel and the pressure instrument. These values affect the final P/T values.

2.2 During heatup, the radial thermal gradients generate a compressive stress at the 1/4t location. As the thermal stresses are compressive, they would tend to resist crack growth. This calculation will conservatively treat the compressive stress intensity factor due to this stress as zero.

2.3 The yield stresses for the reactor vessel material will be taken from the reactor vessel design code of record in an unirradiated condition. The actual material has been irradiated which increases the yield stress. Treating the material as unirradiated produces a conservative stress intensity factor.

2.4 The reactor vessel beltline is the controlling location for the develop RCS P/T limits. This assumption is appropriate because the beltline materials are subjected to neutron irradiation which degrades the materials fracture toughness.

3.0 DESIGN INPUTS

3.1 Reactor Vessel Beltline Material

Base metal material: SA-533 Grade B Class 1 Ref. 4.1, page A-35
Clad Material: Type 304 Stainless Steel Ref. 4.22

3.2 Reactor Vessel Beltline Geometry

Inside Radius to Clad Wetted Surface = 86.656 in Ref. 4.1, page A-11
Clad thickness = 0.156 in. Ref. 4.1, page A-11
Base metal thickness = 8.625 in Ref. 4.1, page A-35

3.3 Reactor Vessel Beltline Material Properties

The reactor vessel was designed and fabricated to the rules of ASME Boiler and Pressure Vessel Code, Section III, 1971 Edition with Addenda through 1973 (Reference 4.4)as identified by the ASME N-1 Certification (Reference 4.5). The previous revisions of this calculation utilize material properties obtained from the 1989 Edition of the ASME Boiler and Pressure Vessel Code, Section III (Reference 4.6) to perform the heat transfer analysis. Justification for use of this Code year was previously documented in Reference 4.22. A summary is provided for completeness.

Review ASME Boiler and Pressure Vessel Code, Section II, Material Specification for SA 533 Grade B Class 1 Vacuum Forged Plated for the 1971 Edition through Summer 1973 Addenda and 1989 Edition (References 4.7 And 4.8, respectively) demonstrate that the chemical composition between the code years is essentially the same. As the thermal properties should be controlled by the chemical composition of this plate material, using the 1989 Edition of Section III is acceptable. In addition, it should be noted that use of the later code edition provides a better representation of this information as this information provided by the 1971 Edition through Summer 1973 Addenda was developed to cover a broader range of materials with more specific information in the 1989 Edition.

Cladding

Temperature, °F	Conductivity, BTU/hr ft °F (Ref. 4.4)	Thermal Diffusivity, ft^2/hr (Ref. 4.4)	Specific Heat[1], Btu/lb °F
70	8.6	0.151	0.1137
100	8.7	0.152	0.1142
150	9.0	0.154	0.1166
200	9.3	0.156	0.1190
250	9.6	0.158	0.1213
300	9.8	0.160	0.1223
350	10.1	0.162	0.1244
400	10.4	0.165	0.1258
450	10.6	0.167	0.1267
500	10.9	0.170	0.1280
550	11.1	0.172	0.1288

[1] Note: Specific Heat (Cp) = Thermal Conductivity / (Density * Thermal Diffusivity) The information was obtained from Reference 4.6. The thermal analysis used the properties from the 1989 Edition of Section XI and was demonstrated to have no impact.

Density = 501 lb/ft^3 (Ref. 4.3)

Base metal

Temperature, °F	Conductivity, BTU/hr ft °F (Ref. 4.4)	Thermal Diffusivity, ft^2/hr (Ref. 4.4)	Specific Heat[1], Btu/lb °F
70	22.3	0.429	0.1061
100	22.6	0.427	0.1080
150	23.1	0.424	0.1112
200	23.4	0.420	0.1137
250	23.7	0.415	0.1165
300	23.8	0.408	0.1190
350	23.8	0.399	0.1217
400	23.8	0.389	0.1249
450	23.7	0.378	0.1280
500	23.5	0.366	0.1310
550	23.2	0.354	0.1337

[1] Note: Specific Heat (Cp) = Thermal Conductivity / (Density * Thermal Diffusivity). The information was obtained from Reference 4.6. The thermal analysis used the properties from the 1989 Edition of Section XI and was demonstrated to have no impact.

Density = 490 lb/ft^3 (Ref. 4.9)

(489 lb/ft^3 actually used which has no affect.)

Adjusted Reference Temperature at 1/4 t (32 EFPY) = 123.6°F (Ref. 4.11)
Adjusted Reference Temperature at 3/4 t (32 EFPY) = 105.8° F (Ref. 4.11)

Yield Strength (Reference 4.4)

Temperature, °F	Yield Strength, ksi
100	50.00
200	47.10
300	45.20
400	44.50

3.4 Thermal Hydraulic Pressure Correction

The maximum dynamic pressure differential between the mid-plane of the reactor vessel down comer region and the wide range pressure transmitter (located on the RHR piping) is:

One RCP Operation $\Delta P = 28.3$ psi (Reference 4.10)
Four RCP Operation $\Delta P = 74$ psi (Reference 4.12)

It has been demonstrated that the static elevation head can be ignored due to the location of the pressure sensor and the limiting reactor vessel material. This has been documented in Reference 4.22.

3.5 Pressure and Temperature Indicator Uncertainties (Reference 4.13)

Wide range temperature and pressure indication instrumentation probable error (uncertainty) will be applied to the RCS Pressure/Temperature limits. These values will provide the worst case information and is based upon a 24 month fuel cycle. These values were obtained from the calculation of record, Reference 4.13.

The instrument uncertainty associated with wide range temperature indication loops 3RCS*TI413A/B and 3RCS*TI423A/B will be applied.

Temperature Uncertainty: 25.3 °F

The instrument uncertainty associated with wide range pressure indication loops 3RCS*PI403 and 3RCS*PI405 will be applied.

Pressure Uncertainty: 115.5 psia

3.6 Adjustment of Gage Pressure to Absolute Pressure

The primary containment pressure is maintained below atmospheric pressure to minimize radioactive release in the event of an emergency. Containment pressure is maintained greater than or equal to 10.6 psia and less than or equal to 14.0 psia (Reference 4.24, page 3/4 6-7. The computations of allowable beltline pressure are based upon a differential or gage pressure. To adjust the resultant pressure, the minimum containment pressure permitted by Technical Specifications (10.6 psia) will be bound by 10 psia in lieu of adding normal atmospheric pressure of 14.7 psia. Consequently, an additional 10 psi will be added to the pressures to obtain an absolute pressure.

4.0 REFERENCES

4.1 CE Report No. CENC-1282-A1, "Addendum 1 to Analytical Report for Northeast Power Company Millstone Unit 3 Reactor Vessel," dated May 1977, Combustion Engineering, Inc.

4.2 ASME Boiler and Pressure Vessel Code, Section XI, Appendix G, 1995 Edition.

4.3 Structural Alloys Handbook, Volume 2, 1986 Edition.

4.4 ASME Boiler and Pressure Vessel Code, Section III, Appendices, 1971 Edition through Summer 1973 Addenda.

4.5 Form N-1 Manufacturers' Data Report Report for Nuclear Vessels, Combustion Engineering, Inc., June 28, 1978.

4.6 ASME Boiler and Pressure Vessel Code, Section III, Appendices, 1989 Edition.

4.7 ASME Boiler and Pressure Vessel Code, Section II, 1971 Edition through Summer 1973 Addenda.

4.8 ASME Boiler and Pressure Vessel Code, Section II, 1989 Edition.

4.9 Combustion Engineering Report No. CENC-1177, "Analytical Report for Northeast Utilities Service Co. Reactor Vessel," 1972.

4.10 Westinghouse Letter SE/SFE/NEU-0238, SMPD Systems Engineering to C. Schwartz, "Millstone COMS/LTOPS Consultation," dated 11/11/1996.

4.11 Calculation 95-SDS-1008MG, Rev. 4, "Calculation of Adjusted Temperatures for the MP2 and MP3 Reactor Vessels," dated 7/6/2000.

4.12 Westinghouse Letter NEU-93-555, Westinghouse to F. R. Dacimo, "Core Delta Pressure Estimate with One RCP Running," dated 3/31/1993.

4.13 NUSCO Calculation 94-ENG-1018-E3, "Millstone Unit 3 COPPS/PORV Loop Uncertainty," Revision 2 and CCN No. 1.

4.14 Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Limit Curves," Section XI, Division 1, Approval date 2/26/1999.

4.15 Regulatory Guide 1.84, "Design and Fabrication Code Case Acceptability, ASME Section III, Division 1," Rev. 31, dated May 1999.

4.16 ASME Boiler and Pressure Vessel Code, Section XI, Appendix G, "Fracture Toughness Criteria for Protection Against Failure," 1995 Edition.

4.17 WRC Bulletin 175, "PVRC Recommendations on Toughness Requirements for Ferritic Materials," August 1972.

4.18 Westinghouse Report WCAP-15405, Rev. 0, "Analysis of Capsule X from the Northeast Nuclear Energy Company Millstone Unit 3 Reactor Vessel Radiation Surveillance Program," dated May 2000.

4.19 "Advanced Strength and Applied Stress Analysis," by Richard G. Budynas.

4.20 ASTM E 185-82, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels, E 706."

4.21 Westinghouse Report WCAP-11878, "Analysis of Capsule U from the Northeast Utilities Service Company Millstone Unit 3 Reactor Vessel Radiation Surveillance Program," dated June 1988.

4.22 NUSCO Calculation 97SDE-01535-M3, Rev. 0, "Millstone U3: Appendix G and COPS Evaluation of RHR Initiation Transient w/Loss of Offsite Power," dated 12/19/00.

4.23 NUSCO Calculation 95-SDS-1007MG, Rev. 04, "Calculation of Initial Properties for CY and Millstone Reactor Vessels," dated 6/30/98.

4.24 Millstone Nuclear Power Station Unit 3 Technical Specification, through amendment 180, change 178..

5.0 METHOD OF ANALYSIS

5.1 Beltline Pressure/Temperature Limits

Development of P/T limits is based upon the requirements provided by 10 CFR 50 Appendix G. 10 CFR 50 Appendix G mandates the use of ASME Boiler and Pressure Vessel Code (referred to as ASME Code), Section XI, Appendix G. In addition to ASME Code, Appendix G, Code Case N-640 (Reference 4.14) has published by ASME Section XI which permits the reference fracture toughness curve, K_{IC}, as found in Appendix A of Section XI, in lieu of K_{IR}, Figure G-2210-1 in Appendix G. It is important to recognize that 10 CFR 50.55a acknowledges Regulatory Guide 1.84 (Reference 4.15) contains those Code Cases which are approved for use. In this instance, Code Case is not approved for use and requires specific approval by the Office of Nuclear Reactor Regulation. Following submittal and upon issuance of an SER from the NRC, the results of this calculation will be acceptable to utilize in normal plant operation. In addition, 10 CFR 50.55(b)(2) permits the use of Section XI including editions through 1995 Edition and addenda through 1996 (subject to the limitations defined of which none apply).

To evaluate the vessel beltline, the requirements of ASME Code, Appendix G, 1995 Edition (Reference 4.2) were followed as augmented by Code Case N-640.A summary of the requirements/process follows. The P/T limits developed as part of this calculation apply to the ferritic components of the RCS as specified by 10 CFR 50 Appendix G.

To evaluate the beltline region, a defect one-fourth the section thickness is postulated (Ref. 4.16, G-2120). This flaw is commonly referred to as the 1/4 t and 3/4 t locations referring to inside and outside surface defects, respectively.

The beltline region is remote from structural discontinuities and the provision of G-2210 (Ref. 4.16) apply. Paragraph G-2212.1 recommends the use of K_{IA} or K_{IR} as the critical reference stress intensity factor. This is a lower bound fracture toughness for materials tested which include dynamic effects and the basis is described by WRC-175 (Reference 4.17). In lieu of K_{IA}, Code Case N-640 provides the recommendation of using K_{IC}, as provided by ASME Code Appendix A. K_{IC} can be expressed by the following equation:

$$K_{IC} = 33.2 + 20.734\exp[0.02(T-RT_{NDT})] \text{ ksi}\sqrt{\text{in}} \qquad \text{(Ref. 4.16, A-4200)}$$

(Note: K_{IR} values will be calculated for information only and will not be used in the calculation of the allowable pressure.)

The RT_{NDT} is the reference nil ductility temperature (°F), and needs to account for irradiation effects (G-2212.2) Irradiation effects are accounted for using the procedures contained in Regulatory Guide 1.99, Revision 2. This has been documented in calculation 95-SDS-1008MG, Rev. 4 (Reference 4.11). The irradiation damage has considered 32 effective full power years (EFPY) of operation using the most recent surveillance capsule evaluation (Reference 4.18). The terminology used for the irradiated

RT_{NDT} is the adjusted reference temperature (ART) which is the summation of the initial RT_{NDT}, the shift in the 30 ft-lb transition temperature and the uncertainty term. The 1/4 t ART and 3/4 t ART are used in place of RT_{NDT} in the computation of K_{IC}.

To compute the applied stress intensity factor, the methods of linear elastic fracture mechanics are used. The loading condition required to be considered are those due to membrane tension (Ref. 4.16, G-2214.1), bending (Ref. 4.16, G-2214.2) and radial thermal gradients (Ref. 4.16, G-2214.3). In the case of the beltline of the reactor vessel, there are no loads due to bending.

To compute the allowable pressure for normal operation (Ref. 4.16, G-2215), a factor of two is required to be applied to the stress intensity factor due to primary stresses. In the case of the beltline, the only significant loading is general primary membrane stresses due to internal pressure and thermal stresses due to the radial thermal gradient developed in the vessel wall due to either heatup or cooldown evolutions. Algebraically, the expression required is as follows for normal operation:

$$K_{IC} < 2K_{IM} + K_{IT}$$

In the case of hydrostatic testing, the factor of safety is reduced to 1.5 on the primary membrane stress and can be depicted as follows:

$$K_{IC} < 1.5K_{IM} + K_{IT}$$

In the case of hydrostatic testing, the curve will be based upon an isothermal condition (< 10 °F/hr).

When performing the heatup evaluation, the 1/4 t and 3/4 t locations will be evaluated. During heatup, the stresses at the 1/4 t location are compressive and the 3/4 t location are tensile. However, the neutron damage is a function of wall thickness, greater at the inside and decreasing through the walls thickness. Consequently, it is necessary to evaluate both locations to ensure the controlling location is determined. To determine the composite heatup limit, the limiting heatup location (1/4 t or 3/4 t) is compared to an isothermal limits and the controlling pressure is used.

To perform the cooldown evaluation, only the 1/4 t location needs to be evaluated because the thermal gradients produce a tensile stress at the inside surface combined with the greater embrittlement provide the limiting location.

The evaluation is performed by first computing K_{IT}. This is performed by first performing a thermal transient heat transfer analysis using the ABAQUS general purpose finite element analysis code. The analysis is performed for the particular rates and temperature ranges of interest. The heat transfer analysis is performed using one dimensional two noded heat transfer element to provide the radial temperature distributions as a function of time. The ability of this code to accurately predict the through wall temperatures as a function of time has been verified using the VISA code as documented in Revision 0 of this calculation. It should be noted that the stainless steel cladding is modeled in the heat transfer analysis but no credit is taken for the cladding in the structural analysis.

The boundary conditions imposed on the model consist of a convective boundary layer on the inside surface to represent an effectively infinite heat transfer coefficient, h (assumed h = 10000 Btu/hr ft^2 °F). The outside of the vessel is assumed to be insulated.

$K_{IT} = M_t * \Delta T_w$ ksi√in (Ref. 4.16, G-2214.3)

where: ΔT_w = the temperature difference through the wall, °F
M_t = is as shown in Ref. 4.16, Fig. G-2214-2.

Then using the 1/4 t and 3/4 t crack tip temperatures, a reference critical stress intensity can be computed using the following equation:

$K_{IC} = 33.2 + 20.734\exp(0.02[T-RT_{NDT}])$ ksi√in

Determining the maximum permissible stress intensity due to membrane stress can be accomplished by solving for K_{IM}.

$K_{IM} = (K_{IR} - K_{IT})/2$ ksi√in

From Ref. 4.12, G-2214.1, K_{IM} can be expressed by the following equation:

$K_{IM} = M_m * \sigma_m$ ksi√in, where:

σ_m = the membrane stress due to internal pressure, ksi
M_m = factor defined by Ref. 4.16, Figure G-2214-1

Note that $\sigma_m = K_{IM}/M_m$ and based upon thick wall vessel theory can be expressed as a function of pressure by the following expression:

$\sigma_m = [a^2 * p/(b^2-a^2)]*[1+(b^2/r^2)]$ (Reference 4.19, page 142)

where: a = vessel inside radius, in. (clad/base metal interface)
b = vessel outside radius, in.
r = radial distance to point being analyzed, in. (i.e., 1/4 t and 3/4 t)
p = internal pressure, ksi (gage)

Consequently, the calculation of allowable pressure for the temperature of interest can be computed by knowing the allowable membrane stress intensity and the vessel geometry by algebraically manipulating the previous two equations. These values will be adjusted with pressure and temperature correction factors which account for indication uncertainty along with static and dynamic pressure differences between the beltline and indicator.

5.2 Additional P/T Requirements

10 CFR 50 Appendix G provides additional limitations on the ferritic materials of the reactor coolant pressure boundary. The following provides a summary of the requirements.

Hydrostatic pressure and leak tests (Core not critical)

1a. With fuel in the vessel, the pressure must not exceed 20% of the preservice hydrostatic test pressure until the vessel closure flange (treated as the cold leg temperature) is equal to or greater than the highest reference temperature (RT_{NDT}) of the material in the closure flange region that is highly stressed by the bolt preload. Note, the beltline limits developed in accordance with ASME Appendix G may be more limiting and would therefore control pressure.

1b. With fuel in the vessel, the temperature of the material in the closure flange region that is highly stressed by the bolt preload must be equal to the reference temperature plus 90°F (RT_{NDT} + 90°F) for the pressure to exceed 20% of the preservice hydrostatic test pressure. Note, the beltline limits developed in accordance with ASME Appendix G may be more limiting and would therefore control pressure.

Normal Operation (including heatup and cooldown), including anticipated operational occurrences

2.a With the core not critical, the pressure must not exceed 20% of the preservice hydrostatic test pressure until the vessel closure flange temperature (treated as the cold leg temperature) is equal to or greater than the highest reference temperature (RT_{NDT}) of the material in the closure flange region that is highly stressed by the bolt preload. Note, the beltline limits developed in accordance with ASME Appendix G may be more limiting and would therefore control pressure.

2.b With the core not critical, the temperature of the material in the closure flange region that is highly stressed by the bolt preload must be equal to the reference temperature plus 120°F (RT_{NDT} + 120°F) for the pressure to exceed 20% of the preservice hydrostatic test pressure. Note, the beltline limits developed in accordance with ASME Appendix G may be more limiting and would therefore control pressure.

2.c With the core critical, the pressure must not exceed 20% of the preservice hydrostatic test pressure when the larger of the vessel closure flange temperature (treated as the cold leg temperature) is equal to or greater than the highest reference temperature plus 40°F (RT_{NDT} + 40°F) of the material in the closure flange region that is highly stressed by the bolt preload or the minimum permissible temperature for inservice system hydrostatic pressure test. In addition, the beltline limits developed in accordance with ASME Appendix G + 40°F must be considered and may be more limiting and would therefore control pressure. Note that these limits are solely to establish margins against non-ductile failure and are not intended to establish temperatures at which the core can be brought critical.

2.d With the core critical, to exceed 20% of the preservice hydrostatic test pressure, the larger of either the vessel closure flange temperature (treated as the cold leg temperature) is equal to or greater than the highest reference temperature plus 160°F (RT_{NDT} + 160°F) of the material in the closure flange region that is highly stressed by the bolt preload or the minimum permissible temperature for inservice system hydrostatic pressure test. In addition, the beltline limits developed in accordance with ASME Appendix G + 40°F must be considered and may be more limiting and would therefore control pressure. Note that these limits are solely to establish margins against non-ductile failure and are not intended to establish temperatures at which the core can be brought critical.

Minimum Boltup Temperature

ASME Boiler and Pressure Vessel Code, Section XI, Appendix G, G-2222(c), recommends that when the vessel flange and shell region are stressed by the full intended bolt preload and by pressure not exceeding 20% of the preservice system hydrostatic test pressure, the minimum metal temperature of the stressed region be at least the initial RT_{NDT} for the material in the stressed region plus any effects of irradiation.

Lowest Service Temperature

ASME Boiler Pressure Vessel Code Section III, NB 2332(b) (Reference 4.4) requires that for piping, pumps and valves, (excluding bolting) with nominal wall thickness greater than 2.5 inches, the lowest service temperature shall not be less than RT_{NDT} + 100°F.

These values will be adjusted with the appropriate pressure or temperature correction factors which account for indication uncertainty along with static and dynamic pressure differences between the beltline and indicator.

5.3 COPS Enable Temperatures

The Cold Overpressure Protection System (COPS) is used to ensure that the P/T limits are not exceeded due to inadvertent mass and energy addition transients. This system is synonymous with Low Temperature Overpressure Protection (LTOP). The temperature ranges which the system shall be aligned and operational are called COPS Enable temperatures. Determination of these temperatures for heatup and cooldown were based upon ASME Code Section XI G-2215 (Ref. 4.16). The minimum COPS enable temperature is when coolant temperatures are less than 200°F or at coolant temperatures corresponding to a reactor vessel metal temperature less than RT_{NDT} + 50°F, whichever is greater. The reactor coolant temperature is defined as the reactor coolant inlet temperature. The RT_{NDT} is the highest ART in the beltline at the 1/4 t location. The vessel metal temperature is the temperature at one-quarter the vessel section thickness from the inner wetted surface. (Note that the metal temperature used in this calculation is the 1/4 t from the clad/base metal interface. This will result in a slightly more conservative [higher] coolant temperature.) These values are determined and then corrected for instrument uncertainty with the cold leg instrumentation.

5.3 Surveillance Capsule Withdrawal Schedule

10 CFR 50 Appendix H provides the requirements relative to the reactor vessel material surveillance program. The requirements associated with the design of the program and the withdrawal schedule must meet the requirements of the edition of ASTM E 185 that is current on the issue date of the ASME Code to which the reactor vessel was purchased. Later editions may be used but only up to and including those editions through 1982. Development of the revised withdrawal schedule will be based upon the ASTM E 185-82 (Reference 4.20).

There has been two surveillance capsule removed and evaluated from Unit 3 to date. Capsule U and Capsule X have been removed and are documented in References 4.18 and 4.21. The most recent capsule evaluation, Capsule X, provides a proposed schedule which will be reviewed as part of the process.

6.0 BODY OF CALCALCULATION

6.1 Beltline P/T Limits

$z := 1 .. 4$

$T_{y_z} :=$	$\sigma_{y_z} :=$
100	50.0
200	47.1
300	45.2
400	44.5

$t := 8.625$ Vessel wall thickness

$a := 86.656$ Vessel Inside Radius, to clad OD

$b := 95.281$ Vessel Outside Radius

$ART_{25} := 124.8$ Limiting adjusted reference temperature at the t/4 location (B9805-1 plate)

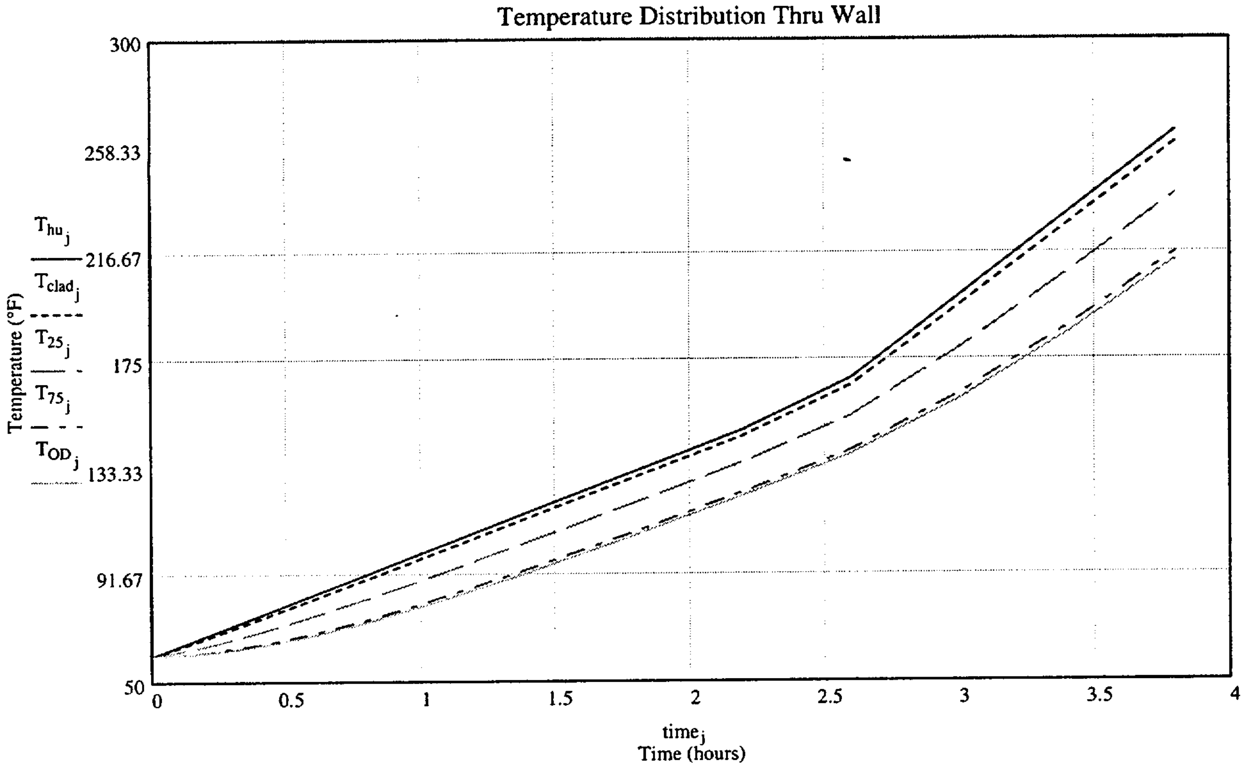
$ART_{75} := 107.0$ Limiting adjusted reference temperature at the 3t/4 location (B9805-1 plate)

$M_t := 0.344$

Calculations For Heatup at 40 °F/hr to 160°F and 80°F/hr to 560°F

Output from ABAQUS code $j := 1 .. 13$

$time_j :=$	$T_{hu_j} :=$	$\sigma_{y_j} :=$	$T_{clad_j} :=$	$T_{25_j} :=$	$T_{75_j} :=$	$T_{OD_j} :=$
0	60	50.0	60.00	60.00	60.00	60.00
0.2	68	50.0	67.11	63.93	61.46	61.22
0.4	76	50.0	74.66	69.40	64.52	63.99
0.6	84	50.0	82.36	75.66	68.87	68.10
0.8	92	50.0	90.14	82.41	74.21	73.24
1.0	100	50.0	97.99	89.50	80.26	79.14
1.4	116	47.1	113.8	104.4	93.79	92.49
1.8	132	47.1	129.7	119.7	108.5	107.1
2.2	148	47.1	145.6	135.4	123.7	122.3
2.6	168	47.1	165.2	153.2	140.0	138.4
3.0	200	47.1	196.2	179.6	161.7	159.6
3.4	232	45.2	227.7	208.9	188.0	185.4
3.8	264	45.2	259.5	239.4	216.8	214.0



Governing Equations (from reference 3)

Delta T $\Delta T_j := T_{clad_j} - T_{OD_j}$

Stress Intensity Factor Due to Radial Thermal Gradient (conservatively taken as zero for the 1/4t flaw)

$M_t := 0.344$ $K_{IT75_j} := M_t \cdot \Delta T_j$ $K_{IT25_j} := 0$

Reference Critical Stress Intensity Factor

$K_{IR25_j} := 26.78 + 1.223 \cdot e^{.0145 \cdot \left(T_{25_j} - ART_{25} + 160\right)}$ $K_{IR75_j} := 26.78 + 1.223 \cdot e^{.0145 \cdot \left(T_{75_j} - ART_{75} + 160\right)}$

$K_{IC25_j} := 33.2 + 20.734 \cdot e^{.02 \cdot \left(T_{25_j} - ART_{25}\right)}$ $K_{IC75_j} := 33.2 + 20.734 \cdot e^{.02 \cdot \left(T_{75_j} - ART_{75}\right)}$

Stress Intensity Factor Due to Membrane Tension

$K_{IM25_j} := \frac{K_{IC25_j} - K_{IT25_j}}{2}$ $K_{IM75_j} := \frac{K_{IC75_j} - K_{IT75_j}}{2}$

Membrane stress

$j := 1..9$ $M_{m25_j} := 2.79$ $\sigma_{m25_j} := \frac{K_{IM25_j}}{M_{m25_j}}$

$j := 10..12$ $M_{m25_j} := 2.85$ $\sigma_{m25_j} := \frac{K_{IM25_j}}{M_{m25_j}}$

$j := 13..13$ $M_{m25_j} := 2.98$ $\sigma_{m25_j} := \frac{K_{IM25_j}}{M_{m25_j}}$

$j := 1..11$ $M_{m75_j} := 2.80$ $\sigma_{m75_j} := \frac{K_{IM75_j}}{M_{m75_j}}$

$j := 12..13$ $M_{m75_j} := 2.93$ $\sigma_{m75_j} := \frac{K_{IM75_j}}{M_{m75_j}}$

Allowable Gage Pressure: $a = 86.656$ $b = 95.281$ $r_{75} := 93.125$ $r_{25} := 88.812$ $j := 1..13$

$$P_{hu25_j} := \frac{\sigma_{m25_j} \cdot \frac{b^2 - a^2}{a^2}}{1 + \frac{b^2}{r_{25}^2}} \cdot 1000 \qquad P_{hu75_j} := \frac{\sigma_{m75_j} \cdot \frac{b^2 - a^2}{a^2}}{1 + \frac{b^2}{r_{75}^2}} \cdot 1000$$

Heatup: Sumary of Results for a 1/4t Flaw

$T_{hu_j} =$	$\Delta T_j =$	$K_{IT25_j} =$	$K_{IC25_j} =$	$K_{IM25_j} =$	$\sigma_{m25_j} =$	$M_{m25_j} =$	$\sigma_{y_j} =$	$\frac{\sigma_{m25_j}}{\sigma_{y_j}} =$	$P_{hu25_j} =$
60	0	0	38.873	19.437	6.967	2.79	50	0.139	676.804
68	5.89	0	39.337	19.669	7.05	2.79	50	0.141	684.881
76	10.67	0	40.047	20.023	7.177	2.79	50	0.144	697.234
84	14.26	0	40.96	20.48	7.34	2.79	50	0.147	713.133
92	16.9	0	42.082	21.041	7.541	2.79	50	0.151	732.661
100	18.85	0	43.435	21.717	7.784	2.79	50	0.156	756.219
116	21.31	0	46.988	23.494	8.421	2.79	47.1	0.179	818.079
132	22.6	0	51.923	25.962	9.305	2.79	47.1	0.198	904.013
148	23.3	0	58.83	29.415	10.543	2.79	47.1	0.224	$1.024 \cdot 10^3$
168	26.8	0	69.79	34.895	12.244	2.85	47.1	0.26	$1.189 \cdot 10^3$
200	36.6	0	95.24	47.62	16.709	2.85	47.1	0.355	$1.623 \cdot 10^3$
232	42.3	0	144.672	72.336	25.381	2.85	45.2	0.562	$2.466 \cdot 10^3$
264	45.5	0	238.357	119.178	39.993	2.98	45.2	0.885	$3.885 \cdot 10^3$

Heatup: Sumary of Results for a 3/4t Flaw

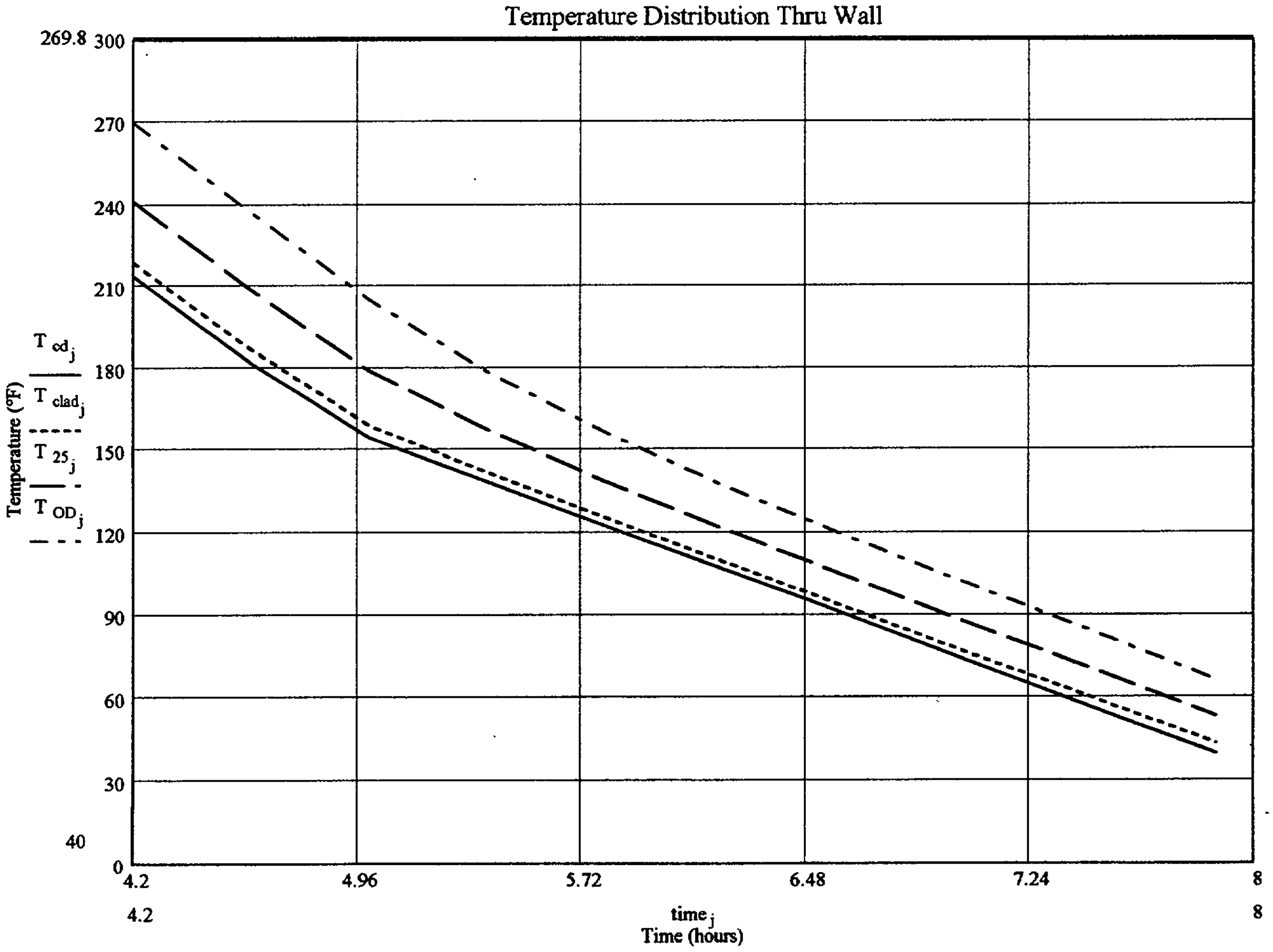
$T_{hu_j} =$	$\Delta T_j =$	$K_{IT75_j} =$	$K_{IC75_j} =$	$K_{IM75_j} =$	$\sigma_{m75_j} =$	$M_{m75_j} =$	$\sigma_{y_j} =$	$\frac{\sigma_{m75_j}}{\sigma_{y_j}} =$	$P_{hu75_j} =$
60	0	0	41.299	20.65	7.375	2.8	50	0.147	752.928
68	5.89	2.026	41.539	19.757	7.056	2.8	50	0.141	720.364
76	10.67	3.67	42.066	19.198	6.856	2.8	50	0.137	699.982
84	14.26	4.905	42.871	18.983	6.78	2.8	50	0.136	692.159
92	16.9	5.814	43.961	19.074	6.812	2.8	50	0.136	695.475
100	18.85	6.484	45.346	19.431	6.94	2.8	50	0.139	708.481
116	21.31	7.331	49.12	20.895	7.462	2.8	47.1	0.158	761.862
132	22.6	7.774	54.565	23.396	8.356	2.8	47.1	0.177	853.049
148	23.3	8.015	62.156	27.07	9.668	2.8	47.1	0.205	987.041
168	26.8	9.219	73.316	32.048	11.446	2.8	47.1	0.243	$1.169 \cdot 10^3$
200	36.6	12.59	95.116	41.263	14.737	2.8	47.1	0.313	$1.505 \cdot 10^3$
232	42.3	14.551	137.971	61.71	21.061	2.93	45.2	0.466	$2.15 \cdot 10^3$
264	45.5	15.652	219.578	101.963	34.8	2.93	45.2	0.77	$3.553 \cdot 10^3$

Calculations for Cooldown at 80 °F/hr to 160 °F and 40 °F/hr to 60 °F.

Output from Abacus code $j := 1 .. 11$

$\mathrm{time}_j :=$	$T_{cd_j} :=$	$\sigma_{y_j} :=$	$T_{clad_j} :=$	$T_{25_j} :=$	$T_{OD_j} :=$
4.2	214	45.2	219.0	241.2	269.8
4.6	182	47.1	187.0	209.0	237.3
5.0	155	47.1	159.4	179.3	205.6
5.4	139	47.1	142.4	157.9	179.0
5.8	123	47.1	126.0	139.3	157.0
6.2	107	47.1	109.8	121.8	137.7
6.6	91	50	93.63	105.1	119.9
7.0	75	50	77.55	88.61	102.9
7.4	59	50	62.39	72.84	86.49
7.6	51	50	54.58	64.78	78.1
7.875	40	50	43.84	53.7	66.65

The metal temperatures at t=7.6 and 7.875 hrs (Tcd =40F) were obtained by linear extrapolation of the data using time points 6.6 hrs and 7.4 hrs.



Governing Equations (from reference 3)

Delta T $\Delta T_j := \left|T_{clad_j} - T_{OD_j}\right|$

Stress Intensity Factor Due to Radial Thermal Gradient

$M_t = 0.344$ $K_{IT_j} := M_t \cdot \Delta T_j$

Reference Critical Stress Intensity Factor

$$K_{IR_j} := 26.78 + 1.223 \cdot e^{.0145 \cdot \left(T_{25_j} - ART_{25} + 160\right)}$$

$$K_{IC_j} := 33.2 + 20.734 \cdot e^{.02 \cdot \left(T_{25_j} - ART_{25}\right)}$$

Stress Intensity Factor Due to Membrane Tension

$$K_{IM_j} := \frac{K_{IC_j} - K_{IT_j}}{2}$$ For a 1/4t flaw

Membrane stress

$j := 1$ $M_{m_j} := 2.97$ $\sigma_{m_j} := \frac{K_{IM_j}}{M_{m_j}}$

$j := 2..4$ $M_{m_j} := 2.83$ $\sigma_{m_j} := \frac{K_{IM_j}}{M_{m_j}}$

$j := 5..11$ $M_{m_j} := 2.77$ $\sigma_{m_j} := \frac{K_{IM_j}}{M_{m_j}}$

Allowable Gage Pressure

$a = 86.656$ $b = 95.281$ $r_{25} = 88.812$ $j := 1..11$

for a 1/4t flaw

$$P_{cd_j} := \frac{\sigma_{m_j} \cdot \frac{b^2 - a^2}{a^2}}{1 + \frac{b^2}{r_{25}^2}} \cdot 1000$$

Cooldown at 80°F/hr to 160°F and 40°F/hr to 60°F: Summary of Results for a t/4 Flaw

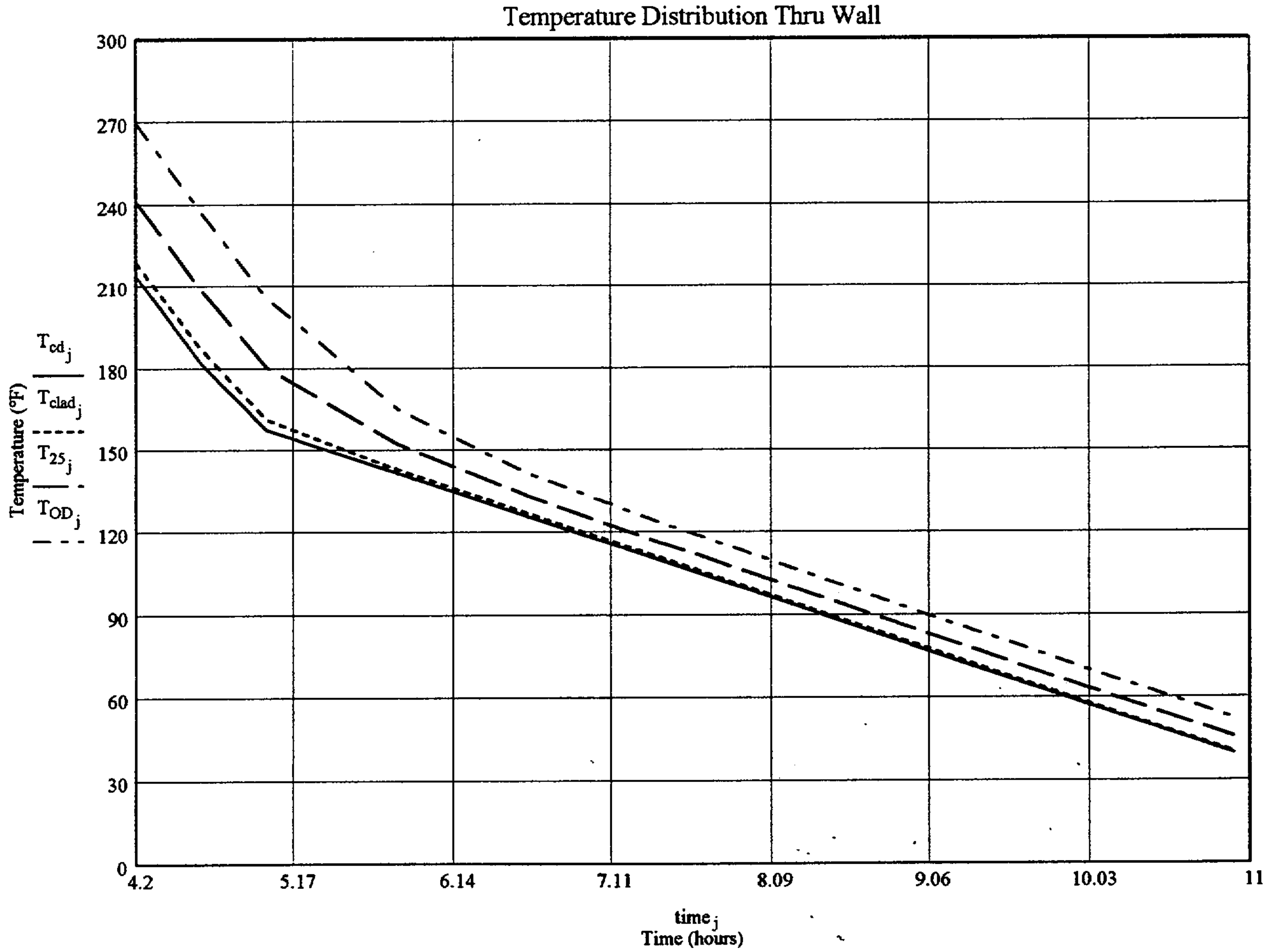
$T_{cd_j} =$	$\Delta T_j =$	$K_{IT_j} =$	$K_{IC_j} =$	$K_{IM_j} =$	$\sigma_{m_j} =$	$M_{m_j} =$	$\sigma_{y_j} =$	$\frac{\sigma_{m_j}}{\sigma_{y_j}} =$	$P_{cd_j} =$
214	50.8	17.475	245.877	114.201	38.451	2.97	45.2	0.851	$3.736 \cdot 10^3$
182	50.3	17.303	144.895	63.796	22.543	2.83	47.1	0.479	$2.19 \cdot 10^3$
155	46.2	15.893	94.869	39.488	13.953	2.83	47.1	0.296	$1.356 \cdot 10^3$
139	36.6	12.59	73.396	30.403	10.743	2.83	47.1	0.228	$1.044 \cdot 10^3$
123	31	10.664	60.909	25.123	9.07	2.77	47.1	0.193	881.116
107	27.9	9.598	52.727	21.564	7.785	2.77	47.1	0.165	756.319
91	26.27	9.037	47.182	19.073	6.885	2.77	50	0.138	668.922
75	25.35	8.72	43.254	17.267	6.234	2.77	50	0.125	605.589
59	24.1	8.29	40.534	16.122	5.82	2.77	50	0.116	565.438
51	23.52	8.091	39.442	15.676	5.659	2.77	50	0.113	549.788
40	22.81	7.847	38.202	15.178	5.479	2.77	50	0.11	532.313

Calculations For Cooldown at 80 °F/hr to 160°F and 20 °F/hr to 60°F.

Output from Abacus code $j := 1..11$

$time_j :=$	$T_{cd_j} :=$	$\sigma_{y_j} :=$	$T_{clad_j} :=$	$T_{25_j} :=$	$T_{OD_j} :=$
4.2	214	45.2	219.0	241.2	269.8
4.6	182	47.1	187.0	209.0	237.3
5.0	158	47.1	161.7	180.5	206.0
5.8	142	47.1	143.5	152.6	165.3
6.6	126	47.1	127.0	133.4	141.9
7.4	110	47.1	110.8	116.4	123.8
8.2	94	50	94.75	100.2	107.1
9.0	78	50	78.73	84.06	90.92
9.8	62	50	62.72	68.03	74.84
10.0	58	50	58.6	64.0	70.8
10.9	40	50	40.5	46.0	52.7

The metal temperatures at t=10.0 and 10.9 hrs (Tcd =40F) were obtained by linear extrapolation of the data using time points 9.0 hrs and 9.8 hrs.



Governing Equations

Delta T $\Delta T_j := \left|T_{clad_j} - T_{OD_j}\right|$

Stress Intensity Factor Due to Radial Thermal Gradient

$M_t = 0.344$ $K_{IT_j} := M_t \cdot \Delta T_j$

Reference Critical Stress Intensity Factor

$$K_{IR_j} := 26.78 + 1.223 \cdot e^{.0145 \cdot \left(T_{25_j} - ART_{25} + 160\right)}$$

$$K_{IC_j} := 33.2 + 20.734 \cdot e^{.02 \cdot \left(T_{25_j} - ART_{25}\right)}$$

Stress Intensity Factor Due to Membrane Tension

$$K_{IM_j} := \frac{K_{IC_j} - K_{IT_j}}{2}$$ For a 1/4t flaw

Membrane stress

$j := 1$ $M_{m_j} := 2.97$ $\sigma_{m_j} := \frac{K_{IM_j}}{M_{m_j}}$

$j := 2..6$ $M_{m_j} := 2.83$ $\sigma_{m_j} := \frac{K_{IM_j}}{M_{m_j}}$

$j := 7..11$ $M_{m_j} := 2.78$ $\sigma_{m_j} := \frac{K_{IM_j}}{M_{m_j}}$

Allowable Gage Pressure

$a = 86.656$ $b = 95.281$ $r_{25} = 88.812$

$j := 1..11$

for a 1/4t flaw

$$P_{cd'_j} := \frac{\sigma_{m_j} \cdot \frac{b^2 - a^2}{a^2}}{1 + \frac{b^2}{{r_{25}}^2}} \cdot 1000$$

Cooldown at 80°F/hr to 160°F and 20°F/hr to 60°F: Summary of Results For a t/4 Flaw

$T_{cd_j} =$	$\Delta T_j =$	$K_{IT_j} =$	$K_{IR_j} =$	$K_{IC_j} =$	$K_{IM_j} =$	$\sigma_{m_j} =$	$M_{m_j} =$	$\sigma_{y_j} =$	$\frac{\sigma_{m_j}}{\sigma_{y_j}} =$	$P_{cd'_j} =$
214	50.8	17.475	94.076	245.877	114.201	38.451	2.97	45.2	0.851	$3.736 \cdot 10^3$
182	50.3	17.303	68.971	144.895	63.796	22.543	2.83	47.1	0.479	$2.19 \cdot 10^3$
158	44.3	15.239	54.689	96.367	40.564	14.333	2.83	47.1	0.304	$1.393 \cdot 10^3$
142	21.8	7.499	45.403	69.354	30.927	10.928	2.83	47.1	0.232	$1.062 \cdot 10^3$
126	14.9	5.126	40.878	57.825	26.35	9.311	2.83	47.1	0.198	904.56
110	13	4.472	37.798	50.728	23.128	8.172	2.83	47.1	0.174	793.95
94	12.35	4.248	35.491	45.877	20.814	7.487	2.78	50	0.15	727.379
78	12.19	4.193	33.673	42.38	19.093	6.868	2.78	50	0.137	667.232
62	12.12	4.169	32.244	39.862	17.846	6.42	2.78	50	0.128	623.659
58	12.2	4.197	31.934	39.346	17.575	6.322	2.78	50	0.126	614.164
40	12.2	4.197	30.75	37.488	16.646	5.988	2.78	50	0.12	581.698

Calculations for Heatup/Cooldown at 0 °F/hr

$j := 1..31$

$T_{fluid0_j} :=$

230
214
200
182
168
158
155
148
142
139
132
126
123
116
110
107
100
94
92
91
84
78
76
75
68
62
60
59
58
51
40

Where:

$T_{25_j} := T_{fluid0_j}$

$T_{OD_j} := T_{fluid0_j}$

Governing Equations for a 1/4t Flaw

Delta T $\Delta T_j := 0$

Stress Intensity Factor Due to Radial Thermal Gradient

$M_t = 0.344$ $K_{IT_j} := M_t \cdot \Delta T_j$

Reference Critical Stress Intensity Factor

$$K_{IR25_j} := 26.78 + 1.223 \cdot e^{.0145 \cdot \left(T_{25_j} - ART_{25} + 160\right)}$$

$$K_{IC25_j} := 33.2 + 20.734 \cdot e^{.02 \cdot \left(T_{25_j} - ART_{25}\right)}$$

Stress Intensity Factor Due to Membrane Tension

$$K_{IM25_j} := \frac{K_{IC25_j} - K_{IT_j}}{2}$$

Membrane stress

$j := 1$ $M_{m_j} := 2.93$ $\sigma_{m25_j} := \frac{K_{IM25_j}}{M_{m_j}}$

$j := 2..6$ $M_{m_j} := 2.86$ $\sigma_{m25_j} := \frac{K_{IM25_j}}{M_{m_j}}$

$j := 7..31$ $M_{m_j} := 2.80$ $\sigma_{m25_j} := \frac{K_{IM25_j}}{M_{m_j}}$

Allowable Gage Pressure

$j := 1..31$ $a = 86.656$ $b = 95.281$ $r_{25} = 88.812$

$$P_{CD0_j} := \frac{\sigma_{m25_j} \cdot \frac{b^2 - a^2}{a^2}}{1 + \frac{b^2}{r_{25}^{\,2}}} \cdot 1000$$

Heatup/Cooldown at 0 °F/hr: Summary of Results for a 1/4t Flaw

T_{fluid0_j} =	ΔT_j =	K_{IT_j} =	K_{IR25_j} =	K_{IC25_j} =	K_{IM25_j} =	σ_{m25_j} =	M_{m_j} =	$\frac{\sigma_{m25_j}}{45.2}$ =	P_{CD0_j} =
230	0	0	83.989	203.196	101.598	34.675	2.93	0.767	$3.369\cdot10^3$
214	0	0	72.143	156.642	78.321	27.385	2.86	0.606	$2.66\cdot10^3$
200	0	0	63.809	126.496	63.248	22.115	2.86	0.489	$2.148\cdot10^3$
182	0	0	55.303	98.29	49.145	17.184	2.86	0.38	$1.669\cdot10^3$
168	0	0	50.063	82.394	41.197	14.405	2.86	0.319	$1.399\cdot10^3$
158	0	0	46.92	73.477	36.738	12.846	2.86	0.284	$1.248\cdot10^3$
155	0	0	46.063	71.131	35.566	12.702	2.8	0.281	$1.234\cdot10^3$
148	0	0	44.202	66.176	33.088	11.817	2.8	0.261	$1.148\cdot10^3$
142	0	0	42.75	62.447	31.223	11.151	2.8	0.247	$1.083\cdot10^3$
139	0	0	42.07	60.744	30.372	10.847	2.8	0.24	$1.054\cdot10^3$
132	0	0	40.594	57.145	28.573	10.205	2.8	0.226	991.377
126	0	0	39.443	54.438	27.219	9.721	2.8	0.215	944.402
123	0	0	38.904	53.201	26.6	9.5	2.8	0.21	922.946
116	0	0	37.734	50.588	25.294	9.034	2.8	0.2	877.616
110	0	0	36.821	48.622	24.311	8.682	2.8	0.192	843.505
107	0	0	36.394	47.724	23.862	8.522	2.8	0.189	827.925
100	0	0	35.466	45.826	22.913	8.183	2.8	0.181	795.008
94	0	0	34.742	44.398	22.199	7.928	2.8	0.175	770.239
92	0	0	34.515	43.959	21.98	7.85	2.8	0.174	762.621
91	0	0	34.403	43.746	21.873	7.812	2.8	0.173	758.925
84	0	0	33.667	42.369	21.184	7.566	2.8	0.167	735.023
78	0	0	33.094	41.332	20.666	7.381	2.8	0.163	717.037
76	0	0	32.913	41.013	20.506	7.324	2.8	0.162	711.505
75	0	0	32.825	40.858	20.429	7.296	2.8	0.161	708.821
68	0	0	32.241	39.858	19.929	7.117	2.8	0.157	691.465
62	0	0	31.786	39.105	19.552	6.983	2.8	0.154	678.404
60	0	0	31.643	38.873	19.437	6.942	2.8	0.154	674.387
59	0	0	31.573	38.761	19.38	6.922	2.8	0.153	672.438
58	0	0	31.504	38.651	19.325	6.902	2.8	0.153	670.528
51	0	0	31.048	37.939	18.969	6.775	2.8	0.15	658.174
40	0	0	30.419	37.003	18.501	6.608	2.8	0.146	641.939

Calculations for Hydrostatic Testing

$j := 1 .. 10$

$T_{fluidhydro_j} :=$	$T_{25_j} :=$
70	70
85	85
100	100
115	115
130	130
145	145
160	160
175	175
190	190
205	205

Governing Equations for a 1/4t Flaw

Delta T $\Delta T_j := 0$

Stress Intensity Factor Due to Radial Thermal Gradient (Reference 3)

$$M_t = 0.344$$

$$K_{IT_j} := M_t \cdot \Delta T_j$$

Reference Critical Stress Intensity Factor

$$K_{IR25_j} := 26.78 + 1.223 \cdot e^{.0145 \cdot \left(T_{25_j} - ART_{25} + 160\right)}$$

$$K_{IC25_j} := 33.2 + 20.734 \cdot e^{.02 \cdot \left(T_{25_j} - ART_{25}\right)}$$

Stress Intensity Factor Due to Membrane Tension

$$K_{IM25_j} := \frac{K_{IC25_j}}{1.5}$$

Membrane stress $i := 1 .. 8$ $k := 9 .. 10$

$M_i := 2.83$ $M_k := 2.89$

$$\sigma_{m25_i} := \frac{K_{IM25_i}}{M_i} \qquad \sigma_{m25_k} := \frac{K_{IM25_k}}{M_k}$$

Allowable Gage Pressure

$a = 86.656$ $b = 95.281$ $r_{25} = 88.812$

$$P_{hydro_j} := \frac{\sigma_{m25_j} \cdot \dfrac{b^2 - a^2}{a^2}}{1 + \dfrac{b^2}{r_{25}^{\,2}}} \cdot 1000$$

Hydrotest: Summary of Results for a 1/4t Flaw

$T_{fluidhydro_j}$ =	ΔT_j =	K_{IT_j} =	K_{IR25_j} =	K_{IC25_j} =	K_{IM25_j} =	σ_{m25_j} =	M_j =	$\frac{\sigma_{m25_j}}{45.2}$ =	P_{hydro_j} =
70	0	0	32.402	40.129	26.753	9.453	2.83	0.209	918.398
85	0	0	33.768	42.554	28.369	10.024	2.83	0.222	973.88
100	0	0	35.466	45.826	30.551	10.795	2.83	0.239	$1.049 \cdot 10^3$
115	0	0	37.576	50.244	33.496	11.836	2.83	0.262	$1.15 \cdot 10^3$
130	0	0	40.199	56.206	37.471	13.241	2.83	0.293	$1.286 \cdot 10^3$
145	0	0	43.46	64.255	42.837	15.137	2.83	0.335	$1.471 \cdot 10^3$
160	0	0	47.513	75.12	50.08	17.696	2.83	0.392	$1.719 \cdot 10^3$
175	0	0	52.55	89.787	59.858	21.151	2.83	0.468	$2.055 \cdot 10^3$
190	0	0	58.811	109.584	73.056	25.279	2.89	0.559	$2.456 \cdot 10^3$
205	0	0	66.594	136.308	90.872	31.444	2.89	0.696	$3.055 \cdot 10^3$

Heatup at 40 °F/hr TO 160°F and 80°F/hr to 560°F: Adjusted Values for use in TS Figure Development

$j := 1 .. 15$

P_{hu} is taken as the lesser value of pressure from the 1/4t, 3/4t, and 0°F/hr calculations. The following table reflects the composite heatup limit for these rates without correction for pressure differences due to flow or elevation and instrumentation uncertainties. These values will be corrected for use in the composite TS figure and the COPS curve.

j =	$T_{hu_j} :=$	$P_{hu_j} :=$
1	60	674.4
2	68	684.9
3	76	697.2
4	84	692.2
5	92	695.5
6	100	708.5
7	116	761.9
8	132	853.0
9	134.7	875.6
10	134.8	876.5
11	148	987.0
12	168	1169
13	200	1505
14	232	2150
15	264	3553

Temperatures will be adjusted by 25.3°F to account for instrument uncertainty and represent indicated cold leg temperature.

$$T_{hu_j} := T_{hu_j} + 25.3$$

Calculated values of pressure will be corrected for the instrument uncertainty for pressure (115.5 psi), the pressure drop across the core (28.3 psi for single pump operation at or below 160°F, and 74 psi for four pump operation above 160°F), and 10 psi to convert to absolute pressure. The temperatures noted above are treated as indicated temperatures after the instrument uncertainties are applied.

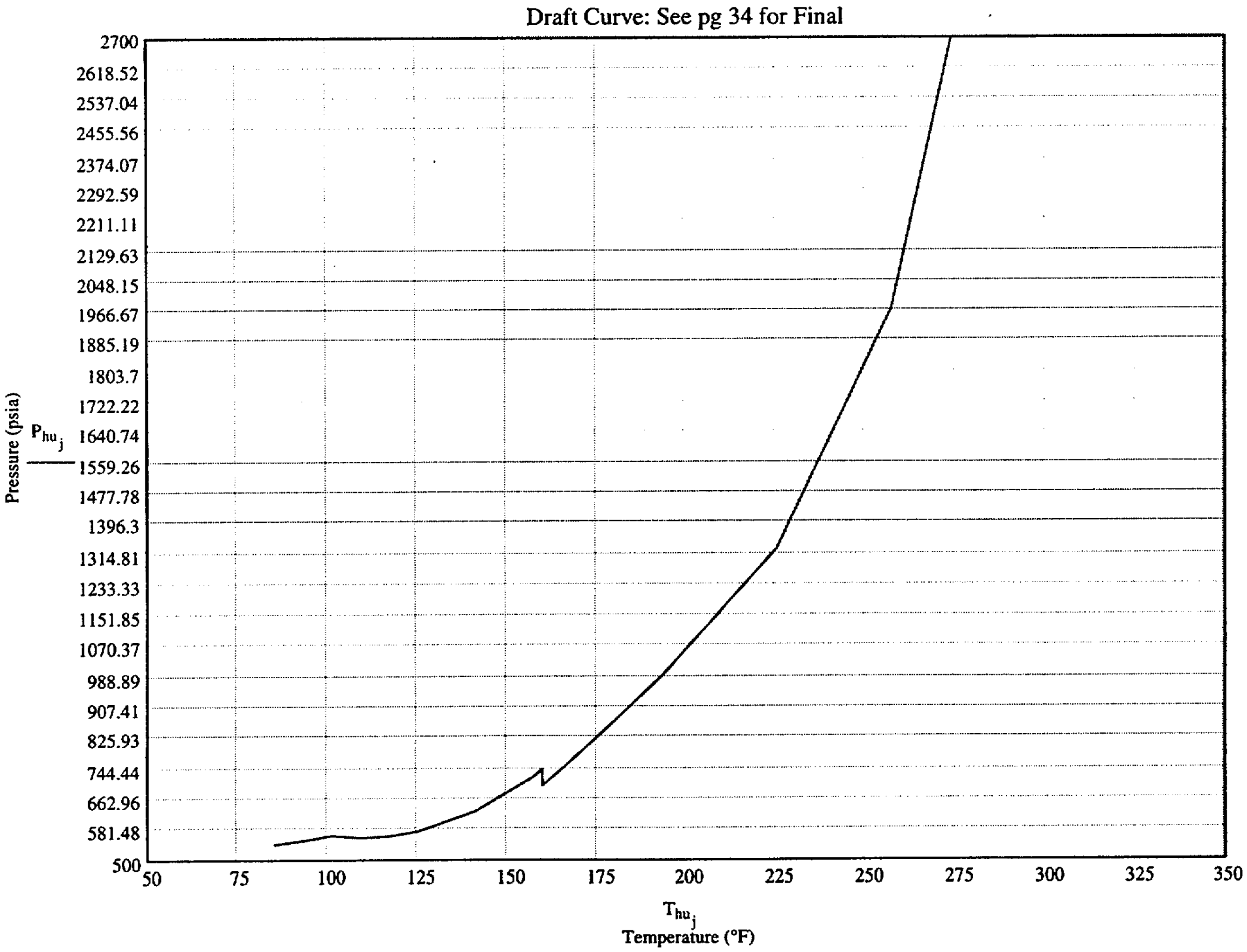
$k := 1 .. 9 \qquad l := 10 .. 15$

$P_{hu_k} := P_{hu_k} - 115.5 - 28.3 + 10$ For indicated $T \le 160$°F

$P_{hu_l} := P_{hu_l} - 115.5 - 74 + 10$ For indicated $T > 160$°F

Thus, for heatup at 40°F/hr to 160°F and 80°F/hr to 560°F:

$T_{hu_j} =$	$P_{hu_j} =$
85.3	540.6
93.3	551.1
101.3	563.4
109.3	558.4
117.3	561.7
125.3	574.7
141.3	628.1
157.3	719.2
160	741.8
160.1	697
173.3	807.5
193.3	989.5
225.3	$1.325\cdot10^{3}$
257.3	$1.97\cdot10^{3}$
289.3	$3.373\cdot10^{3}$


Draft Curve: See pg 34 for Final

Cooldown at 80 °F/hr to 160°F and 40°F/hr to 60°F: Adjusted Values for TS Figure Development

$j := 1 .. 14$

P_{cd} is taken as the lesser value of pressure for the 1/4t and 0°F/hr calculations. The following table reflects the composite cooldown limit for these rates without correction for flow or instrument uncertainties. These values will be corrected for use in the composite TS figure and the COPS setpoint curve. The pressure values for 134.7 and 134.8 F were developed based upon linear interpolation.

j =	$T_{cd_j} :=$	$P_{cd_j} :=$
1	230	3369
2	214	2660
3	182	1669
4	155	1234
5	139	1044
6	134.8	1001
7	134.7	1000
8	123	881.1
9	107	756.3
10	91	668.9
11	75	605.6
12	59	565.4
13	51	549.8
14	40	532.3

Temperatures will be adjusted by 25.3° F to account for instrument uncertainty and represent indicated cold leg temperature.

$$T_{cd_j} := T_{cd_j} + 25.3$$

Calculated values of pressure will be corrected for the instrument uncertainty for pressure (115.5 psi) and the pressure drop across the core, 28.3 psi for one pump operation at or below 160°F, and 74 psi for four pump operation above 160°F), and 10 psi to convert to absolute pressure. The temperatures noted above are treated as indicated temperatures after the instrumentation uncertainties are applied.

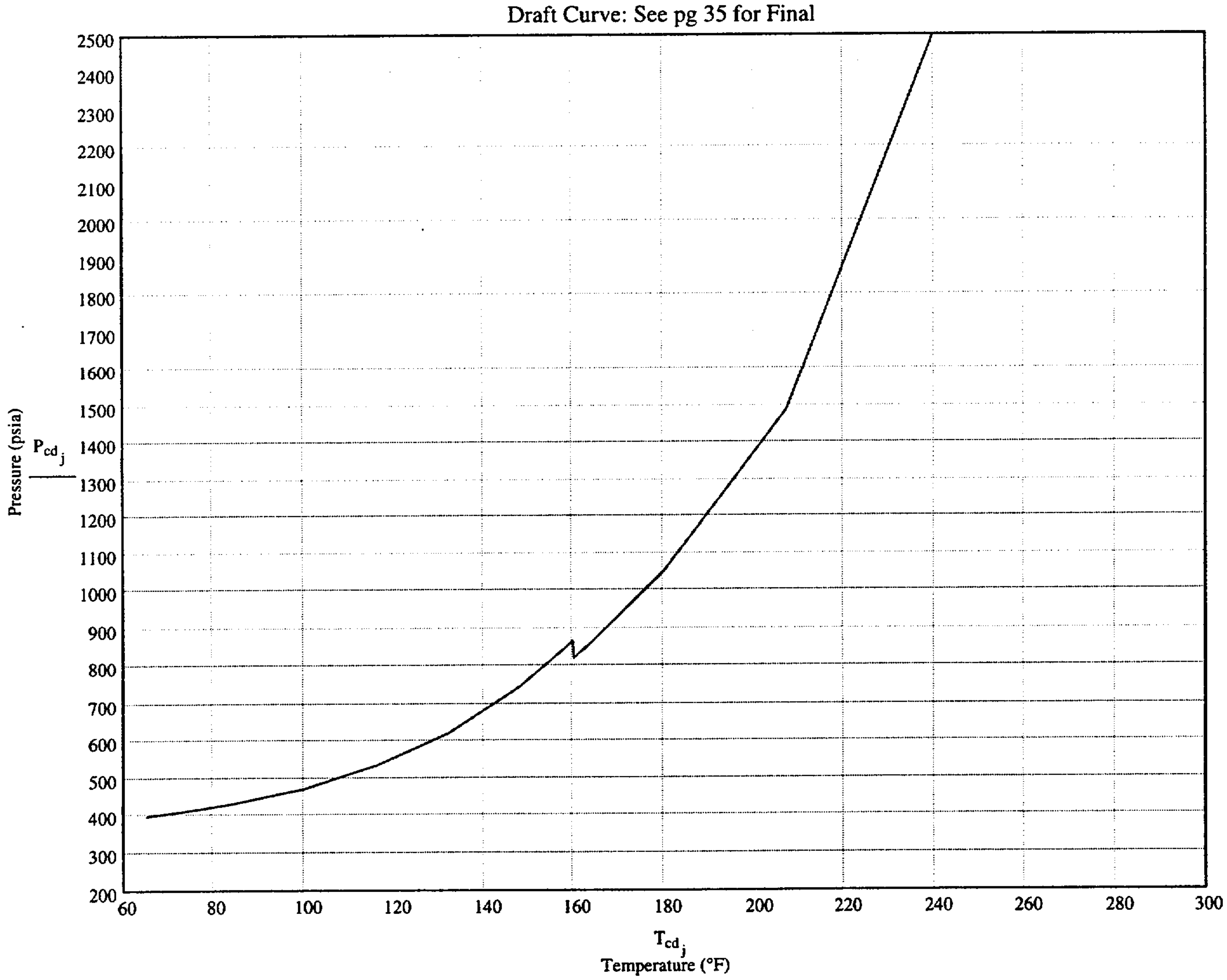
$i := 1 .. 6 \qquad k := 7 .. 14$

$$P_{cd_i} := P_{cd_i} - 115.5 - 74 + 10$$

$$P_{cd_k} := P_{cd_k} - 115.5 - 28.3 + 10$$

Thus, for cooldown at 80 °F/hr to 160°F and 40°F/hr to 60°F.

T_{cd_j} =	P_{cd_j} =
255.3	$3.189 \cdot 10^3$
239.3	$2.481 \cdot 10^3$
207.3	$1.49 \cdot 10^3$
180.3	$1.054 \cdot 10^3$
164.3	864.5
160.1	821.5
160	866.2
148.3	747.3
132.3	622.5
116.3	535.1
100.3	471.8
84.3	431.6
76.3	416
65.3	398.5



Cooldown at 80 °F/hr to 160°F and 20°F/hr to 60°F: Adjusted Values for TS Figure Development

$j := 1..14$

P_{cd} is taken as the lesser value of pressure for the 1/4t and 0°F/hr calculations. The following table reflects the composite cooldown limit for these rates without correction for flow or instrument uncertainties. These values will be corrected for use in the composite TS figure and the COPS setpoint curve. The pressure values for 134.7 and 134.8 F were developed based upon linear interpolation.

$j =$	$T_{cd_j} :=$	$P_{cd'_j} :=$
1	230	3369
2	214	2660
3	182	1669
4	158	1248
5	142	1062
6	134.8	991.2
7	134.7	990.2
8	126	904.6
9	110	794.0
10	94	727.4
11	78	667.2
12	62	623.7
13	58	614.2
14	40	581.7

Temperatures will be adjusted by 25.3° F to account for instrument uncertainty and represent indicated cold leg temperature.

$$T_{cd_j} := T_{cd_j} + 25.3$$

Calculated values of pressure will be corrected for the instrument uncertainty for pressure (115.5 psi) and the pressure drop across the core, 28.3 psi for one pump operation at or below 160°F, and 74 psi for four pump operation above 160°F), and 10 psi to convert to absolute pressure. The temperatures noted above are treated as indicated temperatures after the instrumentation uncertainties are applied.

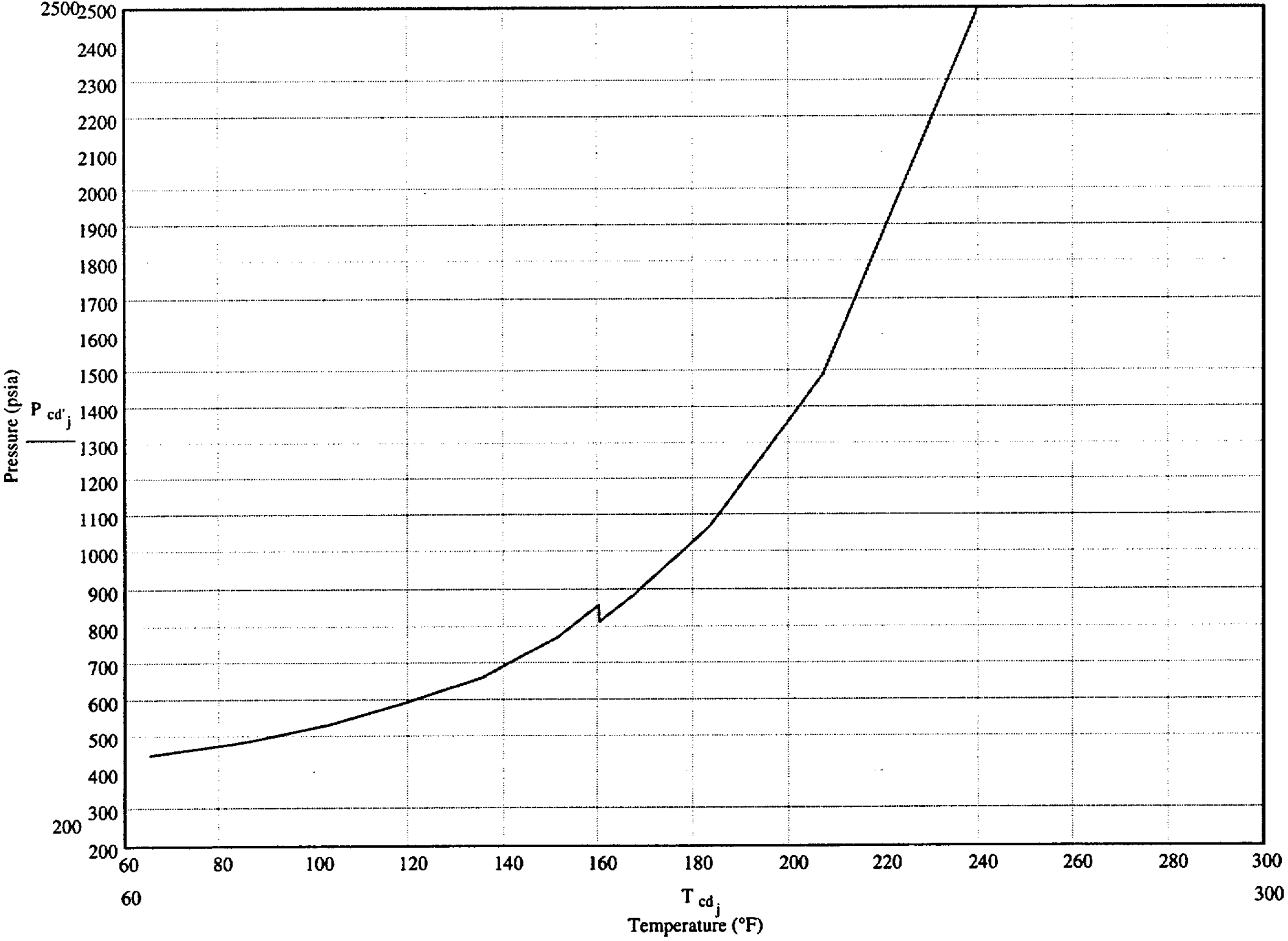
$i := 1..6 \qquad k := 7..14$

$$P_{cd'_i} := P_{cd'_i} - 115.5 - 74 + 10$$

$$P_{cd'_k} := P_{cd'_k} - 115.5 - 28.3 + 10$$

Thus, for cooldown at 80 °F/hr to 160°F and 20°F/hr to 60°F.

T_{cd_j} =	$P_{cd'_j}$ =
255.3	$3.189 \cdot 10^3$
239.3	$2.481 \cdot 10^3$
207.3	$1.49 \cdot 10^3$
183.3	$1.069 \cdot 10^3$
167.3	882.5
160.1	811.7
160	856.4
151.3	770.8
135.3	660.2
119.3	593.6
103.3	533.4
87.3	489.9
83.3	480.4
65.3	447.9


Draft Curve: See pg 35 for Final

Hydrotest : Adjusted Values for use in TS Figure Development

$j := 1 .. 10$

$T_{fluidhydro_j} =$	$P_{hydro_j} =$
70	918.398
85	973.88
100	$1.049 \cdot 10^3$
115	$1.15 \cdot 10^3$
130	$1.286 \cdot 10^3$
145	$1.471 \cdot 10^3$
160	$1.719 \cdot 10^3$
175	$2.055 \cdot 10^3$
190	$2.456 \cdot 10^3$
205	$3.055 \cdot 10^3$

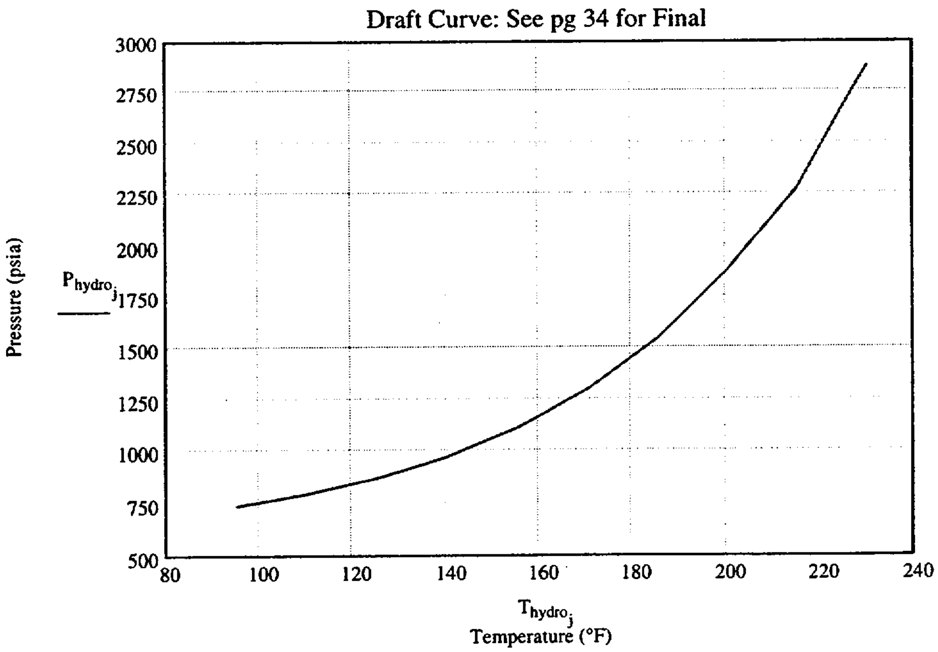
The following table reflects the hydrostatic limit for these rates without correction for flow or instrument uncertainties. These values will be corrected for use in the composite TS figure.

Temperatures will be adjusted by 25.3° F to account for instrument uncertainty and represent indicated cold leg temperature. Calculated values of pressure will be corrected for the instrument uncertainty for pressure (115.5 psi) and the pressure drop across the core of 74 psi for four pump operation, and 10 psi to convert to absolute pressure. The temperatures noted above are treated as indicated temperatures after the instrumentation uncertainties are applied.

$T_{hydro_j} := T_{fluidhydro_j} + 25.3$

$P_{hydro_j} := P_{hydro_j} - 115.5 - 74 + 10$

$T_{hydro_j} =$	$P_{hydro_j} =$
95.3	738.898
110.3	794.38
125.3	869.274
140.3	970.37
155.3	$1.107 \cdot 10^3$
170.3	$1.291 \cdot 10^3$
185.3	$1.54 \cdot 10^3$
200.3	$1.875 \cdot 10^3$
215.3	$2.276 \cdot 10^3$
230.3	$2.875 \cdot 10^3$


Draft Curve: See pg 34 for Final

6.2 Additional P/T Requirements

Preservice hydrostatic test pressure is defined by ASME Code NB-6221(Reference 4.4) to be at least 1.25 times the design pressure. The design pressure of the reactor vessel is 2500 psia (Reference 4.5). Therefore, 20% of preservice hydrostatic test pressure is:

0.2*1.25*2500 psia = 625 psia (20% preservice hydro)

Heatup

In consideration of heatup, the pressure correction consider the effects of static and dynamic pressure difference and instrument uncertainty.

For indicated temperatures less than or equal to 160°F (one RCP operating), the corrected value for consideration in Technical Specifications would be:

625 psia - 28.3 psi - 115.5 psi = 481.2 psia

For indicated temperatures greater than 160°F (four RCP's operating), the corrected value for consideration in Technical Specifications would be:

625 psia - 74.0 psi - 115.5 psi = 435.5 psia

Cooldown

Similarly for cooldown, the pressure correction shall consider the effects of static and dynamic pressure difference and instrument uncertainty.

For indicated temperatures less than or equal to 160°F (one RCP operating), the corrected value for consideration in Technical Specifications would be:

625 psia - 28.3 psi - 115.5 psi = 481.2 psia

For indicated temperatures greater than 160°F (four RCP's operating), the corrected value for consideration in Technical Specifications would be:

625 psia - 74.0 psi - 115.5 psi = 435.5 psia

The temperatures associated with the 20% of preservice hydrostatic test pressure are due to temperature requirements provided by 10 CFR 50 Appendix G and ASME Boiler and Pressure Vessel Code. Each of these conditions are reviewed below for consideration in the development of the Technical Specification Figures. Note that these temperature are corrected for wide range instrument uncertainty associated with sensing cold leg temperature.

1.a Hydrostatic Pressure and leak tests (core not critical), $P \leq 20\%$ Preservice Hydro

To pressurize the vessel while not exceeding 20% of the preservice hydrostatic test pressure, the temperature of the vessel closure flange is equal to the highest RT_{NDT} that is highly stressed by the bolt preload.

The RT_{NDT} for this region has been previously established in this calculation as 40°F. This requirement is equivalent to the minimum boltup temperature provided by the ASME Boiler and Pressure Vessel Code.

Therefore, the minimum boltup temperature including instrumentation uncertainty is:

Minimum boltup temperature = 40°F + 25.3°F = 65.3°F

1.b Hydrostatic Pressure and leak tests (core not critical), $P > 20\ \%$ Preservice Hydro

To exceed 20% of the preservice hydrostatic test pressure, the minimum temperature of the vessel closure flange is equal to the highest RT_{NDT} + 90°F that is highly stressed by the bolt preload.

Again, the RT_{NDT} for this region has been previously established in this calculation as 40°F.

Therefore, the temperature including instrumentation uncertainty is:

Minimum temperature = 40°F +90°F + 25.3°F = 155.3°F

2.a Normal Operation (core not critical), $P \leq 20\%$ Preservice Hydro

As previously calculated for hydrostatic and leak tests (1.a), to pressurize the vessel while not exceeding 20% of the preservice hydrostatic test pressure until the temperature of the vessel closure flange is equal to the highest RT_{NDT} that is highly stressed by the bolt preload.

The RT_{NDT} for this region has been previously established in this calculation as 40°F. This requirement is equivalent to the minimum boltup temperature provided by the ASME Boiler and Pressure Vessel Code.

Therefore, the minimum boltup temperature including instrumentation uncertainty is:

Minimum boltup temperature = 40°F + 25.3°F = 65.3°F

2.b Normal Operation (core not critical), $P > 20\%$ Preservice Hydro

To exceed 20% of the preservice hydrostatic test pressure, the minimum temperature of the vessel closure flange is equal to the highest RT_{NDT} + 120°F that is highly stressed by the bolt preload.

Again, the RT_{NDT} for this region has been previously established in this calculation as 40°F.

Therefore, the temperature including instrumentation uncertainty is:

Minimum temperature = 40°F +120°F + 25.3°F = 185.3°F

2.c Normal Operation (core critical), $P \leq 20\%$ Preservice Hydro

To pressurize the vessel while not exceeding 20% of the preservice hydrostatic test pressure with the core critical the minimum temperature of the vessel closure flange is equal to the highest RT_{NDT} + 40°F that is highly stressed by the bolt preload or the minimum permissible temperature required for inservice system hydrostatic pressure test.

The RT_{NDT} for this region has been previously established in this calculation as 40°F.

Minimum temperature = 40°F +40°F + 25.3°F = 105.3°F

The minimum temperature for inservice system hydrostatic testing is defined by ASME Section XI Article IWB-5000 (Reference 4.) A minimum test pressure of nominal operating pressure is required. Nominal operating pressure is 2250 psia based upon Reference . To achieve this pressure, a temperature in excess of 200°F is require based upon the beltline hydrostatic P/T limits developed previously. Conservatively using a value of 1.08*normal operating pressure provides and test pressure of 2430 psia. Based upon the indicated beltline inservice hydrostatic P/T limits (adjusted for TS), a minimum indicated temperature of 219.2°F was developed based upon linear interpolation.

Consequently, the minimum temperature at which the core can be brought critical while not exceeding the required pressure is 219.2°F.

2.d Normal Operation (core critical), $P > 20\%$ Preservice Hydro

To pressurize the vessel to pressures exceeding 20% of the preservice hydrostatic test pressure with the core critical, the larger of a minimum temperature of the vessel closure flange is equal to the highest RT_{NDT} + 160°F that is highly stressed by the bolt preload or the minimum permissible temperature required for inservice system hydrostatic pressure test.

The RT_{NDT} for this region has been previously established in this calculation as 40°F.

Minimum temperature = 40°F +160°F + 25.3°F = 225.3°F

The minimum temperature for inservice system hydrostatic testing is defined by ASME Section XI Article IWB-5000 (Reference 4.) This was determined conservatively to be 216.9°F.

Consequently, the minimum permissible temperature required to exceed 20% of preservice hydrostatic pressure is 225.3°F.

6.3 COPS Enable Temperatures

The minimum COPS enable temperature is when coolant temperatures are less than 200°F or at coolant temperatures corresponding to a reactor vessel metal temperature less than RT_{NDT} + 50°F, whichever is greater.

The ART for the 1/4 t location was determined to be 124.8°F at 32 EFPY.

The metal temperature corresponding to RT_{NDT} + 50°F is as follows:

1/4 t ART + 50°F = 124.8°F + 50°F = 174.8°F

Cooldown

In the case of cooldown, the COPS enable temperature should be based upon the isothermal profile or just ART + 50°F for the 1/4 t location. The basis for this statement is hat the technical Specifications permit a range of cooldown rates ranging from isothermal to the specified maximum values and the most restrictive enable temperature would be due to the isothermal condition. If you consider the through-wall temperature distributions for linear cooldown scenarios, the fully developed profile would exponentially decay from the reactor vessel OD to ID. As such, if you were to compute a coolant temperature for the applicable rate the resulting temperature would be below the isothermal condition. Therefore, an uncorrected value of 174.8°F was calculated. Adding 25.3°F which represent the instrument uncertainty for the wide range indication loops (3RCS*) provides a value of 200.1°F.

A minimum value of 200°F is required by the ASME Code. Consequently, the controlling value is 200.1°F. It is interpreted that this is the minimum value and instrumentation uncertainty would need to be added to ensure that the system was aligned at this temperature. Therefore, the enable temperature for cooldown is 225.4°F (200.1°F + 25.3°F). Note, higher values can be conservatively used without further justification if additional administrative margin is desired.

Heatup

The heat transfer results for the two heatup scenarios are summarized previously in the calculation. The most conservative enable temperature will be established using the heat transfer output.

Using the tables for each of the heatup evaluated previously, coolant temperatures corresponding to RT_{NDT} + 50°F (174.8°F).

(40°F/hr ≤ 160°F and 80°F/hr > 160°F)

The coolant temperature corresponding to a 1/4 t metal temperature was developed based upon linear interpolation.

$$(174.8-153.2)/(179.6-153.2) = (Tc-168)/(200-168) \quad \therefore Tc = 194.2°F$$

Addition of instrument uncertainty to the coolant temperature provides the enable temperature for heatup of 219.5°F (194.2°F + 25.3°F). Note, higher values can be conservatively used without further justification if additional administrative margin is desired.

6.4 Surveillance Capsule Withdrawal Schedule

The material surveillance capsule withdrawal schedule identifies the number and location of capsules and the approximate withdrawal time and estimated accumulated fluence. This schedule is required to be developed in accordance with ASTM E 185-82 (Reference 4.20).

A withdrawal schedule was developed as part of the most recent capsule evaluation (Capsule X, Reference 4.18). This schedule has been developed to meet the requirements of ASTM E 185-82. However, due to the high lead factors associated with the capsule, the proposed schedule is to remove the third capsule at 12.3 EFPY. Due to the short time duration between capsule withdrawal (the second capsule was removed at 8 EFPY), a review of the requirements is necessary to evaluate a longer time period.

ASTM E 185-82 provides the following guidance of particular interest. Relative to the number of capsule required to be withdrawn and evaluated, the basis is based on the predicted transition temperature shift or possibly the decrease in upper shelf energy.

Based upon review of the current predicted shift in transition temperature at the vessel inside surface of 66°F (Reference 4.23), a minimum of three capsules are required. Note that this transition temperature shift is based on the results the fluence results of the first surveillance capsule which provided significantly higher projected end-of-life (EOL) fluence values.

Withdrawal of the third capsule is to be removed at EOL conditions. Specifically, the requirement is for the capsule to be removed when the capsule has received not less than once or greater than twice the peak EOL fluence. ASTM E 185-82 also identifies that this date may be modified based upon previous tests and this capsule may be held without testing following withdrawal. However, it should be noted that the requirements of 10 CFR 50 Appendix H requires that the capsule be evaluated and a report submitted within one year of withdrawal modifying the standard requirements.

Based upon the Capsule X evaluation, the peak calculated EOL fluence ($E > 1.0$ MeV, 32 EFPY) is 1.97E+19 N/cm^2 and considering license renewal is projected to be 3.31E+19 N/cm^2 (54 EFPY). Based upon ASTM E 185-82, the desired capsule fluence would be from 1.97E+19 n/cm^2 to 3.94E+19 n/cm^2 (two times projected inside surface fluence). Note that the projected vessel inside surface fluence for 54 EFPY is 3.31E+19n/cm^2. It would be desirable to have the capsule receive at least 3.31E+19 n/cm^2 which would provide a value of less than twice the vessel surface fluence at EOL yet accumulate a value equivalent to license extension.

An estimate of the fluence capsule can be made based upon linear interpolation from the peak vessel calculated fluence using linear interpolation and the capsule lead factor. The previous capsule was removed from the vessel during refueling outage six (RFO6) and had accumulated 8.0 EFPY. Assuming 18 month fuel cycles along with a 100% capacity factor and permitting the third capsule to remain in the vessel for three additional cycles would equate to an additional 4.5 EFPY. This would result in a total of 12.5 EFPY for capsule W. Using linear interpolation between 12 EFPY and 16 EFPY the peak vessel inside surface can be estimated to be 7.80E+18 n/cm^2. Multiplying this value by the capsule lead factor (4.32) provides an estimate of the accumulated capsule fluence, 3.37E+19 n/cm^2. Again, assuming the capsule remained in the vessel for four cycles, the accumulated capsule fluence would be (14.0 EFPY) 3.76E+19 n/cm^2. (Note that the capsule fluence values provided in Table 7-1 of Reference 4.18 are incorrect). Based upon the accumulated capsule fluence estimates, pulling the capsule during RFO 10 (14 EFPY) or allowing the capsule to remain in an additional four cycles (18 month fuel cycles) will provide the most value. This will meet all the ASTM requirements and satisfy our own goals. In summary, removing the capsule at 14 EFPY will provide an estimated capsule fluence of 3.76E+19 n/cm^2. This will exceed one time the peak end-of-life (32 EFPY) vessel surface fluence of 1.97E+19 n/cm^2 yet not exceed two times this value, 3.94E+19 n/cm^2. In addition, if license renewal is pursued, the capsule will receive at least one times the peak (54 EFPY) vessel surface fluence of 3.31E+19 n/cm^2.

The following table provides the proposed withdrawal schedule for the Unit 3 material surveillance program. This table has been produced from Reference 4.18 with corrections to the capsule fluence values. In addition the removal time has been increased to 14.0 EFPY and the appropriate fluence based upon the preceding projection.

Millstone Unit 3 Reactor Vessel Surveillance Capsule Withdrawal Schedule

Capsule	Location	Lead Factor(a)	Removal Time (EFPY)(b)	Fluence (n/cm^2, E>1.0MeV)(a)
U	58.5°	4.31	1.3	4.49×10^{18} (c)
X	238.5°	4.37	8.0	2.21×10^{19} (c)
W	121.5°	4.32	14.0	3.76×10^{19} (c,d)
Y(e)	241°	4.11	Standby	--
V(e)	61°	4.11	Standby	--
Z(e)	301.5°	4.32	Standby	--

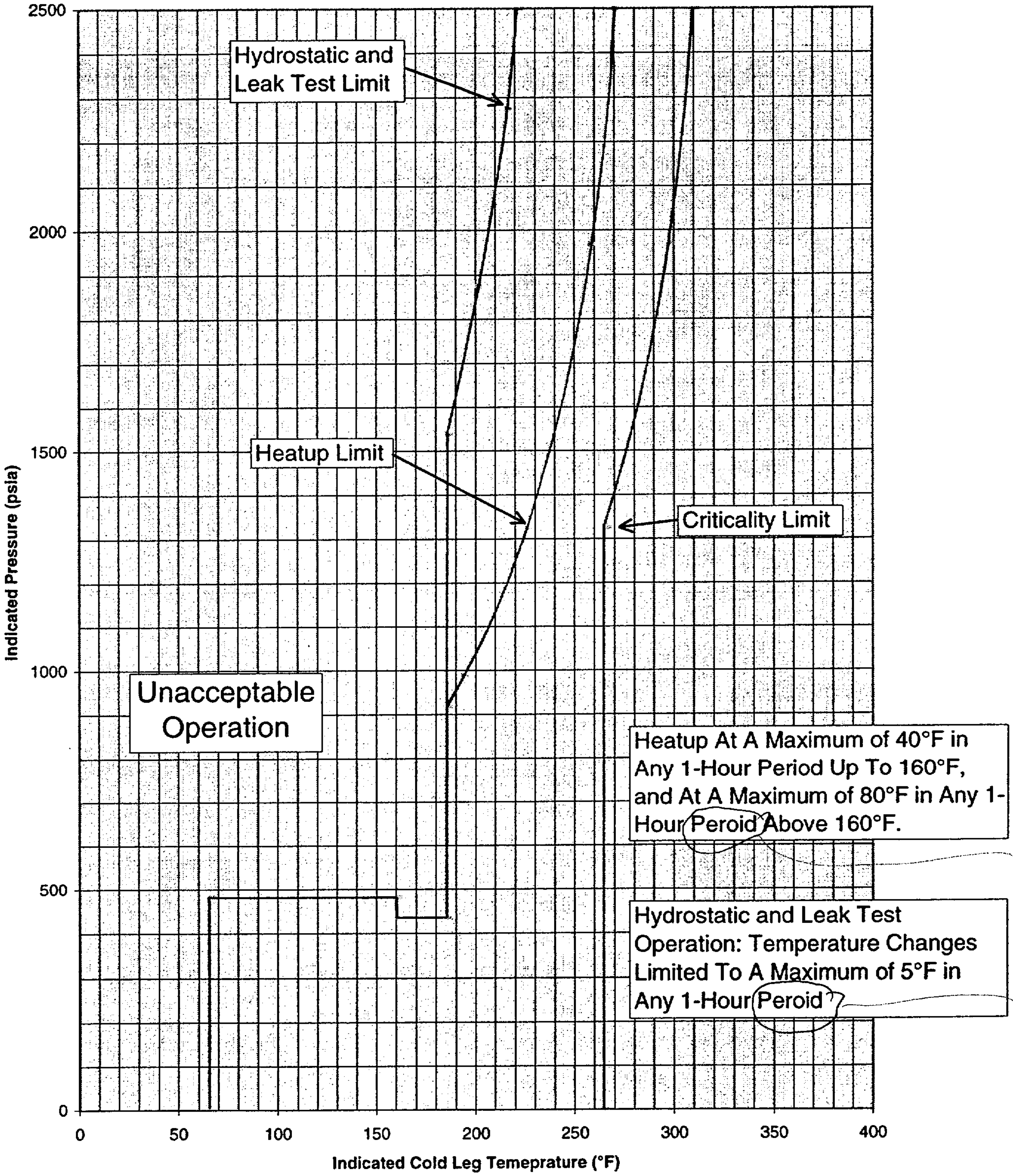
(a) Updated in Capsule X dosimetry analysis (Reference 4.18).
(b) Effective Full Power Years (EFPY) from plant startup.
(c) Plant specific evaluation.
(d) This fluence is not less than once or greater than twice the peak end of license EOL fluence, and is approximately equal to the peak vessel fluence at 54 EFPY.
(e) These capsules will be at the approximate 54 EFPY peak surface (i.e. clad/base metal interface) fluence when capsule W is withdrawn and should be removed a placed in storage when capsule W is removed.

7.0 RESULTS

7.1 Composite RCS P/T Limits Figures for Technical Specifications

The RCS P/T limits provided in the following figures apply to Unit 3 considering a reactor vessel beltline fluence of 1.97×10^{19} n/cm^2, E > 1.0 MeV (Reference 4.11) which corresponds to 32 EFPY. These limits are developed to provide protection against non-ductile failure of ferritic materials at low temperatures. The development of these curves considers all of the requirements developed by this calculation and ensures that the controlling values are used. With use of the controlling values a best fit lower bound curve is generated. A tabulation of specific temperature points from the lower bound best fit curve is provided to assist in the development of procedures.

Millstone 3 Reactor Coolant System
Heatup Limitations for Fluence up to 1.97E+19 n/cm (32 EFPY)



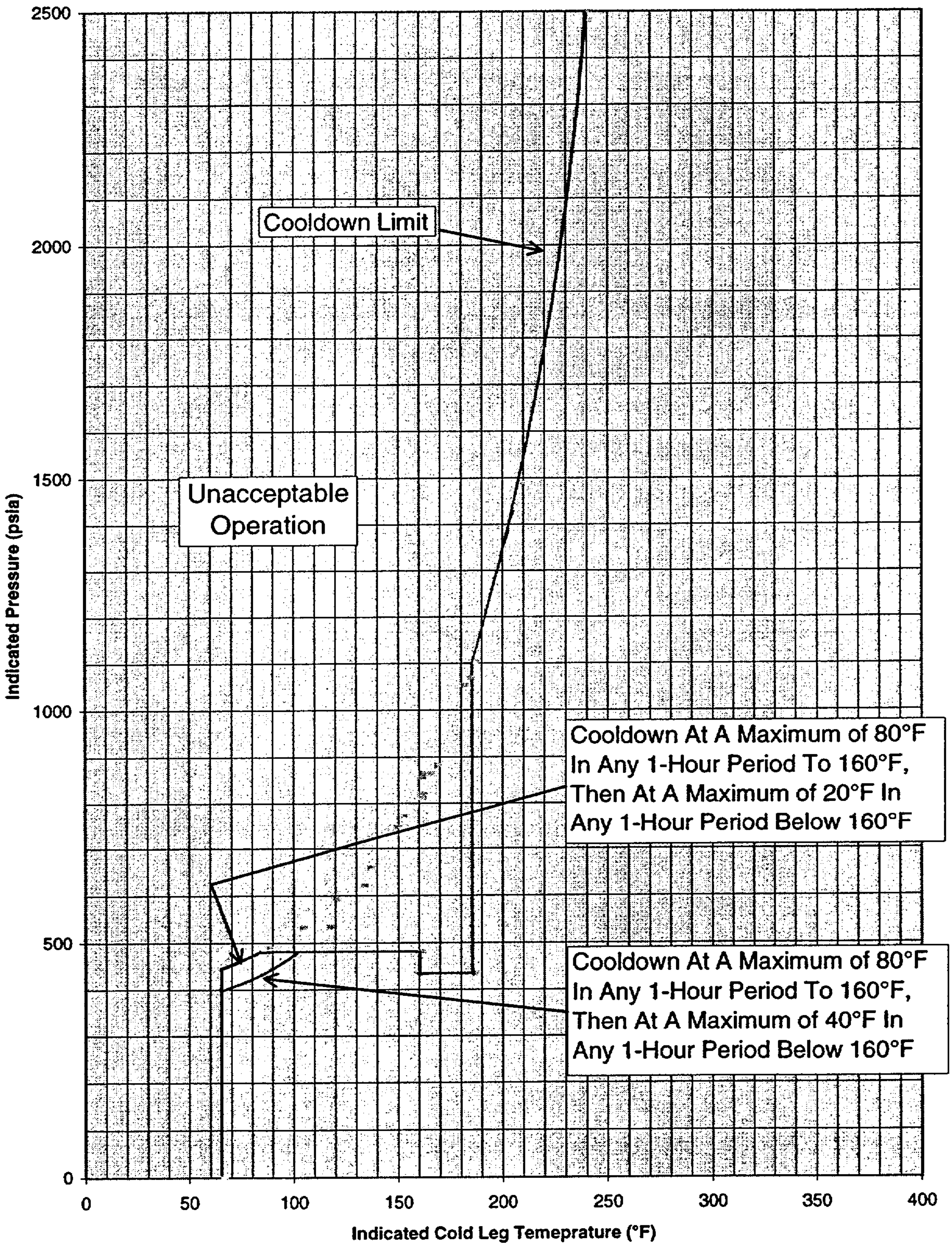
Heatup At A Maximum of 40°F in Any 1-Hour Period Up To 160°F, and At A Maximum of 80°F in Any 1-Hour Peroid Above 160°F.

sp

Hydrostatic and Leak Test Operation: Temperature Changes Limited To A Maximum of 5°F in Any 1-Hour Peroid?

sp

Millstone 3 Reactor Coolant System
Cooldown Limitations for Fluence up to 1.97E+19 n/cm (32 EFPY)



The following is a tabular list of indicated pressure (psia) and indicated cold leg temperature (°F) data characterizing the curves in Figure 3.4-2 "Millstone 3 Reactor Coolant System Heatup Limitations for up to 32 EFPY."

Heatup Limit:

$\text{Temp}_j :=$	$\text{Pressure}_j :=$
65.3	0.0
65.3	481.2
160.0	481.2
160.1	435.5
185.3	435.5
185.4	917.6
210.0	1145
225.3	1325
240.0	1565
257.3	1970
266.0	2200
269.4	2500

Hydrostatic and Leak Test Limit

$\text{Temp}_j :=$	$\text{Pressure}_j :=$
185.4	917.6
185.4	1540
200.3	1875
215.3	2276
220.9	2500

Criticality Limit

$\text{Temp}_j :=$	$\text{Pressure}_j :=$
265.3	0
265.3	1325
287.0	1700
297.3	1970
309.4	2500

The following is a tabular list of indicated pressure (psia) and indicated cold leg temperature (°F) data characterizing the curves in Figure 3.4-3 "Millstone 3 Reactor Coolant System Cooldown Limitations for up to 32 EFPY."

Cooldown at a maximum of 80°F in any 1-hour period to 160°F, then at a maximum of **20°F** in any 1-hour period below 160°F.

$\text{Temp}_j :=$	$\text{Pressure}_j :=$
65.3	447.9
83.3	480.4
83.6	481.2
159.9	481.2
160.0	435.5
185.3	435.5
185.3	1104
207.3	1490
224.0	2000
239.3	2481
239.7	2500

Cooldown at a maximum of 80°F in any 1-hour period to 160°F, then at a maximum of **40°F** in any 1-hour period below 160°F.

$\text{Temp}_j :=$	$\text{Pressure}_j :=$
65.3	398.5
76.3	416.0
84.3	431.6
100.3	471.8
102.7	481.2
159.9	481.2
160.0	435.5
185.3	435.5
185.3	1104
207.3	1490
224.0	2000
239.3	2481
239.7	2500

7.2 COPS Enable Temperatures

The COPS enable temperatures have been generated considering wide range instrument loop uncertainties and are 219.5°F and 225.4°F for heatup and cooldown, respectively. Again, values greater than this may be used administratively and would provide additional conservatism.

```
 Menu  Utilities  Compilers  Help
--------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF334.OUTLIST                     Line 00000385 Col 001 080
                                              A B A Q U S   I N P U T   E C H O


                        5    10    15    20    25    30    35    40    45    50    55    60
                     ----------------------------------------------------------------------
                     *HEADING
                     MP3 COOLDOWN AT 80 F/HR TO 160 AND 20 F/HR TO 60
                     *NODE,NSET=ALL
                     1,-0.013,0.,0.
      CARD     5     2,0.0,0.,0.
                     3,0.0898,0.,0.
                     4,0.1797,0.,0.
                     5,0.2695,0.,0.
                     6,0.3594,0.,0.  ✓
      CARD    10     7,0.4492,0.,0.
                     8,0.5391,0.,0.
                     9,0.6289,0.,0.
                     10,0.7188,0.,0.
                     *ELEMENT,ELSET=CLAD,TYPE=DC1D2
      CARD    15     1,1,2
                     *ELEMENT,ELSET=VESS,TYPE=DC1D2
                     2,2,3
                     3,3,4
                     4,4,5
      CARD    20     5,5,6
                     6,6,7
                     7,7,8
                     8,8,9
Command ===>                                                  Scroll ===> 0027
```

pd

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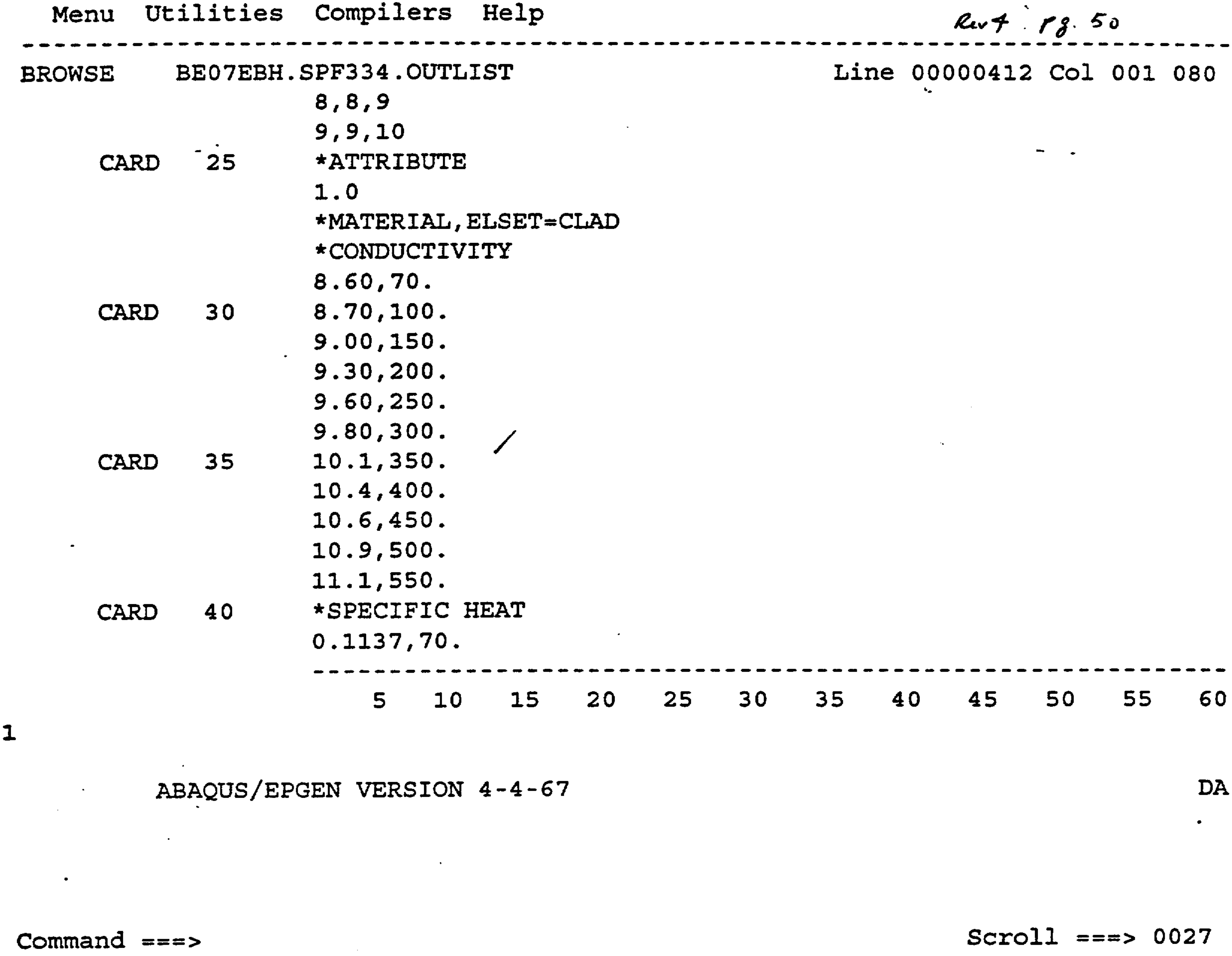

```
  Menu  Utilities  Compilers  Help
--------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF334.OUTLIST                       Line 00000412 Col 001 080
                    8,8,9
                    9,9,10
     CARD   25      *ATTRIBUTE
                    1.0
                    *MATERIAL,ELSET=CLAD
                    *CONDUCTIVITY
                    8.60,70.
     CARD   30      8.70,100.
                    9.00,150.
                    9.30,200.
                    9.60,250.
                    9.80,300.
     CARD   35      10.1,350.
                    10.4,400.
                    10.6,450.
                    10.9,500.
                    11.1,550.
     CARD   40      *SPECIFIC HEAT
                    0.1137,70.
                    ------------------------------------------------------------
                        5    10    15    20    25    30    35    40    45    50    55    60
1

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Command ===>                                                   Scroll ===> 0027
```

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```
 Menu  Utilities  Compilers  Help
------------------------------------------------------------------------------
BROWSE   BE07EBH.SPF334.OUTLIST                     Line 00000439 Col 001 080
                    5    10   15   20   25   30   35   40   45   50   55   60
                -------------------------------------------------------------
                0.1142,100.
                0.1166,150.
                0.1190,200.
     CARD   45  0.1213,250.
                0.1223,300.
                0.1244,350.
                0.1258,400.
                0.1267,450.
     CARD   50  0.1280,500.
                0.1288,550.
                *DENSITY
                501.
                *MATERIAL,ELSET=VESS
     CARD   55  *CONDUCTIVITY
                22.3,70.
                22.6,100.
                23.1,150.
                23.4,200.
     CARD   60  23.7,250.
                23.8,300.
                23.8,350.
                23.8,400.
                23.7,450.
     CARD   65  23.5,500.
                23.2,550.
Command ===>                                                   Scroll ===> 0027
```

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```
  Menu  Utilities  Compilers  Help
------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF334.OUTLIST                      Line 00000466 Col 001 080
                    23.2,550.
                    *SPECIFIC HEAT
                    0.1063,70.
                    0.1082,100.
     CARD    70     0.1114,150.
                    0.1139,200.
                    0.1168,250.
                    0.1193,300.
                    0.1220,350.
     CARD    75     0.1251,400.
                    0.1282,450.
                    0.1313,500.
                    0.1340,550.
                    *DENSITY
     CARD    80     489.
                    *AMPLITUDE,NAME=RAMP,TIME=A,VALUE=A
                    0,550.0,4.875,160.0,9.875,60.0
                    *INITIAL CONDITIONS,TYPE=TEMPERATURE
                    ALL,550.0
     CARD    85     *STEP,INC=500
                    *HEAT TRANSFER,TEMTOL=.001
                    ------------------------------------------------------------
                        5    10    15    20    25    30    35    40    45    50    55    60
1

          ABAQUS/EPGEN VERSION 4-4-67                                          DA


Command ===>                                                  Scroll ===> 0027
```

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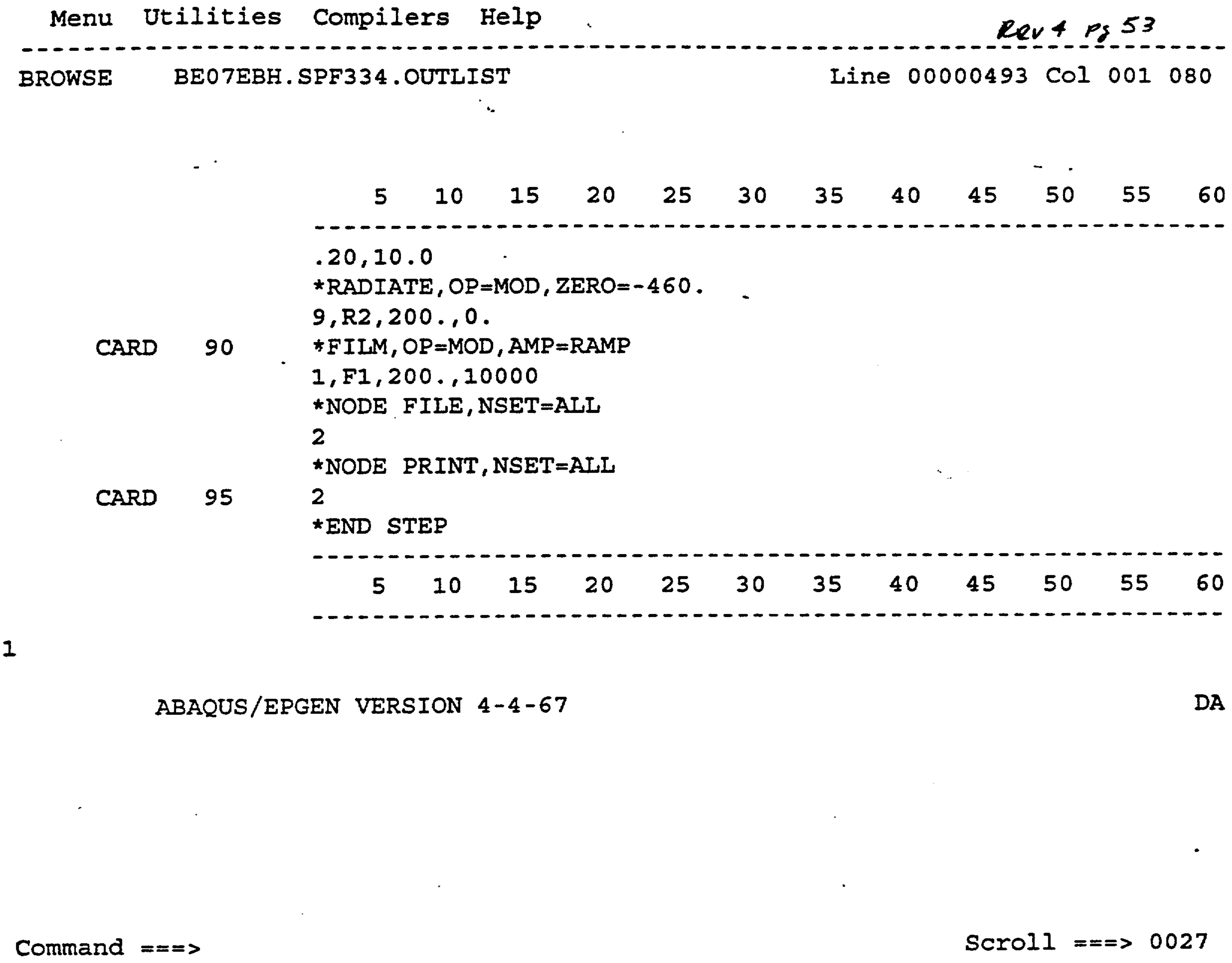

```
 Menu  Utilities  Compilers  Help
--------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF334.OUTLIST                     Line 00000493 Col 001 080


                          5   10   15   20   25   30   35   40   45   50   55   60
                     -----------------------------------------------------------
                     .20,10.0
                     *RADIATE,OP=MOD,ZERO=-460.
                     9,R2,200.,0.
     CARD    90      *FILM,OP=MOD,AMP=RAMP
                     1,F1,200.,10000
                     *NODE FILE,NSET=ALL
                     2
                     *NODE PRINT,NSET=ALL
     CARD    95      2
                     *END STEP
                     -----------------------------------------------------------
                          5   10   15   20   25   30   35   40   45   50   55   60
                     -----------------------------------------------------------
1

           ABAQUS/EPGEN VERSION 4-4-67                                       DA




Command ===>                                                   Scroll ===> 0027
```

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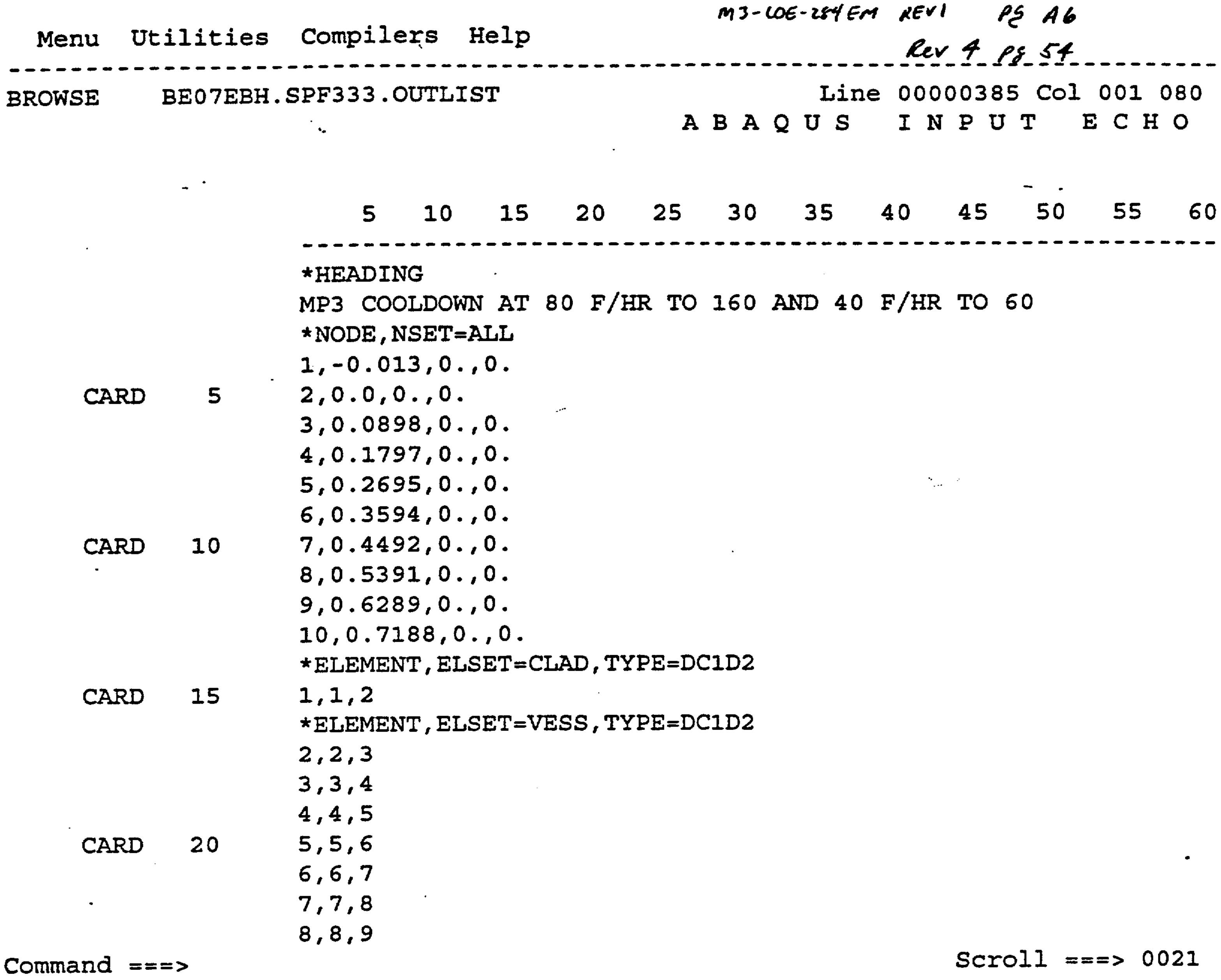

```
  Menu  Utilities  Compilers  Help
-------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF333.OUTLIST                        Line 00000385 Col 001 080
                                              A B A Q U S   I N P U T   E C H O


                    5    10    15    20    25    30    35    40    45    50    55    60
                   -----------------------------------------------------------------
                   *HEADING
                   MP3 COOLDOWN AT 80 F/HR TO 160 AND 40 F/HR TO 60
                   *NODE,NSET=ALL
                   1,-0.013,0.,0.
     CARD     5    2,0.0,0.,0.
                   3,0.0898,0.,0.
                   4,0.1797,0.,0.
                   5,0.2695,0.,0.
                   6,0.3594,0.,0.
     CARD    10    7,0.4492,0.,0.
                   8,0.5391,0.,0.
                   9,0.6289,0.,0.
                   10,0.7188,0.,0.
                   *ELEMENT,ELSET=CLAD,TYPE=DC1D2
     CARD    15    1,1,2
                   *ELEMENT,ELSET=VESS,TYPE=DC1D2
                   2,2,3
                   3,3,4
                   4,4,5
     CARD    20    5,5,6
                   6,6,7
                   7,7,8
                   8,8,9
Command ===>                                                     Scroll ===> 0021
```

pd

```
  Menu  Utilities  Compilers  Help
--------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF333.OUTLIST                     Line 00000412 Col 001 080
                    8,8,9
                    9,9,10
     CARD   25      *ATTRIBUTE
                    1.0
                    *MATERIAL,ELSET=CLAD
                    *CONDUCTIVITY
                    8.60,70.
     CARD   30      8.70,100.
                    9.00,150.
                    9.30,200.
                    9.60,250.
                    9.80,300.
     CARD   35      10.1,350.
                    10.4,400.
                    10.6,450.
                    10.9,500.
                    11.1,550.
     CARD   40      *SPECIFIC HEAT
                    0.1137,70.
                    ------------------------------------------------------------
                        5    10    15    20    25    30    35    40    45    50    55    60
1

           ABAQUS/EPGEN VERSION 4-4-67                                        DA



Command ===>                                                   Scroll ===> 0027
```

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```
 Menu  Utilities  Compilers  Help
--------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF333.OUTLIST                      Line 00000439 Col 001 080

                        5    10   15   20   25   30   35   40   45   50   55   60
                    ------------------------------------------------------------
                    0.1142,100.
                    0.1166,150.
                    0.1190,200.
      CARD    45    0.1213,250.
                    0.1223,300.
                    0.1244,350.
                    0.1258,400.
                    0.1267,450.  ✓
      CARD    50    0.1280,500.
                    0.1288,550.
                    *DENSITY
                    501.
                    *MATERIAL,ELSET=VESS
      CARD    55    *CONDUCTIVITY
                    22.3,70.
                    22.6,100.
                    23.1,150.
                    23.4,200.
      CARD    60    23.7,250.  ✓
                    23.8,300.
                    23.8,350.
                    23.8,400.
                    23.7,450.
      CARD    65    23.5,500.
                    23.2,550.
Command ===>                                                   Scroll ===> 0027
```

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```
  Menu  Utilities  Compilers  Help
--------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF333.OUTLIST                    Line 00000466 Col 001 080
                    23.2,550.
                    *SPECIFIC HEAT
                    0.1063,70.
                    0.1082,100.
     CARD    70     0.1114,150.
                    0.1139,200.
                    0.1168,250.
                    0.1193,300.
                    0.1220,350.
     CARD    75     0.1251,400.
                    0.1282,450.
                    0.1313,500.
                    0.1340,550.
                    *DENSITY
     CARD    80     489.
                    *AMPLITUDE,NAME=RAMP,TIME=A,VALUE=A
                    0,550.0,4.875,160.0,7.375,60.0
                    *INITIAL CONDITIONS,TYPE=TEMPERATURE
                    ALL,550.0
     CARD    85     *STEP,INC=500
                    *HEAT TRANSFER,TEMTOL=.001
                    ------------------------------------------------------------
                        5    10   15   20   25   30   35   40   45   50   55   60
1

          ABAQUS/EPGEN VERSION 4-4-67                                        DA

Command ===>                                                 Scroll ===> 0027
```

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```
  Menu  Utilities  Compilers  Help
-------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF333.OUTLIST                     Line 00000493 Col 001 080


                       5   10   15   20   25   30   35   40   45   50   55   60
                  -------------------------------------------------------------
                  .20,8.0
                  *RADIATE,OP=MOD,ZERO=-460.
                  9,R2,200.,0.
     CARD   90    *FILM,OP=MOD,AMP=RAMP
                  1,F1,200.,10000
                  *NODE FILE,NSET=ALL
                  2
                  *NODE PRINT,NSET=ALL
     CARD   95    2
                  *END STEP
                  -------------------------------------------------------------
                       5   10   15   20   25   30   35   40   45   50   55   60
                  -------------------------------------------------------------
1

         ABAQUS/EPGEN VERSION 4-4-67                                          DA




Command ===>                                                   Scroll ===> 0027
```

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```
  Menu  Utilities  Compilers  Help
-------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF332.OUTLIST                     Line 00000385 Col 001 080
                                              A B A Q U S   I N P U T   E C H O


                        5    10    15    20    25    30    35    40    45    50    55    60
                     ----------------------------------------------------------------------
                     *HEADING
                     MP3 HEATUP AT 40 F/HR TO 160 AND 80 F/HR TO 550
                     *NODE,NSET=ALL
                     1,-0.013,0.,0. ✓
      CARD     5     2,0.0,0.,0. ✓
                     3,0.0898,0.,0. ✓
                     4,0.1797,0.,0. ✓
                     5,0.2695,0.,0. ✓
                     6,0.3594,0.,0. ✓
      CARD    10     7,0.4492,0.,0. ✓
                     8,0.5391,0.,0. ✓
                     9,0.6289,0.,0. ✓
                     10,0.7188,0.,0. ✓
                     *ELEMENT,ELSET=CLAD,TYPE=DC1D2
      CARD    15     1,1,2 ✓
                     *ELEMENT,ELSET=VESS,TYPE=DC1D2
                     2,2,3 ✓
                     3,3,4 ✓
                     4,4,5 ✓
      CARD    20     5,5,6 ✓
                     6,6,7 ✓
                     7,7,8 ✓
                     8,8,9 ✓
Command ===>                                                      Scroll ===> 0002
```

PC
1/2/97

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```
  Menu  Utilities  Compilers  Help
-------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF332.OUTLIST                      Line 00000412 Col 001 080
                    8,8,9 ✓
                    9,9,10 ✓
     CARD  -25      *ATTRIBUTE
                    1.0 ✓
                    *MATERIAL,ELSET=CLAD
                    *CONDUCTIVITY
                    8.60,70. ✓
     CARD   30      8.70,100. ✓
                    9.00,150. ✓
                    9.30,200. ✓
                    9.60,250. ✓
                    9.80,300. ✓
     CARD   35      10.1,350. ✓
                    10.4,400. ✓
                    10.6,450. ✓
                    10.9,500. ✓
                    11.1,550. ✓
     CARD   40      *SPECIFIC HEAT
                    0.1137,70. ✓
                    -----------------------------------------------------------
                        5    10    15    20    25    30    35    40    45    50    55    60
1

          ABAQUS/EPGEN VERSION 4-4-67                                        DA



Command ===>                                                Scroll ===> 0027
```

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```
  Menu  Utilities  Compilers  Help
-------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF332.OUTLIST                      Line 00000439 Col 001 080

                           5    10   15   20   25   30   35   40   45   50   55   60
                      ------------------------------------------------------------
                      0.1142,100.✓
                      0.1166,150.✓
                      0.1190,200.✓
      CARD    45      0.1213,250.✓
                      0.1223,300.✓
                      0.1244,350.✓
                      0.1258,400.✓
                      0.1267,450.✓
      CARD    50      0.1280,500.✓
                      0.1288,550.✓
                      *DENSITY
                      501. ✓
                      *MATERIAL,ELSET=VESS
      CARD    55      *CONDUCTIVITY
                      22.3,70. ✓
                      22.6,100. ✓
                      23.1,150. ✓
                      23.4,200.✓
      CARD    60      23.7,250. ✓
                      23.8,300.✓
                      23.8,350.✓
                      23.8,400. ✓
                      23.7,450. ✓
      CARD    65      23.5,500. ✓
                      23.2,550. ✓
Command ===>                                                      Scroll ===> 0027
```

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 Menu  Utilities  Compilers  Help
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BROWSE    BE07EBH.SPF332.OUTLIST                         Line 00000466 Col 001 080
                    23.2,550.
                    *SPECIFIC HEAT
                    0.1063,70.✓
                    0.1082,100. ✓
     CARD   70      0.1114,150.✓
                    0.1139,200.✓
                    0.1168,250.✓
                    0.1193,300.✓
                    0.1220,350.✓
     CARD   75      0.1251,400.✓
                    0.1282,450.✓
                    0.1313,500.✓
                    0.1340,550.✓
                    *DENSITY
     CARD   80      489.✓
                    *AMPLITUDE,NAME=RAMP,TIME=A,VALUE=A
                    0,60.0,2.5,160.0,7.375,550.0 ✓
                    *INITIAL CONDITIONS,TYPE=TEMPERATURE
                    ALL,60.0
     CARD   85      *STEP,INC=500
                    *HEAT TRANSFER,TEMTOL=.001
                    ----------------------------------------------------------
                        5    10    15    20    25    30    35    40    45    50    55    60
1

          ABAQUS/EPGEN VERSION 4-4-67                                          DA


Command ===>                                                    Scroll ===> 0027
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M3-10E-284EM REV1 PE A/S
Rev 4 Pg 63

```
  Menu  Utilities  Compilers  Help
-------------------------------------------------------------------------------
BROWSE    BE07EBH.SPF332.OUTLIST                       Line 00000493 Col 001 080


                        5    10   15   20   25   30   35   40   45   50   55   60
                    ------------------------------------------------------------
                    .20,8.0
                    *RADIATE,OP=MOD,ZERO=-460.
                    9,R2,200.,0.  ✓
     CARD    90     *FILM,OP=MOD,AMP=RAMP
                    1,F1,200.,10000  ✓
                    *NODE FILE,NSET=ALL
                    2
                    *NODE PRINT,NSET=ALL
     CARD    95     2
                    *END STEP
                    ------------------------------------------------------------
                        5    10   15   20   25   30   35   40   45   50   55   60
                    ------------------------------------------------------------
1

          ABAQUS/EPGEN VERSION 4-4-67                                          DA




Command ===>                                                  Scroll ===> 0027
```

Calculation Review Comment and Resolution Form

(Sheet 1 of)

Calculation Number: M3-LOE284EM Revision: 4 CCN N/A

Calculation Title:

Calc. Originator: Craig Stewart Reviewer (PRINT): Thomas Steahr

This form is intended to document significant comments and their resolutions. Typographical errors and other editorial recommendations may be marked up in the calculation text and presented to the originator

Review Type ☞ ☐Interdiscipline ☒Independent

Reviewer (SIGN) Thomas A Date: 8/9/00

(signature signifies all comments have been resolved to your satisfaction)

Item	Page/Section	Comments	Response
1	Section 5.0	Minor typographical errors and add clarification of acceptable use of calculation results.	Incorporated.
2	Section 6.0	Minor adjustment to M_m and corrections to interpolations.	Incorporated.

p. B1 of B1

p. 64

TOTAL PAGES: 4

CALCULATION CHANGE NOTICE (CCN)

PAGE 1

AFFECTED CALCULATION/PLANT
☐ MP1 ☐ MP2 ☒ MP3 ☐ GENERAL

CALCULATION NO. 94-ENG-1018 E3	REVISION NO. 2	CHANGE NO. 1	CALCULATION ORIGINATED BY: ☒ NU ☐ VENDOR

CALCULATION TITLE
Millstone Unit 3 COPPS/PORV Loop Uncertainty

REFERENCE DCR M3-98040	Safety Evaluation or Screen Attached ☐YES ☒NO	CCN Supports DCR/MMOD? ☒YES ☐NO DCR/MMOD: M3-98040	CCN Supports Other Process? ☐YES ☒NO Reference:

REASON FOR CHANGE

DCR M3-98040 added two cards to the COPPS/PORV circuitry to duplicate the high limit function for the input to the COPPS bistable(s) that existed prior to the circuit rewiring and rescaling implemented by the DCR. As a result of the change, Figure 1 of this calculation needs to be updated to reflect these cards and their impact on the loop block diagram.

DESCRIPTION OF CHANGE & TECHNICAL JUSTIFICATION

Update Figure 1, Block Diagram - PORV Setpoint Uncertainties, of the calculation to reflect the addition of 3RCS*PY405H and 403H as the input of the COPPS bistable(s).

The loop accuracy is based on a combined rack accuracy for all the components in the COPPS circuit and as a result of the DCR the revised COPPS circuitry now contains fewer components. Therefore the rack accuracy value is still bounding and there is no impact on the loop accuracy as calculated in Revision 2 of this calculation. This reflects an as-built condition of the change implemented under DCR M3-98040 and no additional field changes are required as a result of this CCN.

NUCLEAR INDICATOR ☒ CAT 1 ☐ RWQA ☐ SBOQA ☐ FPQA ☐ ATWSQA ☐ NON-QA	AFFECTED CALC PAGES 12

Approvals **(Print & Sign Name)**

Preparer: R N Burnham		Date: 9/8/99
Interdiscipline Reviewer: - N/R -	Discipline: -	Date: -
Interdiscipline Reviewer: - N/R -	Discipline: -	Date: -
Independent Reviewer: WAYNE DARNELL		Date: 9/8/99
Supervisor: DANIEL M. AUBE / Dan M. Aube		Date: 9/8/99

Installation Verification
☒ Calculation represents the installed configuration and approved licensing condition (Calculation of Record)
☐ N/A does not affect plant configuration (e.g., study, hypothetical analysis, etc.)
Preparer/Design Engineer: (Print and Sign) RN Burnham Date: 9/8/99

If applicable:
Superseded by Rev. ______ CCN__________
Preparer/Design Engineer: (Print and Sign) Date:

REC'D 9/9/99
ON HOLD
CDS 10/21/99
CDS QC 11/5/99
NRP yes

Verified Revision 0
Initial Ju Date 6/8/01

DCM FORM 5-5A
Rev. 7
Page 1 of 1

PassPort DATABASE INPUTS CHANGE

Page 2 of 4

Calculation Number: 94-ENG-1018 E3 Revision: 2

Vendor Calculation Number/Other N/A Revision: N/A

CCN NO.: 1 QA ☒ Yes ☐ No Calc Voided: ☐ Yes ☒ No

Superseded By: N/A Supersedes: N/A

CHANGES (Change Codes [CC]: "**A**" = Add; "**D**" = Delete)

Discipline (Up to 10) CC [ ]:

CC	Unit	Project Reference (EWA)	Component Id	Computer Code	Rev. No./ Level No.
A	M3	M3-97143	3RCS*PY-405H	N/A	N/A
A	M3	M3-97143	3RCS*PY-403H	N/A	N/A

CC	PMMS CODES*			Reference Calculation	Rev No.	CCN
	Structure	System	Component			

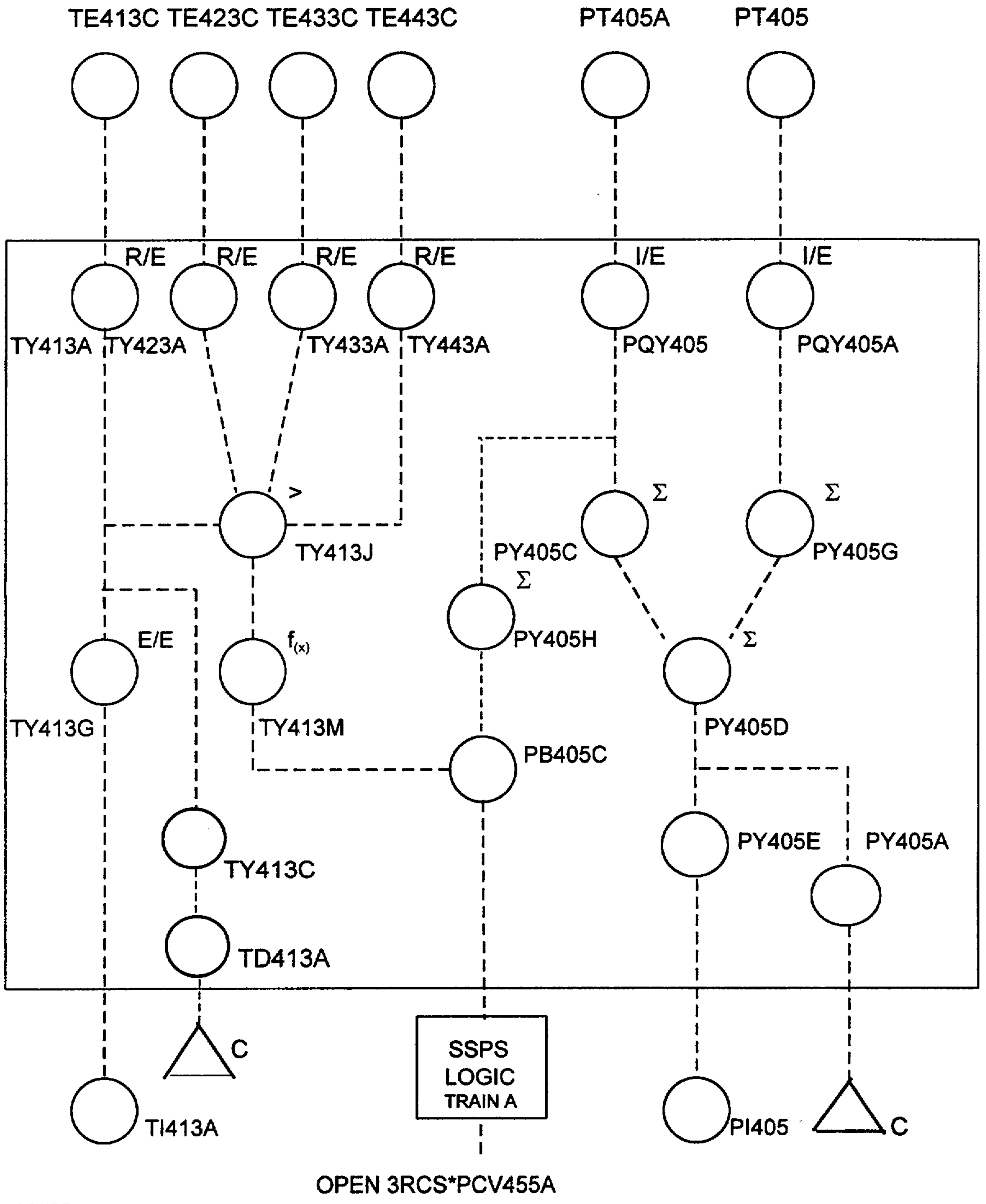
*The codes required must be alpha codes designed for structure, system and component.

*Use a separate line to post information to be entered (one document per line).

CC	Reference Drawing	Sheet	Rev. No.

Comments:

FIGURE 1
BLOCK DIAGRAM - PORV SETPOINT UNCERTAINTIES
(Train A Component ID Numbers Shown, Train B Similar)



NOTES:
1. All equipment is prefixed with 3RCS*.
2. 3RCS*TI423A is similar to 3RCS*TI413A shown.
3. No Main Board indication for 3RCS*TE433C or 3RCS*TE443C .
4. Computer indication similar for 3RCS*TE423/433/443C.

Calculation Review Comment and Resolution Form

(Sheet 1 of 1)

Pg 4 of 4

Calculation Number: 94-ENG-1018 E3 Revision: 2 CCN 1

Calculation Title: Millstone Unit 3 COPPS/PORV Loop Uncertainty

Calc. Originator: R N Burnham Reviewer (PRINT): WAYNE DARNELL

This form is intended to document significant comments and their resolutions. Typographical errors and other editorial recommendations may be marked up in the calculation text and presented to the originator

Review Type ☞ ☐**Interdiscipline** ☒**Independent**

Reviewer (SIGN) WAYNE DARNELL Date: 9/8/99

(signature signifies all comments have been resolved to your satisfaction)

Item	Page/Section	Comments	Response
		NONE	

CALCULATION TITLE PAGE

Total Number of Pages: 24

Millstone Unit 3 COPPS/PORV Loop Uncertainty

TITLE

94-ENG-1018 E3	2	RCS
CALCULATION No.	**Revision No.**	**System Name**

N/A	CS, CB	3301	Various
VENDOR CALCULATION No.	**Structure**	**System Number**	**Component**

NUCLEAR INDICATOR:	Safety Evaluation or Screen Attached	**Calc. Supports DCR/MMOD?**	**Calc. Supports Other Process?**
☒CAT1 ☐RWQA ☐SBOQA ☐FPQA ☐ATWSQA ☐NON-QA	☐YES ☒NO	☒YES ☐NO	☐YES ☒NO

C #

↓	↓
M3-98040	N/A
DCR/MMOD No.	**Reference**

INCORPORATES:

CCN NO:	AGAINST REV.
1	1

Executive Summary

This revision updates the COPPS/PORV uncertainty due to changes implemented under DCR M3-98040:

1. Replacement of the existing Foxboro / Rosemount split range transmitters with different model Rosemount transmitters.
2. Rewiring of the bistables in the wide range pressure instrument loops to take their inputs from the low range transmitter instead of the summed signals generated by both of the split range transmitters.

Due to the extensive changes made during this revsion change bars have been omitted.

Approvals (Print & Sign Name)		
Preparer:R N Burnham		Date: 1/19/99
Interdiscipline Reviewer: Don Asay	Discipline: Tech Support	Date: 2-11-99
Interdiscipline Reviewer : N/R	Discipline:	Date:
Independent Reviewer: WAYNE DARNELL		Date: 2/9/99
Supervisor: Daniel M. Aube /		Date: 2/16/99

Installation Verification

☒ Calculation represents the installed configuration and approved licensing condition (Calculation of Record)

CH 10

☐ N/A does not affect plant configuration (e.g., study, hypothetical analysis, etc.)

CH #9

Preparer/Designer Engineer: (Print and Sign) RN Burnham Date: 6/17/99

REC'D 2-26-99
ON HOLD 3/4/99 VMB
CDS 6/20/99
CDS QC 6/24/99
NRP ✓MC

Verified Revision 2
Initial Date 6/8/01

DCM FORM 5-1A
Rev. 6 Ch. 10
Page 1 of 1

~~Total number of pages: 28~~

REVISION 2
PAGE 2 OF ~~24~~
21

Millstone Unit 3 COPPS/PORV Loop Uncertainty
TITLE

94-ENG-1018-E3	1	
CALCULATION #	**REV #**	**Vendor Calc#**

System RCS **Structure** CONT **Component** Various

Executive Summary

Calculation 94-ENG-1018-E3, "Millstone Unit 3 COPPS/PORV Loop Uncertainty" Revision 1 provides the Channel statistical allowance for the COPPS/PORV bistable and the RCS wide range pressure and temperature indicators (*PI403,*PI405,*TI413A/B and *TI423A/B). These instrument loops provide support for Overpressue Protection Technical Specification 3/4.9.3, Shutdown Monitoring Instrumentation 3.3.3.5 and Accident Monitoring Instrumentation 3.3.3.6.

Reason for Revision:

- Incorporate Methodology of 24 Month Fuel Cycle Evaluation WCAP 14353 " Westinghouse Setpoint Methodology for Indication, Control and Protection Systems for Millstone Nuclear Power Station Unit 3."
- Revise specific component error allowances.
- Include evaluation for both instrument channels A and B to document the dominant CSA.
- Update Calculation Format

~~Verified Revision~~

Does this calculation:	
1. Support a DCR, MMOD, an independent review method for a DCR ,or confirm test results for an installed DCR? If yes, indicate the DCR, MMOD number and/or Test Procedure number.	Yes ☐No ☒
2. Support independent analysis? If yes, indicate the procedure, work control or other reference it supports. WCAP 14353 Rev. 0	Yes ☒No ☐
3. Revise, supersede, or void existing calculations? If yes, indicate the calculation number and revisions. 94-ENG-1018-E3	Yes ☒No ☐
4. Involve QA or QA-related systems, components or structures?	Yes ☒No ☐
5. Impact the Unit licensing basis, including technical specifications, FSAR, procedures or licensing commitments? If yes, identify appropriate change documents. no change	Yes ☐No ☒

Approvals (Print/Signature)	
Preparer Chris Green	Date: 11/18/96
Independent Reviewer Don Asay	Date: 11-19-96
Supervisor Gil Olsen	Date: 11/19/96

REC'D 11-19-96
CTP 1-4-97
NDS 1-7-97

NUC DCM FORM 5-1A
Rev. 03

PassPort DATABASE INPUTs

Page 3

Calculation Number: 94-ENG-1018 E3 Revision: 2

Vendor Calculation Number/Other: N/A Revision: N/A

Ch # 9

CCN # N/A QA ☒ Yes ☐ No Calc Voided: ☐ Yes ☒ No

Superseded By: N/A Supersedes Calc: N/A

Discipline (Up to 10) I

Unit	Project Reference (EWA, DCR or MMOD)	Component Id	Computer Code	Rev. No./ Level No.
M3	M3-98040	3RCS*PT403	N/A	N/A
		3RCS*PT403A		
		3RCS*PT405		
		3RCS*PT405A		
		(Continued)		

PMMS CODES*					
Structure	System	Component	Reference Calculation	Rev No.	CCN
CS	RCS	RTD	PA-93-036-EE-057	0	N/A
CB		XMT			
		IND			
		VLV			
		PWR			
		AMP			

*The codes required must be alpha codes designed for structure, system and component.

*Use a separate line to post information to be entered (one document per line).

Reference Drawing	Sheet	Rev. No.
25212-26902	1	19
25212-26902	3	17
25212-26902	5	16
25212-30343	9A	5
25212-30343	9B	4
25212-30343	9C	5

Comments:

PassPort Data Base Inputs
(Continuation)

Component ID			
3RCS*TE413B	3RCS*TE423B	3RCS*TE433B	3RCS*TE443B
3RCS*TE413C	3RCS*TE423C	3RCS*TE433C	3RCS*TE443C
3RCS*PI403	3RCS*PI405	3RCS*PCV455A	3RCS*PCV456
3RCS*PQY-403	3RCS*PQY-403A	3RCS*PQY-405	3RCS*PQY-405A
3RCS*PY-403C	3RCS*PY-403G	3RCS*PY-405C	3RCS*PY-405G
3RCS*PY-403D	3RCS*PY-405D	3RCS*PB-403C	3RCS*PB-405C
3RCS*TY-413A	3RCS*TY-423A	3RCS*TY-433A	3RCS*TY-443A
3RCS*TY-413B	3RCS*TY-423B	3RCS*TY-433B	3RCS*TY-443B
3RCS*TY-413J	3RCS*TY-413K	3RCS*TY-413M	3RCS*TY-413P
~~3RCS*TY-413A~~	~~3RCS*TY-413B~~	~~3RCS*TY-423A~~	~~3RCS*TY-423B~~
3RCS*TI413A	3RCS*TI413B	3RCS*TI423A	3RCS*TI423B

repeats
PB
3/4/90

PMMS Codes		
Structure	System	Component
		COM
		GEN

Reference Drawing	Sheet	Rev. #
25212-30343	9D	4
25212-30343	9E	2
25212-30343	10A	5
25212-30343	10B	4
25212-30343	10C	5
25212-30343	10D	2
25212-30343	17A	4
25212-30343	17B	4
25212-30343	17D	3
25212-30343	18A	7
25212-30343	18B	3
25212-30343	18D	4
25212-30343	29A	4
25212-30343	29B	4
25212-30343	30A	5
25212-30343	30B	5
25212-30343	41A	5
25212-30343	41B	3
25212-30343	42A	5
25212-30343	42B	4
25212-30343	55A	6
25212-30343	55B	2
25212-30343	56A	5
25212-30343	56B	5

TABLE OF CONTENTS

Total Pages = 24

1.0 Purpose

This calculation will determine the total probable error of the Cold Overpressure Protection System (COPPS) Power-operated Relief Valve (PORV) actuation bistable and pressure and temperature indicators in instrument loops 3RCS*PT403, 3RCS*PT405 & 3RCS*TE413,423,433,443B/C. This calculation is based on a 24 month fuel cycle plus an allowance for unscheduled extensions. This calculation is applicable for normal plant heatup and cooldown evolutions and will not address Loss of Coolant Accidents (LOCA's), High Energy Line Breaks (HELB's) and radiation effects

2.0 Summary of Results

INSTRUMENT CHANNEL	CSA % SPAN(SPAN)	CSA ENG UNITS
3RCS*PI403 3RCS*PI405	3.85(3000)	115.5 PSIA
3RCS*TI413A/B 3RCS*TI423A/B	3.62(700)	25.3 °F

Table 1. Summary of results for Heatup/Cooldown Post OBE Curve using Mainboard Indicators.

INSTRUMENT CHANNEL	CSA % SPAN(SPAN)	CSA ENG UNITS
PRESSURE BISTABLE (0-1000)	2.13(1000)	21.3 PSIA
TEMPERATURE BISTABLE	2.32(700)	16.2 °F

Table 2. Summary of results for COPPS Post OBE Curve.

INSTRUMENT CHANNEL	CSA % SPAN(SPAN)	CSA ENG UNITS
PRESSURE COMPUTER PNT	1.83(3000)	54.9 PSIA
TEMPERATURE COMPUTER PNT	2.33(700)	16.3 °F

Table 3. Summary of results using PPC Indication without post OBE effects.

3.0 References/Design Inputs

3.1 Licensing Basis References

3.1.1 Unit 3 Technical Specifications.

3.1.2 MP3 FSAR Section(s)
- Section Nos. 5.2.2.11, 5.2.2.11.1 thru 5.2.2.11.4, 7.6.8, 7.6.8.1 thru 7.6.8.3.
- Appendix 3B, Environmental Design Conditions (Zones: CS-01, Containment Structure - Inside the Crane Wall; CS-02, Containment Structure - Outside the Crane Wall; CB-02, Control Building-47'-6").

3.2 Design Basis Summary References

3..2.1 None

3.3 Design Basis Specification References

3.3.1 SP-M3-IC-025, Rev. 0, Guidelines for Calculating Instrument Setpoints, Uncertainties, and Scaling.

3.3.2 SP-M3-IC-026, Rev. 0, Westinghouse Setpoint Methodology for Indication, Control, and Protection Systems.
- WCAP-10991, Rev. 5, Westinghouse Setpoint Methodology for Protection Systems, June 1995.
- WCAP-14353, Rev. 0, Westinghouse Setpoint Methodology for Indication, Control and Protection Systems for Millstone Nuclear Power Station, July 1995

3.3.3 SP-M3-EE-0333, Rev. 0, MP3 Environmental Conditions for Equipment Qualification

3.4 Design Basis Drawing References

3.4.1 P&IDs
- 25212-26902 Sh.1 of 6, Rev.19 (12179-EM-102A)
- 25212-26902 Sh.3 of 6, Rev.17 (12179-EM-102C)
- 25212-26902 Sh.5 of 6, Rev.16 (12179-EM-102E)

3.4.2 Loop Drawings
- 25212-30343, Sh. 9A, Rev 5
- 25212-30343, Sh. 9B, Rev 4
- 25212-30343, Sh. 9C, Rev 5
- 25212-30343, Sh. 9D, Rev 4
- 25212-30343, Sh. 9E, Rev 2
- 25212-30343, Sh. 10A, Rev 5

- 25212-30343, Sh. 10B, Rev 4
- 25212-30343, Sh. 10C, Rev 5
- 25212-30343, Sh. 10D, Rev 2
- 25212-30343, Sh, 17A, Rev 4
- 25212-30343, Sh, 17B, Rev 4
- 25212-30343, Sh, 17D, Rev 3
- 25212-30343, Sh, 18A, Rev 7
- 25212-30343, Sh, 18B, Rev 3
- 25212-30343, Sh, 18D, Rev 4
- 25212-30343, Sh, 29A, Rev 4
- 25212-30343, Sh, 29B, Rev 4
- 25212-30343, Sh, 30A, Rev 5
- 25212-30343, Sh, 30B, Rev 5
- 25212-30343, Sh, 41A, Rev 5
- 25212-30343, Sh, 41B, Rev 3
- 25212-30343, Sh, 42A, Rev 5
- 25212-30343, Sh, 42B, Rev 4
- 25212-30343, Sh, 55A, Rev 6
- 25212-30343, Sh, 55B, Rev 2
- 25212-30343, Sh, 56A, Rev 5
- 25212-30343, Sh, 56B, Rev 5

3.5 Design Basis Calculation References

3.5.1 Calculation No. PA-93-036-EE-057, Rev. 0, "Cold Overpressurization Instrumentation Data" dated July 12, 1994.

3.6 Equipment Manufacturer's References

3.6.1 OIM 001-003, Westinghouse 7300 Process Instrumentation Equipment Reference Manual (I&C Library W-04-13A).

3.6.2 WCAP-10072, Rev. 8, "Process Control Systems Scaling Manual for Millstone Unit 3",Vol. 1 and Vol. 2.

3.6.3 WCAP 14040-NP-A "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves", Rev. 2, January 1996.

3.6.4 Rosemount Product Data Sheet PDS 2514 Rev. 4/87 "Model 1154 Alphaline Nuclear Pressure Transmitter."

3.6.5 25212-662-007VTM, "Model 1154 Series H Alphaline Nuclear Pressure Transmitter".

3.7 Procedure References

3.7.1 MP3 Surveillance Procedure SP3442A02, "RCS Wide Range Temperature Calibration", Rev. 2, October 28, 1992.

3.7.2 MP3 Surveillance Form SP3442J01-1, "RCS Wide Range Pressure Calibration Channel I", Rev. 3, December 20, 1995.

3.7.3 MP3 Surveillance Form SP3442J01-2, "RCS Wide Range Pressure Calibration Channel 2", Rev. 3, December 20, 1995.

3.7.4 Millstone process Computer Analog Input Calibration Procedure, No. COP 2102/22102/32102.

3.8 Design Change References

3.8.1 DCR M3-98040

3.8.2 DCN DM3-00-1018-98

3.9 Other References

3.9.1 NRC Information Notice 93-58, Nonconservatism in Low-Temperature Overpressure Protection for Pressurized Reactors, July 26, 1993.

3.9.2 NRC Branch Technical Position RSB 5-2, "Overpressurization Protection of Pressurized Water Reactors While Operating At Low Temperatures", Rev. 1, dated November 1988.

3.9.3 Memo No. ARR-94-017 from A. R. Roby dated June 6, 1994.

4.0 Assumptions

4.1 This calculation is based on the installed instrumentation and does not account for Reactor Coolant Pump dynamic head losses and PORV overshoot.

4.2 The calculation assumes that the pressure readings come from the centerline of the RCS. It is noted that the pressure instrumentation is mounted at an elevation 9′ 4″ below the centerline of the hot leg. The difference in actual elevation and the elevation assumed in the calculation leads to an approximate 4 psi bias increase on the pressure measurement.

4.3 Only post OBE seismic effects will be included.

4.4 Additional assumptions are stated in Section 6 within the individual sections where they apply.

5.0 Method of Calculation

The calculation utilizes the standards of preparation, reviewing and approving as set forth in the Design Control Manual Chapter 5.

The calculation tabulates the individual CSA terms for each component considering the full span of the instrument channel (0-3000 PSIA, 0-700 °F) for the main control board indicators, computer points and temperature bistables. The full span of the low range transmitter (0-1000 PSIA) was used for the pressure bistables. Sensor CSA tabulations are done for the low range transmitter (0-1000 PSIA), the high range transmitter (800-3000 PSIA), and one Weed RTD since all eight are identical (0-700 °F). Rack CSA terms are done for the bistable strings, the 0-3000 PSIA indicators and the 0-700 °F indicators. The CSA components are then combined taking into account the individual instrument spans in the SRSS method as described in reference 3.3.1. A summary table is provided to clearly indicate the respective CSA channel values.

Instrumentation for PORV Cold Overpressure Protection Trains A/B is described as follows:

Pressure transmitters 3RCS*PT405A/403A and 3RCS*PT405/403 sense wide range Reactor Coolant System (RCS) hot leg pressure and provide 4-20 mA DC signals to signal converters 3RCS*PQY405/403 and 3RCS*PQY405A/403A respectively. The two transmitters are Rosemount split-ranged, one for the low range(0-1000) and one for the high range (800-3000), to provide improved overall accuracy. The 0-10 VDC output signals are processed through summing amplifiers 3RCS*PY405C/403C and 3RCS*PY405G/403G and then combined by summing amplifier 3RCS*PY405D/403D to provide an analog signal to wide range pressure indicator 3RCS*PI405/403 and a plant process computer point. Loop power supply 3RCS*PQY405/403 provides input to signal comparator 3RCS*PB405C/403C.

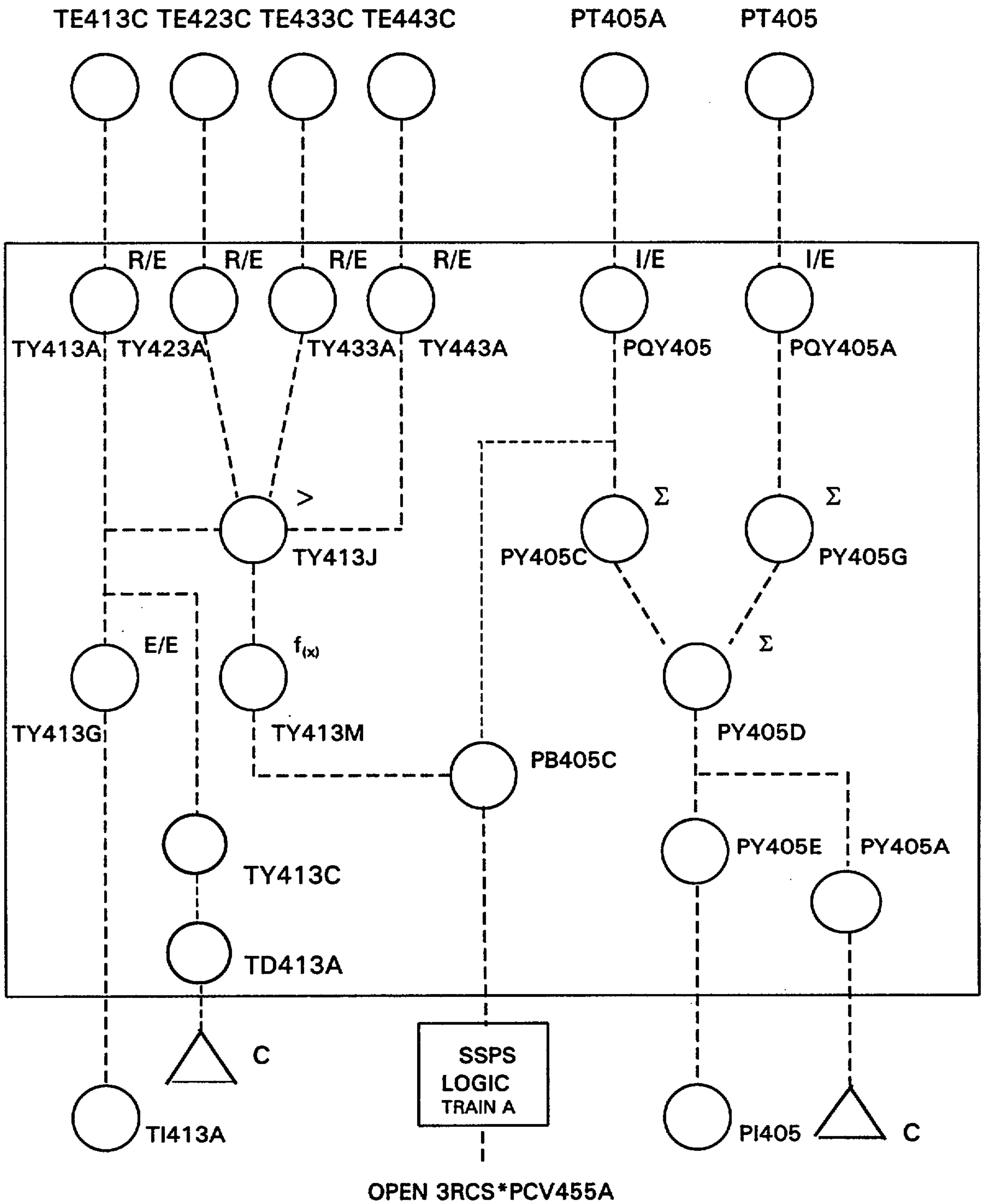
Resistance temperature detectors (RTDs) 3RCS*TE413C/B, 423C/B, 433C/B and 443C/B are used to monitor the wide range RCS hot/cold leg temperature. Each RTD signal is converted to 0-10 VDC via the associated R/E converters 3RCS*TY413A/B, 423A/B, 433A/B or 443A/B. The output signals of these four R/E converters are auctioneered through summing amplifier 3RCS*TY413J/K to select the lowest indicated temperature. This low selected temperature signal is then processed in function generator 3RCS*TY413M/P where a PORV pressure setpoint is calculated.

R/E converters 3RCS*TY413A/B and 3RCS*TY423A/B also provide analog signals to wide range temperature indicators 3RCS*TI413A/B and 3RCS*TI423A/B at Main Control Board 2. Each temperature indicator 3RCS*TE413C/B, 423C/B, 433C/B, and 443C/B feeds a plant process computer point.

The output signal of function generator 3RCS*TY413M/P is sent to signal comparator 3RCS*PB405C/403C for comparison with an RCS pressure signal from 3RCS*PT405A/403A via loop power supply 3RCS*PQY405/403. If the RCS pressure is equal to or greater than the PORV pressure setpoint, a bistable output is generated to open Train A PORV (3RCS*PCV455A)/Train B PORV (3RCS*PCV456) via Solid State Protection System (SSPS) Train A/B.

A block diagram of the PORV Cold Overpressure Protection Loop Train A/B is shown in Figure 1.

FIGURE 1
BLOCK DIAGRAM - PORV SETPOINT UNCERTAINTIES
(Train A Component ID Numbers Shown, Train B Similar)



NOTES:
1. All equipment is prefixed with 3RCS*.
2. 3RCS*TI423A is similar to 3RCS*TI413A shown.
3. No Main Board indication for 3RCS*TE433C or 3RCS*TE443C .
4. Computer indication similar for 3RCS*TE423/433/443C.

6.0 Body of Calculation

References 3.3.1 and 3.3.2 describe the method used to combine instrument uncertainties. The values used for the various components and their sources are described as follows:

6.1 Process Measurement Accuracy (PMA)

This term includes errors in the plant variable measurement up to but not including the sensor.

Per Reference 3.3.2, PMA associated with the low range transmitter is ± 0.0 %.

Per Reference 3.3.2, PMA associated with the high range transmitter is ± 0.0 %.

Per Reference 3.3.2, PMA associated with the Weed RTD is ± 2.0 %.

6.2 Primary Element Accuracy (PEA)

PEA typically accounts for errors due to metering devices such as elbows, venturis and annubars. There are no effects from elbows, venturis or annubars associated with these instrument strings. Therefore, the PEA term for the sensor strings is 0.0%.

6.3 Sensor Calibration Accuracy (SCA)

This term is the accuracy to which the sensor can be calibrated in the field as indicated by the surveillance procedures used to calibrate these sensors, expressed as a percentage of channel span.

Per Reference 3.6.4, SCA associated with the low range transmitter is ± 0.25 %.

Per Reference 3.6.5, SCA associated with the high range transmitter is ± 0.25 %.

Per Reference 3.3.2, SCA associated with the Weed RTD is ± 0.3 %.

note: RTD self-heating effects and RTD lead-balance errors are not available from the manufacturer and will not be included in this calculation.

6.4 Sensor Reference Accuracy (SRA)

This term is the accuracy to which the sensor can acheive in the field per vendor specifications, expressed as a percentage of calibrated span of the channel.

Per Reference 3.6.4, SRA for the low range transmitter is ± 0.25 %.

Per Reference 3.6.5, SRA for the high range transmitter is ± 0.25 %.

Per Reference 3.3.2, SRA for the Weed RTD is ± 0.4 %.

6.5 Sensor Drift (SD)

This term accounts for variations in the sensor accuracy over the calibration interval corresponding to a fuel cycle of 24 months plus an extension of 6 months. This term is provided per a statistical evaluation of past plant calibration data contained in reference 3.3.2.

SD for the low range pressure transmitter for 30 months is ± 0.6%.

SD for the high range pressure transmitter for 30 months is ± 0.3%.

SD for the wide range RTDs for 30 months is ± 0.1%

6.6 Sensor Temperature Effects (STE)

This term accounts for the error due to difference in temperature when the instrument is calibrated and the normal ambient temperature at operating conditions. Assumed is a $\underline{+}$50 °F shift of temperature which is congruent with the design assumption contained in reference 3.3.2.

Per reference 3.6.4, STE for Rosemount 1154 range code 4-9 transmitters (low range transmitter) is defined as:

STE = 0.75%(URL)+0.50%(SPAN) per 100 °F change
STE = [0.0075*(1000)+0.005*(1000)]*0.50
STE = (6.3/1000)*100
STE= ± 0.63 %.

Per reference 3.6.5, STE for Rosemount 1154 Series H range code 4-9 transmitters (high range transmitter) is defined as:

STE = 0.25%(URL)+0.50%(SPAN) per 50 °F change
STE = [0.0025(3000)+0.005(2200)]*1.0
STE = (18.4/2200)*100
STE = ± 0.84%

RTDs are not affected by temperature affects, therefore, STE for the wide range RTD is ± 0.0 %.

6.7 Sensor Pressure Effects (SPE)

Sensor pressure effect applies to differential pressure devices and accounts for the effect on accuracy due to the differences in static pressure between calibration and operation.

Pressure sensors are not affected by SPE, the SPE for the wide range pressure transmitters is ± 0.0 %.

Per Reference 3.3.2, SPE for the Weed RTDs is ± 0.0 %.

6.8 Rack Calibration Accuracy (RCA)

The rack calibration is the overall accuracy to which rack-mounted, signal conditioning components are calibrated in the plant as indicated by the surveillance procedures, expressed as a percentage of calibrated span. The following attributes are typically considered for each rack component in determining the overall RCA:

- Reference Accuracy
- Linearity
- Repeatability
- Power supply variation effect

Per reference 3.3.2 the RCA for the pressure signal bistable is ± 0.4 %.

Per reference 3.3.2 the RCA for the temperature signal bistable is ± 0.6 %.

Per reference 3.3.2 the RCA for the pressure signal indicator string including the 0-3000 psia main board indication is ± 1.7 %.

Per reference 3.3.2 the RCA for the temperature signal indicator string including the 0-700°F indicator is ± 1.5 %.

Per reference 3.3.2 the RCA for the pressure computer point is ± 0.3 %

Per reference 3.3.2 the RCA for the temperature computer point is ± 0.4%

6.9 Rack Drift (RD)

This term accounts for variations in the calibration of rack-mounted, signal conditioning components over calibration interval which corresponds to a fuel cycle of 24 months plus an extension of 6 months. The drift data for the individual rack components is expressed as a percentage of calibrated span. This term is provided per a statistical evaluation of past plant calibration data contained in reference 3.3.2 unless otherwise noted.

RD for pressure/temperature signal bistable string is ± 0.3 %.

RD for pressure signal indicator string including the 0-3000 psia main board indication is ± 1.5 %.

RD for the wide range temperature indicator string including the 0-700°F main board

RD for the wide range temperature indicator string including the 0-700°F main board indicator is ± 2.0%.

RD for the wide range pressure computer point is ± 0.3%.

RD for the wide range temperature computer point is ± 0.6%.

6.10 Rack Temperature Effects (RTE)

This term accounts for the error due to the difference in temperature when the rack is calibrated versus normal ambient operating temperature. Instrument racks 3RPS*RAKSET1 (Process Cabinet Protection Set 1) and 3RPS*RAKSET2 (Process Cabinet Protection Set 2) are located in the Instrument Rack Room El. 47'-6" of the Control Building which is a controlled environment as described in Reference 3.6.

Per Reference 3.3.2, RTE for pressure/temperature signal bistable / indicator / computer string is ± 0.5 %.

6.11 Measurement and Test Equipment Allowance (MTE)

MTE is the error introduced by test equipment.

Per Reference 3.3.2, MTE associated with the low range transmitter is ± 0.3 %.

Per Reference 3.3.2, MTE associated with the high range transmitter is ± 0.3 %.

Per Reference 3.3.2, MTE associated with the Weed RTD is ± 0.3 %.

Per reference 3.3.2 the MTE for the pressure signal bistable is ± 0.3 %.

Per reference 3.3.2 the MTE for the temperature signal bistable string is ± 0.0 %. (Note: This is because component MTE accuracy exceeds a 1:10 ratio).

Per reference 3.3.2 the MTE for the pressure signal indicator string including the 0-3000 psia main board indication is ± 0.3 %.

Per reference 3.3.2 the MTE for the temperature signal indicator string including the 0-700°F indicator is ± 0.0 %. (Note: This is because component MTE accuracy exceeds a 1:10 ratio).

Per reference 3.3.2 the MTE for the pressure computer point is ± 0.3 %

Per reference 3.3.2 the MTE for the temperature computer point is ± 0.0%. (Note: This is because component MTE accuracy exceeds a 1:10 ratio).

6.12 Radiation Allowance (RA)

The instrumentation is installed in the following environments: (Containment Structure Elevations. 4'- 0" & 18'- 0" and Control Building-El. 47'-6") (Reference 3.1.2). This calculation is based on normal plant heatup and cooldown evolutions and will not include radiation effects.

6.13 LOCA/HELB Effects (DLH)

This term accounts for the effects on accuracy of the sensor during the first 24 hours of the post accident environment. This calculation is based on normal plant heatup and cooldown evolutions and will not include LOCA or HELB effects.

6.14 LOCA/HELB Effects (PLH)

This term accounts for the effects on accuracy of the sensor after the first 24 hours of the post-accident environment, expressed as a percentage of calibrated span.

Since DLH is not included, PLH will not be included in the calculation.

6.15 Indicator Readability (OIA)

This term accounts for the overall accuracy of the indicator (IA) such as accuracy, resolution, drift, temperature effect and a readability allowance (R). The readability allowance accounts for parallax distortion when reading analog indicators. This term shall be equal to the percentage of full scale represented by one-half of the smallest increment on the indicator scale, or one percent of full scale, whichever is smaller.

The smallest increment for the wide range pressure indicator is 100 PSIA and the scale is 0-3000 PSIA. The smaller value is one-half of the minor division which is 50 PSIA.

$R_{\text{PRESS IND}}$ = (1/2 of minor division/indicator span)(100%)
$R_{\text{PRESS IND}}$ = ± (50 PSIA/3000 PSIA) (100%)
$R_{\text{PRESS IND}}$ = ± 1.7 % of span

The smallest increment for the wide range temperature indicator is 20°F and the scale is 0-700°F. The smaller value is one-half of the minor division which is 10°F.

$R_{\text{TEMP IND}}$ = (1/2 of minor division/indicator span)(100%)
$R_{\text{TEMP IND}}$ = ± (10° F/700_F) (100%)
$R_{\text{TEMP IND}}$ = ± 1.4 % of span

6.16 Overall Computer Accuracy (OCA)

This term accounts for the overall accuracy of computing devices such as the plant process computer input A/D converter.

Per reference 3.3.1, OCA or device accuracy for the plant process computer is 0.2%. However, this inaccuracy is already included in the RCA for the computer loops. Therefore, an OCA of 0.0% is used in the computer point CSA equations.

6.16 Insulation Resistance Effects (IRE)

This term accounts for the effects of degradation in the insulation resistance of cables, terminal blocks & containment penetrations in a post accident environment. The insulation resistance decreases are caused by elevated temperatures and/or the effects of moisture from LOCA's, HELB's or Main Steam Line Break (MSLB)s. Since the COPS does not provide a protective function during an accident, IR losses will not be considered in this calculation.

6.17 Seismic Allowance (SA)

Per Ref. 3.3.2, this term is the effect on accuracy of the sensor due to seismic in the normal and post accident environment expressed as a percentage of span. The term is derived from the qualification test report or manufacturer published data and used to determine SA as a bias error.

Per Ref. 3.6.4 and 3.6.5, the SA for the wide range pressure transmitters after an OBE and Safe Shutdown Earthquake (SSE) is 0.5% URL.

SA(low range) = 0.5*(1000/1000) = ± 0.5 %

SA(high range) = 0.5*(3000/2200) = ± 0.682 % use ± 0.7 %.

Manufacturer's data for the seismic effects on the Westinghouse 7300 Process Rack signal bistable string are not available. Since the rack components are composed of electronic circuits with no mechanical or pneumatic moving parts, the seismic effects on the signal bistable string are considered negligible and are not included in the calculation. This is reinforced by analysis contained in Ref. 3.3.2.

SA for the Weed RTDs is considered negligible.

6.18 Other Effects

No other effects are considered to be significant for the preparation of this calculation.

6.19 CSA CALCULATIONS

The Channel Statistical allowances (CSA) for the wide range pressure loops per the equation in Reference 3.3.2 is shown below with siesmic effect added as a bias:

$$\mathrm{CSA} = \{(\mathrm{PMA})^2 + (\mathrm{PEA})^2 + [(\mathrm{SCA} + \mathrm{SMTE})^2 + (\mathrm{SD} + \mathrm{SMTE})^2 + (\mathrm{STE})^2 + (\mathrm{SPE})^2 + (\mathrm{SRA})^2]*(G_1)^2 + (\mathrm{RCA} + \mathrm{RMTE})^2 + (\mathrm{RD} + \mathrm{RMTE})^2 + (\mathrm{RTE})^2 + (\mathrm{OIA}_{\mathrm{PI}})^2\}^{1/2} + \mathrm{BIAS}*(G_1) = \%\ \text{of span}$$

where G_1 is the relative gain associated with the transmitter split ranges.

Note: Because the bistable signals are derived only from the low range transmitters correction to the 3000 psia span is not required.

The plant process computer CSA equations are meant to support a normal heat up/cooldown curve and therefore do not include any seismic effects. Any curve generated with these CSAs is not applicable for all plant conditions. The indicator CSAs do incorporate post seismic effects and and are applicable for all plant conditions.

It should be noted that portions of the rack effects (RCA and RD) used in the pressure bistable CSA equations are a combination of temperature and pressure rack errors. These values are in given terms of the pressure channel and cannot be separated out. These values were developed from historical operating data during the COPPS bistable calibration. This will be treated as a conservatism for the purposes of the calculation.

Pressure Bistable

$$\mathrm{CSA}_{\mathrm{BISTABLE}} = \{(0.0)^2 + (0.0)^2 + [(0.25 + 0.3)^2 + (0.6 + 0.3)^2 + (0.63)^2 + (0.0)^2 + (0.25)^2]*(1.0)^2 + (0.4 + 0.3)^2 + (0.3 + 0.3)^2 + (0.5)^2 + (0.0)^2\}^{1/2} + 0.5(1.0) = \%\ \text{of span}$$

$\mathrm{CSA}_{\mathrm{BISTABLE}} = 2.13$ % of 1000 psi span

Low Range Pressure Indication and Computer

The low range channel summing amplifier 3RCS*PY403C/405C has a gain (G) of (1000/3000) or 0.33. Each sensor term will be compensated for the gain value and is shown below:

$$\mathrm{CSA}_{0\text{-}3000\ \mathrm{psi\ IND}} = \{(0.0)^2 + (0.0)^2 + [(0.25 + 0.3)^2 + (0.6 + 0.3)^2 + (0.63)^2 + (0.0)^2 + (0.25)^2]*(0.33)^2 + (1.7 + 0.3)^2 + (1.5 + 0.3)^2 + (0.5)^2 + (1.7)^2\}^{1/2} + 0.5(0.33) = \%\ \text{of span}$$

$\mathrm{CSA}_{0\text{-}3000\ \mathrm{psi\ IND}} = 3.42$ % of 3000 psi span

$$CSA_{COMP\ IND} = \{(0.0)^2 + (0.0)^2 + [(0.25 + 0.3)^2 + (0.6 + 0.3)^2 + (0.63)^2 + (0.0)^2 + (0.25)^2]*(0.33)^2 + (0.3 + 0.3)^2 + (0.3 + 0.3)^2 + (0.5)^2 + (0.0)^2\}^{1/2} + 0.5(0.33) = \%\ \text{of span}$$

$CSA_{COMP\ IND}$ = 1.24 % of 3000 psi span

High Range Pressure Indication and Computer

The high range channel summing amplifier 3RCS*PY403G/405G has a gain (G) of (2200/3000) or 0.733. Each sensor term will be compensated for the gain value and is shown below:

$$CSA_{0\text{-}3000\ psi\ IND} = \{(0.0)^2 + (0.0)^2 + [(0.25 + 0.3)^2 + (0.3 + 0.3)^2 + (0.84)^2 + (0.0)^2 + (0.25)^2]*(0.733)^2 + (1.7 + 0.3)^2 + (1.5 + 0.3)^2 + (0.5)^2 + (1.7)^2\}^{1/2} + 0.7(0.733) = \%\ \text{of span}$$

$CSA_{0\text{-}3000\ psi\ IND}$ = 3.85% of 3000 psi span

$$CSA_{COMP\ IND} = \{(0.0)^2 + (0.0)^2 + [(0.25 + 0.3)^2 + (0.3 + 0.3)^2 + (0.84)^2 + (0.0)^2 + (0.25)^2]*(0.733)^2 + (0.3 + 0.3)^2 + (0.3 + 0.3)^2 + (0.5)^2 + (0.0)^2\}^{1/2} + 0.7(0.733) = \%\ \text{of span}$$

$CSA_{COMP\ IND}$ = 1.83% of 3000 psi span

Temperature Bistable, Indication and Computer

The CSA for the wide range temperature loops per the equation in Reference 3.3.2 is shown below:

$$CSA = \{(PMA)^2 + (PEA)^2 + [(SCA + SMTE)^2 + (SD + SMTE)^2 + (STE)^2 + (SPE)^2 + (SRA)^2 + (RCA + RMTE)^2 + (RD + RMTE)^2 + (RTE)^2 + (OIA_{PI})^2\}^{1/2} + BIAS = \%\ \text{of span}$$

The sensor wide range temperature terms are low auctioneered in order to select the lowest temperature reading out of four inputs. Since the sensor errors are treated as random errors, it is mathematically plausible to assume that the chance of all four inputs reading high at the same time is a one in sixteen chance (6%). Conversely, 94% of the time the sensor error will be in the conservative direction. However, standard practice dictates that the low auctioneering circuit be ignored and the uncertainty be treated as if it is a single sensor term feeding the loop.

The COPPS bistable is calibrated by selecting a single temperature input value and varying the pressure input. This data was tracked, compiled and used as input for the 95/95 drift analysis. Portions of the rack effects (RCA, RD and RTE) used in the temperature bistable CSA equations are a combination of temperature and pressure rack errors accounted for in the pressure bistable equation. These effects are accounted for in the COPPS pressure bistable CSA equation and therefore will not be reproduced in the COPPS temperature bistable CSA equation.

$CSA_{BISTABLE} = \{(2.0)^2 + (0.0)^2 + (0.3 + 0.3)^2 + (0.1 + 0.3)^2 + (0.0)^2 + (0.0)^2 + (0.4)^2 + (0.6 + 0.0)^2 + (0.3 + 0.0)^2 + (0.5)^2 + (0.0)^2\}^{1/2} + 0.0 =$ % of span

$CSA_{BISTABLE} = 2.32\%$ of 700 °F span

$CSA_{0\text{-}700\ °F\ IND} = \{(2.0)^2 + (0.0)^2 + (0.3 + 0.3)^2 + (0.1 + 0.3)^2 + (0.0)^2 + (0.0)^2 + (0.4)^2 + (1.5 + 0.0)^2 + (2.0 + 0.0)^2 + (0.5)^2 + (1.4)^2\}^{1/2} + 0.0 =$ % of span

$CSA_{0\text{-}700\ °F\ IND} = 3.62\%$ of 700 °F span

$CSA_{COMP\ IND} = \{(2.0)^2 + (0.0)^2 + (0.3 + 0.3)^2 + (0.1 + 0.3)^2 + (0.0)^2 + (0.0)^2 + (0.4)^2 + (0.4 + 0.0)^2 + (0.6 + 0.0)^2 + (0.5)^2 + (0.0)^2\}^{1/2} + 0.0 =$ % of span

$CSA_{COMP\ IND} = 2.33\%$ of 700 °F span

7.0 Design Verification

Design Review is the design verification method used in this calculation to provide assurance that the calculation is correct and satisfactory. Design Reviews were conducted at the discipline level. Concerns have been addressed and resolutions documented on attached DCM Forms (Form 5-1C), in accordance with DCM Chapter 4, Design Inputs and Design Verification, and DCM Chapter 5, Calculations.

		Bistable 0-1000 psi	Indicator 0-3000 psi	Computer 0-3000 psi
Low Range Press Trans				
PMA		0	0	0
PEA		0	0	0
SCA		0.25	0.25	0.25
SRA		0.25	0.25	0.25
SMTE		0.3	0.3	0.3
SD		0.6	0.6	0.6
STE		0.63	0.63	0.63
SPE		0	0	0
RCA		0.4	1.7	0.3
RMTE		0.3	0.3	0.3
RD		0.3	1.5	0.3
RTE		0.5	0.5	0.5
OIA		0	1.7	0
G1		1	0.333	0.333
BIAS		0.5	0.5	0.5
CSA Equation	% span	2.13	3.42	1.24

			Indicator 0-3000 psi	Computer 0-3000 psi
High Range Press Trans				
PMA		N/A	0	0
PEA		N/A	0	0
SCA		N/A	0.25	0.25
SRA		N/A	0.25	0.25
SMTE		N/A	0.3	0.3
SD		N/A	0.3	0.3
STE		N/A	0.84	0.84
SPE		N/A	0	0
RCA		N/A	1.7	0.3
RMTE		N/A	0.3	0.3
RD		N/A	1.5	0.3
RTE		N/A	0.5	0.5
OIA		N/A	1.7	0
G1		N/A	0.733	0.733
BIAS		N/A	0.7	0.7
CSA Equation	% span		3.85	1.83

Temperature Channel		Bistable 0-700 degF	Indicator 0-700 degF	Computer 0-700 degF
PMA		2	2	2
PEA		0	0	0
SCA		0.3	0.3	0.3
SRA		0.4	0.4	0.4
SMTE		0.3	0.3	0.3
SD		0.1	0.1	0.1
STE		0	0	0
SPE		0	0	0
RCA		0.6	1.5	0.4
RMTE		0	0	0
RD		0.3	2	0.6
RTE		0.5	0.5	0.5
OIA		0	1.4	0
G1		1	1	1
BIAS		0	0	0
CSA Equation	% span	2.32	3.62	2.33

ATTACHMENT B

Calculation Review Comment and Resolution Form

(Sheet 1 of 1)

Calculation Number: 94-ENG-1018 E3 **Revision:** 2 **CCN** N/A

Calculation Title: Millstone Unit 3 COOPS/PORV Loop Uncertainty

Calc. Originator: R N Burnham **Reviewer (PRINT):** WAYNE DARNELL

This form is intended to document significant comments and their resolutions. Typographical errors and other editorial recommendations may be marked up in the calculation text and presented to the originator

Review Type ☞ ☐**Interdiscipline** ☒**Independent**

Reviewer (SIGN) WAYNE DARNELL **Date:** 2/9/99

(signature signifies all comments have been resolved to your satisfaction)

Item	Page/Section	Comments	Response
		NO COMMENTS	

Approved 9-28-99 Effective 10-5-99

CALCULATION TITLE PAGE

Total Number of Pages: 38

Millstone 3: PORV Setpoint Curves for the Cold Overpressure System for 32 EFPY

TITLE

94-ENG-01042C3 ~~94-ENG-1042 C3~~ MB 5-1-01	4	RCS
CALCULATION No.	**Revision No.**	**System Name**

N/A	CS	3301	RXV
VENDOR CALCULATION No.	**Structure**	**System Number**	**Component**

N/A
VENDOR NAME

①

NUCLEAR INDICATOR: ☒CAT1 ☐RWQA ☐SBOQA ☐FPQA ☐ATWSQA ☐NON-QA	Safety Evaluation or Screen Attached ☐YES ☒NO	**Calc. Supports DCR/MMOD?** ☐YES ☒NO	**Calc. Supports Other Process?** ☒YES ☐NO

INCORPORATES:

CCN NO:	AGAINST REV.
1, 2, 3, 4, 5	3

N/A	PTSCR
DCR/MMOD No.	**Reference**
	TSCR 3-11-00

Executive Summary

This calculation establishes revised COPS setpoint curves for Unit 3 as well as summarizes operational restrictions while COPS is require to be operational. These revised curves are applicable through 32 EFPY and utilize revised beltline P/T limits which were developed using Code Case N-640. This revision incorporates revised instrumentation uncertainties. Note that this constitutes a major revision. CCN 1, 2, 3, 4, and 5 were incorporated.

This information will be used to prepare a Technical Specification Change Package and an exemption request.

RECD 4-16-01
ON HOLD 5-8-01 ~~4-10-01~~ MB 5/17/01
CDS
CDS QC
MDS

Approvals (Print & Sign Name)		
Preparer:Craig D. Stewart Craig D. Stewart		Date: 12/14/00
Interdiscipline Reviewer: Michael Hess M D Hess	Discipline: System Eng.	Date: 2/12/01
Interdiscipline Reviewer :	Discipline:	Date:
Independent Reviewer:Tom Steahr Thomas A. Steahr		Date: 1/2/01
Supervisor: N.P. SACCO		Date: 4/10/01

Installation Verification

☐ Calculation represents the installed configuration and approved licensing condition (Calculation of Record)

☐ N/A does not affect plant configuration (e.g., study, hypothetical analysis, etc.)

Preparer/Designer Engineer: (Print and Sign) Date:

FOR INFORMATION ONLY

DCM Form 5-1A
Rev. 7 Ch. 1
Page 1 of 1

Approved 9-28-99 Effective 10-5-99

PassPort DATABASE INPUTs

Page 2

MB 5-1-01

Calculation Number: ~~94-ENG-1042 C3~~ 94-ENG-01042C3 Revision: 4

Vendor Calculation Number/Other: N/A Revision: N/A

CCN # N/A QA ☒ Yes ☐ No Calc Voided: ☐ Yes ☒ No

Superseded By: N/A Supersedes Calc: N/A

Discipline (Up to 10) L, N

Unit (M1, M2, M3)	Project Reference (EWA, DCR or MMOD)	Component Id	Computer Code	Rev. No./ Level No.
M3	N/A	3RCS*REV1	N/A	N/A

①

PMMS CODES*					
Structure	System	Component	Reference Calculation MB 5-1-01	Rev No.	CCN
CS	RCS	VES	M3-LOE ~~284 EM~~ -00284EM	4	N/A
			97SDE ~~01535 M3~~ -01535M3	1	N/A
			94-ENG ~~1018 E3~~ -01018E3	2	1
			~~12179~~ NP(B)-208-FC	2	1, 2

*The codes required must be alpha codes designed for structure, system and component.

Reference Drawing	Sheet	Rev. No.
25212-26904	1	41
25212-26902	3	20
25212-26912	1	40
25212-29001	8005	1

Comments:

NOTE: Avoid multiple item references on a line, e.g., LT 1210 A-D requires four separate lines. ①

Table of Contents

1.0 OBJECTIVE

The purpose of this calculation is to develop revised power operated relief valve (PORV) setpoint curves for the Millstone Unit 3 cold overpressure protection system (COPS). This revision is made to update the setpoint curves to utilize the revised pressure/temperature (P/T) limits for the Millstone Unit 3 through 32 effective full power years (EFPY) of operation.

This calculation will also document the basis for using the residual heat removal (RHR) system relief valves for COPS and calculate a minimum vent size which will ensure the RCS is incapable of being pressurized above a predetermined value satisfying COPS. This calculation will use the most current instrument uncertainties.

Note, this revision is major and therefore revision bars have not been incorporated. CCN 1 through 5 of Revision 3 have been considered and where appropriate incorporated into this revision.

2.0 SCOPE

In general, this calculation ensures that the peak transient pressures due to postulated mass and energy transients which would potentially result in an overpressurization event do not exceed the appropriate limit. This calculation will identify the pressure relief mechanisms (i.e., PORV's , RHR relief valves, vents) and the limits which represent the controlling condition (i.e., reactor vessel beltline P/T limits, PORV discharge piping, etc.).

This calculation summarizes the transient overshoot and undershoot pressures associated with the limiting mass and energy addition transient. This information currently exists and will be used as input to the evaluation. These overshoot pressures are used in conjunction with operational restrictions required to ensure that an appropriate setpoint is established which ensures the applicable P/T limits are not exceeded. The applicable limits have typically already been developed and are design inputs to this calculation. This calculation will clarify operational restrictions necessary to achieve these goals. In addition, the undershoot pressures due to a PORV 2.0 second closure time will be used to review the minimum pressure to assess potential reactor coolant pump seal damage.

3.0 ASSUMPTIONS

3.1 Reactor coolant pump (RCP) operation will be assumed based upon the indicated cold leg temperature (T_C):

> During heatup, one RCP will be permitted to operate with $T_C \leq 160°F$. When $T_C > 160°F$, up to four RCP's may be operated.
>
> During cooldown, up to four RCP's can be operated while $T_C > 160°F$, one RCP may be operated with $T_C \leq 160°F$. (Note: operation of one RCP below 160°F down to the minimum boltup temperature was provided to permit greater flexibility and the intent to assist in cooling the steam generators down further prior to stopping the final RCP.)

Note: these pump restrictions affect the dynamic pressure losses between the vessel and the pressure instrument. This is an operational restriction affecting the final P/T values and needs to be consistent with operation.

3.2 The dynamic and static pressure differences between the pressure transducers in the hot legs and the pressure in the pressurizer PORV piping will be ignored. This is conservative for flow and no-flow conditions as the pressure would be significantly lower due to line losses and elevation head.

3.3 The reactor coolant pump (RCP) configuration (Reference 5.20) was reviewed to assess seal pressure relative to pump discharge pressure. Charging pump flow is normally introduced and travels both up the shaft to the no. 1 seal or down the shaft through the labyrinth seals and exits into the RCS flow region between the impeller and the diffuser. The pressure in the vicinity of the no. 1 seal is not known relative to the RCS discharge pressure. However, the pressure in the impeller discharge region should be higher than the suction side pressure.

This calculation will assume that the seal pressure is equal to pump discharge pressure since the seal region discharges into the RCS flow stream after the impeller. This would be an optimum situation. This would permit the flow induced (velocity head) pressure drop through the reactor vessel to be added to the PORV setpoint curve to represent the pressure at the pump discharge (seals).

To assess a more limiting condition, the pump seal pressure is assumed to be the same as that measured by the hot leg pressure transducer or no correction will be applied to the PORV setpoint curves to assess seal integrity.

Using both these approaches provide assurance to the degree of potential risk to seal integrity.

3.4 It is assumed that the main board indication of RCS Tcold, which may be used to determine when an RCP may be started or maintained in operation, is accurate. No main board indication instrument uncertainties need be included in the COPS setpoint curve. This assumption was previously justified in Rev. 3, CCN 003.

The justification provided was that the automatic actuation circuitry accounts for maximum temperature and pressure uncertainties. Due to the methodology of the setpoint development, the temperature at which the RCP's are started and or maintained in service can affect the PORV opening logic.

When the first RCP is started, a 50 °F temperature correction is added to account for the fact that during a heat injection transient, the RCS temperature indicators could see a higher Steam Generator secondary water side temperature due to the "slug" of primary side water inside the Steam Generator passing by the temperature element. An additional 17 °F was added to account for the PORV actuation loop uncertainty. This bounds the Plant Process Computer (PPC) where RCS temperature could be read. Although the PPC would most likely be used to start an RCP, there is no procedural requirement to do so. The main board indication could also be used for the same purpose.

The time which the plant would remain in this condition would be very limited due to the transient nature. The likely hood of an overpressurization transient occurring during this time frame is very low.

Additional justification was provided by Reference 5.10. It provides these additional points relative to RHR initiation which can be extrapolated to this application:

1. Indication of both the hot and cold leg temperature (one each per loop) is provided in the control room via main board indicators, main board recorders, and/or the PPC.
2. There are multiple instruments loops measuring the same parameters and the likelihood that they all would be at worst case conditions and all reading low at the same time is unlikely.
3. The multiple indications provide the operators with sufficient sources of information to determine if a specific instrument loop is malfunctioning and should be ignored.

This information was used in the previous submittal regarding the COPS setpoint curves in B16845 (Reference 5.26). Specifically, it stated that no main board indication needs to be considered and the assumption that it is accurate.

4.0 DESIGN INPUTS

4.1 Isothermal Reactor Vessel Beltline Pressure/Temperature Limits (Normal Operation), Ref. 5.1. These limits have no corrections applied and represent the isothermal beltline P/T limits developed using K_{Ic} and projected material irradiation damage through 32 EFPY (surface fluence = 1.97 x 10^{19} n/cm^2). Note that in this instance, protection of the actual limits, not indicated limits (TS limits), shall be used as the basis of establishing the setpoint curves.

Table 1
Isothermal Beltline Pressure/Temperature Limits (Uncorrected)

Fluid Temperature, °F	Allowable Pressure, psig
40	641.9
51	658.2
58	670.5
59	672.4
60	674.4
62	678.4
68	691.5
75	708.8
76	711.5
78	717.0
84	735.0
91	758.9
92	762.6
94	770.2
100	795.0
107	827.9
110	843.5
116	877.6
123	922.9
126	944.4
132	991.4
139	1054
142	1083
148	1148
155	1234
158	1248
168	1399
182	1669
200	2148
214	2660
230	3369

4.2 Thermal Hydraulic Pressure Correction

The maximum dynamic pressure differential between the mid-plane of the reactor vessel down comer region and the wide range pressure transmitter (located on the RHR piping) is:

One RCP Operation ΔP = 28.3 psi	(Reference 5.2)
Four RCP Operation ΔP = 74 psi	(Reference 5.3)

It has been demonstrated that the static elevation head can be ignored due to the location of the pressure sensor and the limiting reactor vessel material. This has been documented in Reference 5.4.

4.3 Pressure and Temperature Indicator Uncertainties (Reference 5.5)

Wide range temperature and pressure indication instrumentation probable error (uncertainty). These values will provide the worst case information and is based upon a 24 month fuel cycle. These values were obtained from the calculation of record, Reference 5.5.

The instrument uncertainty associated with wide range temperature indication loops 3RCS*TI413A/B and 3RCS*TI423A/B will be applied.

Temperature Uncertainty: 25.3 °F

The instrument uncertainty associated with wide range pressure indication loops 3RCS*PI403, 3RCS*PI403A and 3RCS*PI405, 3RCS*PI405A will be applied.

Pressure Uncertainty: 115.5 psia

4.4 Pressure and Temperature Uncertainties Associated with the PORVs 3RCS*PCV455 and 3RCS*456 (Reference 5.5)

The instrument loop associated with sensing cold/hot leg temperature is used to establish the PORV pressure. The maximum value is selected.

Temperature Uncertainty:	16.2 °F	(Temperature Bistable)
Pressure Uncertainty:	21.3 psia	(Pressure Bistable)

4.5 Plant Process Computer (PPC) Temperature Indication Uncertainties (Reference 5.5)

The uncertainty associated with establishing RCS temperature using the PPC is bounded by the wide range indication instrument uncertainty values. (See Section 4.3.)

PPC Temperature Uncertainty: 16.3 °F

4.6 PORV Overshoot (Reference 5.6)

The most recent predictions of PORV overshoot values due to mass and energy addition transients is provided by Reference 5.6. The overshoot values for the mass injection event are a function of mass injection flow rate and is independent of PORV setpoint. In the case of the heat injection transients, the overshoots are a function of both RCS/SG temperatures. This information is provided for 4 (N) loop and 3 (N-1) loop operation. The following provides a conservative consolidation of this information to be applied in the development of the setpoint curves.

Review of the mass injection event provides a maximum overshoot of 35 psi for the N-1 loop configuration. This value bounds N loop operation and all lower injection rates (< 550 gpm).

Review of the heat injection events provide a maximum overshoot of 49 psi for the N and N-1 loop configuration given a 50 °F temperature differential (SG hotter than the RCS) between the RCS and the steam generator with the RCS at 250 °F. This overshoot values is conservative for lower RCS temperatures where the SG temperature is no more than 50 °F hotter and for both N and N-1 loop configurations.

Based upon the previous information, bounding values were developed by adding the overshoot pressure to the correction and choosing the maximum for the specific defined temperature ranges. Note: the PORV opening time analyzed was 0.85 seconds considering mass and energy addition events.

Therefore, the overshoot values are as follows:

For RCS temperatures, $T \leq 250$ °F, ΔP above setpoint pressure = 49 psi
For RCS temperatures, $T > 250$ °F, ΔP above setpoint pressure = 35 psi

4.7 Adjustment of Gage Pressure to Absolute Pressure

The primary containment pressure is maintained below atmospheric pressure to minimize radioactive release in the event of an emergency. Containment pressure is maintained greater than or equal to 10.6 psia and less than or equal to 14.0 psia (Reference 5.7, page 3/4 6-7. The calculation of the allowable beltline pressure are based upon a differential or gage pressure. To adjust the resultant pressure, the minimum containment pressure permitted by Technical Specifications (10.6 psia) will be bound by 10 psia in lieu of adding normal atmospheric pressure of 14.7 psia. Consequently, an additional 10 psi will be added to the beltline pressures to obtain an absolute pressure.

4.8 PORV Piping Design Pressure (References 5.8 and 5.9)

Maximum Permissible Discharge Piping Pressure = 800 psi

4.9 Summary of Pertinent Energy and Mass Addition Transient Analyses Assumptions (Reference 5.6)

The maximum primary to secondary temperature differential is 50°F for the starting of the first idle reactor coolant pump.

Water solid conditions of the RCS were assumed.

4.10 COPS Enable Temperatures (Reference 5.1)

The development of COPS Enable Temperatures were performed using the guidance of ASME Boiler and Pressure Vessel Code, Section XI, Appendix G. The minimum required values for heatup and cooldown were developed which include the wide range instrument uncertainty. These values are summarized below.

Table 2
COPS Enable Temperatures through 32 EFPY

Unit 3 COPS Enable Temperatures through 32 EFPY (with instrument Uncertainty)	
Heatup	225.4 °F
Cooldown	219.5 °F

4.11 PORV Undershoot (Reference 5.6)

This calculation will evaluate the impact of a PORV opening on the integrity of the RCP seal. Based upon CCN 05, the PORV closure time which has been justified and analyzed is 2.0 seconds. Previous CCN's (1, 2 and 5) had addressed the impact of the PORV closing time increasing. The significance of the undershoot is that it can challenge RCP seal integrity should a PORV open due to a COPS transient. Therefore, it is prudent to attempt to establish a setpoint which provides low temperature overpressure protection of the reactor vessel (the limiting RCS component) and at the same time minimize the risk to equipment which may be affected.

To do this, one of the most beneficial attributes is to have as high as a setpoint as possible while still providing low temperature overpressure protection. Use of Code Case N-640 will provide the maximum fracture toughness thereby providing the least restrictive pressures for the selected heatup and cooldown rates. Another method to minimize undershoot are to have high mass input rates which is adverse to low temperature overpressure protection and would provide higher transient pressures and result in a lower setpoint curve and smaller operational window. Closure stroke time is another direct method of controlling the undershoot.

Given the current constraints, the maximum undershoot would be associated with the heat injection event as can be seen from Tables B and D of Reference 5.6. (Note, the maximum undershoot for mass addition would be 165 psi assuming the highest setpoint and full charging pump flow (approx. 550 GPM).) Review of Reference 5.6 provides the results of regression analyses which were performed to provide best estimate values of undershoot. These regression analyses are linear and are for either specific temperatures with the PORV setpoint being the variable or the for a constant PORV setpoint with the temperature being the variable. While the maximum undershoot of 239 psi for bounding conditions could be utilized, an initial evaluation provided unacceptable results. In lieu of the overly conservative and simple approach, the undershoot will be estimated using the results from the linear regression analysis. The approach will be to determine the undershoot due to the heat injection transient based upon the PORV setpoint at the specified temperatures. The N-1 loop configuration is controlling and will be used. Then based on the results at the specified temperatures, these undershoot values will be established for the setpoint temperatures based upon linear interpolation/extrapolation.

4.12 RCP Seal Integrity Requirements (Reference 5.11) ccn01

The RCP #1 seal pressure requirement is 200 psid (Refer to Westinghouse Product Update S-009, #1 Seal Normal Operating Range). Based on an RCS Pressure of 300 psia and a maximum backseat pressure of 100 psia in the seal return line, which is derived from the set pressure of the relief valve for the Volume Control Tank (VCT), results in an acceptable differential pressure of 200 psid across the seal.

For MP3, the actual set pressure for the VCT relief valve 3CHS*RV8120 is 85 psig (see P&ID 25212-26904, Sheet 1, Rev. 41, Reference 5.12) Thus, the seal integrity pressure is 285 psig or 300 psia. The normal operating pressure of the VCT is 15 to 60 psig (Reference 5.13). Thus, under normal operating conditions, with the VCT at 60 psig, the required RCS pressure can be 25 psia lower or 275 psia instead of 300 psia.

<u>5.0 REFERENCES</u>

5.1 NNECO Calculation M3-LOE-284-EM, Revision 4, "Millstone 3: Pressure/Temperature Limits for 32 EFPY."

5.2 Westinghouse Memo No. SE/FSE-NEU-0283, "Millstone COMS/LTOPS Consultation," dated November 11,1996.

5.3 Westinghouse Memo No. NEU-93-555, "Core Delta Pressure Estimate with One RCP Running," dated March 31, 1993

5.4 NUSCO Calculation 97SDE-01535-M3, Rev. 1, "Millstone U3: Appendix G and COPS Evaluation of RHR Initiation Transient w/Loss of Offsite Power," dated 12/19/00.

5.5 NUSCO Calculation 94-ENG-1018-E3, Rev. 2, "Millstone Unit 3 COPPS/PORV Loop Uncertainty," Revision 2 and CCN No. 1.

5.6 Westinghouse Memo No. NEU-98-083, "Northeast Utilities Service Company Millstone Unit 3, Revised Cold Overprotection System (COMS) Analysis Undershoot Study with 2 second PORV Stroke Close Time," dated November 5,1998.

5.7 MP3 Technical Specifications through Amendment.

5.8 Westinghouse Memo No. NEU-5595, "Northeast Utilities Service Company, Millstone Nuclear Power Unit No.3, COMS Design Transients," dated April 3, 1985.

5.9 Vendor Calculation No. 12179-NP(B)-208-FC, Pressurizer SRV Forcing Functions due to Steam Discharge," dated 2/10/98 and CCN 01 and 02.

5.10 Letter MP3-DE-97-1125, "RCS Temperature Measurement Uncertainties - RHR Initiation," dated August 18, 1997.

5.11 CCN 01 to NNECO Calculation No 94-ENG-1042 C3, Rev. 3, "Millstone 3: PORV Setpoint Curves for the Cold Overpressure Protection System for 10 EFPY," dated June 6, 1997.

5.12 P&ID 25212-26904, Sheet 1, Rev. 41, "Piping and Instrumentation Diagram, Chemical and Volume Control."

5.13 Westinghouse Letter NEU-1940

5.14 Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Limit Curves," Section XI, Division 1, Approval date 2/26/1999.

5.15 Regulatory Guide 1.84, "Design and Fabrication Code Case Acceptability, ASME Section III, Division 1," Rev. 31, dated May 1999.

5.16 ASME Boiler and Pressure Vessel Code, Section XI, Appendix G, "Fracture Toughness Criteria for Protection Against Failure," 1995 Edition.

5.17 Westinghouse Report WCAP-14040-NP-A, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves," dated January 1996.

5.18 NU Drawing 25212-26902 Sheet 3 of 6, Rev. 20, "Millstone Nuclear Power Station - Unit 3, Piping and Instrumentation Diagram, Reactor Coolant System."

5.19 NNECO Memo NME-SD-97-171, "Millstone Unit No. 3, Impact of Lower PORV Setpoint Curves on the RCP Seal Integrity," dated April 14, 1997.

5.20 NU Drawing 25212-29001 sheet 8005, Rev. 01, "General Assembly Reactor Coolant Pump."

5.21 ERC 25212-ER-97-016, Rev. 0, "Verification of RHS Suction Relief Valve Capacity," dated February 3, 1997.

5.22 Millstone III Plant Design Data System Line Designation Table.

5.23 "Flow of Fluids Through Valves, Fittings, and Pipe," CRANE Technical Paper No. 410.

5.24 WCAP 11640, Rev. 0, "Cold Overpressure Mitigation System Deletion Report," dated March 1988.

5.25 NU Drawing 25212-26912, Sheet 1, Rev. 40, "Millstone Nuclear Power Station - Unit 3, Piping and Instrumentation Diagram, Low Pressure Safety Injection."

5.26 NU Letter to the NRC, B16485, dated November 14, 1997.

5.27 Westinghouse Calculation SAE/FSE-C-NEU-0020, NU Calc. No. 98ENG-01608-M3, Rev. 0, "Millstone 3 COMS Cold Shutdown Vent Sizing."

6.0 METHOD OF ANALYSIS

6.1 COPS Setpoint Development

6.1.1 Setpoint Curves Based Upon Beltline Pressure/Temperature Limits

The development of the P/T limits was based ASME Section XI Code Case N-640 (Reference 5.14) which permits the reference fracture toughness curve, K_{IC}, as found in Appendix A of Section XI, in lieu of K_{IR}, Figure G-2210-1 in Appendix G. It is important to recognize that 10 CFR 50.55a acknowledges Regulatory Guide 1.84 (Reference 5.15) which contains those Code Cases which are approved for use. In this instance, Code Case N-640 is not approved for use and requires specific approval by the Office of Nuclear Reactor Regulation. Following submittal and upon issuance of an SER from the NRC, the results of this calculation will be acceptable to utilize in normal plant operation. In addition, 10 CFR 50.55(b)(2) permits the use of Section XI including editions through 1995 Edition and addenda through 1996 (subject to the limitations defined of which none apply).

ASME Section XI, Appendix G (Reference 5.16) recommends LTOP systems limit the pressure in the vessel to 110% of the beltline P/T limits. However, the guidance provided by Code Case N-640 recommends LTOP systems limit the pressure in the vessel to 100% of the beltline P/T limits when K_{Ic} is used. Therefore, the reactor vessel pressures will not be permitted to exceed 100% of the beltline P/T limits. The beltline P/T which will be protected are those associated with the isothermal condition as low temperature overpressure events have historically been isothermal. This approach has been supported by Westinghouse and the NRC as documented in WCAP-14040-NP-A, Reference 5.17.

The approach taken by Westinghouse and previously used in the setpoint development is to have staggered setpoints for each valve (i.e., a low and high setpoint curve). This approach will permit one valve to relieve the transient without excessive undershoot which would occur if both valves were to open simultaneously. It also addresses single failure as if the first valve fails to open the second valve opening setpoint has also been selected to protect the isothermal curve. The primary focus of the PORV setpoint curve is to provide protection from overpressurizing the reactor vessel. That is, the PORV are intended to be overpressure protection for the NSSS components. This is consistent with WCAP-14040-NP-A (Reference 5.17) and the SER which states that the setpoint selection shall provide protection against the upper limit and shall take precedence over the lower limit (minimum RCS pressure associated with the RCP seals).

The COPS is an automatic system which utilizes existing temperature elements to monitor RCS temperature in combination with pressure transmitters to monitor pressure. The COPS setpoint curves provides pressure as a function of temperature. If the system pressure exceeds the setpoint pressure for the specific temperature, a signal is generated to open the PORV. As such no operator action is required to open the valves.

A temperature uncertainty of 16.2 °F associated with the temperature bistable as described in Section 4.4 will be considered. Main Board indication and PPC temperature uncertainties are not considered. As discussed in Section 3.4, no instrument uncertainty is necessary to account for the start of an RCP. The pressure uncertainty associated with the instrumentation of 21.3 psia will be applied.

To establish the high setpoint curve consideration of instrument uncertainty, RCP operation to account for dynamic pressure effects, and PORV overshoot will be included. The high setpoint curve will use one times the valve overshoot. The same consideration will be given to the development of the low setpoint curve. However, the development of the low setpoint curve will use two times the valve overshoot to accomplish staggered setpoints.

In addition, since the PORV setpoint circuitry is based upon an automated system, when an RCP is started it is possible for the temperature instrument to read up to 50 °F higher due to the steam generator being permitted to be as much as 50 °F above the RCS temperature (design basis transient). If this were to occur without considering this effect, the PORV setpoint would automatically be adjusted upward without the vessel having an adequate time to respond (increase in temperature). Consequently, the curve will also be adjusted by adding an additional 50 °F to account for this.

6.1.2 PORV Discharge Piping

Review of the loadings for the PORV discharge piping show that the maximum pressurizer pressure assumed was 800 psia (@350°F) for water discharge (Reference 5.9). To ensure that the COPS setpoint curve maintains this piping qualification assumption, the setpoint will be established ensuring that 800 psia pressurizer pressure is not exceeded. Utilizing the maximum overshoot and instrument uncertainty will insure that the pressurizer pressure is not exceeded. Note, due to the location of the pressure sensor (hot legs) it is conservative to ignore the flow induced pressure drop through the vessel and is appropriate for no flow conditions.

6.1.3 Composite COPS Setpoint Curves

Composite curves are generated considering the controlling pressure from the beltline COPS setpoint curve and the PORV discharge piping curve. These curves are plotted as a function of temperature and pressure. Note that these curves are only required at temperature less than or equal to the enable temperature. The maximum enable temperature associated with heatup or cooldown is plotted along with the setpoint curves to depict the PORV setpoint window.

6.2 Minimum Vent Size to Insure Overpressure Protection

Once the RCS is depressurized, an adequate size vent exposed to the containment atmosphere will maintain the RCS at pressures below the Appendix G limits during a design basis COPS event. To establish this requirement, it is assumed that the one of the PORV's are removed form the line. Since the design basis for the COPS events include the single failure of one PORV to open, it is known that this line is capable of mitigating the design basis transients with the valve in place.

Westinghouse developed the minimum vent area required for COPS in Reference 5.27. This was performed due to the replacement of the PORV block valves under DCR M3-97007 (Reference 5.28). These replacement block valves had a smaller inside diameter than the previously installed valves. Review of Reference 5.27, provided several cases which would satisfy the overpressure protection requirements. The following summary is provided:

1) Removal of a PORV with the newly installed valve will limit pressure to 61.2 psig given the maximum charging flow of 560 GPM. The flow area is 3.976 in^2 and is based upon the block valve flow diameter of 2.25 inches.
2) Removal of a PORV with a minimum flow area of 2.0 in^2 will limit pressure to 139.9 psig given the maximum charging flow of 560 GPM. The flow area 2.0 in^2 is based upon a postulated block valve flow diameter of 1.596 inches.
3) Removal of a PORV with a minimum flow area of 1.022 in^2 will limit pressure to 500 psig given the maximum charging flow of 560 GPM. The flow area 1.022 in^2 is based upon a postulated block valve flow diameter of 1.141 inches.

The three cases are based upon a depressurized RCS which is consistent with establishing an RCS vent. The mass addition event was the only COPS transient considered. The energy addition event was deemed incredible as the RCS is depressurized with an open vent and the start of an RCP is governed by procedure.

The minimum vent size selected for Technical Specifications will be the 2.0 in^2. This will limit the pressure to 139.9 psig which is less than the minimum beltline pressure and is also less than the RHR system relief valve setpoint of 440 psig (Reference 5.25).

6.3 Reactor Coolant Pump Seal Integrity Assessment

The issue of RCP seal damage due to a COPS design basis event was identified due to pressure falling back down below the setpoint value and the PORV taking a finite length of time to stroke closed. During the time it takes the valve to close the pressure continues to decrease. If the RCS pressure drops below 300 psia, it is possible to damage the seal cartridge (References 5.19). While seal damage is not desired, it is important to recognize that the primary purpose of the cold overpressure protection system is to ensure that the brittle fracture limits of the ferritic RCS materials (the reactor vessel is the limiting component) are not exceeded during the limiting design basis transients. RCP seal integrity will be reviewed in this calculation to identify if the seals may be challenged to ensure that proper controls are identified by procedure to minimize this risk.

To assess this event, the undershoot values due to the mass and energy addition events have been provided by Reference 5.6 and summarized in Section 4.11. The specific undershoot values have been calculated assuming a two second closure time and are a function of the PORV setpoint and RCS temperature (Reference 5.6). To assess the impact of the PORV opening, the potential pressures during the event will be conservatively established considering N-1 loop operation and compared to the minimum pressure of 300 psia.

It should be noted that the pressure transducer are on instrument lines which are off two of the hot legs between the reactor vessel and the steam generator. The setpoint curves established to protect the vessel account for the dynamic losses through the vessel. There were no static elevation corrections required due to the location of the pressure transducer relative to the reactor vessel beltline. In the case of the RCP's seals, the primary side pressure is better represented by RCP discharge pressure (See assumption 3.3). The dynamic pressure losses used to protect the reactor vessel while the RCP's are operating are not necessary. However, when there is no flow, the pressure in the vessel is approximately the same pressure at the RCP (neglecting any small elevation differences). Consequently, flow induced corrections are not required to protect the RCP seals. The dynamic pressure differences which were subtracted to develop the setpoint curve to protect the reactor vessel will added back to the setpoint pressure. In addition the effect of the dynamic head will be considered assuming that the pump seal pressure is the same as provided by the hot leg pressure transducer This will be addressed for the low setpoint curve (the most restrictive curve) and resultant pressure will be compared to the minimum RCP seal pressure of 300 psia considering the pressure undershoot.

6.4 Review of RHR Relief Valve Capability for COPS Use

At reduced RCS temperatures, the residual heat removal (RHR) system is aligned to the RCS to continue the cooldown process as cooling the plant through steaming the steam generators becomes less effective. The RHR system contains pressure relief valves which are designed to protect the RHR system from overpressurization. Since alignment of the RHR relief valves to the RCS can be established, these valve provide an additional means of providing low temperature overpressure protection to the RCS. In order to credit use of these valves, it is necessary to establish the relief capacity of the valves, the setpoint of the valves and the valve accumulation. In addition, any differences in pressure between the RHR relief valve and reactor vessel should be considered.

RHR relief valve capacity has been reviewed and established in Reference 5.21. This memo conclude that the relief valve and piping is adequate to mitigate the limiting LTOP transient. Utilizing this information, the maximum pressure will be calculated and compared to the most restrictive isothermal reactor beltline pressure (the limiting RCS component).

7.0 BODY OF CALCALCULATION

7.1 COPS Setpoint Development

7.1.1 Setpoint Curves Based Upon Beltline Pressure/Temperature Limits

Development of the COPS setpoint curve will need to encompass both heatup and cooldown scenarios. Consistent with the assumption regarding reactor coolant pump (RCP) operation, heatup and cooldown usage is the same providing identical flow induced pressure losses. Again for heatup and cooldown, the pump operation is summarized as:

> During heatup and cooldown, one RCP will be permitted to operate with $T_C \leq 160°F$. When $T_C > 160°F$, up to four RCP's may be operated.

Based upon the RCP operation, the maximum dynamic pressure differential between the mid-plane of the reactor vessel down comer region and the wide range pressure transmitter (located on the RHR piping) is:

One RCP Operation $\Delta P = 28.3$ psi	(Reference 5.2)
Four RCP Operation $\Delta P = 74$ psi	(Reference 5.3)

To accommodate either 4 loop or 3 loop operation, the more conservative overshoot values associated with 3 and 4 loop operation will be used.

Values to be applied, developed from the combination of 3 and 4 loop values and consideration of both mass and energy transients:

For temperatures, $T \leq 250°F$, ΔP above setpoint pressure = 49 psi
For temperatures, $T > 250$ °F, ΔP above setpoint pressure = 35 psi

Instrumentation uncertainty will also be considered in the establishment of the setpoint curve. The values associated with COPS are as follows:

Temperature Bistable = 16.2 °F   Pressure Bistable = 21.3 psia

To accommodate the PORV temperature circuitry (temperature bistable) inaccuracy a bounding value of 17.0 °F will be used. The temperature correction of 17 °F is applied first. The following Table summarizes the pressure corrections to be applied to generate the high and low COPS setpoint curve based upon the beltline P/T limits and the corresponding temperature ranges. Table 3 was generated based upon the preceding input.

Table 3
Summary of **Independent** Pressure Correction vs. RCS Temperature

Temperature, °F	No. of RCP's	ΔP flow, psi	Overshoot, psi	Pressure Instrument Inaccuracy, psi	Adjustment to Obtain Abs. Pressure, psi
T ≤ 160	1	28.3	49.0	21.3	10
160 < T ≤ 250	4	74	49.0	21.3	10
T > 250	4	74	35.0	21.3	10

Table 4
Summary of **Total** Pressure Correction Factors for **High** Setpoint Curve vs. RCS Temperature

Temperature, °F	Combination of Pressure Correction Factors, psi	Total Pressure Correction, psi
T ≤ 160	-28.3-49.0-21.3+10	-88.6
160 < T ≤ 250	-74-49.0-21.3+10	-134.3
T > 250	-74-35.0-21.3+10	-120.3

Table 5
Summary of **Total** Pressure Correction Factors for **Low** Setpoint Curve vs. RCS Temperature

Temperature, °F	Combination of Pressure Correction Factors, psi	Total Pressure Correction, psi
T ≤ 160	-28.3-(2*49.0)-21.3+10	-137.6
160 < T ≤ 250	-74-(2*49.0)-21.3+10	-183.3
T > 250	-74-(2*35.0)-21.3+10	-155.3

Table 6
COPS High Setpoint Curve Determination For Beltline

Fluid Temperature, °F (Uncorrected)	**Fluid Temperature, °F (Corrected)**	Allowable Pressure, psig (Uncorrected)	**PORV Allowable Setpoint Pressure, psig (Corrected)**
40[1]	**57** (40 + 17)	641.9	**553.3** (641.9- 88.6)
40[1]	**107** (40 + 17 + 50)	641.9	**553.3** (641.9- 88.6)
51	**118** (51 + 17 +50)	658.2	**569.6** (658.2 - 88.6)
58	**125** (58 + 17 +50)	670.5	**581.9** (670.5 - 88.6)
59	**126** (59 + 17 +50)	672.4	**583.8** (672.4 - 88.6)
60	**127** (60 + 17 +50)	674.4	**585.8** (674.4 - 88.6)
62	**129** (62 + 17 +50)	678.4	**589.8** (678.4 - 88.6)
68	**135** (68 + 17 +50)	691.5	**602.9** (691.5 - 88.6)
75	**142** (75 + 17 +50)	708.8	**620.2** (708.8 - 88.6)
76	**143** (76 + 17 +50)	711.5	**622.9** (711.5 - 88.6)
78	**145** (78 + 17 +50)	717.0	**628.4** (717.0 - 88.6)
84	**151** (84 + 17 +50)	735.0	**646.4** (735.0 - 88.6)
91	**158** (91 + 17 +50)	758.9	**670.3** (758.9 - 88.6)
92	**159** (92 + 17 +50)	762.6	**674.0** (762.6 - 88.6)
93[2]	**160**(93 + 17 +50)		**677.8** (766.4 - 88.6)
93.1[2]	**160.1**(93.1 + 17 +50)		**632.5** (766.8 - 134.3)
94	**161** (94 + 17 +50)	770.2	**635.9** (770.2 - 134.3)
100	**167** (100 + 17 +50)	795.0	**660.7** (795.0 - 134.3)
107	**174** (107 + 17 +50)	827.9	**693.6** (827.9 - 134.3)
110	**177** (110 + 17 +50)	843.5	**709.2** (843.5 - 134.3)
116	**183** (116 + 17 +50)	877.6	**743.3** (877.6 - 134.3)
123	**190** (123 + 17 +50)	922.9	**788.6** (922.9 - 134.3)
126	**193** (126 + 17 +50)	944.4	**810.1** (944.4 - 134.3)
132	**199** (132 + 17 +50)	991.4	**857.1** (991.4 - 134.3)
139	**206** (139 + 17 +50)	1054	**919.7** (1054 - 134.3)
142	**209** (142 + 17 +50)	1083	**948.7** (1083 - 134.3)
148	**215** (148 + 17 + 50)	1148	**1013.7** (1148 - 134.3)
155	**222** (155 + 17 + 50)	1234	**1099.7** (1234 - 134.3)
158	**225** (158 + 17 + 50)	1248	**1113.7** (1248 - 134.3)
168	**235** (168 + 17 + 50)	1399	**1264.7** (1399 - 134.3)
182	**249** (182 + 17 + 50)	1669	**1534.7** (1669 - 134.3)
183[2]	**250** (183 + 17 + 50)		**1561.3** (1695.6 - 134.3)
183.1[2]	**250.1** (183 + 17 +50)		**1578.0** (1698.3 - 120.3)
200	**267** (200 + 17 + 50)	2148	**2027.7** (2148 - 120.3)
214	**281** (214 + 17 + 50)	2660	**2539.7** (2660 - 120.3)
230	**297** (230 + 17 + 50)	3369	**3248.7** (3369 - 120.3)

1 - This value represents the minimum boltup temperature (uncorrected) which lowest temperature the reactor vessel can be tensioned and pressurized.

2 - This value was generated by linear interpolation to accommodate changes in the applied correction factors at the specific temperatures.

Table 7
COPS Low Setpoint Curve Determination For Beltline

Fluid Temperature, °F (Uncorrected)	**Fluid Temperature, °F (Corrected)**	Allowable Pressure, psig (Uncorrected)	**PORV Allowable Setpoint Pressure, psig (Corrected)**
40[1]	**57** (40 + 17)	641.9	**504.3** (641.9- 137.6)
40[1]	**107** (40 + 17 + 50)	641.9	**504.3** (641.9- 137.6)
51	**118** (51 + 17 + 50)	658.2	**520.6** (658.2 -137.6)
58	**125** (58 + 17 + 50)	670.5	**532.9** (670.5 -137.6)
59	**126** (59 + 17 + 50)	672.4	**534.8** (672.4 -137.6)
60	**127** (60 + 17 + 50)	674.4	**536.8** (674.4 -137.6)
62	**129** (62 + 17 + 50)	678.4	**540.8** (678.4 -137.6)
68	**135** (68 + 17 + 50)	691.5	**553.9** (691.5 -137.6)
75	**142** (75 + 17 + 50)	708.8	**571.2** (708.8 -137.6)
76	**143** (76 + 17 + 50)	711.5	**573.9** (711.5 -137.6)
78	**145** (78 + 17 + 50)	717.0	**579.4** (717.0 - 137.6)
84	**151** (84 + 17 + 50)	735.0	**597.4** (735.0 - 137.6)
91	**158** (91 + 17 + 50)	758.9	**621.3** (758.9 - 137.6)
92	**159** (92 + 17 + 50)	762.6	**625.0** (762.6 - 137.6)
93[2]	**160** (93 + 17 +50)		**628.8** (766.4 - 137.6)
93.1[2]	**160.1** (93.1+17+50)		**583.5** (766.8 - 183.3)
94	**161** (94 + 17 + 50)	770.2	**586.9** (770.2 - 183.3)
100	**167** (100 + 17 + 50)	795.0	**611.7** (795.0 - 183.3)
107	**174** (107 + 17 + 50)	837.9	**644.6** (827.9 - 183.3)
110	**177** (110 + 17 + 50)	843.5	**660.2** (843.5 - 183.3)
116	**183** (116 + 17 + 50)	877.6	**694.3** (877.6 - 183.3)
123	**190** (123 + 17 + 50)	922.9	**739.6** (922.9 - 183.3)
126	**193** (126 + 17 + 50)	944.4	**761.1** (944.4 - 183.3)
132	**199** (132 + 17 + 50)	991.4	**808.1** (991.4 - 183.3)
139	**206** (139 + 17 + 50)	1054	**870.7** (1054 - 183.3) ✓
142	**209** (142 + 17 + 50)	1083	**899.7** (1083 - 183.3) ✓
148	**215** (148 + 17 + 50)	1148	**964.7** (1148 - 183.3) ✓
155	**222** (155 + 17 + 50)	1234	**1050.7** (1234 - 183.3) ✓
158	**225** (158 + 17 + 50)	1248	**1064.7** (1248 - 183.3) ✓
168	**235** (168 + 17 + 50)	1399	**1215.7** (1399 - 183.3) ✓
182	**249** (182 + 17 + 50)	1669	**1485.7** (1669 - 183.3) ✓
183[2]	**250** (183 + 17 + 50)		**1512.3** (1695.6✓- 183.3)
183.1[2]	**250.1** (183 + 17 +50)		**1543.0** (1698.3✓- 155.3)
200	**267** (200 + 17 + 50)	2148	**1992.7** (2148 - 155.3)
214	**281** (214 + 17 + 50)	2660	**2504.7** (2660 - 155.3)
230	**297** (230 + 17 + 50)	3369	**3213.7** (3369 - 155.3)

1 - This value represents the minimum boltup temperature (uncorrected) which lowest temperature the reactor vessel can be tensioned and pressurized.

2 - This value was generated by linear interpolation to accommodate changes in the applied correction factors at the specific temperatures.

7.1.2 PORV Discharge Piping

The PORV discharge piping has been designed for two phase flow with a water solid pressurizer at a maximum pressure of 800 psia. To ensure that this condition is not exceeded, the maximum PORV overshoot of 39 psi and the instrumentation uncertainty of 21.3 psi shall be subtracted to establish the high setpoint curve. The low setpoint curve will be established the same way with two times the PORV overshoot.

High Setpoint

Required PORV Setpoint for PORV Discharge Piping =
800 psia - 21.3 psid - 49 psid = 729.7 psia

Low Setpoint

Required PORV Setpoint for PORV Discharge Piping =
800 psia - 21.3 psid - 2*49 psid = 680.7 psia

Note that this pressure does not include any pressure losses through the upstream piping and the upstream valves nor does it include any elevation differences or dynamic losses. Use of this pressure is conservative to ensure the limiting piping pressure is met. This pressure applies at all temperatures.

7.1.3 Composite COPS Setpoint Curves

Each of the high and low setpoint curves for the beltline are over laid with the PORV discharge piping pressure. The lower bound values of the two curves at temperatures below the enable temperatures (Heatup = 225.4 °F, Cooldown = 219.5 °F) represents the composite setpoint curve. The following figures are a graphical representation of the comparison using the conservative enable temperature of 225.4 °F.

Figure 1
Composite PORV High Setpoint Curve

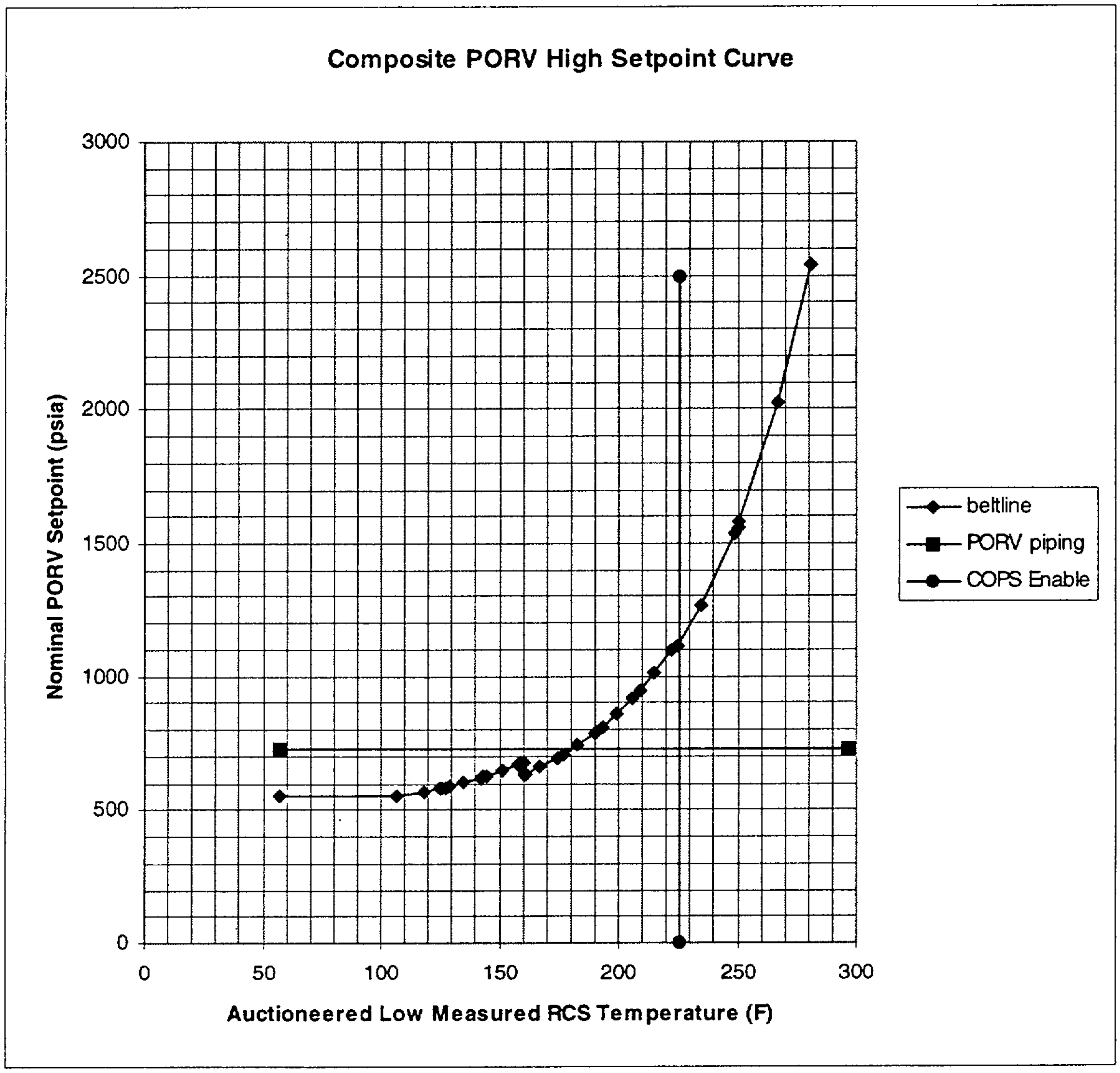
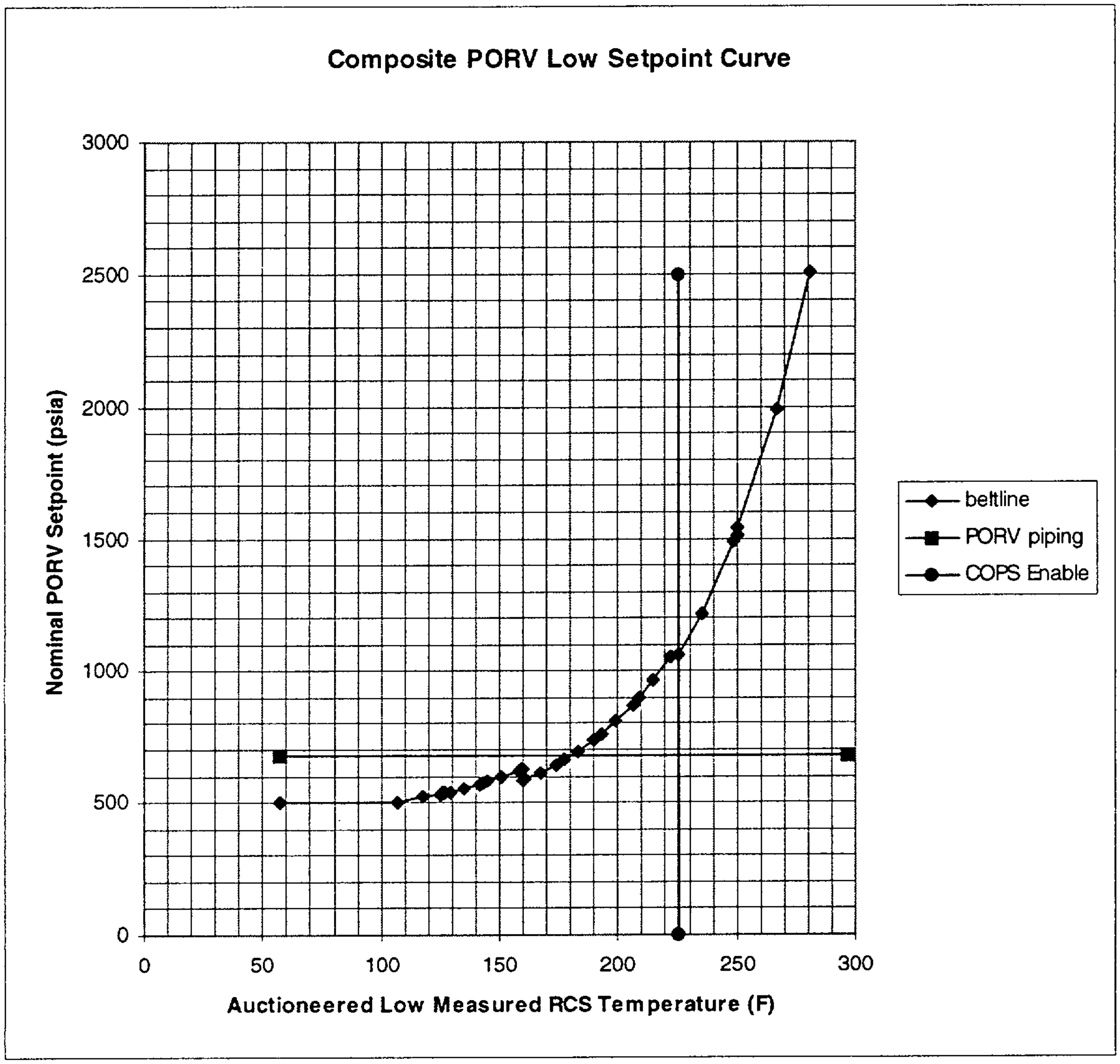


Figure 2
Composite PORV Low Setpoint Curve



7.2 Minimum Vent Size to Insure Overpressure Protection

The PORV's are located on line 3-RCS-003-69-1 and 3-RCS-003-67-1 (Reference 5.18). These pipes are 3 inch schedule 160 (Reference 5.22). The block valves upstream of the PORV's provide the most restrictive flow area of 3.976 in^2 based upon a block valve flow diameter of 2.25 in (Reference 5.27).

Analysis demonstrate that removal of a PORV with a minimum flow area of 2.0 in^2 will limit pressure to 139.9 psig at the low core support plate given the maximum charging flow of 560 GPM. The flow area 2.0 in^2 is based upon a postulated block valve flow diameter of 1.596 inches. (The actual valve configuration will provide a maximum pressure of 61.2 psig.)

The reduced area will provide some flexibility should it be necessary to vent through a different path. Engineering analysis will be necessary to justify the alternate path and the associated peak pressure. This calculation does not provide this justification.

This area also ensures the pressure does not exceed the RHR system relief valve pressure of 440 psig (Reference 5.25 locations A-7 and C-3). This ensures that the pressure does not challenge the RHR system should a COPS event occur.

7.3 Reactor Coolant Pump Seal Integrity

The lower bound composite PORV low setpoint curve was identified in Figure 2. It is represented by the lower portion of the beltline COPS curve and the COPS setpoint curve to protect the PORV piping. To identify the risk associated to the seals, it is necessary to evaluate the undershoot from the PORV setpoint curve.

Based upon linear interpolation, the beltline low setpoint curve is intersected by the PORV piping setpoint curve at 180.6 °F (corrected temperature). Above this point the setpoint is limited by the PORV piping setpoint pressure of 680.7 psia.

Based upon Reference 5.6 (see section 4.11), the undershoot is a function of setpoint pressure, number of operating loops and RCS temperature ($\Delta T = 50$ °F). The maximum undershoot occurs for the N-1 loop configuration and will be used as a bounding condition. Subtracting the value from the setpoint curve will provide the pressurizer pressure. In addition, the dynamic pressure difference is added back to the PORV setpoint curve allowable pressure (Corrected). The dynamic pressure difference values as a function of temperature were identified in Table 5.

To determine the undershoot, a review of Reference 5.6, Tables B and D were performed. This review clarified that the heat addition event provides the controlling conditions. That is the mass injection event will be encompassed by evaluating the heat addition events. To do this, the linear regression results provided by Reference 5.6 page 3 and 4 were used. Again, the N-1 (3) loop configuration provides conservative results relative to N (4)-loop operation. Two formulas are provided, one providing the undershoot as a function of the setpoint for defined temperatures and the second providing the undershoot as a function of temperature for defined setpoint values. The approach chosen to determine the undershoot was to utilize the formula for undershoot as a function of PORV setpoint and the low setpoint curve (temperature versus PORV setpoint pressure). Undershoot was calculated at temperatures enveloping the setpoint temperature. Linear interpolation between the two undershoot values to obtain the specific value at the setpoint temperature.

The following expression was used as provided by Reference 5.6:

Undershoot = M*setpoint +B, where; M = slope and B = intercept

The following table provides the results of the regression analysis to be used for N-1 loop operation, also provided by Reference 5.6.

Undershoot as a Function of Setpoint: N-1 loop Operation

RCS Temperature (°F)	Slope (M)	Intercept (B)
70	0.223	81.8
100	0.201	72.7
150	0.163	86.2
200	0.188	69.8
250	0.189	65.0
300	0.156	67.9

To assess the impact of the PORV opening, the potential RCS pressures resulting form the undershoot will be conservatively established considering N-1 loop operation and compared to the minimum pressure of 300 psia.

The following example is provided for 118°F and a PORV setpoint of 520.6 psia.

Using the formula, the undershoot will be calculated at 100°F and 150°F for the PORV setpoint of 520.6 psia.

Undershoot (@100°F) = 0.201* 520.6 + 72.7 = 177.3 psi
Undershoot (@150°F) = 0.163* 520.6 + 86.2 = 171.1 psi

Linear interpolation provides an undershoot at 118°F of 175.1 psi.

The resulting RCS pressure can be computed by subtracting the undershoot from the setpoint and adding the flow induced pressure difference.

520.6 psia -175.1 psi + 28.3 psi = 373.8 psia

Since this pressure exceeds the desired pressure of 300 psia, a seal integrity issue is not expected.

Note that the entire setpoint curve was not evaluated as the controlling region is at the lowest temperatures.

Table 8
Pump Pressure @ RCP due to Undershoot

Fluid Temperature, °F (Corrected)	**PORV Allowable Pressure, psig (Corrected)**	**Undershoot (psi)**	**Pressure @ RCP, psig**
57	504.3	**203.0**	**329.6** (504.3 - 203.0+ 28.3)
107	504.3	**173.3**	**359.3** (504.3 - 173.3+ 28.3)
118	520.6	**175.1**	**373.8** (520.6 - 175.1+ 28.3)
125	532.9	**176.4**	**384.8** (532.9 - 176.4+ 28.3)
126	534.8	**176.6**	**386.5** (534.8 - 176.6+ 28.3)
127	536.8	**176.9**	**388.2** (536.8 - 176.9+ 28.3)
129	540.8	**177.3**	**391.8** (540.8 - 177.3+ 28.3)
135	553.9	**178.8**	**403.4** (553.9 - 178.8+ 28.3)
142	571.2	**180.6**	**418.9** (571.2 - 180.6+ 28.3)
143	573.9	**180.9**	**421.3** (573.9 - 180.9+ 28.3)
145	579.4	**181.5**	**426.2** (579.4 - 181.5+ 28.3)
151	597.4	**183.5**	**442.2** (597.4 - 183.5+ 28.3)
158	621.3	**187.3**	**462.3** (621.3 - 187.3+ 28.3)
159	625.0	**187.9**	**465.4** (625.0 - 187.9+ 28.3)
160	628.8	**188.6**	**468.5** (628.8 - 188.6+ 28.3)
160.1	583.5	**180.9**	**476.6** (583.5 - 180.9 + 74)
161	586.9	**181.5**	**479.4** (586.9 - 181.5 + 74)

Review of the results show that the predicted pressure at the pump would not be expected to fall below approximately 330 psia. This maintains approximately 30 psi (330 - 300) margin to the minimum RCP seal pressure of 300 psia.

As a second check, if the dynamic head was not accounted for, there would be a reduction in the margin down to 1.3 psi, (the existing margin minus the velocity head or 29.6 psi - 28.3 psi).

In both cases, margin exists between the predicted RCS pressure and the desired RCS pressure of 300 psia. These are both conservative estimates of the available margin. To assure equipment protection, credit could be taken to account for normal operation pressure of the VCT providing additional margin of approximately 25 psi to assure that the necessary seal differential pressure of 200 psid was maintained.

7.4 Review of RHR Relief Valve Capability for COPS Use

Heat Addition Transient

The design basis heat addition transient for MP3 is the start of an RCP with an RCS temperature as high as 150 °F and the steam generators as high as 200 °F (Reference 5.24, page 13-2). A single RHR relief valve with a capacity of at least 470 GPM would maintain the peak pressure below the valve accumulation pressure (Reference 5.24, page 13-2). Since the flow capacity of an RHR relief valve is 560 GPM (Reference 5.21), the valve accumulation pressure will not be exceeded.

Mass Addition Transient

The design basis mass addition transient for MP3 is the maximum flow from a single charging pump (Reference 5.24, page 13-3). The relief capacity of the RHR relief valve must be greater that the maximum flow from a single charging pump. A charging pump flow has a maximum flow rate of 560 GPM (Reference 5.24, page 3/4 5-6). Since the flow capacity of an RHR relief valve is 560 GPM, the valve accumulation pressure will not be exceeded.

Peak Pressure at the Reactor vessel Beltline

The peak pressure at the reactor vessel beltline is equal to the sum of the accumulation pressure of the RHR relief valve plus the ΔP between the valves and the vessel.

$SP = 440$ psig The valve setpoint (Reference 5.25 locations A-7 and C-3)

$ACC = SP*10\%$ The accumulation

$ACC = 44$ psi

$\Delta P = 63$ psi The ΔP between the RHR suction relief valves and the vessel beltline due to elevation head, frictional losses and velocity head (Reference 5.2). Note that this ΔP is for temperatures below 200 °F. For a fixed setpoint relief valve the only temperature of interest is at the lowest temperature (Approx. 70 °F) since, by inspection of the beltline pressure/temperature limits, the allowable pressure increases exponentially with increasing temperature. The controlling allowable pressure from Reference 5.1 is 658.2 psig.

$P = SP + ACC + \Delta P$

$P = 547$ psig

Note that the 3% tolerance on valve setpoint is not explicitly accounted for in the calculation of peak pressure at the reactor vessel beltline. This is because Westinghouse analysis models the valve as commencing to open at the setpressure plus the 3% tolerance, and full open at the set pressure plus 10% accumulation (Reference 5.24, page 10-2).

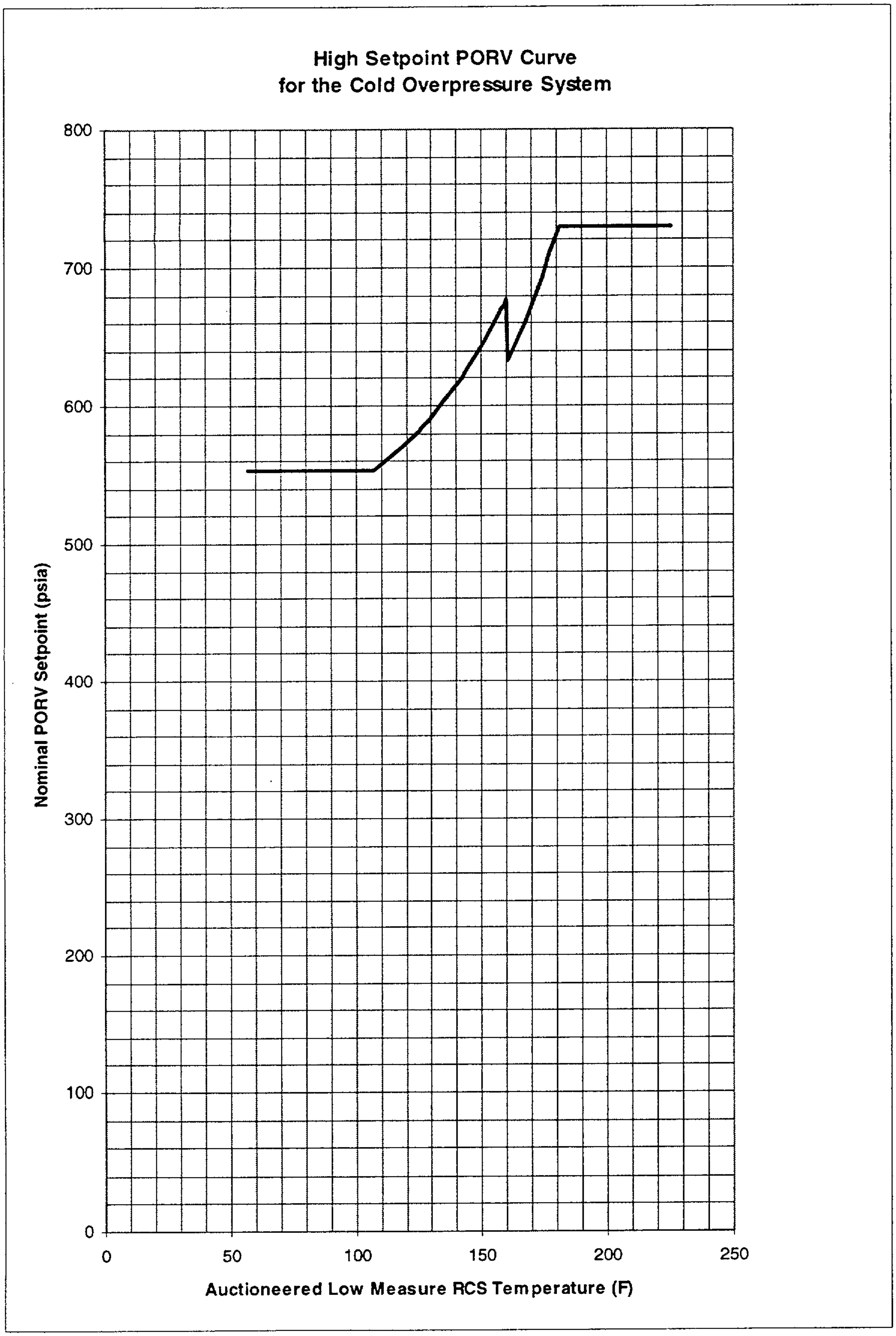
8.0 RESULTS

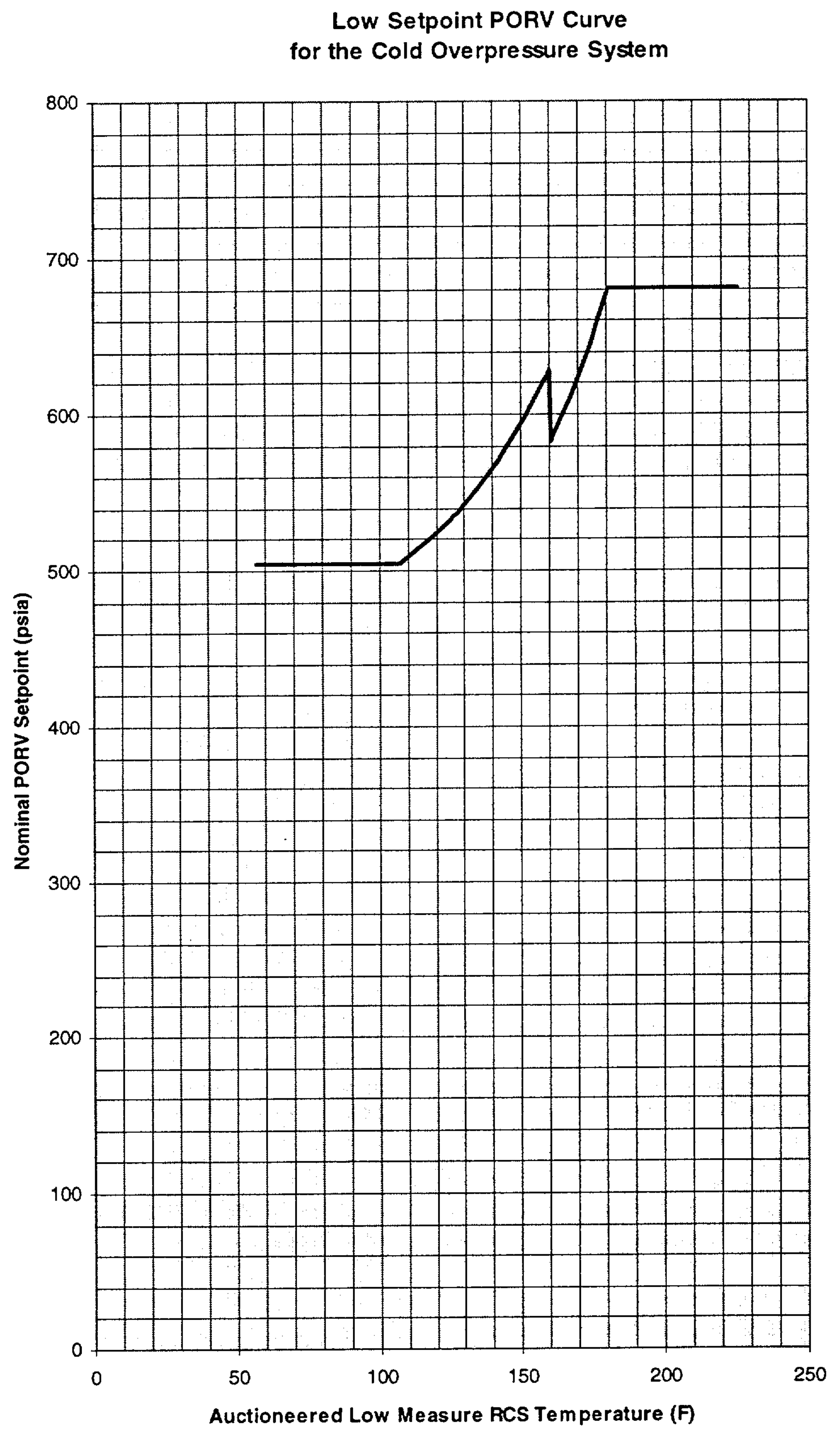
8.1 COPS Setpoint Figures for Technical Specifications

The PORV setpoint curve for use during COPS operation has been developed using the isothermal beltline P/T limits considering a reactor vessel beltline fluence of 1.97×10^{19} n/cm^2, E > 1.0 MeV (Reference 5.1) which corresponds to 32 EFPY. In addition, the setpoint curve also considers the design conditions associated with the PORV discharge piping relative to this mode of operation. These setpoint curves represent the maximum pressure versus temperature for use in the Technical Specifications. These curves have been developed up to the minimum enable temperatures. It should be noted that the pressure resulting from the COPS setpoint curve may be less restrictive than the RCS P/T limits associated with heatup and cooldown while in the COPS region. Administrative controls should be implemented to ensure that the RCS P/T heatup and cooldown limitations are not exceeded. In addition, once above the minimum enable temperatures, the pressure should again be administratively controlled to ensure that the appropriate RCS P/T limits are not exceeded. When establishing the actual setpoint, pressure values which are lower than the setpoint curves are acceptable although the potential for seal damage is increased as the undershoot increases with reduced setpoints and there is currently very little margin.

The COPS enable temperatures for heatup and cooldown were 225.4 °F and 219.5 °F for heatup and cooldown respectively. Note that the Technical Specification figures have considered the bounding value of 225.4 °F for both heatup and cooldown.

Note that the beltline P/T limits were developed using Code Case N-640 which requires an exemption request and NRC approval prior to implementation.


High Setpoint PORV Curve
for the Cold Overpressure System
Nominal PORV Setpoint (psia)
800
700
600
500
400
300
200
100
0
0
50
100
150
200
250
Auctioneered Low Measure RCS Temperature (F)


Low Setpoint PORV Curve
for the Cold Overpressure System
Nominal PORV Setpoint (psia)
800
700
600
500
400
300
200
100
0
0
50
100
150
200
250
Auctioneered Low Measure RCS Temperature (F)

8.2 Minimum Vent Size to Insure Overpressure Protection

The minimum vent size shall be 2.0 in^2 and will be established by removing one of the PORV's (valves). This will ensure that the peak pressure does not exceed the isothermal beltline P/T limit.

8.3 Reactor Coolant Pump Seal Integrity

Reactor coolant pump seal integrity was reviewed to assess the potential to have seal damage due to a COPS event and the transient would result in a reduced RCS system pressure given a finite length of time for the PORV to close. It has been concluded that the undershoot pressures resulting from the COPS design basis transient and a 2.0 second closure stroke time pose no challenge to RCP seal integrity. There are no restrictions required to ensure RCP seal integrity during an RCP pump start other than the limitations imposed based upon the design basis transient assumptions.

8.4 Review of RHR Relief Valve Capability for COPS Use

Use of the RHR relief suction valve have been shown capable of providing the requisite protection during the COPS mode of operation. Use of these valves by themselves or in conjunction with the PORV's will provide adequate relief. A combination of two valves must be used at all times.

One constraint regarding the RHR valves currently exists and is summarized by the design basis statement as follows:

The design basis heat addition transient for MP3 is the start of an RCP with an RCS temperature as high as 150 °F and the steam generators as high as 200 °F (Reference 5.24, page 13-2). A single RHR relief valve with a capacity of at least 470 GPM would maintain the peak pressure below the valve accumulation pressure (Reference 5.24, page 13-2). Since the flow capacity of an RHR relief valve is 560 GPM (Reference 5.21), the valve accumulation pressure will not be exceeded.

8.5 Summary of Pertinent Operational Restrictions

The results of this calculation identify the necessary requirements to provide adequate low temperature overpressure protection with the Cold Over Pressurization System at Unit 3. Discussion of RCP seal integrity issues are also provided.

The maximum number of permissible operating reactor coolant pumps as a function of corresponding reactor vessel inlet temperature are as follows for heatup and cooldown:

Table 9
RCP Operation for Normal Heatup and Normal Cooldown

No. of RCP's Operating	Cold Leg Temperature Range, T_c, °F, Indicated
1	$T_c \leq 160$
4	$T_c > 160$

The design basis transients were assumed to be water solid. Adequate relieving capacity will be established in the case of a steam bubble in the pressurizer. It is beneficial to operate with a steam bubble as it provides a cushion and operator action time in comparison to water solid operation.

The PORV stroke time open/close of 0.85/2.0 seconds has been assumed. The open time is critical for ensuring that the peak transient pressure does not exceed the applicable limit. In the case of the closure time, this value is used to review undershoot relative to RCP seal integrity. This stroke time conservatively provides approximately 30 psi margin between the minimum seal pressure of 300 psia and the minimum RCS pressure. An increase in the stroke time will increase the undershoot and may challenge RCP seal integrity. In addition, administratively reducing the setpoint at the low pressures (<503.0 psig, 300 psig required for RCP operation plus 203.0 psi maximum undershoot) will further increase the risk of seal damage. A reduced setpoint will also result in greater undershoot have a cumulative effect on the risk to the RCP seals. Note that the primary purpose of the PORV's is to provide overpressure protection to the ferritic boundary components and this attribute shall receive precedence.

Only one charging pump is permitted while below the COPS enable temperature. The analysis assumption was full or non-throttled charging flow. Reductions in charging flow will result in lower peak transient pressures but will also provide greater setpoint undershoot which may challenge RCP seal integrity.

While the PORV's are being used for low temperature overpressure protection, the maximum temperature for the start of the first idle RCP is 250 °F. The steam generators were assumed to be 50°F hotter than the RCS for the energy addition analysis. In the case when an RHR relief valve is being used for low temperature overpressure protection, the maximum temperature for the start of the first idle RCP is 150 °F. Again, the steam generators were assumed to be 50°F hotter than the RCS for the energy addition analysis

The isothermal beltline P-T limit and the PORV discharge piping form the basis for establishing the PORV setpoint curve. It should be noted that the pressure resulting from the COPS setpoint curve may be less restrictive than the RCS P/T limits associated with heatup and cooldown while in the COPS region. Administrative controls should be implemented to ensure that the RCS P/T heatup and cooldown limitations are not exceeded. In addition, once above the minimum enable temperatures and with no automatic protection from the PORV's, the pressure should again be administratively controlled to ensure that the appropriate RCS P/T limits are not exceeded.

Calculation Review Comment and Resolution Form

(Sheet 1 of 1)

Calculation Number: 94-ENG-1042 C3 Revision: 4 CCN N/A

Calculation Title: Millstone 3: PORV Setpoint Curves for the Cold Overpressure System for 32 EFPY

Calc. Originator: Craig Stewart Reviewer (PRINT): Tom Steahr

This form is intended to document significant comments and their resolutions. Typographical errors and other editorial recommendations may be marked up in the calculation text and presented to the originator

Review Type ☐ **Interdiscipline** ☒ **Independent**

Reviewer (SIGN) Thomas A Steahr Date: 9/6/00

(signature signifies all comments have been resolved to your satisfaction)

Item	Page/Section	Comments	Response
		No significant comments, only minor editorial comments	Incorporated

Calculation Review Comment and Resolution Form

(Sheet 1 of 2)

Calculation Number: 94-ENG-1042 C3 Revision: 4 CCN NA

Calculation Title: Millstone 3 PORV Setpoint Curves for the Cold Overpressure System for 32 EFPY

Calc. Originator: Craig D. Stewart Reviewer (PRINT): Michael D. Hess

This form is intended to document significant comments and their resolutions. Typographical errors and other editorial recommendations may be marked up in the calculation text and presented to the originator

Review Type ☐ XInterdiscipline ☐Independent

Reviewer (SIGN) ______ Date: ______

(signature signifies all comments have been resolved to your satisfaction)

Item	Page/Section	Comments	Response
1	5 of 35/3.1	Refueling schedulers might want to run RCPs below 120F to facilitate the cool-down.	PT limit calc. revised to permit RCP operation down to min. boltup temp. Carried forward into this calc.
2	14 of 35/6.1.1	The third paragraph implies that the PORV set-point curves are different to prevent both valves from opening at once. My understanding from the last calculation was that the curves were different to accommodate different instrument uncertainties applied to either loop due to different pressure instrument manufacturers.	Per Mike Hess: Don Asay verified that the instruments were changed-out and now have similar instrument uncertainties. No change to the calculation is required.
3	15 of 35/6.1.1	Second paragraph from the top, first sentence does not appear to be a sentence.	Corrected sentence
4	16 of 35/6.2	Second paragraph assumes the pipe size to be the limiting flow area for a pressurizer vent. A subsequent change made the block valves the limiting flow area. Westinghouse Calculation SAE/FSE-C-NEU-0020 documents that the actual required area is 2.0 square inches. Please change the Technical Specification from 5.4 square inches to 2.0 square inches. Also this calculation needs to be changed from 5.4 square inches to the block valve area, Sections 7.2 and 8.2.	The subject calculation was reviewed. In fact, a vent area of 1.022in² is adequate for COPS and limits pressure to 500psig. The 2.0 in² vent size will limit pressure to ~140psig satisfying COPS as well as concern for other aligned systems. Will incorporate 2.0 in².

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Calculation Review Comment and Resolution Form (Continued)

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Item	Page/Section	Comments	Response
5	18 of 35/7.1.1	The last paragraph identified an instrument uncertainty to be applied to the operator's decision for the correct temperature to start an RCP.. However, section 3.4 states that "the main board indication to RCS T-cold, which may be used to determine when an RCP may be started or maintained in operation, is accurate. It appears the Section 7.1.1 is overly conservative.	⑤ Clarification has been added to the text. Instrument Uncertainty due the the operator using the main board instruments off PPC have not been included.
6	32 of 35/8.3	Add note that seal damage at reduced pressure is an economic concern and not a safety concern.	⑥ The current TS and Licensing perspective requires that the RCP seals be protected making it a safety issue. This will be addressed as part of the license amendment request and is not really appropriate at this time. Not addressed.