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Michael R. Kansler
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May 28, 2003
NL-03-093

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Mail Stop O-P1-17
Washington, DC 20555-0001

SUBJECT: Indian Point Nuclear Generating Unit No.3
Docket No. 50-286
Proposed Changes to Technical Specifications:
Pressure-Temperature and Overpressure Protection
System Limits for Up To 20 Effective Full Power Years

REFERENCES:

(1) NRC letter to Mr. James Knubel, "Indian Point Nuclear Generating Unit No. 3 – Issuance of Amendment re: Extension for Pressure/ Temperature Limit Curves and Overpressure Protection System Setpoints (TAC No. MA8813)", dated October 5, 2000.

(2) NRC letter to Mr. Michael Kansler, "Indian Point Nuclear Generating Unit No. 3 – Issuance of Amendment re: 1.4 Percent Power Uprate (TAC No. MB5297)", dated November 26, 2002.

(3) NRC letter to Mr. James Knubel, "Issuance of Amendment for Indian Point Nuclear Generating Unit No. 3 (TAC No. M99928)", dated April 10,1998.

Dear Sir:

Pursuant to 10 CFR 50.90, Entergy Nuclear Operations, Inc, (ENO) hereby requests the following amendment to the Operating License for Indian Point 3 Nuclear Generating Unit No.3.

This amendment request seeks to revise Figure 3.4.3-1; Figure 3.4.3-2; Figure 3.4.3-3; Section LCO 3.4.7 Note 3; Section LCO 3.4.10 Applicability and Required Action B.2; Section LCO 3.4.12 Note, Applicability, Required Action C.1.1, Required Action E.2.1, SR 3.4.12.6 Note, SR 3.4.12.8 Note 1 and SR 3.4.12.9 Note 1; Figure 3.4.12-1; Figure 3.4.12-2; Figure 3.4.12-3 and Figure 3.4.12-4 of the Indian Point 3 Technical Specifications. Specifically, the Pressure-Temperature (P/T) and Overpressure Protection System (OPS) limits are being revised from 16.17 Effective Full Power Years (EFPYs) to 20 EFPYs. Reference 1 contained a SER which approved a 16.2 EFPYs limit (Amendment 202). The current limit of 16.17 EFPYs was approved by Amendment 213 (Reference 2). The limit was reduced from 16.2 to 16.17 EFPYs as part of the Appendix K uprate package that was approved by Reference 2. The expiration date reduction was due to the higher power rating, not due to a change in vessel embrittlement analysis methodology.

Attachment I provides the analysis of the proposed change to the Technical Specifications. Attachment II provides a markup of the Technical Specifications and Bases for the changes. The Bases changes that appear in Attachment II are being provided for information purposes, only. Attachment III provides the Westinghouse technical analysis, "Final Report on Pressure-Temperature Limits for Indian Point Unit 3 NPP, Rev.1". Attachment III provides a report

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by Westinghouse describing the work that Westinghouse performed in support of updating the Pressure-Temperature limits including the methodologies they used. Attachments IV and V provide the Entergy Nuclear Operations Inc. documents, "Technical Evaluation for Revision to Pressure-Temperature Curves – Indian Point Unit 3 Nuclear Power Plant" and "Calculation IP3-CALC-RCS-02444 Rev 2 – Generation of Pressure/Temperature Curves in the Technical Specifications", respectively. Attachment IV provides an ENO summary of the total effort involved in establishing new heatup and cooldown curves, new OPS curves, revised expiration criteria, incorporation of revised instrument uncertainties and other technical details associated with the revised expiration criteria. Attachment V provides a copy of an ENO calculation which uses the information from Attachment III to revise the seven figures that are being changed, as discussed in Attachment I.

An exemption from 10 CFR Part 50, Section 50.60(a) and Appendix G is being submitted separately. The new proposed Indian Point 3 P/T and OPS curves were developed using Code Case N-640, which modifies the methods of ASME Code Section XI, Appendix G. The NRC has approved similar exemption requests allowing the use of Code Case N-640 for several nuclear plants including Indian Point Unit No. 2, Calvert Cliffs, Brunswick, Fort Calhoun and Monticello. The only aspect of Code Case N-514 allowed by Code Case N-640 is to determine the OPS enable temperature. The P/T and OPS limits themselves are determined exclusively using the Code Case N-640 methodology.

The proposed Technical Specification changes still utilize the Westinghouse/Combustion Engineering methodology and Code Case N-514 (as applied to OPS enable temperature derivation) with the major difference being that Code Case N-514 has been incorporated into Reg. Guide 1.147, Rev. 12. Therefore, an exemption to use Code Case N-514 is not necessary. The Westinghouse/ Combustion Engineering methodology was previously approved by the NRC for Indian Point 3 (Reference 3).

The proposed change has been evaluated in accordance with 10 CFR 50.91 (a)(1) using the criteria of 10 CFR 50.92 (c) and ENO has determined that this proposed change involves no significant hazards considerations. The bases for these determinations are included in the attached submittal.

Indian Point 3 is currently operating with Technical Specification requirements, which are valid up to 16.17 EFPYs. Indian Point 3 is expected to exceed 16.17 EFPYs approximately November 30, 2003. Therefore, approval of this proposed amendment is requested by November 15, 2003 to allow time for amendment implementation.

There are no new commitments identified in this letter. If you have any questions, please contact Ms. Charlene Faison at 914-272-3378.

I declare under penalty of perjury that the foregoing is true and correct. Executed on 05/28/03

Very truly yours,

Michael Kansler
President
Entergy Nuclear Operations, Inc.

Attachments:

I. Analysis of Proposed Technical Specification Change
II. Proposed Technical Specification and Bases Changes (markup)
III. Westinghouse report "Final Report on the Pressure-Temperature Limits for Indian Point Unit 3 NPP", WCAP-16037, Rev. 1
IV. "Technical Evaluation for Revision to Pressure-Temperature Curves – Indian Point Unit 3 Nuclear Power Plant", Entergy Nuclear Operations, Inc.
V. ENO calculation "Calculation IP3-CALC-RCS-02444 Rev 2 – Generation of Pressure/Temperature Curves in the Technical Specifications"

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ATTACHMENT I

ANALYSIS OF PROPOSED

TECHNICAL SPECIFICATION CHANGES REGARDING

PRESSURE-TEMPERATURE AND OVERPRESSURE PROTECTION

SYSTEM LIMITS

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NO. 3
DOCKET NO. 50-286

1.0 DESCRIPTION

This submittal is a request to amend Operating License DPR-64, Docket No. 50-286 for Indian Point Nuclear Generating Unit No. 3.

This amendment request seeks to revise several pages of Section 3.4, including figures, of the Indian Point 3 Technical Specifications. Specifically, the Pressure-Temperature (P/T) and Overpressure Protection System (OPS) limits are being revised from16.17 Effective Full Power Years (EFPYs) to 20 EFPYs. The previous limit of 16.2 EFPYs was approved by the NRC in Amendment 202 (Reference 1) and was adjusted to 16.17 EFPYs, in Amendment 213 (Reference 2) to support the Appendix K uprate effort. The expiration date reduction was due to higher power rating, not due to a change in vessel embrittlement methodology. An explicit list of changes is contained in Section 2.0 below.

2.0 PROPOSED CHANGES

A. Indian Point 3 Technical Specification Figures 3.4.3-1, 3.4.3-2 and 3.4.3-3, currently state:

"...for the service period up to 16.17 EFPY,..."

The proposed amendment will revise the curves (included in Attachment II), and the above statement contained on all three figures to read:

"...for the service period up to **20** EFPY,..."

B. Indian Point 3 Technical Specification Figures 3.4.3-1, 3.4.3-2 and 3.4.3-3 currently state:

"RT_{NDT} After 16.17 EFPY: ¼ T = 214 Deg F
¾ T = 172 Deg F"

The proposed amendment will revise the above statement contained on all three figures to read:

"RT_{NDT} After **20** EFPY: ¼ T = **230.1** Deg F
¾ T = **188.8** Deg F"

The above statement will, also, be moved to another location on Figures 3.4.3-1 and 3.4.3-3. Also, the 'Material Properties basis" information is being relocated on Figures 3.4.3-1 and 3.4.3-3.

C. Indian Point 3 Technical Specification Figures 3.4.3-1, 3.4.3-2 and 3.4.3-3 currently state:

"<u>Pressure:</u> 43 psi for $0 \leq P \leq 1500$ psig,..."

The proposed amendment will revise the above statement to read:

"<u>Pressure:</u> **37** psi for $0 \leq P \leq 1500$ psig,..."

D. The reference to "1989 psig @ 348.0°F" is being eliminated from Figure 3.4.3-3. Also, "@ 367°F" will be changed to "@ **340**°F" on Figure 3.4.3-3.

E. Indian Point 3 Technical Specification Figure 3.4.12-1 is entitled, in part:

"...PORV Setpoint for LTOP (OPS), 16.17 EFPY"

The proposed amendment will revise the curve (included in Attachment II), and, the above statement to read:

"...PORV Setpoint for LTOP (OPS), **20** EFPY"

"**20 EFPY**","**OPS Enable Temperature 319°F**" and " **Note: OPS Enable Temperature includes an allowance of 14.4°F for instrument uncertainty and margin.**" are, also, being added to Figure 3.4.12-1.

F. Indian Point 3 Technical Specification Figures 3.4.12-2 and 3.4.12-3, are entitled, in part:

"Pressurizer Limitations for OPS Inoperable, 16.17 EFPY..."

The proposed amendment will revise the curves, and, the titles of both figures to read:

"Pressurizer Limitations for OPS Inoperable, **20** EFPY..."

G. Indian Point 3 Technical Specification Figures 3.4.12-2 and 3.4.12-3 currently state:

"Figure applicable to 16.17 EFPY"

The proposed amendment will revise both Figures to read:

"Figure applicable to **20** EFPY"

H. Indian Point 3 Technical Specification Figures 3.4.12-2 and 3.4.12-3 currently state:

"Pressure: 43 psi"

The proposed amendment will revise both Figures to read:

"Pressure: **37** psi"

Also, the instrument uncertainty listing is being relocated on Figures 3.4.12-2 and 3.4.12-3.

I. Indian Point 3 Technical Specification Figure 3.4.12-4, is entitled, in part:

"...Primary Side, 16.17 EFPY"

The proposed amendment will revise the curve and the title of Figure 3.4.12-4 to read:

"...Primary Side, **20** EFPY"

Also, Figure 3.4.12-4 has been revised to read:

"Curve includes a primary/secondary temperature **instrument uncertainty** allowance of 36°F"

J. BASES changes to complement the aforementioned proposed Technical Specification changes are also being made and are provided in Attachment II. The changes include adding WCAP-16037, Rev 1 to two locations as references. Also, the Appendix G limit of 411°F (the point at which pressurizer safety valves protect Appendix G limits) is being revised to 380°F(the same point as calculated under the revised methodology). In addition, a discussion regarding the criticality curve is being deleted because ENO procedures and other LCOs (LCO 3.4.2) prohibit criticality below 540°F. This restriction makes the criticality limit, as established in Attachment IV, unnecessary and possibly confusing. Therefore, for the purpose of clarity, the paragraph will be deleted.

3.0 BACKGROUND

This Technical Specification (TS) amendment proposes to revise the Effective Full Power Years (EFPY) limit associated with the Pressure-Temperature (P/T) and Overpressure Protection System (OPS) curves. The P/T limit curves define an acceptable region for normal plant operation. They limit the pressure and temperature changes during Reactor Coolant System (RCS) heatup and cooldown to within the design assumptions and the stress limits for cyclic operation.

The low temperature overpressurization protection (LTOP) system controls reactor coolant system (RCS) pressure at low temperatures so the integrity of the reactor coolant boundary is not compromised by violating the pressure and temperature limits of 10 CFR 50, Appendix G. The current Indian Point 3 Technical Specifications associated with RCS heatup and cooldown are based on a designated expiration date of 16.17 EFPYs which corresponds to a calculated limiting Adjusted Reference Temperature (ART) of 214°F at the1/4 vessel thickness and 172°F at the 3/4 vessel thickness. The proposed amendment seeks to revise this limit to 20 EFPYs which corresponds comparably to a calculated ART of 230.1°F at the ¼ vessel thickness and 188.8°F at the ¾ vessel thickness. The analysis is based on the current rated thermal power of 3067.4 MWt, with allowances for normal core peripheral flux variations from cycle to cycle.

4.0 TECHNICAL ANALYSIS

The P/T limits were developed per the requirements of 10 CFR 50 Appendix G. This appendix describes the requirements for developing the P/T limits and provides the general basis for these limitations. The margins of safety against fracture provided by the P/T limits using the requirements of 10 CFR Part 50, Appendix G are equivalent to those recommended in the ASME Boiler and Pressure Vessel Code Section III, Appendix G. The general guidance provided in those procedures has been utilized to develop the Indian Point 3 P/T limits with the requisite margin of safety for the heatup and cooldown conditions.

The Reactor Pressure Vessel beltline P/T limits were based upon the irradiation damage prediction methods of Regulatory Guide 1.99, Revision 2. This methodology has been used to calculate the limiting material Adjusted Reference Temperatures (ART) for Indian Point 3.

The crack initiation reference stress intensity factor K_{IC} was utilized for determining the fracture toughness of the beltline. The use of K_{IC} as the basis for establishing the reference fracture toughness limit, K_{IR}, value for the vessel is currently outlined in ASME Code Case N-640. An exemption request to use Code Case N-640 is being submitted separately.

The P/T limits for the reactor vessel, were evaluated in accordance with 10 CFR 50 Appendix G for two representative points in the RPV life time corresponding to 15 and 34.7 EFPYs The events analyzed are the isothermal 20, 50, 80 and 100°F/hr cooldown conditions and the isothermal 20, 40 and 60°F/hr heatup conditions. These conditions were analyzed to provide a database of thermal results for use in establishing LTOP enable/disable temperatures. Included in the events analyzed is the in–service hydrostatic test. Based on the P/T limit analyses, no limiting values are anticipated to be reached for the reactor vessel service life up to 31.4 EFPYs. Therefore, the expiration date of all the curves cannot exceed 31.4 EFPYs. The expiration limit was further reduced to 20 EFPYs to retain the OPS enable temperature of 319°F. It should be noted that the current limit of 319°F was based on an actual enable temperature of 289°F plus 30°F instrument uncertainty. As shown in Attachment V the revised instrument uncertainty for the OPS enable temperature is 14.4°F. Therefore, the new expiration date is based is based on an actual enable temperature of 304.6°F plus 14.4°F instrument uncertainty. The analysis that calculates the 20 EFPYs can be found in Attachment IV and V.

Attachment III provides a copy of the Westinghouse report entitled, "Final Report on Pressure-Temperature Limits for Indian Point Unit 3 NPP". Attachment III provides a report by Westinghouse describing the work that Westinghouse performed in support of updating the Pressure-Temperature limits including the methodologies they used. Attachment IV contains a copy of an Entergy Nuclear Operations, Inc. (ENO) analysis entitled "Technical Evaluation for Revision to Pressure-Temperature Curves – Indian Point Unit 3 Nuclear Power Plant". Attachment IV provides an ENO summary of the total effort involved in establishing new heatup and cooldown curves and the new OPS curves, among other changes. Also, Attachment V transmits the ENO calculation entitled "Calculation IP3-CALC-RCS-0244 Rev 2 – Generation of Pressure/ Temperature Curves in the Technical Specifications". Attachment V provides a copy of an ENO calculation which uses the information from Attachment III to revise the seven figures that are being changed, as discussed in Attachment I.

5.0 REGULATORY ANALYSIS

The family of Technical Specification curves, including heatup, cooldown, OPS, pump start, and curves to support OPS inoperability are collectively referred to in this section as " P/T and OPS curves" for ease of review.

5.1 No Significant Hazards Consideration

Entergy Nuclear Operations, Inc. has evaluated whether or not a significant hazards consideration is involved with the proposed amendment by focusing on the three standards set forth in 10 CFR 50.92, "Issuance of Amendment," as discussed below:

1. Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?

Response: No.

The probability of occurrence of an accident previously evaluated for Indian Point 3 is not altered by the proposed amendment to the technical specifications (TSs). The accidents remain the same as currently analyzed in Final Safety Analysis Report (FSAR) as a result of changes to the P/T and LTOP limits. The new P/T and LTOP limits were based on the NRC approved, for Indian Point 3, Westinghouse/Combustion Engineering methodology along with American Society of Mechanical Engineers (ASME) Code (Boiler and Pressure Vessel Code) alternatives including Code Case N-640. Code Case N-640 has been accepted for use by the NRC but has not been incorporated into Reg. Guide 1.147, Rev. 12, at this time. An exemption is being submitted separately for the use of Code Case N-640. The proposed changes do not impact the integrity of the reactor coolant system pressure boundary (RCPB) as a result of this change. In addition there is no increase in the potential for the occurrence of a loss of coolant accident. The probability of any design basis accident is not affected by the change, nor are the consequences of any design basis accident affected by the proposed change. The proposed P/T limit curves and LTOP limits are not considered to be an initiator or contributor to any accident currently evaluated in the Indian Point 3 FSAR. These new limits ensure the long term integrity of the RCPB.

Fracture toughness test data are obtained from material specimens contained in capsules that are periodically withdrawn from the reactor vessel. These data permit determination of the conditions under which the vessel can be operated with adequate safety margins against non-ductile fracture throughout its service life. A new reactor vessel specimen was withdrawn at the most recent refueling outage and will be analyzed over the next year to enhance the database used to predict the fracture toughness requirements using projected neutron fluence calculations. For each analyzed transient and steady state condition, the allowable pressure is determined as a function of reactor coolant temperature considering postulated flaws in the reactor vessel beltline, inlet nozzle, outlet nozzle, and closure head.

The predicted radiation induced ΔRT_{NDT} (shift in reference temperature nil-ductility transition) was calculated using the respective reactor vessel beltline copper and nickel contents and the neutron fluence applicable to normal plant performance through the remainder of the operating license, using the most up-to-date cross sections methodologies, as documented in the recent Appendix K power uprate report.

Therefore, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Does the proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?

Response: No.

The proposed changes to the P/T and the LTOP limits will not create a new accident scenario. The requirements to have P/T and LTOP protection are part of the licensing basis of Indian Point 3. The proposed changes reflect the change in vessel material properties acknowledged and managed by regulation and the best data available in response to NRC Generic Letter 92-01, Revision 1. The approach used meets NRC and ASME regulations and guidelines. The Westinghouse/Combustion Engineering methodology has been approved for use at Indian Point 3 by the NRC. Code Case N-640 has been found acceptable by the NRC to be used at other nuclear plants. By separate letter ENO is requesting an exemption to use Code Case N-640 because the Code Case has not been incorporated in Regulatory Guide 1.147, Rev. 12, at this time. The adjusted reference temperatures for fracture toughness are consistent with that previously provided to the NRC to the NRC. The data analysis for the vessel specimen removed to date, confirm that the vessel materials are responding as predicted.

Therefore, the proposed change does not create the possibility of a new or different kind of accident from any previously evaluated.

3. Does the proposed change involve a significant reduction in a margin of safety?

Response: No.

The existing P/T curves and LTOP limits in the technical specifications are reaching their expiration period for the number of years at effective full power operation. The revision of the P/T limits and curves will ensure that Indian Point 3 continues to operate within margins allowed by 10 CFR 50.60 and the ASME Code. The material properties used in the analysis are based on results established through Westinghouse/Combustion Engineering material reports for copper and nickel content. The material properties were evaluated in parallel using statistical methodology. The results are consistent and for conservative purposes, the more restrictive result is used. The application of Code Case N-640 presents alternative procedures for calculating P/T and LTOP temperatures and pressures in lieu of that established for ASME Section XI, Appendix G-2215. This Code alternative allows certain assumptions to be conservatively reduced. However, the procedures allowed by Code Case N-640 still provide significant conservatism and ensure an adequate margin of safety in the development of P/T operating and pressure test limits to prevent non-ductile fractures.

Therefore, the proposed change does not involve a significant reduction in a margin of safety.

Based on the above, Entergy Nuclear Operations, Inc. concludes that the proposed amendment presents no significant hazards consideration under the standards set forth in 10 CFR 50.92 (c), and, accordingly, a finding of "no significant hazards consideration" is justified.

5.2 Applicable Regulatory Requirements / Criteria

The proposed amendment is consistent with General Design Criteria 14 and 31 of 10 CFR 50 Appendix A. In addition, the P/T limits were developed per the requirements of 10 CFR 50 Appendix G. The Westinghouse/ Combustion Engineering methodology was approved by the NRC for use at Indian Point 3, Amendment 179, April 10, 1998.

On April 10, 1998, the NRC also approved an exemption that permitted the use of Code Case N-514 in place of the safety margins required by 10 CFR Part 50 to determine the low temperature overpressure parameters. Revision 12 to Reg. Guide 1.147 was issued May 1999 incorporating Code Case N-514. Therefore, while ENO will still use sections of Code Case N-514, applicable to OPS enable temperature derivation, an exemption request is not required.

ASME Code Case N-640 was also utilized as described in Section 4.0, above. ASME Code Case N-640 has not been incorporated in Reg. Guide 1.147. Therefore, an exemption request from the requirements of 10 CFR Part 50, Appendix G to allow use of ASME Code Case N-640, "Alternate Reference Fracture Toughness for Development of P-T Curves for ASME Section XI, Division I", which modifies the methods of ASME Code, Section XI, Appendix G, is being submitted to the NRC separately.

5.3 Environmental Considerations

The proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

6.0 PRECEDENCE

The existing Technical Specifications have P/T and OPS curves based on Appendix G of 10 CFR Part 50, Westinghouse/Combustion Engineering methodology and Code Case N-514. The Westinghouse/Combustion Engineering methodology and Code Case N-514 were approved for use at Indian Point 3 by the NRC. The Westinghouse/ Combustion Engineering methodology was approved by the NRC by letter dated April 10,1998.

The proposed Technical Specification changes still utilize the Westinghouse/Combustion Engineering methodology and Code Case N-514 (only as applied to OPS enable temperature derivation) with the major difference being that Code Case N-514 has been incorporated into Reg. Guide 1.147, Rev. 12. Therefore, an exemption to use Code Case N-514 is not necessary.

An exemption from 10 CFR Part 50, Section 50.60(a) and Appendix G is being submitted separately. The new proposed Indian Point 3 P/T and OPS curves were developed using Code Case N-640, which modifies the methods of ASME Code Section XI, Appendix G. The NRC has approved similar exemption requests allowing the use of Code Case N-640 for several nuclear plants including Indian Point Unit No. 2, Calvert Cliffs, Brunswick, Fort Calhoun and Monticello. The only aspect of Code Case N-514 allowed by Code Case N-640 is to determine the OPS enable temperature. The P/T and OPS limits themselves are determined exclusively using the N-640 methodology.

ATTACHMENT II

MARKUP OF TECHNICAL SPECIFICATION AND BASES

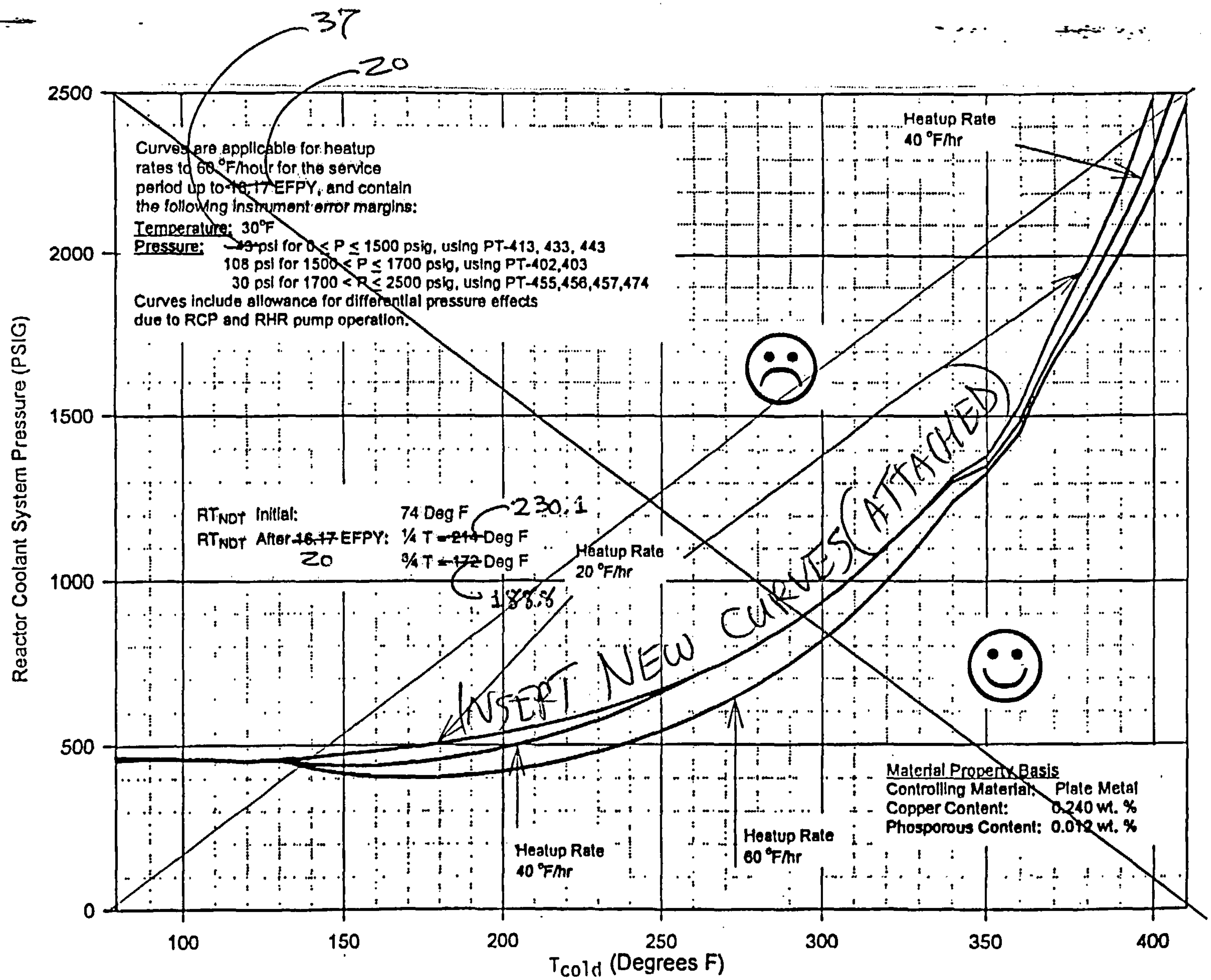
FOR PROPOSED CHANGES REGARDING

PRESSURE-TEMPERATURE AND OVERPRESSURE PROTECTION

SYSTEM LIMITS

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NO. 3
DOCKET NO. 50-286

Figure 3.4.3-1:
Heatup Limitations for the Reactor Coolant System



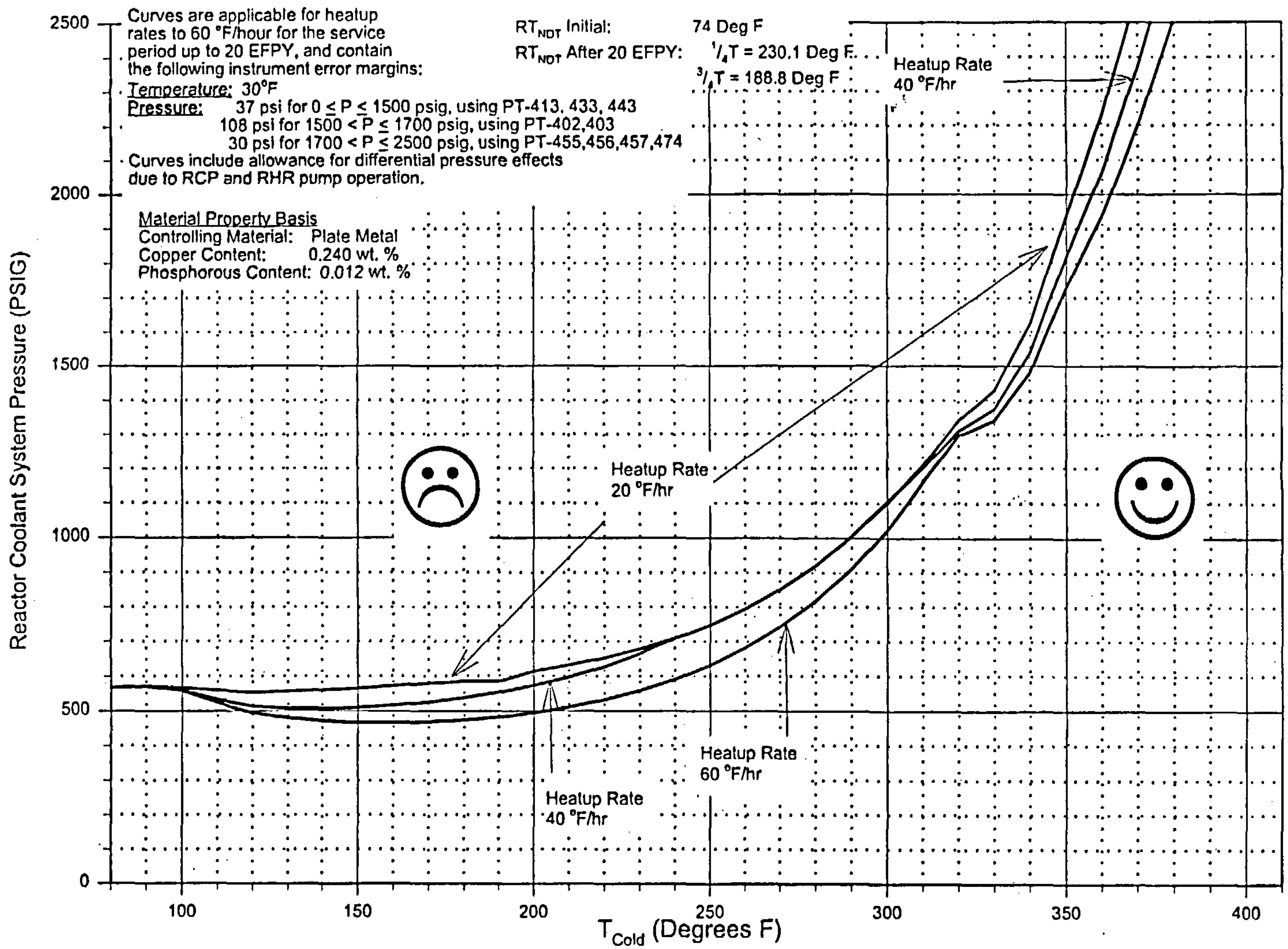


Figure 3.4.3-1:
Heatup Limitations for Reactor Coolant System

Figure 3.4.3-2:
Cooldown Limitations for the Reactor Coolant System

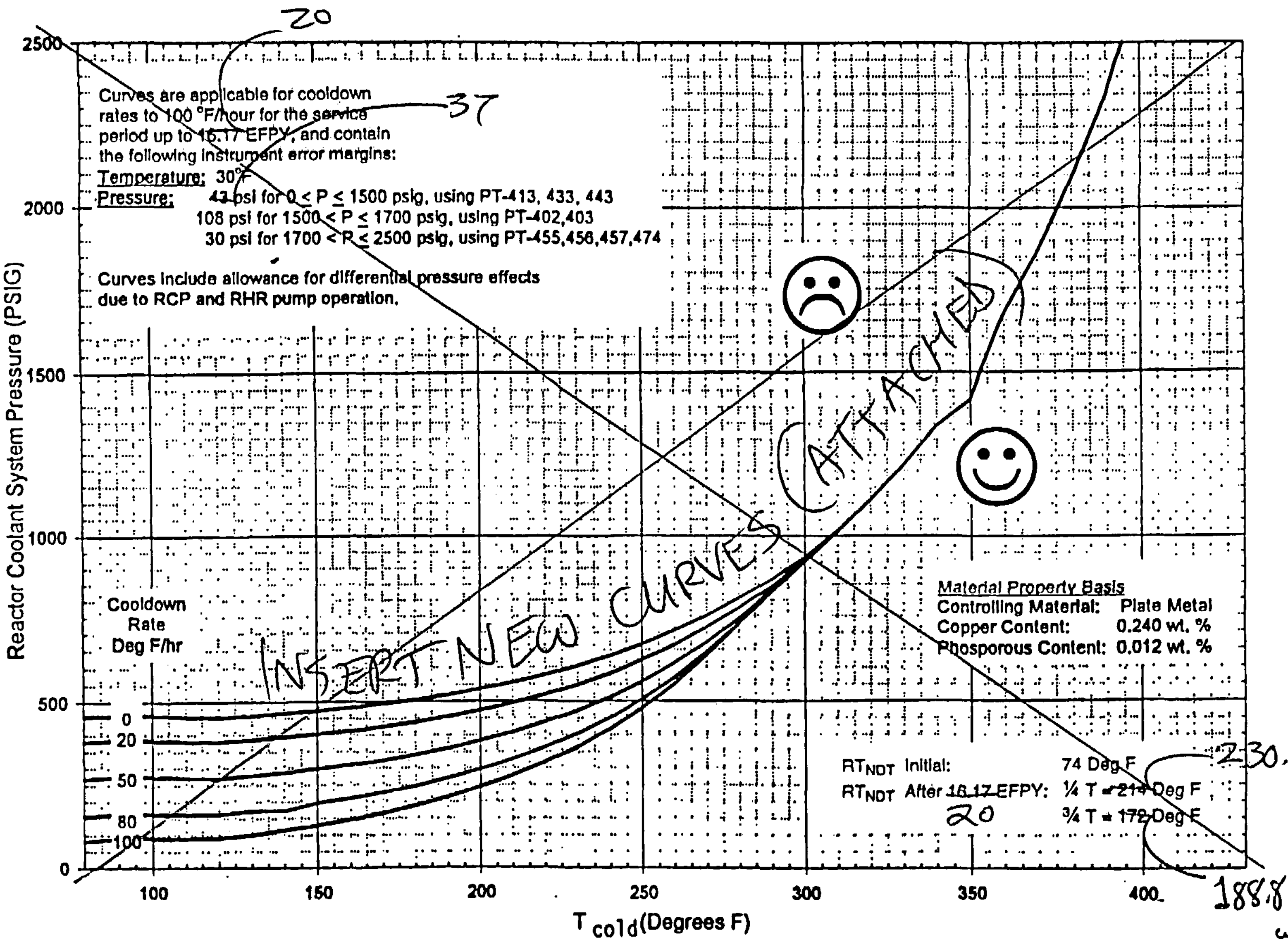


Figure 3.4.3-2:
Cooldown Limitations for Reactor Coolant System

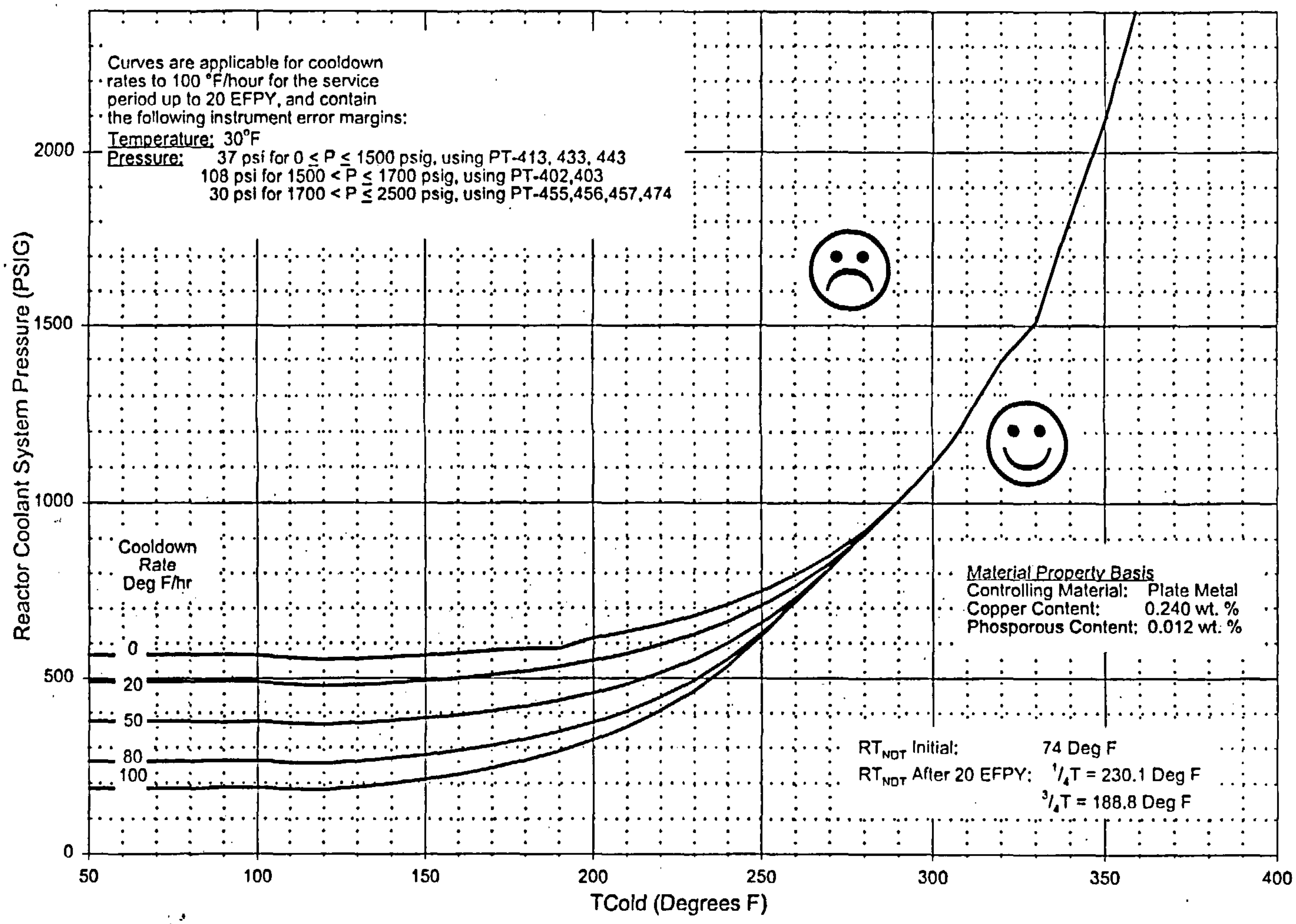


Figure 3.4.3-3:
Hydrostatic and Inservice Leak Testing Limitations for the Reactor Coolant System

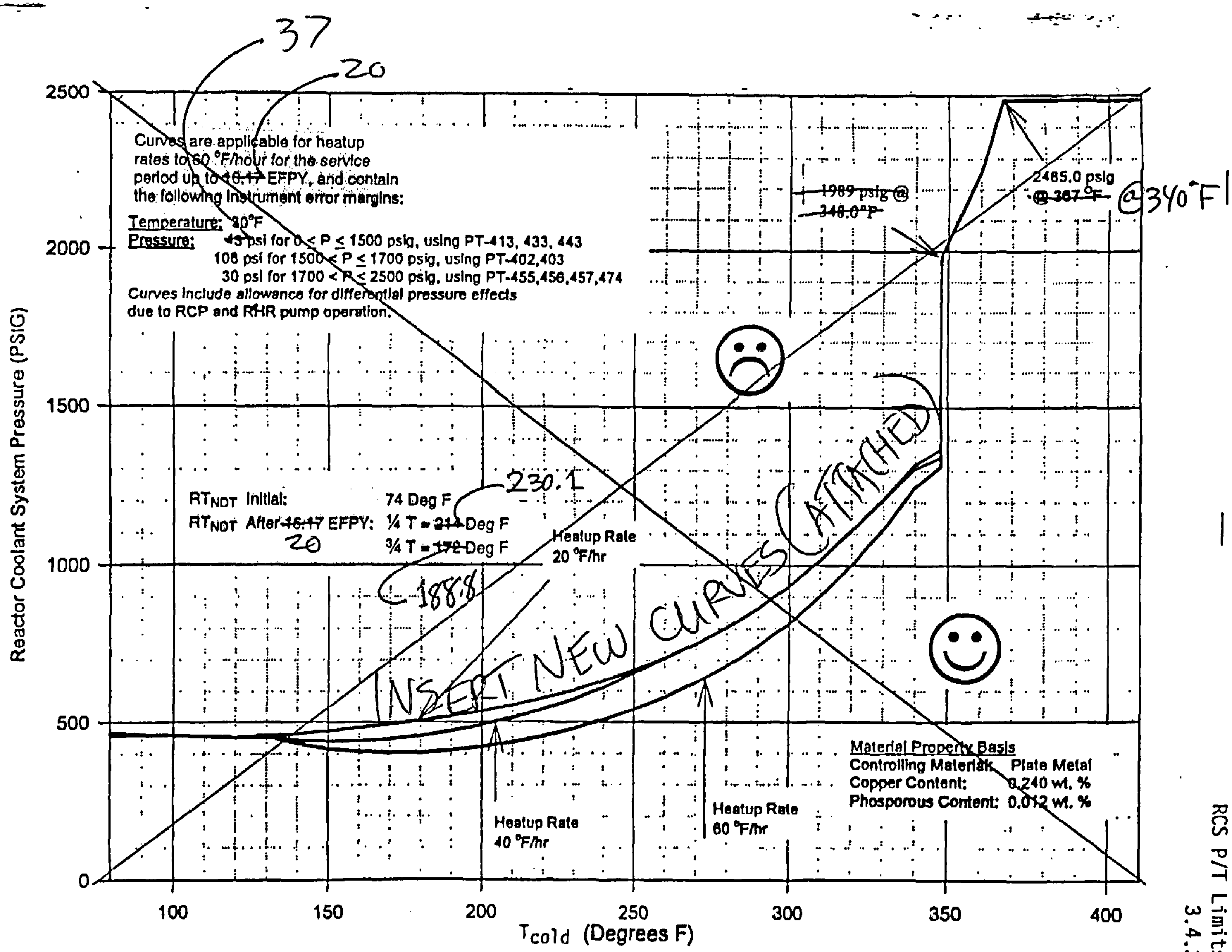
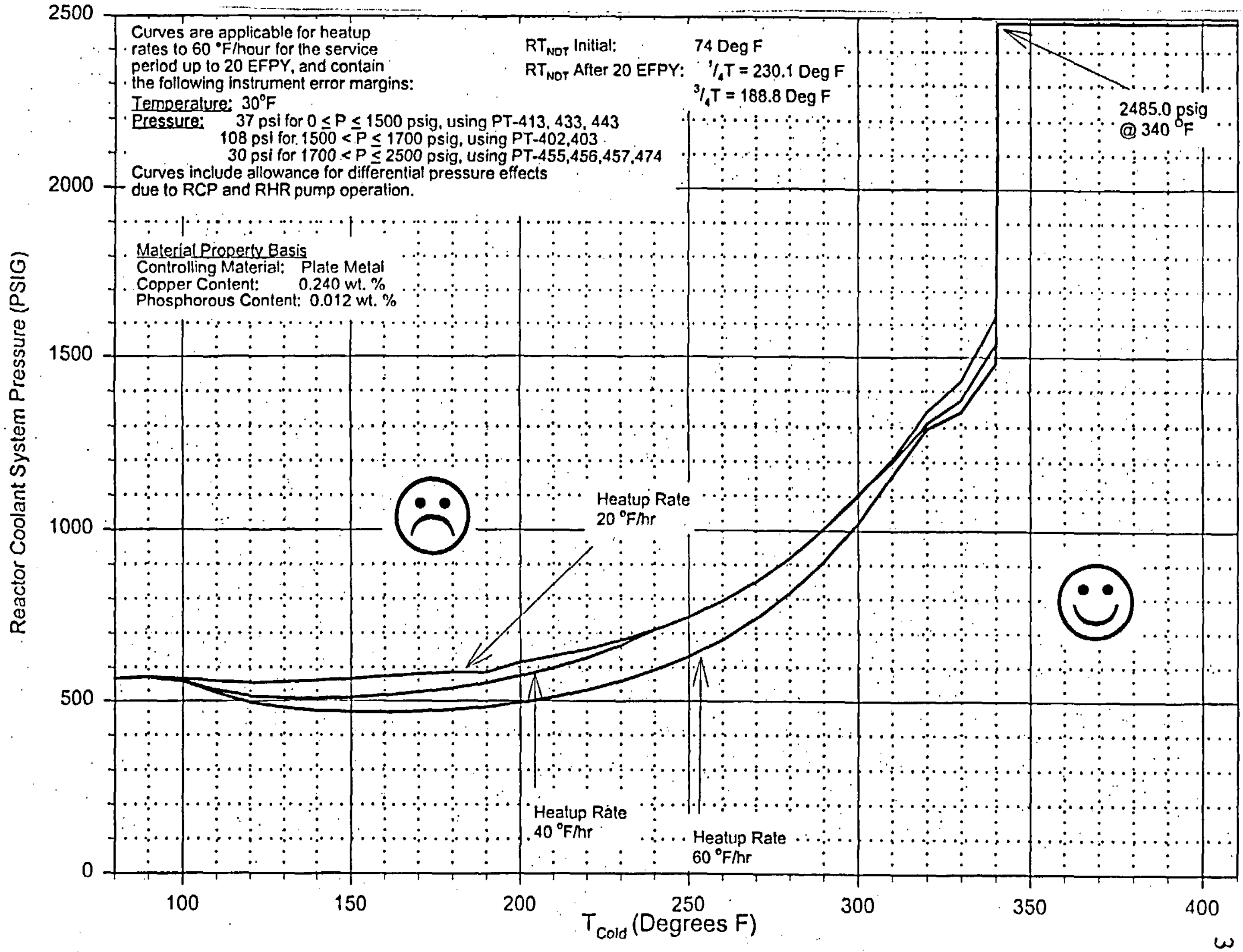


Figure 3.4.3-3:
Hydrostatic and Inservice Leak Testing Limitations for Reactor Coolant System



20 EFPY

OPS ENABLE TEMPERATURE 319°F

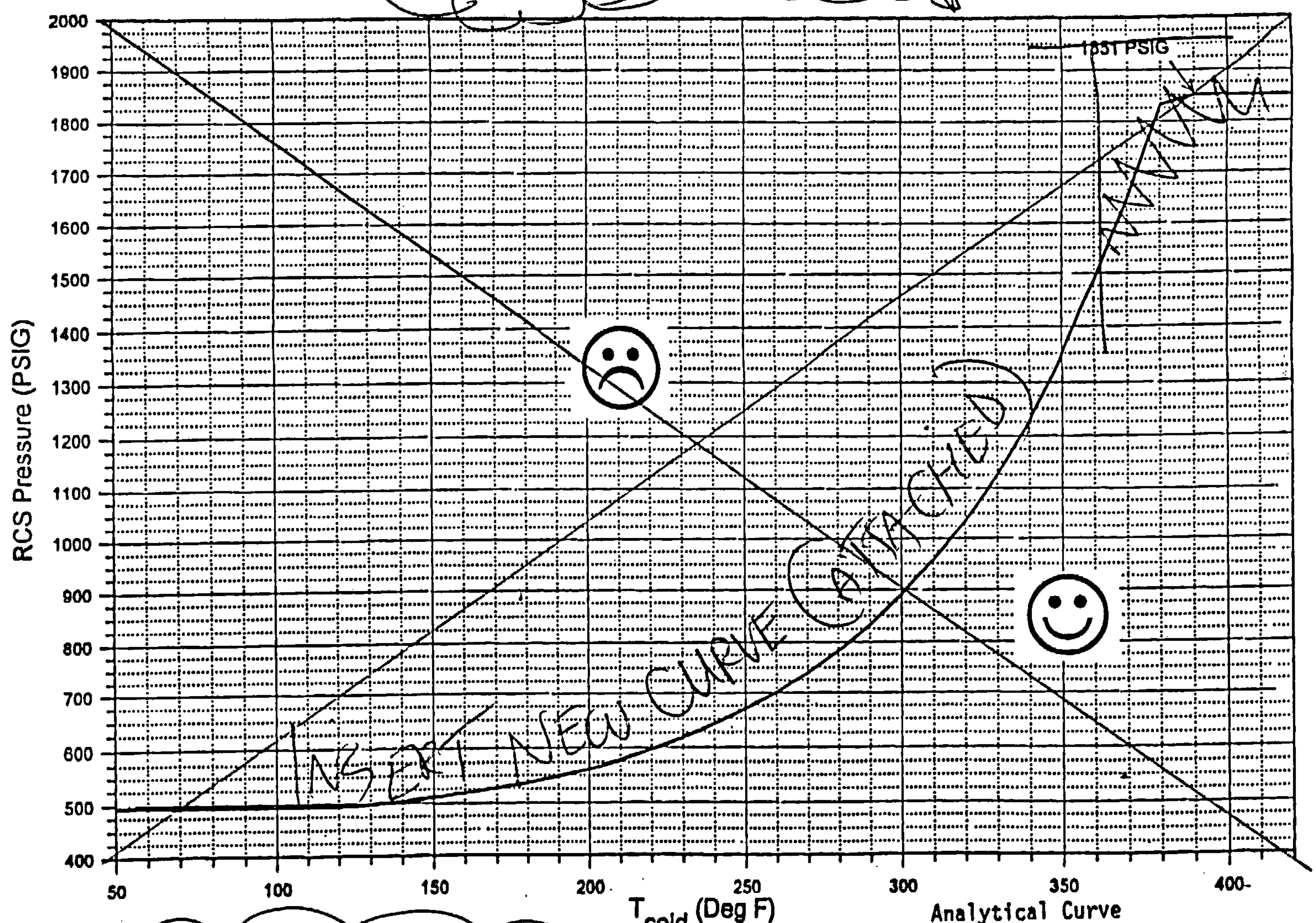
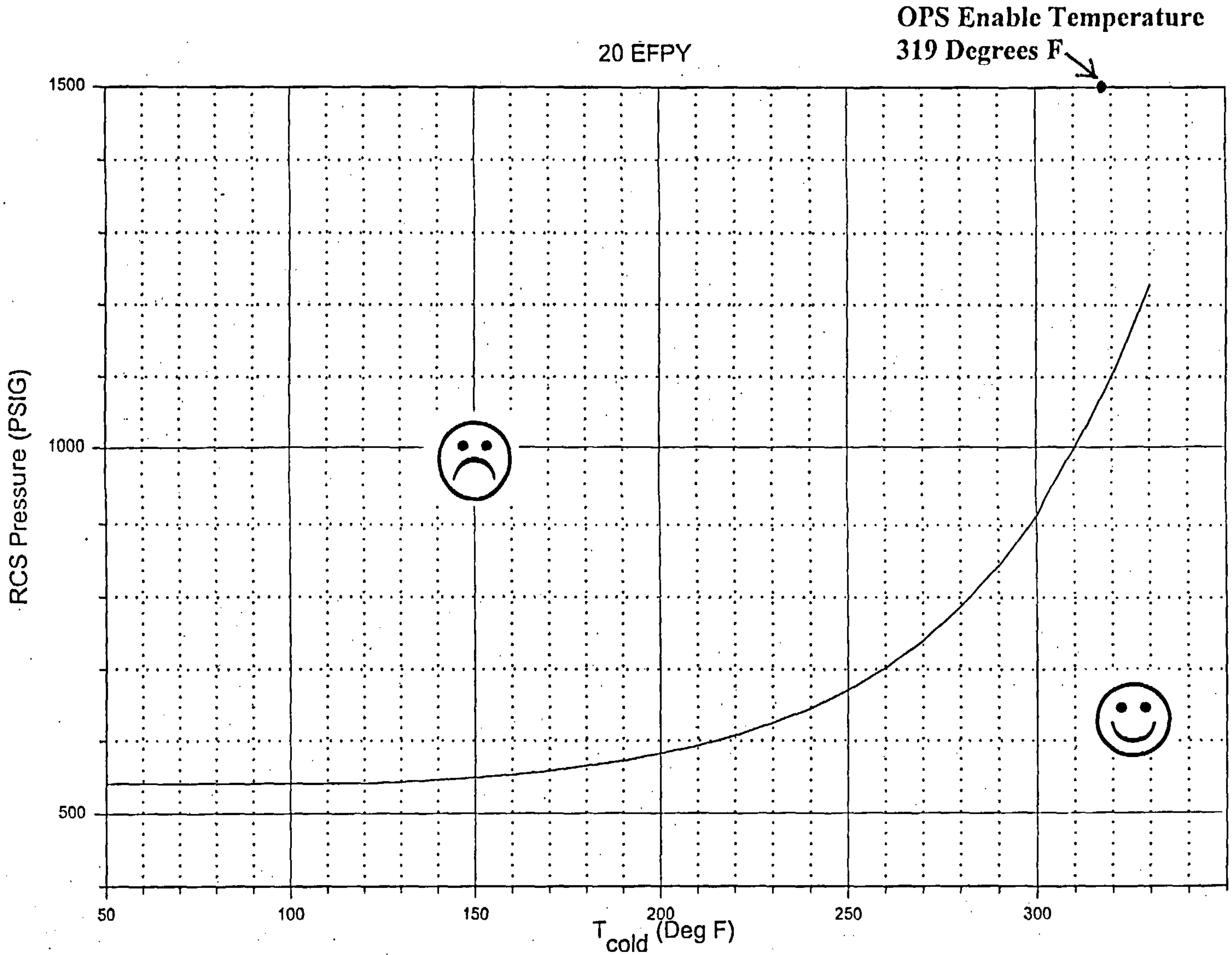


Figure 3.4.12-1: Maximum Allowable Nominal PORV Setpoint for LTOP (OPS), ~~16.17~~ 20 EFPY

NOTE: OPS ENABLE TEMPERATURE INCLUDES AN ALLOWANCE OF 14.4°F FOR INSTRUMENT UNCERTAINTY AND MARGIN

Figure 3.4.12-1: Maximum Allowable Nominal PORV Setpoint for LTOP (OPS), 20 EFPY



Note: OPS Enable Temperature includes an allowance of 14.4 degF for instrument uncertainty and margin.

Analytical Curve

INSERT NEW CURVES (ATTACHED)

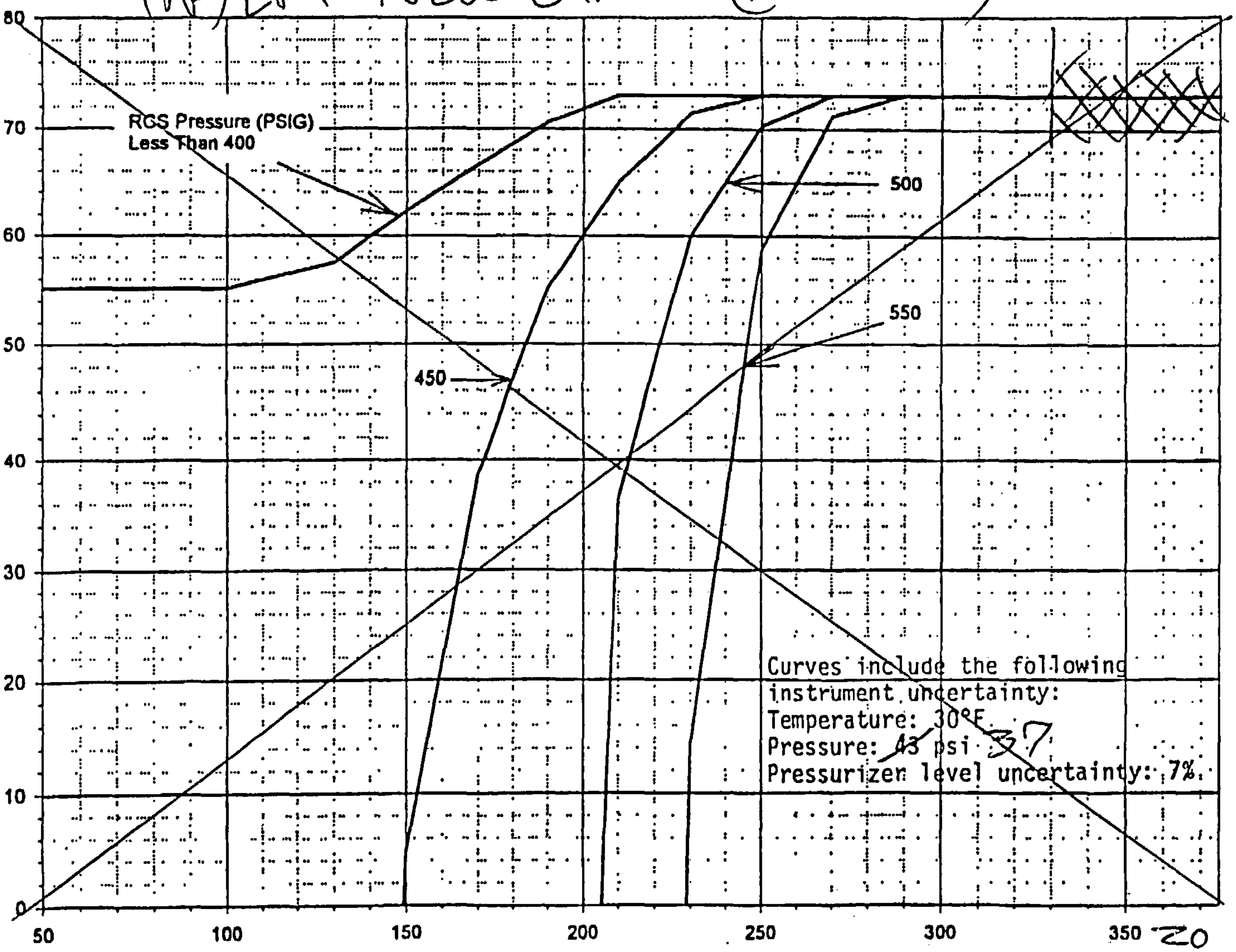
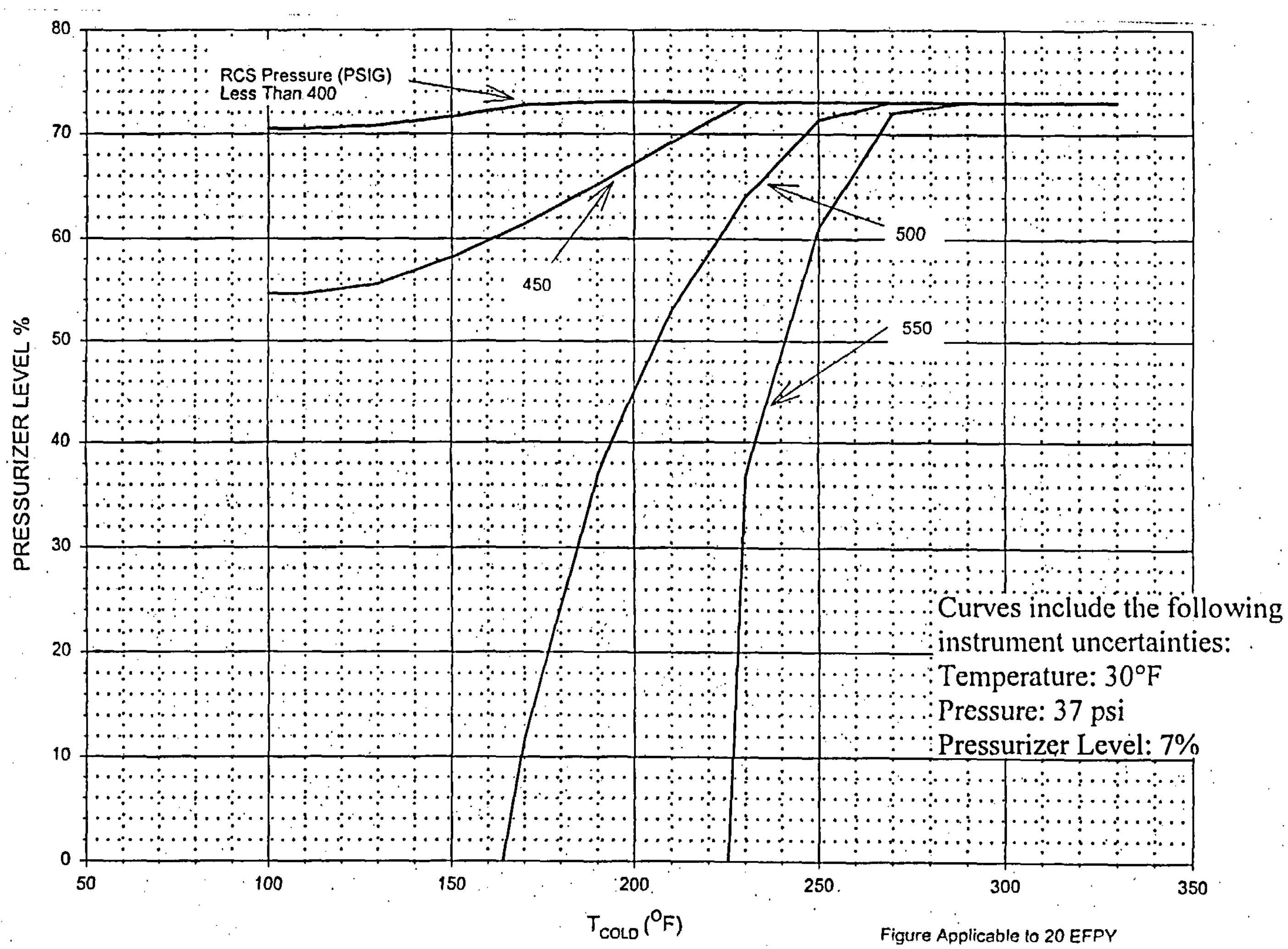


Figure applicable to ~~16.17~~ 20 EFPY

Curves represent maximum allowable pressurizer level for the conditions defined.

Figure 3.4.12-2: Pressurizer Limitations for OPS Inoperable, ~~16.17~~ 20 EFPY (Up to one charging pump capable of feeding the RCS)

Figure 3.4.12-2: Pressurizer Limitations for OPS Inoperable, 20 EFPY (Up to one charging pump capable of feeding the RCS)



Curves represent maximum allowable pressurizer levels for the conditions defined

INSERT NEW CURVES (ATTACHED)

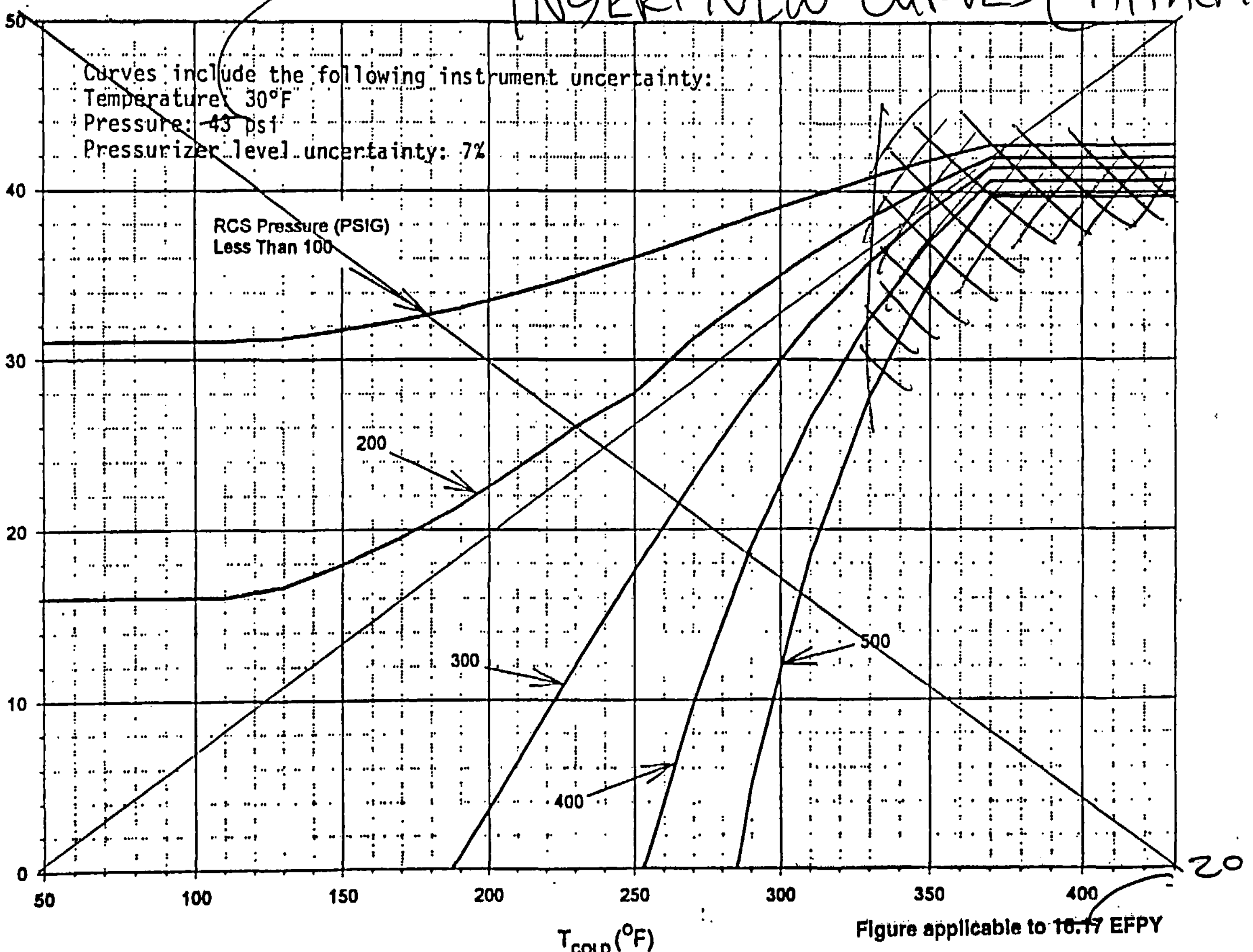


Figure applicable to ~~16.17~~ 20 EFPY

Curves represent maximum allowable pressurizer level for the conditions defined.

Figure 3.4.12-3: Pressurizer Limitations for OPS Inoperable, ~~16.17~~ 20 EFPY
(Up to three charging pumps and/or one safety injection pump capable of feeding RCS)

Figure 3.4.12-3: Pressurizer Limitations for OPS Inoperable, 20 EFPY
(Up to three charging pumps and/or one safety injection pump capable of feeding the RCS)

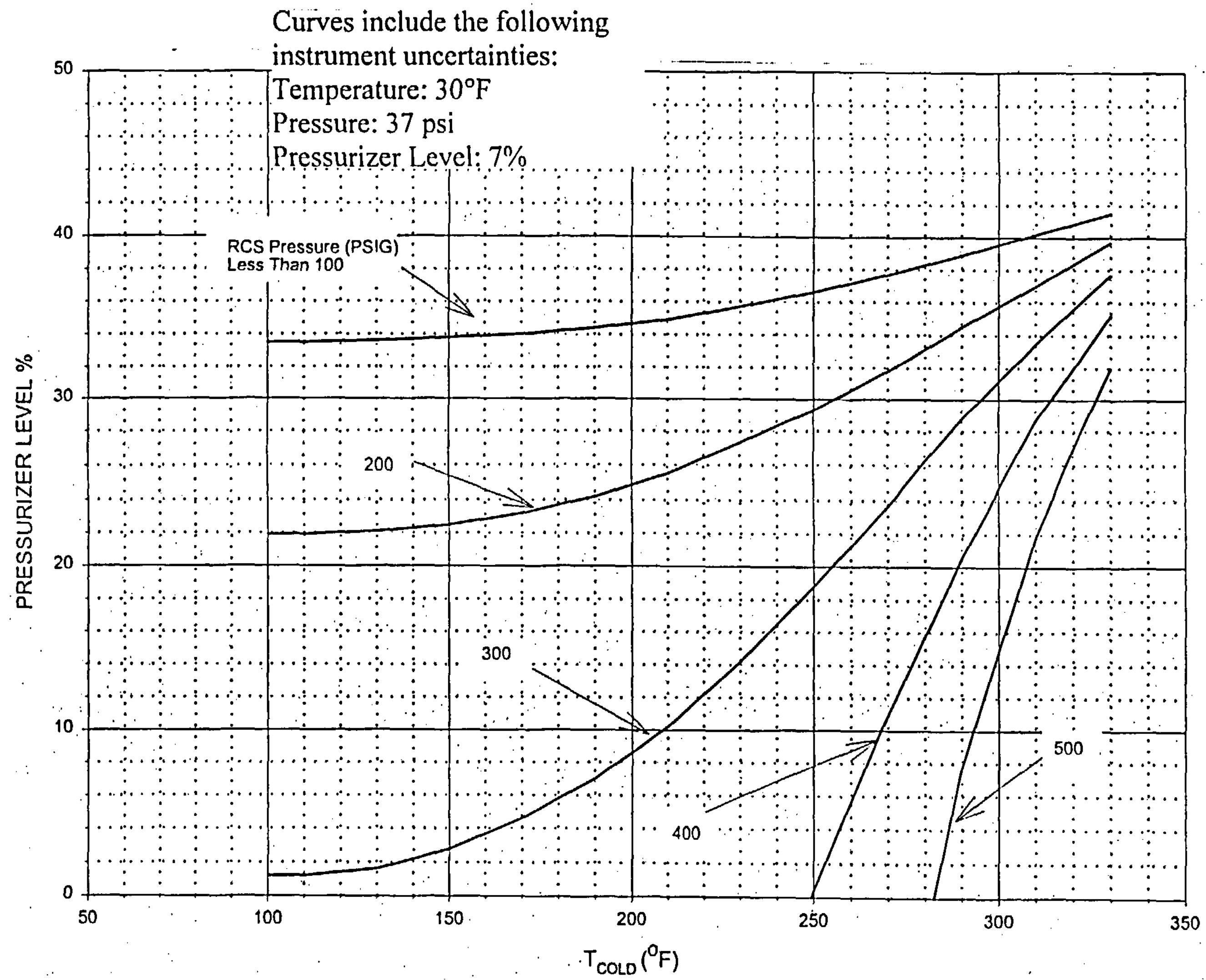


Figure Applicable to 20 EFPY

Curves represent maximum allowable pressurizer levels for the conditions defined

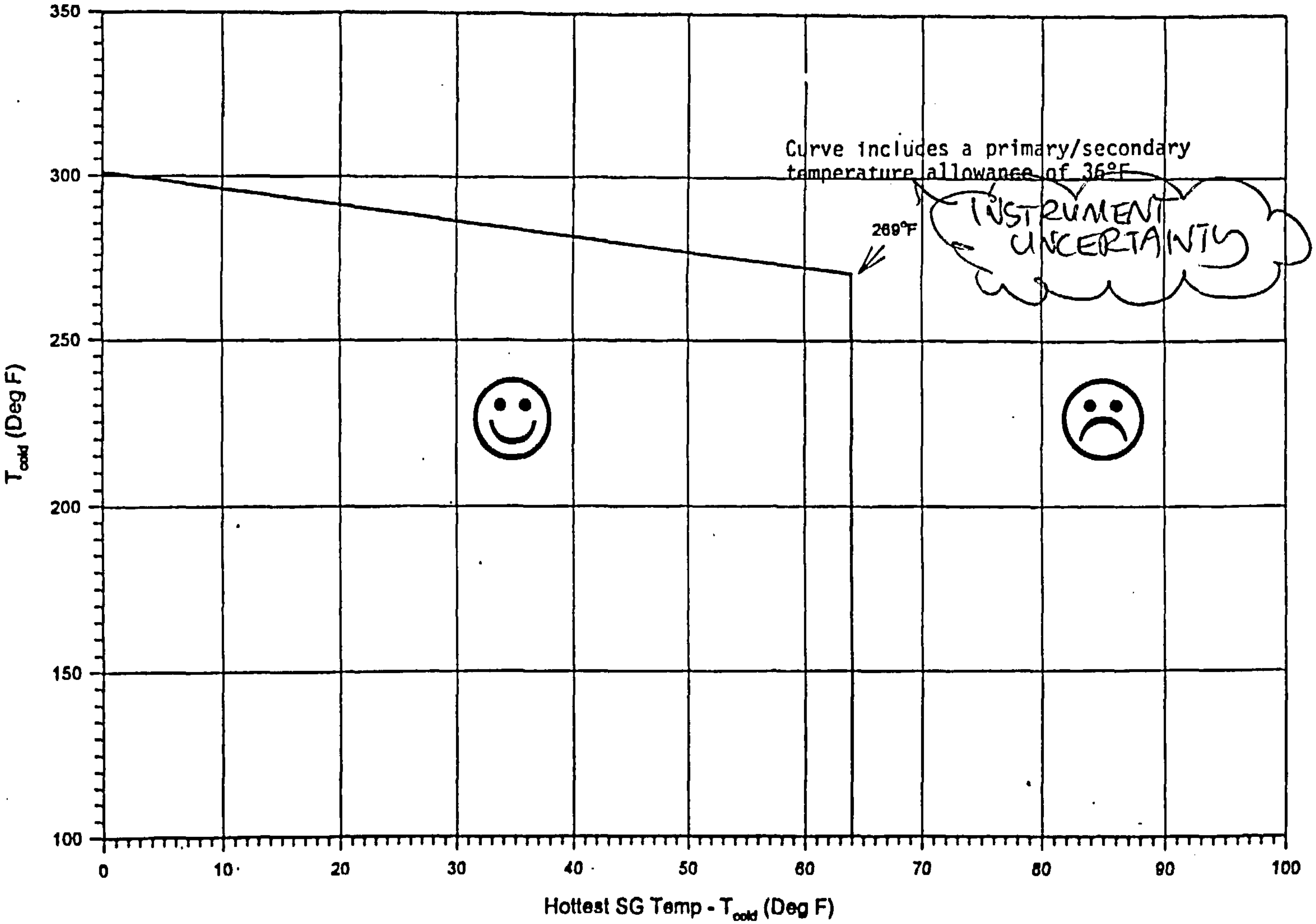


Figure 3.4.12-4: Secondary Side Limitations for RCP Start With Secondary Side Hotter than Primary Side, ~~16.17~~ 20 EFPY

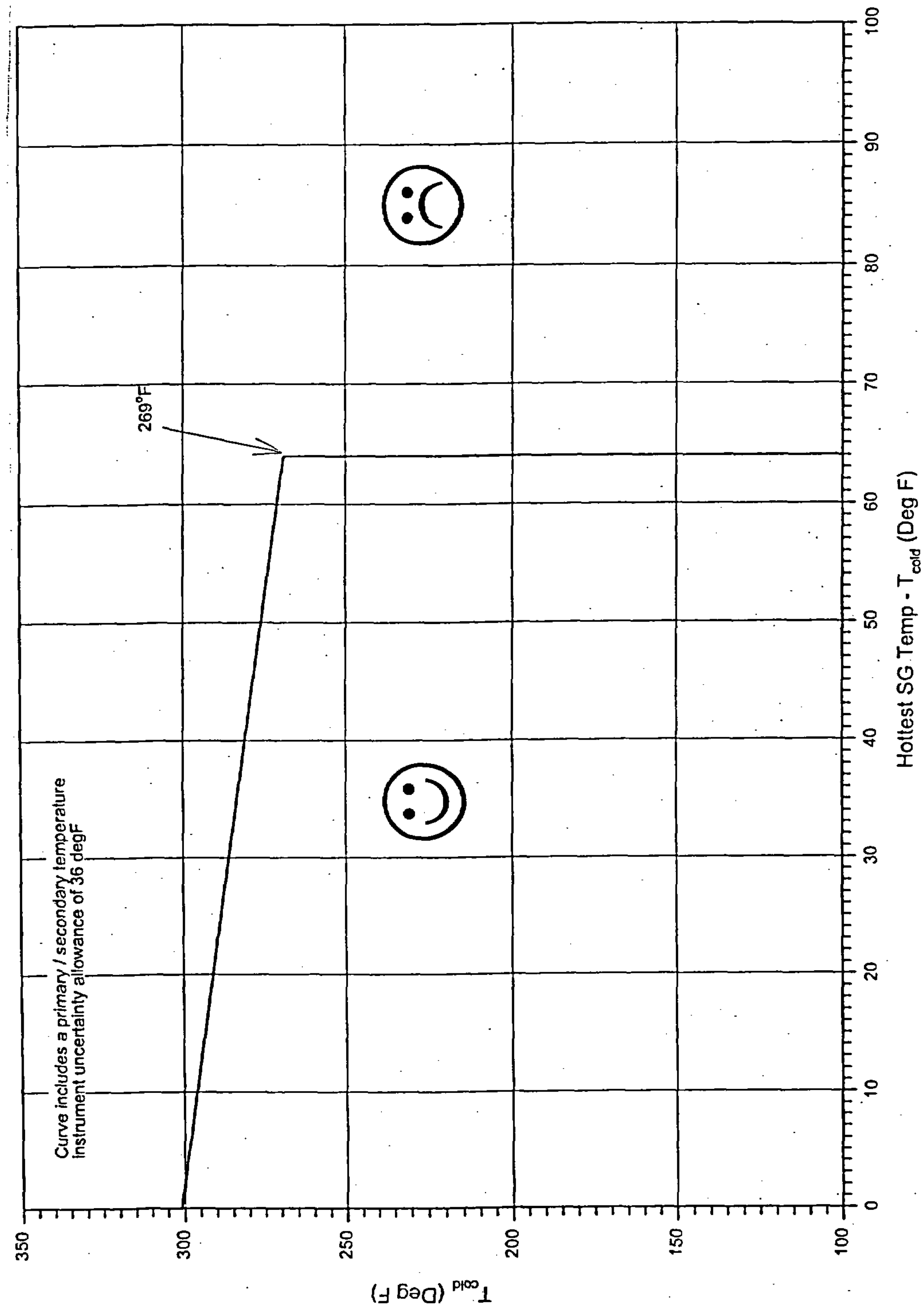


Figure 3.4.12-4: Secondary Side Limitations for RCP Start with Secondary Side Hotter than Primary Side, 20 EFPY

BASES

BACKGROUND (continued)

10 CFR 50, Appendix G (Ref. 2), requires the establishment of P/T limits for specific material fracture toughness requirements of the RCPB materials. Reference 2 requires an adequate margin to brittle failure during normal operation, anticipated operational occurrences, and system hydrostatic tests. It mandates the use of the American Society of Mechanical Engineers (ASME) Code, Section III, Appendix G (Ref. 3).

The neutron embrittlement effect on the material toughness is reflected by increasing the nil ductility reference temperature (RT_{NDT}) as exposure to neutron fluence increases.

The actual shift in the RT_{NDT} of the vessel material will be established periodically by removing and evaluating the irradiated reactor vessel material specimens, in accordance with ASTM E 185 (Ref. 4) and Appendix H of 10 CFR 50 (Ref. 5). The operating P/T limit curves will be adjusted, as necessary, based on the evaluation findings and the recommendations of Regulatory Guide 1.99 (Ref. 6).

The P/T limit curves are composite curves established by superimposing limits derived from stress analyses of those portions of the reactor vessel and head that are the most restrictive. At any specific pressure, temperature, and temperature rate of change, one location within the reactor vessel will dictate the most restrictive limit. Across the span of the P/T limit curves, different locations are more restrictive, and, thus, the curves are composites of the most restrictive regions.

The heatup curve represents a different set of restrictions than the cooldown curve because the directions of the thermal gradients through the vessel wall are reversed. The thermal gradient reversal alters the location of the tensile stress between the outer and inner walls.

~~The criticality limit curve includes the Reference 2 requirement that it be ≥ 40°F above the heatup curve or the cooldown curve, and not less than the minimum permissible temperature for ISLH testing. However, the criticality curve is not operationally limiting; a more restrictive limit exists in LCO 3.4.2, "RCS Minimum Temperature for Criticality."~~

(continued)

BASES (continued)

REFERENCES

1. WCAP-7924-A, July 1972.
2. 10 CFR 50, Appendix G.
3. ASME, Boiler and Pressure Vessel Code, Section III, Appendix G.
4. ASTM E 185-70.
5. 10 CFR 50, Appendix H.
6. Regulatory Guide 1.99, Revision 2, May 1988.
7. ASME, Boiler and Pressure Vessel Code, Section XI, Appendix E.
8. WCAP-16037 Rev 1, "Final Report on Pressure-Temperature Limits for Indian Point Unit 3 NPP," Westinghouse Elec. Co., May 2003

BASES

BACKGROUND (continued)

in the event of loss of inventory, then pumps can be made available through manual actions. Charging pumps and low pressure injection systems are available to provide makeup even when LTOP requirements are applicable.

When configured to provide low temperature overpressure protection, the PORVs are part of the Overpressure Protection System (OPS). LTOP for pressure relief can consist of either the OPS (two PORVs with reduced lift settings), or a depressurized RCS and an RCS vent of sufficient size. Two PORVs are required for redundancy. One PORV has adequate relieving capability to keep from overpressurization for the required coolant input capability.

PORV Requirements

The Overpressure Protection System (OPS) provides the low temperature overpressure protection by controlling the Power Operated Relief Valves (PORVs) and their associated block valves with pressure setpoints that vary with RCS cold leg temperature. Specifically, cold leg temperature signals from three RCS loops are supplied to three associated function generators that calculate the maximum RCS pressures allowed at those temperatures. The maximum RCS pressure limits at any RCS temperature correspond to the 10 CFR 50, Appendix G, limit curve maintained in the Pressure and Temperature Limits Report and are used as the OPS pressure setpoint. Having the setpoints of both valves within the limits in Figure 3.4.12-1 ensures that the Reference 1 limits will not be exceeded in any analyzed event.

In addition to generating the OPS pressure setpoint, the same cold leg temperature signals are used to "arm" the OPS when RCS temperature falls below the temperature at which low temperature overpressure protection is required (319°F). Each PORV opens when a two-out-of-two (temperature and pressure) coincidence logic is satisfied. OPS is "armed" when RCS temperature falls below the temperature that satisfies one half of the two-out-of-two (temperature-pressure) coincidence logic. When OPS is enabled, the PORVs will open if RCS pressure exceeds the calculated pressure setpoint that varies with RCS temperature.

THIS TEMPERATURE INCLUDES AN ALLOWANCE OF 14.4°F FOR INSTRUMENT UNCERTAINTY AND MARGIN.

(continued)

BASES

BACKGROUND (continued)

RCS; or, an RCS vent with opening greater than or equal to one pressurizer code safety valve flange and up to two HHSI pumps capable of injecting into the RCS will satisfy LTOP requirements because either configuration ensures pressure limits are not exceed during a transient. Alternately, an RCS vent of ≥ 2.00 square inches coupled with a pressurizer level ≤ 0% and up to two HHSI pumps capable of injecting into the RCS will satisfy LTOP requirements because it ensures a minimum of 10 minutes for operator action before pressure limits are exceeded during a transient. The vent path(s) must be above the level of reactor coolant, so as not to drain the RCS when open.

APPLICABLE SAFETY ANALYSES

Safety analyses (Ref. 3) demonstrate that the reactor vessel is adequately protected against exceeding the Reference 1 P/T limits. In MODES 1, 2, and 3, with RCS cold leg temperature exceeding 411°F, the pressurizer safety valves will prevent RCS pressure from exceeding the Reference 1 limits. At 319°F and below, overpressure prevention falls to two OPERABLE PORVs in conjunction with the Overpressure Protection System (OPS) or to a depressurized RCS and a sufficient sized RCS vent. Each of these means has a limited overpressure relief capability. Alternately, if redundant PORVs are not Operable, Low Temperature Overpressure protection may be maintained by limiting the pressurizer level to within limits specified in Figure 3.4.12-2 and Figure 3.4.12-3 consistent with the number of charging pumps and number of high head safety injection (HHSI) pumps capable of injecting into the RCS. This approach is acceptable because pressurizer level can be established to either accommodate any anticipated pressure surge or allow operators time to react to any unanticipated pressure surge.

When the RCS temperature is greater than the LTOP arming temperature (i.e., ≥ 319°F) but below the minimum temperature at which the pressurizer safety valves lift prior to violation of the 10 CFR 50, Appendix G, limits (i.e., ≤ ~~411°F~~), administrative controls in the Technical Requirements Manual (TRM) (Ref. 4) are used to limit the potential for exceeding 10 CFR 50, Appendix G,

380°F

(continued)

BASES

LCO (continued)

power is available to the two valves and their control circuits. The OPS is OPERABLE for LTOP when there are three OPERABLE RCS pressure channels and three OPERABLE RCS temperature channels. The OPS is still OPERABLE when an inoperable RCS pressure or temperature channel is in the tripped condition. OPS is considered OPERABLE for meeting LCO 3.4.12 requirements even if one or two RCS cold leg temperatures is above the LTOP Applicability limit.

An RCS vent is OPERABLE when open with an area of ≥ 2.00 square inches.

Each of these methods of overpressure prevention is capable of mitigating the limiting LTOP transient.

APPLICABILITY

This LCO is applicable whenever the RHR System is not isolated from the RCS to protect the RHR system piping. When all RCS cold leg temperatures are ≥ 319°F, RHR system piping is adequately protected by making the accumulators and all HHSI pumps incapable of injecting into the RCS. Therefore, a Note in the LCO specifies that requirements for the OPS System and/or an RCS vent are not Applicable when all RCS cold leg temperatures are ≥ 319°F.

This LCO is applicable to provide protection for the RCS pressure boundary in MODE 4 when any RCS cold leg temperature is < 319°F, in MODE 5, and in MODE 6 when the reactor vessel head is on. The pressurizer safety valves provide overpressure protection that meets the Reference 1 P/T limits above 319°F. When the reactor vessel head is off, overpressurization cannot occur. Although LTOP is not Applicable when the RCS temperature is greater than the LTOP arming temperature (i.e., ≥ 319°F) but below the minimum temperature at which the pressurizer safety valves lift prior to violation of the 10 CFR 50, Appendix G, limits (i.e., ~~≤ 411°F~~), administrative controls in the Technical Requirements Manual (TRM) (Ref. 4) are used to limit the potential for exceeding 10 CFR 50, Appendix G, limits.

380°F

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.4.12.8 and SR 3.4.12.9 (continued)

SR 3.4.12.8 and SR 3.4.12.9 are each modified by two Notes. Note 1 specifies that these SRs are required as a condition for pump starting only when the RCS is below the LTOP arming temperature. Note 2 specifies that meeting either SR 3.4.12.8 or SR 3.4.12.9 ensures that pump starting prerequisites are met.

REFERENCES

1. 10 CFR 50, Appendix G.
2. Generic Letter 88-011, NRC Position on Radiation Embrittlement of Reactor Vessel Materials and its Impact on Plant Operations.
3. IP3 Low Temperature Overpressurization System Analysis Final Report, August 24, 1984, in conjunction with ASME Code Case N-514, Low Temperature Overpressure Protection, February 12, 1992.
4. IP3 Technical Requirements Manual.
5. 10 CFR 50, Section 50.46.
6. 10 CFR 50, Appendix K.
7. WCAP-16037 Rev 1, "Final Report on Pressure-Temperature Limits for Indian Point Unit 3 NPP," Westinghouse Elec. Co., May 2003

ATTACHMENT III

WESTINGHOUSE REPORT

WCAP-16037, REV. 1

"FINAL REPORT ON

PRESSURE-TEMPERATURE LIMITS FOR

INDIAN POINT UNIT 3 NPP"

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT NUCLEAR GENERATING UNIT NO. 3
DOCKET NO. 50-286

Westinghouse Non-Proprietary Class 3

WCAP-16037
Revision 1

May 2003

Final Report on Pressure-Temperature Limits for Indian Point Unit 3 NPP

Westinghouse

WCAP-16037
Revision 1

May 2003

Final Report

on

Pressure-Temperature Limits

for

Indian Point Unit 3 NPP

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Windsor, Connecticut 06095-0500

Westinghouse Non-Proprietary Class 3

WCAP-16037, Rev. 1

Final Report

on

Pressure-Temperature Limits

for

Indian Point Unit 3 NPP

May 2003

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1.0 INTRODUCTION

This report was prepared as a part of an effort to update the Pressure-Temperature (P-T) limits for Indian Point Unit 3 (IP3) Nuclear Power Plant (NPP) based on requirements given in Reference 16 using the crack initiation reference stress intensity factor K_{IC} for determining the fracture toughness of the beltline material. The use of K_{IC} as the basis for establishing the reference fracture toughness limit, K_{IR}, value for the vessel is currently outlined in ASME Code Case N-640 (Ref. 17).

The following sections describe the basis for development of reactor vessel P-T limitations for the Indian Point Unit 3 NPP. These limits are calculated to meet the regulations of 10 CFR Part 50 Appendix A (Ref. 1), Design Criterion 14 and Design Criterion 31. These design criteria require that the reactor coolant pressure boundary be designed, fabricated, erected, and tested in order to have an extremely low probability of abnormal leakage, of rapid failure, and of gross rupture. The criteria also require that the reactor coolant pressure boundary be designed with sufficient margin to assure that when stressed under operation, maintenance, and testing the boundary behaves in a non-brittle manner and the probability of rapidly propagating fracture is minimized.

The P-T limits are developed per the requirements of 10 CFR 50 Appendix G (Ref. 2). This appendix describes the requirements for developing the P-T limits and provides the general basis for these limitations. The margins of safety against fracture provided by the P-T limits using the requirements of 10 CFR Part 50 Appendix G are equivalent to those recommended in the ASME Boiler and Pressure Vessel Code Section III, Appendix G, "Protection Against Nonductile Failure" (Ref. 3). The general guidance provided in those procedures has been utilized to develop the Indian Point Unit 3 NPP P-T limits with the requisite margins of safety for the heatup and cool down conditions.

The Reactor Pressure Vessel (RPV) beltline P-T limits are based upon the irradiation damage prediction methods of Regulatory Guide 1.99 Revision 02 (Ref. 4). This methodology has been used to calculate the limiting material Adjusted Reference Temperatures (ART) for Indian Point Unit 3.

For the reactor vessel this report provides P-T limits in accordance with 10 CFR 50 Appendix G for two representative points in the RPV life time corresponding to 15, and 34.7 Effective Full Power Years (EFPY). The events analyzed are the isothermal, 20, 50, 80 and 100°F/hr cooldown conditions and the isothermal, 20, 40 and 60°F/hr heatup conditions. These conditions were analyzed to provide a database of thermal results for use in establishing Low Temperature Overpressure Protection (LTOP) enable/disable temperatures. Included in the events analyzed are the in-service hydrostatic test and core critical conditions. Note that pressure and temperature values provided in this report do not include correction factors.

In addition, Appendix A of this report provides an Upper Shelf Energy (USE) Evaluation at the end-of-license (EOL) using updated fluence methodology and considering the power uprate. The Upper Shelf Energy Evaluation was performed at 34.7 EFPY that was determined from the P-T limit curve optimization.

Based upon the P-T limit analyses presented in this report, no limiting vessel operability issues are anticipated to exist for the reactor pressure vessel up to 34.7 EFPY. However, note that the current 10 CFR 50.61 PTS Screening Criteria limit of Adjusted Reference Temperature of 270 °F will be exceeded at approximately 31.4 EFPY based on Table 2-3.

2.0 ADJUSTED REFERENCE TEMPERATURE PROJECTIONS [1]

2.1 INTRODUCTION

In this section, the calculation of the fast neutron (E > 1.0 MeV) fluence experienced by the Indian Point Unit 3 reactor pressure vessel is described. This calculation included a plant specific evaluation through the completion of the eleventh fuel cycle as well as projections for future operation based on continued use of low leakage fuel management with an assumed power uprate at the onset of the twelfth fuel cycle. Using the guidance established in Regulatory Guide 1.99, Revision 2, these fluence projections along with established material properties are used to determine adjusted reference temperatures at the surface, 1/4 thickness, and 3/4 thickness locations for the limiting vessel material, Plate B2803-3.

2.2 FLUENCE CALCULATION

Plant specific neutron fluence evaluations for the Indian Point Unit 3 pressure vessel materials were completed using methods that follow the guidance and meet the requirements of Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence" (Ref. 5). In this evaluation, the fast neutron exposure expressed in terms of neutron fluence (E > 1.0 MeV) was established on a fuel cycle specific basis for the first twelve operating cycles at Indian Point Unit 3. Projections for future operation were then made using a conservative representation of the low leakage fuel cycles currently in place at Indian Point Unit 3. These projections also account for a power uprate from 3025 MWt to 3068 MWt occurring at the onset of cycle 12.

The transport calculations were carried out using the following three-dimensional flux synthesis technique:

$$\phi(r,\theta,z) = [\phi(r,\theta)] \cdot [\phi(r,z)]/[\phi(r)]$$

where $\phi(r,\theta,z)$ is the synthesized three-dimensional neutron flux distribution, $\phi(r,\theta)$ is the two-dimensional transport solution in r,θ geometry, $\phi(r,z)$ is the two-dimensional solution for a cylindrical reactor model using the actual axial core power distribution, and $\phi(r)$ is the one-dimensional solution for a cylindrical reactor model using the same source per unit height as that used in the r,θ two-dimensional calculation.

[1] Obtained from Reference 15.

For the Indian Point Unit 3 analysis, all of the transport calculations were carried out using the DORT discrete ordinates code Version 3.1 (Ref. 6) and the BUGLE-96 cross-section library (Ref. 7). The BUGLE-96 library provides a 67 group coupled neutron-gamma ray cross-section data set produced specifically for light water reactor application. In these analyses, anisotropic scattering was treated with a P_5 legendre expansion and the angular discretization was modeled with an S_{16} order of angular quadrature. Energy and space dependent core power distributions as well as system operating temperatures were treated on a fuel cycle specific basis.

In Section 2.3 of this report, the results of the plant specific fluence evaluation through the completion of the eleventh operating fuel cycle as well as the fluence projections for future operation at uprated power are tabulated along with the Adjusted Reference Temperatures for the limiting beltline material.

In addition to the plant specific transport calculations, neutron dosimetry sensors from the first three surveillance capsules withdrawn from the Indian Point Unit 3 reactor were re-evaluated using current dosimetry evaluation methodology. These dosimetry re-evaluations were used to validate, but not to modify, the plant specific neutron transport calculations. That is, the comparisons of calculation and measurement were used solely to demonstrate that the analytical results satisfy the requirements of Regulatory Guide 1.190.

The Measurement/Calculation (M/C) ratios for each fast neutron sensor reaction rate from the three surveillance capsules withdrawn from Indian Point Unit 3 are summarized below.

Table 2-1: Surveillance capsule M/C ratios for each fast neutron sensor reaction rate

Reaction	M/C Ratio		
	Capsule T	Capsule Y	Capsule Z
Cu-63(n,α)	1.21	1.10	1.13
Fe-54(n,p)	1.23	1.01	1.01
Ni-58(n,p)	1.16	0.98	0.91
U-238(n,f)		1.09	
Np-237(n,f)		1.13	
Average	1.20 (2.9%)	1.06 (6.1%)	1.01 (10.8%)

Note: The numbers in parentheses represent the percentage standard deviation of the capsule data sets.

This plant specific data set shows consistent behavior for all reactions within the constraint of an allowable 20% (1σ) uncertainty in the calculated results. The overall M/C ratio for the 11 sample data set is 1.09 with an associated standard deviation of 9.3%. The observed average M/C ratios for the individual capsules range from 1.01 to 1.20.

2.3 ADJUSTED REFERENCE TEMPERATURE CALCULATIONS

In order to develop P-T limits for the reactor vessel, Adjusted Reference Temperatures (ART) for the Indian Point Unit 3 controlling beltline material were determined. From Reference 8, the controlling beltline material was determined to be plate B2803-3 from the lower shell.

The Adjusted Reference Temperature (ART) vs. neutron fluence distributions for the controlling material were calculated using Equations 1, 2, and 3 from Regulatory Guide 1.99 (Ref. 4) as follows:

$$ART = \text{Initial } RT_{NDT} + \Delta RT_{NDT} + \text{Margin}$$

$$\Delta RT_{NDT} = (CF)\, f^{(0.28 - 0.10 \log f)}$$

$$f = f_{surf}\,(e^{-0.24X})$$

In the preceding equations,

ART	=	The adjusted reference temperature.
Initial RT_{NDT}	=	The reference temperature of the unirradiated material.
ΔRT_{NDT}	=	The radiation induced shift in reference temperature.
Margin	=	The quantity added to obtain conservative values of ART.
CF	=	The material chemistry factor as defined in Reg. Guide 1.99 (see Appendix B)
f_{surf}	=	The fluence factor, defined as [Fluence (E > 1.0 MeV)]/[10^{19}], at the pressure vessel inner radius.
f	=	The fluence factor at a depth, X, into the pressure vessel wall.
X	=	The depth into the pressure vessel wall expressed in inches.

In applying these equations to plate B2803-3, the following material properties were extracted from Tables 7-1 and 7-7 of Reference 8.

Table 2-2: Material Properties of Plate B2803-3.

	Material ID	CF [°F]	Initial RT_{NDT} [°F]	Margin [°F]
CF Based on Material Chemistry	B2803-3	160.0	74	34
CF Based on Surv. Capsule Data	B2803-3	170.9	74	17

The baseline fast neutron (E > 1.0 MeV) exposure at the pressure vessel inner radius was taken from the plant specific analysis of the Indian Point Unit 3 pressure vessel described in Section 2.2 of this report. The specific baseline fluence used in the current evaluation represented the maximum neutron exposure along the 45 degree azimuth at the end of fuel cycle 11 (13.7 EFPY). Projections of neutron fluence beyond 13.7 EFPY were based on a neutron flux level of 9.00×10^9 n/cm^2-s as specified in Reference 18. Results of the ART calculation are provided in Tables 2-3 and 2-4.

Table 2-3: ART (°F) as a Function of Fast Neutron Fluence (E > 1.0 MeV, for EFPY 13.7-35.3)

Operating Time	f			CF = 160; Margin = 34°F			CF = 170.9; Margin = 17°F		
[efpy]	Surface	1/4T	3/4T	Surface	1/4T	3/4T	Surface	1/4T	3/4T
13.7	0.536	0.319	0.113	240.1	217.8	178.8	232.1	208.3	166.6
16.0	0.600	0.358	0.127	245.1	222.6	182.6	237.5	213.4	170.7
16.3	0.610	0.364	0.129	245.8	223.3	183.2	238.2	214.1	171.3
16.7	0.620	0.370	0.131	246.6	224.0	183.8	239.0	214.9	171.9
17.0	0.630	0.375	0.133	247.3	224.7	184.3	239.8	215.6	172.5
17.4	0.640	0.381	0.135	248.0	225.3	184.9	240.5	216.3	173.1
17.7	0.650	0.387	0.138	248.7	226.0	185.4	241.3	217.0	173.7
18.1	0.660	0.393	0.140	249.4	226.6	185.9	242.0	217.7	174.2
18.4	0.670	0.399	0.142	250.0	227.3	186.5	242.7	218.4	174.8
18.8	0.680	0.405	0.144	250.7	227.9	187.0	243.4	219.1	175.4
19.1	0.690	0.411	0.146	251.4	228.6	187.5	244.1	219.8	175.9
19.5	0.700	0.417	0.148	252.0	229.2	188.0	244.8	220.4	176.5
19.8	0.710	0.423	0.150	252.6	229.8	188.5	245.5	221.1	177.0
20.2	0.720	0.429	0.152	253.3	230.4	189.0	246.2	221.7	177.6
20.5	0.730	0.435	0.155	253.9	231.0	189.5	246.8	222.4	178.1
20.9	0.740	0.441	0.157	254.5	231.6	190.0	247.5	223.0	178.6
21.2	0.750	0.447	0.159	255.1	232.2	190.5	248.1	223.6	179.1
21.6	0.760	0.453	0.161	255.7	232.7	191.0	248.7	224.2	179.6
21.9	0.770	0.459	0.163	256.3	233.3	191.5	249.4	224.8	180.1
22.3	0.780	0.465	0.165	256.8	233.9	191.9	250.0	225.4	180.7
22.6	0.790	0.471	0.167	257.4	234.4	192.4	250.6	226.0	181.2
23.0	0.800	0.477	0.169	258.0	235.0	192.9	251.2	226.6	181.6
23.3	0.810	0.483	0.171	258.5	235.5	193.3	251.8	227.2	182.1
23.7	0.820	0.489	0.174	259.1	236.1	193.8	252.4	227.8	182.6
24.1	0.830	0.495	0.176	259.6	236.6	194.2	253.0	228.3	183.1
24.4	0.840	0.501	0.178	260.2	237.1	194.7	253.5	228.9	183.6
24.8	0.850	0.507	0.180	260.7	237.6	195.1	254.1	229.5	184.0
25.1	0.860	0.513	0.182	261.2	238.1	195.6	254.7	230.0	184.5
25.5	0.870	0.519	0.184	261.8	238.7	196.0	255.2	230.6	185.0
25.8	0.880	0.524	0.186	262.3	239.2	196.4	255.8	231.1	185.4
26.2	0.890	0.530	0.188	262.8	239.7	196.8	256.3	231.6	185.9
26.5	0.900	0.536	0.191	263.3	240.1	197.3	256.9	232.2	186.3
26.9	0.910	0.542	0.193	263.8	240.6	197.7	257.4	232.7	186.8
27.2	0.920	0.548	0.195	264.3	241.1	198.1	257.9	233.2	187.2
27.6	0.930	0.554	0.197	264.7	241.6	198.5	258.4	233.7	187.7
27.9	0.940	0.560	0.199	265.2	242.1	198.9	258.9	234.2	188.1
28.3	0.950	0.566	0.201	265.7	242.5	199.3	259.4	234.7	188.5
28.6	0.960	0.572	0.203	266.2	243.0	199.7	259.9	235.2	189.0
29.0	0.970	0.578	0.205	266.6	243.5	200.1	260.4	235.7	189.4
29.3	0.980	0.584	0.207	267.1	243.9	200.5	260.9	236.2	189.8
29.7	0.990	0.590	0.210	267.5	244.4	200.9	261.4	236.7	190.2
30.0	1.000	0.596	0.212	268.0	244.8	201.3	261.9	237.1	190.7
30.4	1.010	0.602	0.214	268.4	245.3	201.7	262.4	237.6	191.1
30.7	1.020	0.608	0.216	268.9	245.7	202.1	262.8	238.1	191.5
31.1	1.030	0.614	0.218	269.3	246.1	202.4	263.3	238.5	191.9
31.4	1.040	0.620	0.220	269.8	246.6	202.8	263.8	239.0	192.3
31.8	1.050	0.626	0.222	270.2	247.0	203.2	264.2	239.5	192.7
32.1	1.060	0.632	0.224	270.6	247.4	203.6	264.7	239.9	193.1
32.5	1.070	0.638	0.227	271.0	247.8	203.9	265.1	240.4	193.5
32.9	1.080	0.644	0.229	271.4	248.2	204.3	265.6	240.8	193.9
33.2	1.090	0.650	0.231	271.9	248.7	204.7	266.0	241.2	194.2
33.6	1.100	0.656	0.233	272.3	249.1	205.0	266.5	241.7	194.6
33.9	1.110	0.662	0.235	272.7	249.5	205.4	266.9	242.1	195.0
34.3	1.120	0.668	0.237	273.1	249.9	205.7	267.3	242.5	195.4
34.6	1.130	0.673	0.239	273.5	250.3	206.1	267.7	243.0	195.8
35.0	1.140	0.679	0.241	273.9	250.7	206.4	268.2	243.4	196.1
35.3	1.150	0.685	0.243	274.2	251.1	206.8	268.6	243.8	196.5

Table 2-4: ART (°F) as a Function of Fast Neutron Fluence (E > 1.0 MeV, for EFPY 35.7-54.7)

Operating Time	f			CF = 160; Margin = 34°F			CF = 170.9; Margin = 17°F		
[efpy]	Surface	1/4T	3/4T	Surface	1/4T	3/4T	Surface	1/4T	3/4T
35.7	1.160	0.691	0.246	274.6	251.4	207.1	269.0	244.2	196.9
36.0	1.170	0.697	0.248	275.0	251.8	207.5	269.4	244.6	197.2
36.4	1.180	0.703	0.250	275.4	252.2	207.8	269.8	245.0	197.6
36.7	1.190	0.709	0.252	275.8	252.6	208.1	270.2	245.4	198.0
37.1	1.200	0.715	0.254	276.1	253.0	208.5	270.6	245.8	198.3
37.4	1.210	0.721	0.256	276.5	253.3	208.8	271.0	246.2	198.7
37.8	1.220	0.727	0.258	276.9	253.7	209.1	271.4	246.6	199.0
38.1	1.230	0.733	0.260	277.2	254.1	209.5	271.8	247.0	199.4
38.5	1.240	0.739	0.263	277.6	254.4	209.8	272.1	247.4	199.7
38.8	1.250	0.745	0.265	277.9	254.8	210.1	272.5	247.8	200.1
39.2	1.260	0.751	0.267	278.3	255.1	210.4	272.9	248.2	200.4
39.5	1.270	0.757	0.269	278.7	255.5	210.8	273.3	248.5	200.8
39.9	1.280	0.763	0.271	279.0	255.9	211.1	273.6	248.9	201.1
40.2	1.290	0.769	0.273	279.3	256.2	211.4	274.0	249.3	201.4
40.6	1.300	0.775	0.275	279.7	256.5	211.7	274.4	249.7	201.8
41.0	1.310	0.781	0.277	280.0	256.9	212.0	274.7	250.0	202.1
41.3	1.320	0.787	0.279	280.4	257.2	212.3	275.1	250.4	202.4
41.7	1.330	0.793	0.282	280.7	257.6	212.6	275.5	250.8	202.8
42.0	1.340	0.799	0.284	281.0	257.9	213.0	275.8	251.1	203.1
42.4	1.350	0.805	0.286	281.3	258.2	213.3	276.2	251.5	203.4
42.7	1.360	0.811	0.288	281.7	258.6	213.6	276.5	251.8	203.7
43.1	1.370	0.817	0.290	282.0	258.9	213.9	276.8	252.2	204.1
43.4	1.380	0.822	0.292	282.3	259.2	214.2	277.2	252.5	204.4
43.8	1.390	0.828	0.294	282.6	259.6	214.5	277.5	252.9	204.7
44.1	1.400	0.834	0.296	282.9	259.9	214.7	277.9	253.2	205.0
44.5	1.410	0.840	0.299	283.3	260.2	215.0	278.2	253.6	205.3
44.8	1.420	0.846	0.301	283.6	260.5	215.3	278.5	253.9	205.6
45.2	1.430	0.852	0.303	283.9	260.8	215.6	278.9	254.2	206.0
45.5	1.440	0.858	0.305	284.2	261.1	215.9	279.2	254.6	206.3
45.9	1.450	0.864	0.307	284.5	261.5	216.2	279.5	254.9	206.6
46.2	1.460	0.870	0.309	284.8	261.8	216.5	279.8	255.2	206.9
46.6	1.470	0.876	0.311	285.1	262.1	216.8	280.1	255.6	207.2
46.9	1.480	0.882	0.313	285.4	262.4	217.0	280.5	255.9	207.5
47.3	1.490	0.888	0.315	285.7	262.7	217.3	280.8	256.2	207.8
47.6	1.500	0.894	0.318	286.0	263.0	217.6	281.1	256.5	208.1
48.0	1.510	0.900	0.320	286.3	263.3	217.9	281.4	256.9	208.4
48.3	1.520	0.906	0.322	286.5	263.6	218.2	281.7	257.2	208.7
48.7	1.530	0.912	0.324	286.8	263.9	218.4	282.0	257.5	209.0
49.0	1.540	0.918	0.326	287.1	264.2	218.7	282.3	257.8	209.2
49.4	1.550	0.924	0.328	287.4	264.4	219.0	282.6	258.1	209.5
49.8	1.560	0.930	0.330	287.7	264.7	219.2	282.9	258.4	209.8
50.1	1.570	0.936	0.332	287.9	265.0	219.5	283.2	258.7	210.1
50.5	1.580	0.942	0.335	288.2	265.3	219.8	283.5	259.0	210.4
50.8	1.590	0.948	0.337	288.5	265.6	220.0	283.8	259.3	210.7
51.2	1.600	0.954	0.339	288.8	265.9	220.3	284.1	259.6	211.0
51.5	1.610	0.960	0.341	289.0	266.2	220.6	284.4	259.9	211.2
51.9	1.620	0.966	0.343	289.3	266.4	220.8	284.6	260.2	211.5
52.2	1.630	0.971	0.345	289.6	266.7	221.1	284.9	260.5	211.8
52.6	1.640	0.977	0.347	289.8	267.0	221.3	285.2	260.8	212.1
52.9	1.650	0.983	0.349	290.1	267.3	221.6	285.5	261.1	212.3
53.3	1.660	0.989	0.351	290.3	267.5	221.9	285.8	261.4	212.6
53.6	1.670	0.995	0.354	290.6	267.8	222.1	286.0	261.7	212.9
54.0	1.680	1.001	0.356	290.9	268.1	222.4	286.3	262.0	213.1
54.3	1.690	1.007	0.358	291.1	268.3	222.6	286.6	262.2	213.4
54.7	1.700	1.013	0.360	291.4	268.6	222.9	286.9	262.5	213.7

2.4 CREDIBILITY EVALUATION OF SURVEILLANCE DATA

Regulatory Guide 1.99, Revision 2, describes general procedures acceptable to the NRC staff for calculating the effects of neutron radiation embrittlement of the low-alloy steels currently used for light-water-cooled reactor vessels. Position C.2 of Regulatory Guide 1.99, Revision 2, describes the method for calculating the adjusted reference temperature and Charpy upper-shelf energy of reactor vessel beltline materials using surveillance capsule data. The methods of Position C.2 can only be applied when two or more credible surveillance data sets become available from the reactor in question.

To date there have been three surveillance capsules removed from the Indian Point Unit 3 reactor vessel. In past analysis, these surveillance data sets have been shown to be credible. However due to changes in the calculational methods, the capsule fluences of the three withdrawn capsules have changed slightly. Therefore criterion 3 from Regulatory Guide 1.99, Revision 2 is re-evaluated below to ensure the data is still credible and applicable to Indian Point Unit 3 NPP. Criterion 3 is the only criteria that will be checked since it is the only criteria that involves fluences, fluence factors and chemistry factors, all which have changed.

<u>EVALUATION:</u>

Criterion 3: When there are two or more sets of surveillance data from one reactor, the scatter of ΔRT_{NDT} values about a best-fit line drawn as described in Regulatory Position 2.1 normally should be less than 28°F for welds and 17°F for base metal. Even if the fluence range is large (two or more orders of magnitude), the scatter should not exceed twice those values. Even if the data fail this criterion for use in shift calculations, they may be credible for determining decrease in upper shelf energy if the upper shelf can be clearly determined, following the definition given in ASTM E185-82.

The functional form of the least squares method as described in Regulatory Position 2.1 will be utilized to determine a best-fit line for this data and to determine if the scatter of these ΔRT_{NDT} values about this line is less than 28°F for welds and less than 17°F for the plate. The best-fit line as described in Regulatory Position 2.1 of Regulatory Guide 1.99, Revision 2 is described on the following page.

Table 2-5: Indian Point Unit 3 Surveillance Capsule Data

Material	Capsule	Capsule f[a] (10^{19} n/cm^2)	FF[b]	ΔRT_{NDT}[c] (°F)	FF·ΔRT_{NDT} (°F)	FF^2
Inter. Shell Plate B2803-3 (Longitudinal)	T	0.263	0.636711	137	87.22943	0.405401
	Z	1.04	1.010975	170	171.8657	1.02207
Intermediate Shell Plate B2803-3 (Transverse)	T	0.263	0.636711	118	75.13192	0.405401
	Y	0.692	0.896754	150	134.513	0.804167
	Z	1.04	1.010975	155	156.7011	1.02207
	SUM:				625.4412	3.659109
	$CF_{B2803\text{-}3} = \Sigma(FF \cdot RT_{NDT}) \div \Sigma(FF^2) = (625.4412) \div (3.659109) = 170.9$[d]					

<u>Notes:</u>

(a) f = fluence from Reference 20

(b) FF = fluence factor = $f^{(0.28-0.1 \cdot \text{Log} f)}$

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values (from WCAP-11815 (Ref 9) and WCAP-10300 (Ref 10))

(d) Values shown are based on Excel Spreadsheet.

The scatter of ΔRT_{NDT} values about the functional form of a best-fit line drawn as described in Regulatory Position 2.1 is presented in Table 2-6.

Table 2-6: Best Fit Evaluation for Indian Point Unit 3 Surveillance Materials

Base Material	CF (°F)	FF	Measured ΔRT_{NDT} (30 ft-lb) (°F)	Best Fit[a] ΔRT_{NDT} (°F)	Scatter of ΔRT_{NDT} (°F)	< 17°F (Base Metals) < 28°F (Weld Metal)
Inter. Shell Plate B2803-3 (Longitudinal)	170.9	0.636	137	108.69	28.31	No
	170.9	1.010	170	172.61	-2.61	Yes
Intermediate Shell Plate B2803-3 (Transverse)	170.9	0.636	118	108.69	9.31	Yes
	170.9	0.896	150	153.13	-3.13	Yes
	170.9	1.010	155	172.61	-17.61	No

<u>Notes:</u>

(a) Best Fit Line Per Equation 2 of Reg. Guide 1.99 Rev. 2 Position 1.1.

Table 2-6 indicates that two of the five measured plate ΔRT_{NDT} values are outside of the 1σ scatter band. One of the two values outside the scatter band is only out by 0.61°F which can be attributed to rounding errors in the calculations of Fluence and Chemistry Factors and knowing that the measured RT_{NDT} values were taken from a hand-fit plot. In addition, if the Best Estimate Fluences were used instead of the calculated values, the scatter becomes approximately 15°F, which is within the 1σ scatter band. Therefore, based on engineering judgement, the plate data meets this criterion and the surveillance data is deemed credible.

3.0 GENERAL APPROACH FOR CALCULATING PRESSURE-TEMPERATURE LIMITS

The PTCURVE computer code is used to calculate the reactor vessel beltline P-T limits. The methodology described hereafter is consistent with Westinghouse procedure to develop P-T Limits Curves and has been favorably reviewed by the NRC.

The reactor vessel beltline region is analyzed assuming a semi-elliptical surface flaw oriented in the axial direction with a depth of one quarter of the reactor vessel beltline thickness. The assumed flaw has an aspect ratio of one to six. The postulated flaw is analyzed at both the inside diameter location (referred to as the 1/4t location) and the outside diameter location (referred to as the 3/4t location) to assure the most limiting condition is achieved.

At each of the postulated flaw locations the Mode I stress intensity factor K_I, produced by each of the specified loadings is calculated and the summation of the K_I values is compared to a reference stress intensity K_{IR}, which is the critical value of K_I at the material temperature. The result of this method is a relationship of pressure versus temperature for reactor vessel operating limits, which conservatively preclude brittle fracture.

K_{IR} is obtained from a reference fracture toughness curve for reactor vessel low alloy steels and is defined in Appendices A and G to Section XI of the ASME Code (Ref. 11 and 12). Since ASME Code Case N-640 (Ref. 17) is used, K_{IR} equals K_{IC}, and is defined as the lower bound of the static initiation critical K_I value measured as a function of temperature.

This governing curve is defined by the following expression:

$$K_{IR} = K_{IC} = 33.20 + 2.806e^{[0.02\cdot(T - RT_{NDT} + 100)]}$$

K_{IR} = reference stress intensity factor, Ksi $\sqrt{in}$

K_{IC} = crack initiation reference stress intensity factor, Ksi $\sqrt{in}$

T = temperature at the assumed flaw tip, °F

RT_{NDT} = adjusted reference nil ductility temperature at assumed flaw tip, °F

For any instant during the postulated heatup or cooldown, K_I is calculated at the metal temperature and at the adjusted RT_{NDT} at the tip of the flaw. The temperature distribution and the temperature at the flaw tip are calculated using a one-dimensional three-noded isoparametric finite element suitable for one-dimensional radial conduction-convection heat transfer analysis.

The fracture mechanics algorithms make use of a superposition technique using influence coefficients for calculating the Mode I stress intensity factors. In general, the thermal stress intensity factors are found using the temperature difference through the wall as a function of transient time. They are then subtracted from the available K_{IR} value to find the allowable pressure stress intensity factor and consequently the allowable pressure.

In general, the expression used to derive P-T limits is:

$$2K_{IM} + K_{IT} < K_{IR} \text{ (Ref. 12)}$$

K_{IM}	= Allowable Pressure Stress Intensity Factor, Ksi $\sqrt{in}$
K_{IT}	= Thermal Stress Intensity Factor, Ksi $\sqrt{in}$
K_{IR}	= Reference Stress Intensity Factor, Ksi $\sqrt{in}$

The superposition technique used here is based on the temperature profile rather than on the stress profile, as is typically done. A third order polynomial fit to the temperature distributions in the wall was used and is given by:

$$T(x) = C_0 + C_1\left(1-\frac{x}{h}\right) + C_2\left(1-\frac{x}{h}\right)^2 + C_3\left(1-\frac{x}{h}\right)^3$$

$T(x)$	= Temperature at radial location x from inside wall surface, °F
C_0-C_3	= Coefficients in polynomial fit
x	= Distance through beltline wall, in
h	= Beltline wall thickness, in

The unit K_I values are calculated for each term of the polynomial using a two-dimensional finite element code. These unit values are used to determine the total K_I value for the applied loads under any general temperature profile in the wall that occurs during the thermal transient.

The thermal stress intensity factor is represented by the following expression:

$$K_{IT}(a) = \sum_{i=0}^{3} C_i K_i^*$$

K_{IT}	= thermal stress intensity factor
C_i	= coefficients in polynomial fit
K_i^*	= polynomial influence coefficients

Temperature-based influence coefficients for determination of the thermal stress intensity factor, K_{IT} are used. These were computed using a two-dimensional reactor vessel model with a crack adjusted to account for three-dimensional effects using methods from Reference 13.

Isothermal and transient conditions were analyzed at the selected value of 34.7 EFPY in Reference 21 to generate revised P-T Limits for IP3 NPP using ASME Code Case N-640. The ART used for 34.7 EFPY corresponds to a 17% increase over the current ART at 1/4t and is a direct result of ASME Code Case N-640. The cooldown transient was analyzed at rates of 20 °F/hr, 50 °F/hr, 80 °F/hr and 100 °F/hr and began at a bulk coolant temperature of 550 °F and terminated at 50 °F. The heatup transient was analyzed at rates of 20 °F/hr, 40 °F/hr, and 60 °F/hr and began at a bulk temperature of 50 °F and terminated at 550 °F. The hydrostatic limits were obtained only for the isothermal condition over the same bulk temperature range.

4.0 COOLDOWN LIMIT ANALYSIS

During cooldown, pressure membrane and thermal bending stresses act together in tension at the reactor vessel inside wall. This results in the pressure stress intensity factor K_{IM}, and the thermal stress intensity factor K_{IT}, acting in unison creating a high stress intensity. At the reactor vessel outside wall the tensile pressure stress and the compressive thermal stress act in opposition, resulting in a lower total stress than at the inside wall location. Also neutron embrittlement, the shift in RT_{NDT} and the reduction in fracture toughness are less severe at the outside wall compared to the inside wall location. Consequently, the inside flaw location is more limiting for the cooldown event.

Utilizing the material metal temperature and adjusted RT_{NDT} at the 1/4t and 3/4t locations, the reference stress intensities are determined. From the finite element method used for the heat transfer analysis, the through wall temperature gradient is calculated for the assumed cooldown rate to determine the thermal stress intensity factor. In general, the thermal stress intensity factors are found using the temperature difference through the wall as a function of transient time. They are then subtracted from the available K_{IR} value to find the allowable pressure stress intensity factor and consequently the allowable pressure.

The cooldown P-T curves are thus generated by calculating the allowable pressure on the reference flaw at the 1/4t and 3/4t locations based upon:

$$K_{IM} = \frac{K_{IR} - K_{IT}}{2}$$

K_{IM} = Allowable pressure stress intensity factor as a function of coolant temperature, Ksi $\sqrt{in}$

K_{IR} = Reference stress intensity factor as a function of coolant temperature, Ksi $\sqrt{in}$

K_{IT} = Thermal stress intensity factor as a function of coolant temperature, Ksi $\sqrt{in}$

To develop a minimum P-T limit for the cooldown event, the isothermal P-T limit must be calculated. The isothermal P-T limit is then compared to the P-T limit associated with a cooling rate and the more restrictive allowable P-T limit is chosen. This results in a minimum limit curve for the reactor vessel beltline. Table 4-1 and Figure 4-1 provide the results for isothermal and 20°F/hr, 50°F/hr, 80°F/hr, and 100°F/hr cooldown P-T limits.

Table 4-1: Indian Point Unit 3 P-Allowable vs. RCS Temperature, Cooldown, Uncorrected (LTOP Based, ART + 17%), 34.7 EFPY

RCS	P-Allowable (ksig), 34.7 EFPY				
Temp (°F)	Isothermal	20°F/hr	50°F/hr	80°F/hr	100°F/hr
50	0.625	0.548	0.433	0.318	0.243
60	0.627	0.550	0.435	0.321	0.246
70	0.629	0.552	0.438	0.325	0.250
80	0.631	0.555	0.441	0.329	0.256
90	0.634	0.558	0.446	0.335	0.262
100	0.637	0.562	0.451	0.341	0.270
110	0.641	0.567	0.457	0.350	0.279
120	0.646	0.573	0.465	0.359	0.291
130	0.653	0.581	0.474	0.372	0.305
140	0.660	0.590	0.486	0.386	0.323
150	0.670	0.601	0.500	0.404	0.344
160	0.681	0.614	0.517	0.426	0.370
170	0.695	0.631	0.538	0.453	0.402
180	0.713	0.651	0.564	0.486	0.440
190	0.733	0.676	0.596	0.526	0.488
200	0.759	0.706	0.634	0.575	0.545
210	0.790	0.742	0.681	0.635	0.616
220	0.828	0.787	0.738	0.708	0.701
230	0.875	0.842	0.808	0.797	0.806
240	0.932	0.909	0.893	0.906	0.932
250	1.001	0.991	0.998	1.001	1.001
260	1.086	1.086	1.086	1.086	1.086
270	1.189	1.189	1.189	1.189	1.189
280	1.316	1.316	1.316	1.316	1.316
290	1.471	1.471	1.471	1.471	1.471
300	1.659	1.659	1.659	1.659	1.659
310	1.890	1.890	1.890	1.890	1.890
320	2.171	2.171	2.171	2.171	2.171
330	2.515	2.515	2.515	2.515	2.515
340	2.935	2.935	2.935	2.935	2.935
350	3.448	3.448	3.448	3.416	3.349
360	3.723	3.645	3.528	3.418	3.352
370	3.723	3.645	3.528	3.419	3.356
380	3.723	3.645	3.528	3.421	3.360
390	3.723	3.645	3.529	3.424	3.365
400	3.723	3.645	3.529	3.427	3.370
410	3.723	3.645	3.530	3.431	3.377
420	3.723	3.645	3.531	3.435	3.385
430	3.723	3.645	3.532	3.441	3.394
440	3.723	3.645	3.534	3.448	3.405
450	3.723	3.645	3.536	3.456	3.417
460	3.723	3.645	3.540	3.466	3.432
470	3.723	3.645	3.544	3.479	3.449
480	3.723	3.645	3.550	3.494	3.470
490	3.723	3.646	3.559	3.512	3.494
500	3.723	3.647	3.571	3.535	3.522
510	3.723	3.649	3.587	3.562	3.554
520	3.723	3.653	3.609	3.596	3.593
530	3.723	3.663	3.639	3.636	3.637
540	3.723	3.684	3.680	3.683	3.685
550	3.723	3.723	3.723	3.723	3.723

NOTE: Linear interpolation between two consecutive cooldown rates can be employed in order to calculate cooldown rates not included in this table.

Table 4-2: Indian Point Unit 3 P-Allowable vs. RCS Temperature, Minimum Cooldown Comparison of 15 EFPY and 34.7 EFPY, Uncorrected

RCS	Minimum Cooldown P-Allowable (ksig)	
Temp (°F)	15 EFPY K_{IA}	34.7 EFPY K_{IC}
50	0.161	0.243
60	0.168	0.246
70	0.175	0.250
80	0.184	0.256
90	0.195	0.262
100	0.206	0.270
110	0.220	0.279
120	0.236	0.291
130	0.255	0.305
140	0.276	0.323
150	0.301	0.344
160	0.329	0.370
170	0.362	0.402
180	0.400	0.440
190	0.444	0.488
200	0.494	0.545
210	0.554	0.616
220	0.622	0.701
230	0.700	0.797
240	0.790	0.893
250	0.893	0.991
260	0.998	1.086
270	1.105	1.189
280	1.209	1.316
290	1.316	1.471
300	1.436	1.659
310	1.574	1.890
320	1.734	2.171
330	1.919	2.515
340	2.133	2.935
350	2.380	3.349
360	2.665	3.352
370	2.996	3.356
380	3.300	3.360
390	3.300	3.365
400	3.300	3.370
410	3.300	3.377
420	3.300	3.385
430	3.300	3.394
440	3.300	3.405
450	3.300	3.417
460	3.300	3.432
470	3.300	3.449
480	3.300	3.470
490	3.300	3.494
500	3.300	3.522
510	3.300	3.554
520	3.300	3.593
530	3.300	3.636
540	3.300	3.680
550	3.300	3.723

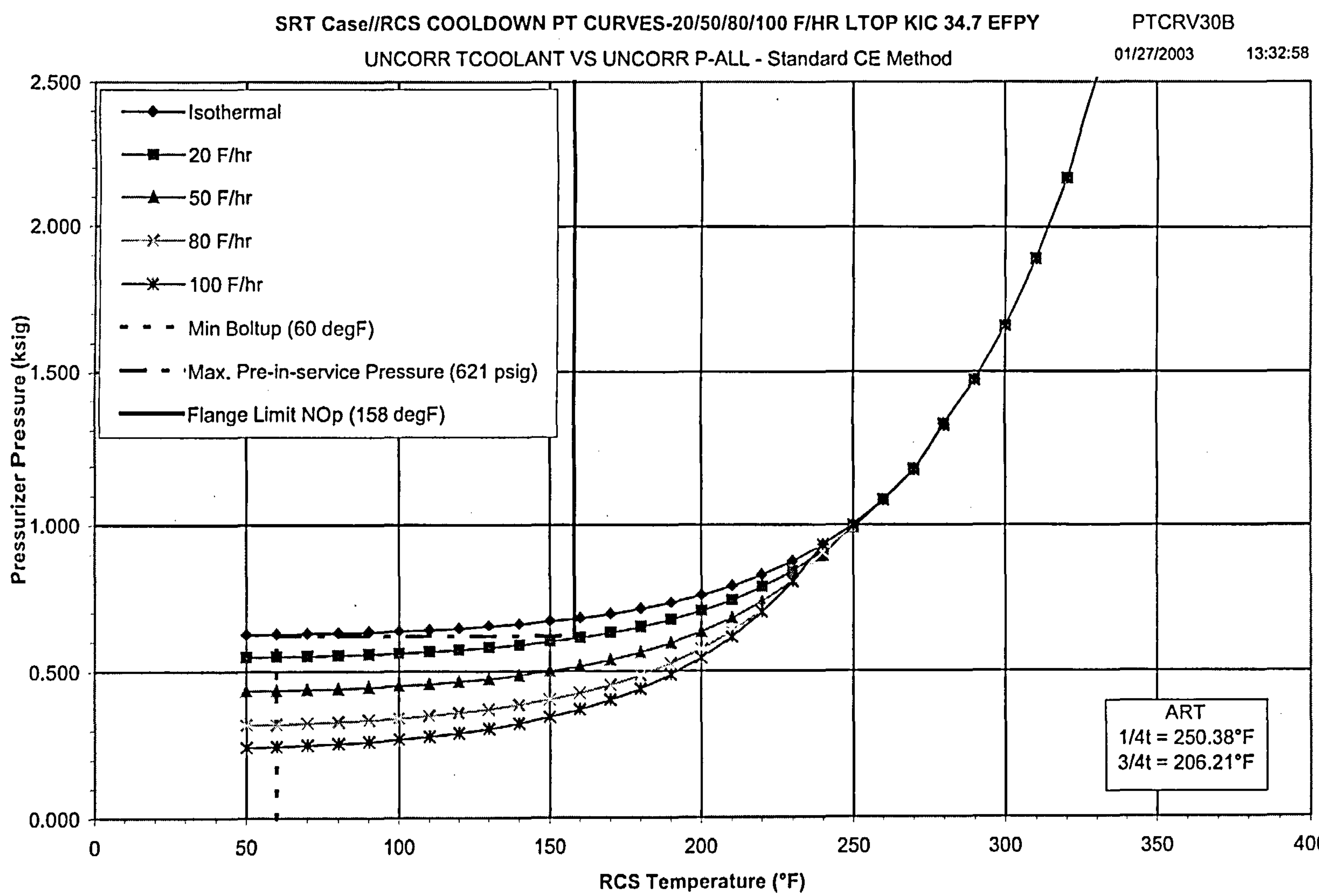


Figure 4-1: Indian Point Unit 3, Beltline P-T Limits, Cooldown, Uncorrected, 34.7 EFPY (LTOP Based)

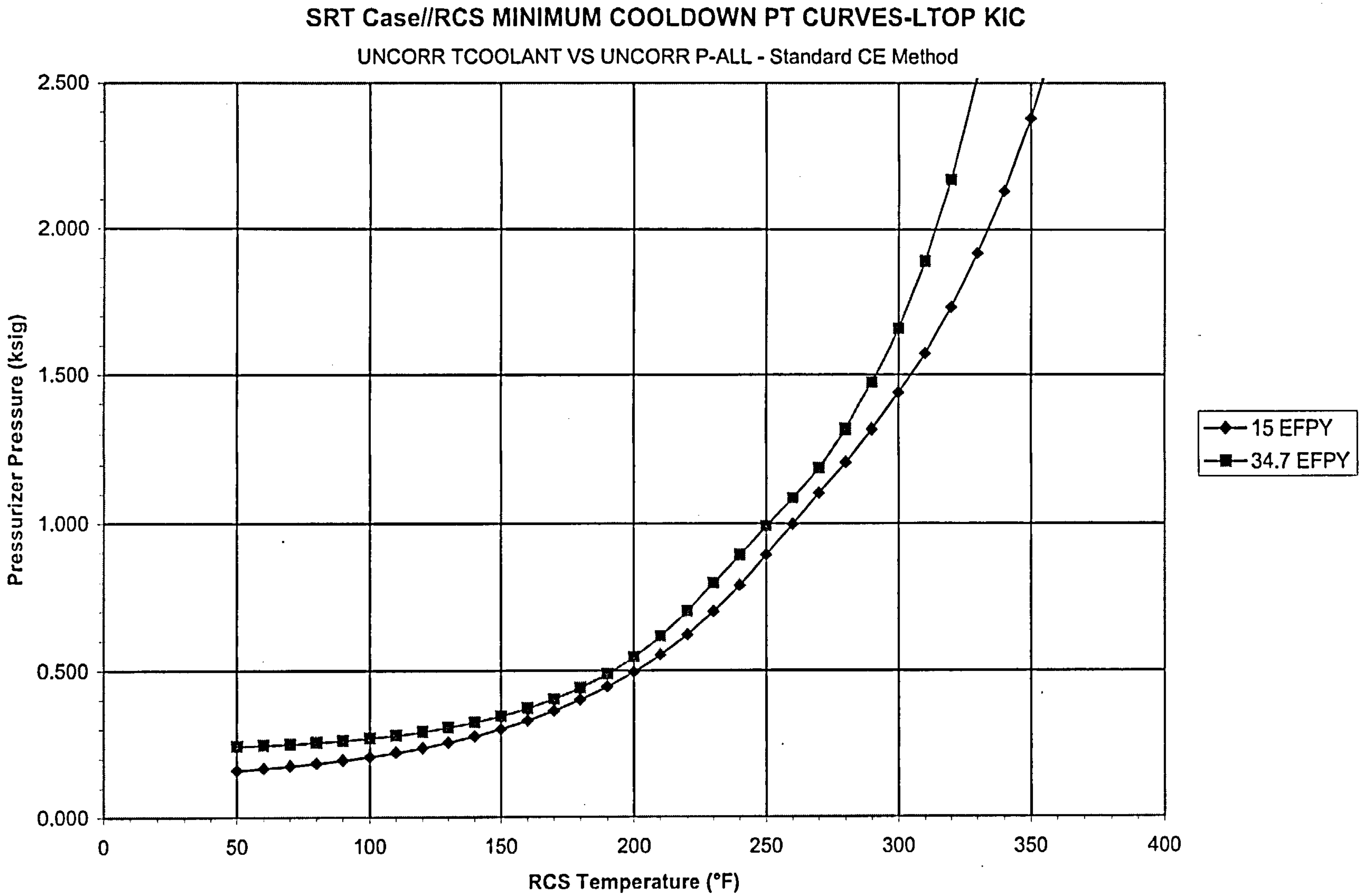


Figure 4-2: Indian Point Unit 3 P-Allowable vs. RCS Temperature, Minimum Cooldown Comparison of 15 EFPY and 34.7 EFPY, Uncorrected

5.0 HEATUP LIMIT ANALYSIS

During heatup, the thermal bending stress is compressive at the reactor vessel inside wall and is tensile at the reactor vessel outside wall. Internal pressure creates a tensile stress at the inside wall and outside wall locations. Consequently, the outside wall location has the larger total stress when compared to the inside wall. However, neutron embrittlement, shift in material RT_{NDT}, and reduction in fracture toughness are greater at the inside location than the outside. Therefore, results from both the inside and outside flaw locations must be compared to assure that the most limiting condition is recognized.

As described in the cooldown case, the reference stress intensity is calculated at the metal temperature and the adjusted RT_{NDT} at the tip of the flaw. Using a finite element method for the heat transfer analysis, the temperature profile through the wall and the metal temperatures at the tip of the flaw are calculated for the transient history. This information is used to calculate the thermal stress intensity factor at the 1/4t and 3/4t locations using the calculated wall gradient and thermal influence coefficients. The allowable pressure stress intensity is then determined by superposition of the thermal stress intensity factor with the available reference stress intensity at the flaw tip. The allowable pressure is derived from the calculated allowable pressure stress intensity factor.

A sign change occurs in the thermal stress through the reactor vessel beltline wall. Assuming a reference flaw at the 1/4t location, the thermal stress tends to alleviate the pressure stress indicating the isothermal steady state is the limiting P-T limit. However, the isothermal condition may not always provide the limiting P-T limit for the 1/4t location during a heatup transient. This is due to the difference between the base metal temperature and the Reactor Coolant System (RCS) fluid temperature at the inside wall. For a given heatup rate (non-isothermal), the differential temperature through the clad and film increases as a function of thermal rate, resulting in a crack tip temperature which is lower than the RCS fluid temperature. Therefore to ensure the accurate representation of the 1/4t P-T limit during heatup, both the isothermal and heatup rate dependent P-T limits are calculated to ensure the limiting condition is recognized. These limits account for clad and film differential temperatures and for the gradual increase in wall differential temperatures with time, as do the cooldown limits.

To develop minimum P-T limits for the heatup transient, the isothermal conditions at 1/4t and 3/4t, 1/4t heatup, and 3/4t heatup P-T limits are compared for a given thermal rate. Then, the most restrictive P-T limits are combined resulting in a minimum limit curve for the reactor vessel beltline for the heatup event. Table 5-1 and Figure 5-1 provide the results for isothermal and 20°F/hr, 40°F/hr and 60°F/hr heatup P-T limits.

Table 5-1: Indian Point Unit 3 P-Allowable vs. RCS Temperature, Heatup, Uncorrected (LTOP Based, ART + 17%), 34.7 EFPY

RCS Temp (°F)	P-Allowable (ksig), 34.7 EFPY			
	Isothermal	20°F/hr	40°F/hr	60°F/hr
50	0.625	0.625	0.625	0.625
60	0.627	0.627	0.627	0.627
70	0.629	0.629	0.622	0.620
80	0.631	0.631	0.604	0.594
90	0.634	0.634	0.594	0.575
100	0.637	0.637	0.589	0.561
110	0.641	0.641	0.588	0.552
120	0.646	0.646	0.591	0.548
130	0.653	0.653	0.597	0.547
140	0.660	0.660	0.606	0.549
150	0.670	0.670	0.618	0.554
160	0.681	0.681	0.634	0.563
170	0.695	0.695	0.654	0.575
180	0.713	0.713	0.678	0.592
190	0.733	0.733	0.708	0.613
200	0.759	0.759	0.745	0.639
210	0.790	0.790	0.790	0.672
220	0.828	0.828	0.828	0.712
230	0.875	0.875	0.875	0.762
240	0.932	0.932	0.932	0.824
250	1.001	1.001	1.001	0.899
260	1.086	1.086	1.086	0.991
270	1.189	1.182	1.187	1.103
280	1.316	1.289	1.279	1.241
290	1.471	1.421	1.390	1.376
300	1.659	1.581	1.526	1.492
310	1.890	1.777	1.693	1.633
320	2.171	2.016	1.896	1.806
330	2.515	2.309	2.145	2.017
340	2.935	2.665	2.448	2.275
350	3.448	3.101	2.818	2.590
360	3.723	3.634	3.271	2.974
370	3.723	3.723	3.723	3.444
380	3.723	3.723	3.723	3.723
390	3.723	3.723	3.723	3.723
400	3.723	3.723	3.723	3.723
410	3.723	3.723	3.723	3.723
420	3.723	3.723	3.723	3.723
430	3.723	3.723	3.723	3.723
440	3.723	3.723	3.723	3.723
450	3.723	3.723	3.723	3.723
460	3.723	3.723	3.723	3.723
470	3.723	3.723	3.723	3.723
480	3.723	3.723	3.723	3.723
490	3.723	3.723	3.723	3.723
500	3.723	3.723	3.723	3.723
510	3.723	3.723	3.723	3.723
520	3.723	3.723	3.723	3.723
530	3.723	3.723	3.723	3.723
540	3.723	3.723	3.723	3.723
550	3.723	3.723	3.723	3.723

NOTE: Linear interpolation between two consecutive heatup rates can NOT be employed in order to calculate heatup rates not included in this table.

Table 5-2: Indian Point Unit 3 P-Allowable vs. RCS Temperature, Minimum Heatup Comparison of 15 EFPY and 34.7 EFPY, Uncorrected

RCS	Minimum Heatup P-Allowable (ksig)	
Temp (°F)	15 EFPY K_{IA}	34.7 EFPY K_{IC}
50	0.572	0.625
60	0.576	0.627
70	0.580	0.620
80	0.585	0.594
90	0.591	0.575
100	0.595	0.561
110	0.568	0.552
120	0.551	0.548
130	0.541	0.547
140	0.537	0.549
150	0.539	0.554
160	0.546	0.563
170	0.557	0.575
180	0.574	0.592
190	0.594	0.613
200	0.620	0.639
210	0.651	0.672
220	0.688	0.712
230	0.732	0.762
240	0.783	0.824
250	0.843	0.899
260	0.913	0.991
270	0.993	1.103
280	1.087	1.241
290	1.195	1.376
300	1.320	1.492
310	1.465	1.633
320	1.633	1.806
330	1.769	2.017
340	1.919	2.275
350	2.092	2.590
360	2.293	2.974
370	2.525	3.444
380	2.793	3.723
390	3.102	3.723
400	3.300	3.723
410	3.300	3.723
420	3.300	3.723
430	3.300	3.723
440	3.300	3.723
450	3.300	3.723
460	3.300	3.723
470	3.300	3.723
480	3.300	3.723
490	3.300	3.723
500	3.300	3.723
510	3.300	3.723
520	3.300	3.723
530	3.300	3.723
540	3.300	3.723
550	3.300	3.723

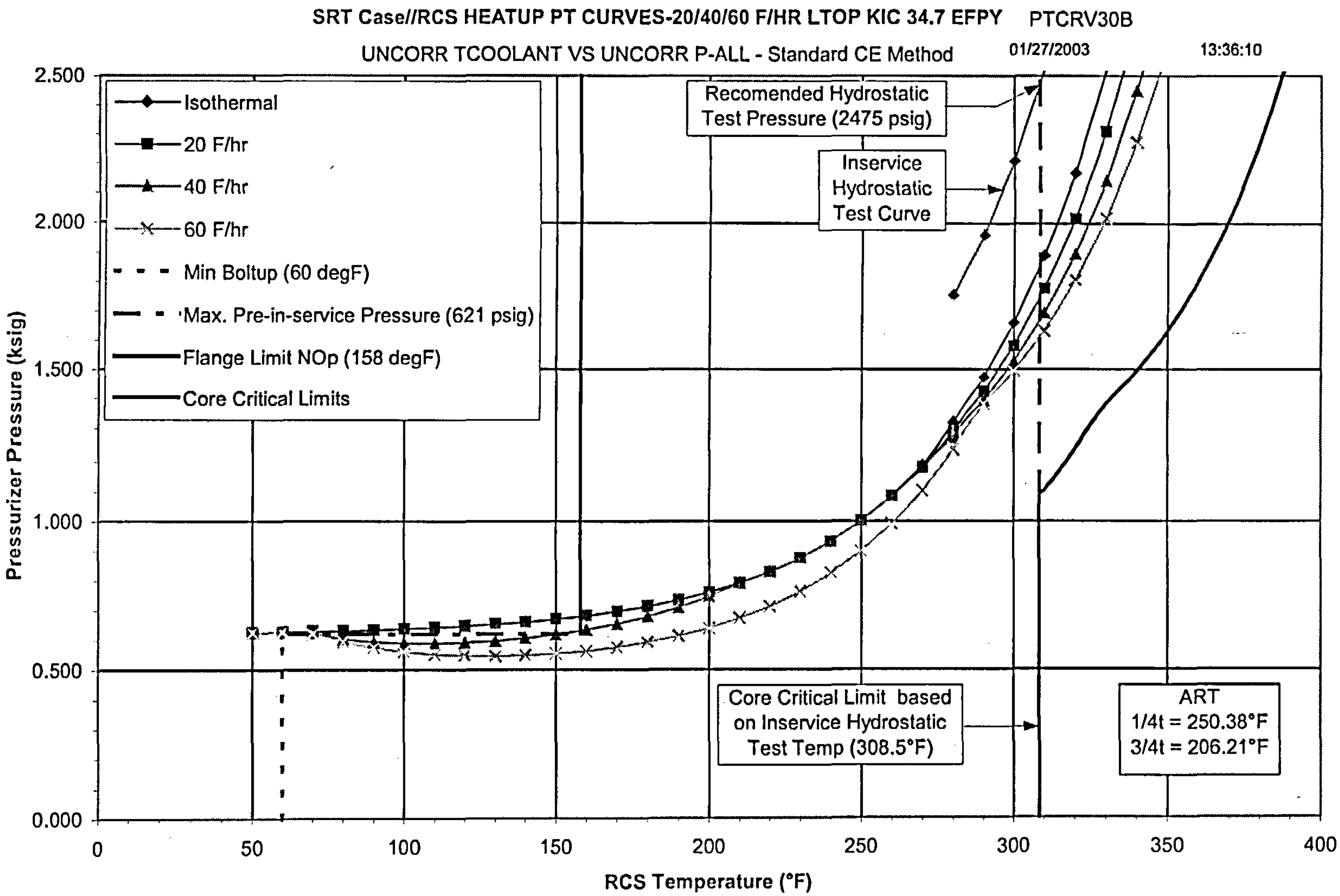


Figure 5-1:Indian Point Unit 3, Beltline P-T Limits, Heatup, Uncorrected, 34.7 EFPY (LTOP Based)

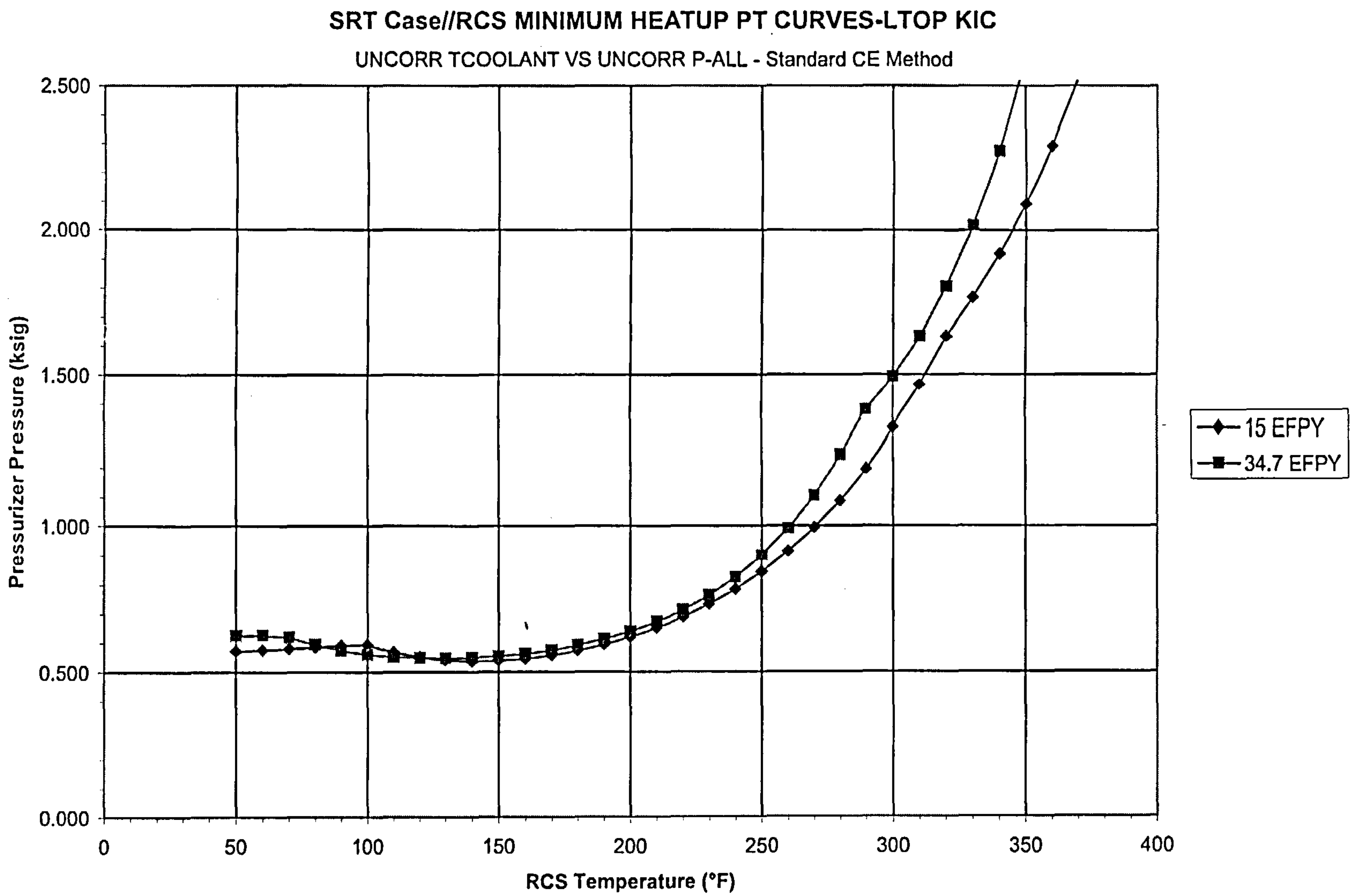


Figure 5-2: Indian Point Unit 3 P-Allowable vs. RCS Temperature, Minimum Heatup Comparison of 15 EFPY and 34.7 EFPY, Uncorrected

6.0 HYDROSTATIC TEST AND CORE CRITICAL LIMIT ANALYSIS

Hydrostatic test limits have been calculated for 34.7 EFPY using the methodology of the ASME Boiler and Pressure Vessel Code, Section XI, Appendix G (Ref. 12). The governing equation for determination of hydrostatic test limits is:

$$1.5 \cdot K_{IM} + K_{IT} < K_{IR}$$

The procedure is the same as when calculating normal operation heatup and cooldown limits with the exception of the factor of safety that is applied to the allowable pressure stress intensity (K_{IM}). The PTCURVE code was utilized to do this calculation by changing the applied factor of safety from 2.0 for normal operation to 1.5 for hydrostatic limits.

The purpose of the hydrostatic test limit is to establish the minimum temperature required at the corresponding hydrostatic test pressure. It is Westinghouse's practice to recommend that the in-service hydrostatic test for CE NSSS designs be performed at a test pressure corresponding to 1.1 times the Operating Pressure with the reactor core not critical. Under these conditions, 10 CFR Part 50, Appendix G requires that the minimum temperature for the RV must be at least as high as the RT_{NDT} for the limiting material in the closure flange region plus 90°F. However, the beltline hydrostatic test limits at the recommended test pressure are more limiting. Hence, it is only necessary to show the beltline in-service hydrostatic test limits in the vicinity of this pressure.

To define minimum temperature criteria for core critical operation, Appendix G to 10 CFR Part 50 specifies the following Pressure-Temperature Limits and Minimum Temperature Requirements. The Core Critical Limit is presented in Table 6-2 and graphically on the Heatup plot, Figure 5-1.

- Pressure-Temperature Limit Requirements:

ASME Section XI, Appendix G Limits plus 40°F apply throughout the entire range of the RCS pressure.

- Minimum Temperature Requirements:

In the case when the RCS pressure is less than or equal to 20% of the pre-service hydrostatic test pressure (PHTP), the minimum temperature requirement for the RV must be at least as high as the RT_{NDT} for the limiting material in the closure flange region stresses by bolt preload plus 40°F, or the minimum permissible temperature for the in-service hydrostatic pressure test, whichever is larger. In the case when the RCS pressure is greater than 20% of the PHTP, the minimum temperature requirement for the RV must be at least as high as the RT_{NDT} for the limiting material in the closure flange region stresses by bolt preload plus 160°F, or the minimum permissible temperature for the in-service hydrostatic pressure test, whichever is larger.

According to Appendix G to 10 CFR Part 50, the calculation below specifies P-T limits for core critical operation to provide additional margin during actual power operation.

In-service hydrostatic pressure: $= (1.1 \times \text{Operating Pressure}) + \text{instrumentation uncertainty}$
$= (1.1 \times 2{,}250 \text{ psia}) + 30 \text{ psi}$
$= 2{,}505 \text{ psia}$

Pressure instrumentation uncertainty of 30 psi was obtained from Reference 14.

The minimum temperature for core critical operation and hydrostatic test is the temperature corresponding to the in-service hydrostatic pressure, which is 308.5°F. This temperature was calculated from Table 6-1 by interpolation to the uncorrected pressure of 2,475 psia which was conservatively used in lieu of gauge pressure.

Table 6-1: Indian Point Unit 3 P-Allowable vs. RCS Temperature, Hydrostatic, Uncorrected (LTOP Based, ART + 17%), 34.7 EFPY

RCS Temp (°F)	P-Allowable (ksig), 34.7 EFPY Isothermal
50	0.833
60	0.835
70	0.838
80	0.841
90	0.845
100	0.849
110	0.855
120	0.862
130	0.870
140	0.881
150	0.893
160	0.908
170	0.927
180	0.950
190	0.978
200	1.012
210	1.054
220	1.104
230	1.166
240	1.242
250	1.335
260	1.448
270	1.586
280	1.755
290	1.961
300	2.212
310	2.520
320	2.895
330	3.354
340	3.914
350	4.598
360	4.964
370	4.964
380	4.964
390	4.964
400	4.964
410	4.964
420	4.964
430	4.964
440	4.964
450	4.964
460	4.964
470	4.964
480	4.964
490	4.964
500	4.964
510	4.964
520	4.964
530	4.964
540	4.964
550	4.964

Table 6-2: Indian Point Unit 3 P-Allowable vs. RCS Temperature, Core Critical Limit for 34.7 EFPY, Uncorrected

Core Critical Limit	
Temp (°F)	P-Allowable (ksig)
300	0.991
308.5	0.00
308.5	1.0862
310	1.103
320	1.241
330	1.376
340	1.492
350	1.633
360	1.806
370	2.017
380	2.275
390	2.590
400	2.974
410	3.444

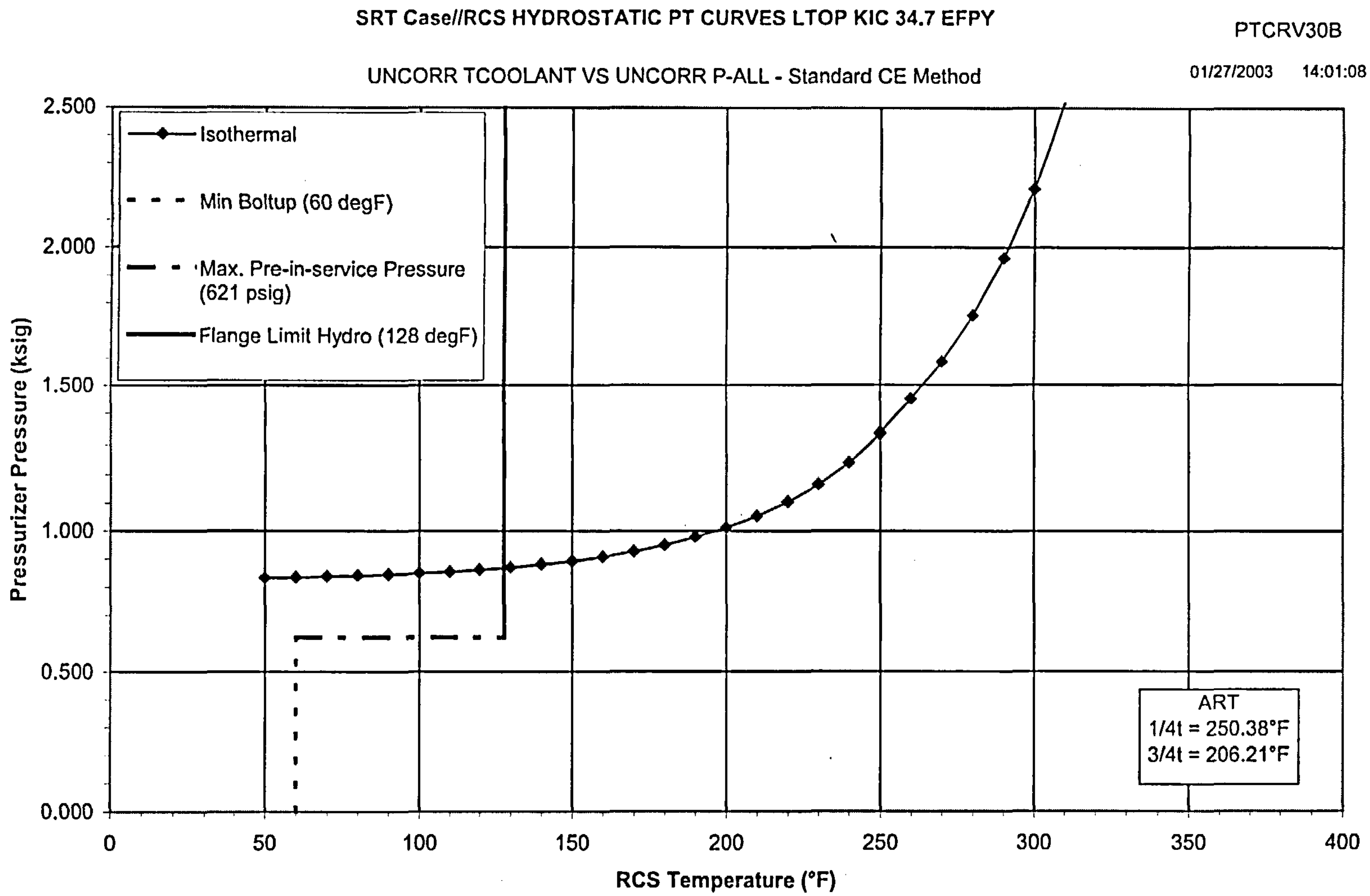


Figure 6-1: Indian Point Unit 3, Beltline P-T Limits, Hydrostatic, Uncorrected, 34.7 EFPY (LTOP Based)

7.0 MINIMUM BOLTUP TEMPERATURE

Westinghouse Engineering has reviewed the minimum boltup temperature requirements for the Indian Point Unit 3 reactor pressure vessel. According to Paragraph G-2222 of the ASME Boiler and Pressure Vessel (B&PV) Code, Section XI, Appendix G, the reactor vessel may be bolted up and pressurized to 20 percent of the initial hydrostatic test pressure at the initial RT_{NDT} of the material stressed by the boltup. Therefore, since the most limiting initial RT_{NDT} value is 38°F (vessel flange), the reactor vessel can be bolted up at this temperature. However, based on historical practices and engineering judgement, Westinghouse recommends a bolt up temperature of no less than 60°F.

8.0 MAXIMUM PRE-IN-SERVICE HYDROSTATIC PRESSURE

The maximum pre-in-service hydrostatic pressure serves as a regulatory breakpoint in the development of P-T limits and is defined by 10CFR50 Appendix G (Ref. 2) as twenty percent of Pre-service Hydrostatic Test Pressure (PHTP). The PHTP is defined as 1.25 times the Design Pressure. The function of maximum pre-in-service hydrostatic pressure in the development of P-T limits is to provide a transition between various temperature-only based P-T limits, such as minimum boltup or flange limits.

20% of Pre-service Hydrostatic Test Pressure:

$$= (1.25 \times \text{Design Pressure}) \times 0.20$$
$$= (1.25 \times 2{,}485 \text{ psig}) \times 0.20$$
$$= 621 \text{ psig}$$

9.0 FLANGE LIMITS

Per 10CFR50 Appendix G, the temperature of the closure flange regions must exceed the initial RT_{NDT} of the material by at least 120°F for normal operation and by 90°F for inservice hydrostatic test and leak testing when the pressure exceeds twenty percent of pre-service hydrostatic test pressure.

$$Flange_{Normal\ Op} = \text{Initial } RT_{NDT} + 120°F = 38°F + 120°F = 158°F$$

$$Flange_{Hydro} = \text{Initial } RT_{NDT} + 90°F = 38°F + 90°F = 128°F$$

The initial RT_{NDT} obtained from Reference 19 (vessel flange).

10.0 LTOP ENABLE/DISABLE TEMPERATURES

ASME Boiler and Pressure Vessel Code Section XI, Appendix G (Ref. 12) has defined the LTOP systems to become effective at coolant temperatures less than 200°F or at coolant temperatures corresponding to reactor vessel temperatures less than RT_{NDT} + 50°F, whichever is greater.

The LTOP enable temperature for cooldown is based on the isothermal P-T limit. The LTOP enable temperature is therefore equal to the 1/4t adjusted reference temperature of 250.38°F, for 34.7 EFPY plus 50°F.

LTOP Enable Temperature = 250.38°F + 50°F= 300.38°F

For heatup, the LTOP disable temperatures along with the limiting location and temperature difference between the flaw tip location and the RCS fluid for the analyzed heatup rates are given below. The PTCURVE code heat transfer results were utilized to determine LTOP disable Temperatures shown in Table 10-1. These values do not include a temperature correction factor.

Table 10-1: LTOP Disable Temperatures

Heatup Rate (°F/hr)	Limiting Condition	LTOP Disable Temperature (°F)
20	1/4t	308.52
40	1/4t	316.66
60	1/4t	324.80

11.0 DATA

Reactor Vessel Data:

Design Pressure = 2,500 psia

Design Temperature = 650°F

Normal Operating Pressure = 2,250 psia

Beltline Thickness = 8.625 inch

Inside Radius to Clad-Base Metal Interface = 86.906 inch

Cladding Thickness = 7/32 inch

Material – SA302 Grade B @ 300°F

Thermal Conductivity = 24.7 Btu/hr-ft-°F

Young's Modulus = 28.0 × E6 psi

Coefficient of Thermal Expansion = 7.77 × E-6 in/in-°F

Yield Stress = 44,500 psi

*Density = 489 lbm/ft^3

*Specific heat = 0.120 Btu/lb-°F

Note: * The density and the specific heat values are for typical carbon steel.

Adjusted RT_{NDT} Values for 34.7 EFPY (CF = 160°F, Margin = 34°F):

1/4t = 250.38°F

3/4t = 206.21°F

Note: Table 2-3 and Table 2-4 show Adjusted RT_{NDT} Values for a CF of 160°F with a Margin of 34°F and a CF of 170°F and a Margin of 17°F as a function of EFPY. A conservatively Adjusted RT_{NDT} for a CF of 160°F with a Margin of 34°F was chosen.

Film coefficient for heat transfer:

The film coefficient for heat transfer equals 1000 Btu/hr-ft^2-°F.

12.0 REREFENCES

1. Code of Federal Regulations, 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants", January 1988.
2. Code of Federal Regulations, 10 CFR Part 50, Appendix G, "Fracture Toughness Requirements", January 1988.
3. ASME Boiler and Pressure Vessel Code Section III, Appendix G, "Protection Against Nonductile Failure", 1986 Edition.
4. Regulatory Guide 1.99, "Radiation Embrittlement of Reactor Vessel Materials", U.S. Nuclear Regulatory Commission, Revision 2, May 1988.
5. Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence," U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, March 2001.
6. RSICC Computer Code Collection CCC-650, "DOORS3.1 One-, Two-, and Three-Dimensional Discrete Ordinates Neutron/Photon Transport Code System," Radiation Shielding Information Center, Oak Ridge National Laboratory, August 1996.
7. RSIC Data Library Collection DLC-185, "BUGLE-96 Coupled 47 Neutron, 20 Gamma Ray Group Cross-Section Library Derived from ENDF/B-VI for LWR Shielding and Pressure Vessel Dosimetry Applications," Radiation Shielding Information Center, Oak Ridge National Laboratory, March 1996.
8. Westinghouse Letter LTR-EMT-02-53, "Reactor Vessel Integrity Analysis Results for the Indian Point Unit 3 Uprating," J. H. Ledger, February 28, 2002.
9. Westinghouse WCAP-11815, "Analysis of Capsule Z from the New York Power Authority Indian Point Unit 3 Reactor Vessel Radiation Surveillance Program", March 1988.
10. Westinghouse WCAP-10300, "Analysis of Capsule Z from the New York Power Authority Indian Point Unit 3 Reactor Vessel Radiation Surveillance Program", March 1983.
11. ASME Boiler and Pressure Vessel Code, 1995 Edition and addenda through the 1996 Addenda, Section XI, Appendix A, "Analysis of Flaws".
12. ASME Boiler and Pressure Vessel Code, 1995 Edition and addenda through the 1996 Addenda, Section XI, Appendix G, "Fracture Toughness Criteria for Protection Against Failure".
13. "Semi-Elliptical Cracks in a Cylinder Subjected to Stress Gradients", J. Heliot, R.C. Labbens and Pellisser-Tanon ASTM Special Technical Publication 677, August 1979.
14. New York Power Authority, Calculation No. IP3-CALC-RCS-02444 Rev. 1, "Generation of All Curves Associated with the Pressure-Temperature Limits Report (PTLR)", F. Gumble, dated 02/27/98.
15. Westinghouse Letter LTR-REA-03-25, "WCAP Input for Indian Point Unit 3 PTLR", S. L. Anderson, March 4, 2003.
16. Westinghouse Order, Customer P.O. 4500516405, "Update of Pressure Temperature Curves for Indian Point Unit 3", dated 09/18/02.
17. Cases of ASME Boiler and Pressure Vessel Code, Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Limit Curves," Section XI, Division 1, dated February 26, 1999.

18. Entergy Letter NEA-02-218, *Indian Point Unit 3 Neutron Flux Estimate for Projections*, Floyd Gumble (Entergy) to John Ghergurovich (Westinghouse), October 22, 2002.

19. Westinghouse Electric Co. L.L.C., WCAP-15024, Rev. 1, "Indian Point Unit 3 Heatup and Cooldown Limit Curves for Normal Operation", J. H. Ledger, April 2001.

20. Westinghouse Letter LTR-REA-02-21, "Neutron Fluence Projections for Indian Point Unit 3 Uprate", S. L. Anderson, February 27, 2002.

21. Westinghouse Calculation Note CN-CI-02-68, Rev. 0, "Indian Point 3 Appendix G Pressure-Temperature Limits and LTOP Enable Temperatures", M. Zajec, March 2003.

APPENDIX A: UPPER SHELF ENERGY CALCULATION AT 34.7 EFPY

PREDICTED USE VALUES @ 34.7 EFPY

Methodology

Per Regulatory Guide 1.99, Revision 2, the Charpy upper-shelf energy is assumed to decrease as a function of fluence and copper content as indicated in Figure 2 of the guide (Figure A-1 of this WCAP) when surveillance data is not used. Linear interpolation is permitted. In addition, if surveillance data is to be used, the decrease in upper-shelf energy may be obtained by plotting the reduced plant surveillance data on Figure A-1 and fitting the data with a line drawn parallel to the existing lines as the upper bound of all the data. This line should be used instead of the existing graph.

The 34.7 EFPY USE can be predicted using the EOL 1/4T fluence projection, the copper content of the beltline materials and/or the results of the capsules tested to date using Figure A-1. The peak vessel clad/base metal interface fluence value will be used to determine the 34.7 EFPY USE of all the beltline materials.

Inputs

The Indian Point Unit 3 reactor vessel beltline region minimum thickness is 8.625 inches. Per LTR-REA-02-123, the peak 34.7 EFPY fluence is 1.13×10^{19} n/cm^2. By definition in Reg. Guide 1.99, Rev. 2, the corresponding 1/4T fluences used to predict EOL USE is 6.73×10^{18} n/cm^2. All copper values and initial USE values that appear in Table A-1 were verified within Calcnote CN-EMT-02-7.

Table A-1: Predicted 34.7 EFPY USE Calculations for all the Beltline Region Materials

Material	Weight % of Cu	1/4T EOL Fluence (10^{19} n/cm^2)	Unirradiated USE (ft-lb)	Projected USE Decrease[a] (%)	Projected EOL USE (ft-lb)
Intermediate Shell Plate B2802-1	0.20	0.673	102	27	74
Intermediate Shell Plate B2802-2	0.22	0.673	97	28	70
Intermediate Shell Plate B2802-3	0.20	0.673	95	27	69
Lower Shell Plate B2803-1	0.19	0.673	72	25	54
Lower Shell Plate B2803-2	0.22	0.673	94	28	68
Lower Shell Plate B2803-3	0.24	0.673	68	19(b)	55
Intermediate and Lower Shell Weld Longitudinal Weld Seams (Heat # 34B009)	0.19	0.673	112	30	78
Intermediate to Lower Shell Circumferential weld Seams (Heat # 13253)	0.22	0.673	111	32	75

Notes:

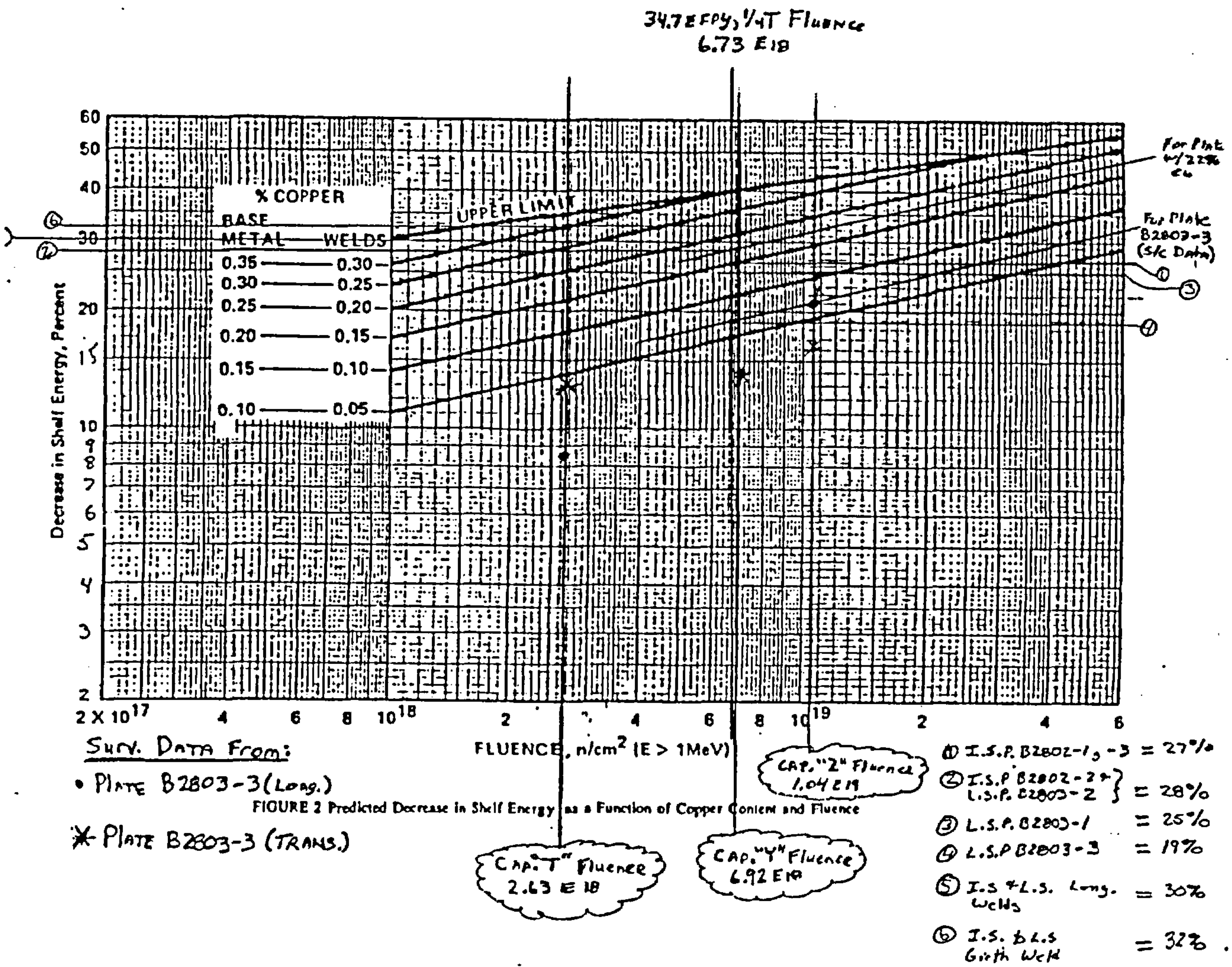
(a) Values are deduced from Figure A-1 (same as Figure 2 of Regulatory Guide 1.99, Revision 2, Predicted Decrease in Upper Shelf Energy as a Function of Copper and Fluence)

(b) Calculated using Surveillance Capsule Data from Indian Point Unit 3 Surveillance Capsules T, Y and Z.

Conclusion:

By reviewing Figure A-1 and Table A-1 above, one can see that all beltline materials will be maintained above 50 ft-lbs up to 34.7 EFPY.

Figure A-1: Regulatory Guide 1.99, Revision 2, Predicted Decrease in Upper Shelf Energy as a Function of Copper and Fluence



APPENDIX B: CHEMISTRY FACTOR DERIVATION

Table B-1: Indian Point Unit 3 Reactor Vessel Unirradiated Toughness Properties

Material Description		Cu (%)	Ni (%)	Initial RT_{NDT}
Intermediate Shell Plate	B2802-1	0.20	0.50	5
Intermediate Shell Plate	B2802-2	0.22	0.53	-4
Intermediate Shell Plate	B2802-3	0.20	0.49	17
Lower Shell Plate	B2803-1	0.19	0.47	49
Lower Shell Plate	B2803-2	0.22	0.52	-5
Lower Shell Plate	B2803-3	0.24	0.52	74
Intermediate and Lower Shell Weld Longitudinal Weld Seams (Heat 34B009)	2-042 A,B,C 3-042 A,B,C	0.19	1.0	-56
Intermediate to Lower Shell Circumferential weld Seams (Heat 13253)	9-042	0.22	0.73	-54

Table B-2: Indian Point Unit 3 Surveillance Capsule Data[(d)]

Material	Capsule	Capsule f[(a)]	FF[(b)]	ΔRT_{NDT}[(c)]	$FF \cdot \Sigma RT_{NDT}$	FF^2
Inter. Shell Plate B2803-3 (Longitudinal)	T	0.263	0.636	137	87.229	0.405
	Z	1.04	1.010	170	171.865	1.022
Intermediate Shell Plate B2803-3 (Transverse)	T	0.263	0.636	118	75.131	0.405
	Y	0.692	0.896	150	134.513	0.804
	Z	1.04	1.010	155	156.701	1.022
				SUM:	625.441	3.659
	$CF_{B2803\text{-}3} = \Sigma(FF \cdot RT_{NDT}) \div \Sigma(FF^2) = (625.441) \div (3.659) = 170.9$					

<u>Notes</u>:

(a) f = fluence from Letter LTR-REA-02-21 "Neutron Fluence Projections for Indian Point Unit 3 Uprate" S. L. Anderson February 27, 2002.

(b) FF = fluence factor = $f^{(0.28-0.1 \cdot \log f)}$

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values (from WCAP-11815 and WCAP-10300)

(d) Values shown in table have not been rounded.

Table B-3: Summary of the Indian Point Unit 3 Beltline Material Chemistry Factor Values Based on Regulatory Guide 1.99, Revision 2, Position 1.1 and Position 1.2

Material		Chemistry Factor	
		Position 1.1	Position 2.1
Intermediate Shell Plate	B2802-1	137	---
Intermediate Shell Plate	B2802-2	152	---
Intermediate Shell Plate	B2802-3	136	---
Lower Shell Plate	B2803-1	128	---
Lower Shell Plate	B2803-2	150	---
Lower Shell Plate[a]	B2803-3	160	170.9
Intermediate and Lower Shell Weld Longitudinal Weld Seams (Heat 34B009)	2-042 A,B,C 3-042 A,B,C	224	---
Intermediate to Lower Shell Circumferential weld Seams (Heat 13253)	9-042	189	---

Notes:

(a) Indicates surveillance material.

WCAP-16037, Rev. 0

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ATTACHMENT IV

TECHNICAL EVALUATION FOR REVISION TO

PRESSURE-TEMPERATURE CURVES-

INDIAN POINT UNIT 3 NUCLEAR POWER PLANT

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NO. 3
DOCKET NO 50-286

Technical Evaluation for Revision to Pressure-Temperature Curves
Indian Point Unit 3 Nuclear Power Plant

Summary

The accompanying proposed amendment to the Indian Point Unit 3 (IP3) Technical Specifications updates the seven Pressure-Temperature (P/T) curves associated with neutron embrittlement of the reactor vessel, and the associated protections required under Appendix G.

Although a significant number of pages are being revised, there is considerable duplication. In summary, the following changes are made:

1. Heatup and cooldown curves are revised in accordance with the methodology represented in Reference 1. Expiration date of curves increases from 16.17 Effective Full-Power Years (EFPY) to 20 EFPY.
2. Overpressure Protection System (OPS) curves are derived from the isothermal cooldown curve (References 1 and 2). Expiration Date of curves increases from 16.17 EFPY to 20 EFPY.
3. Revision to the point above the OPS enable temperature at which the safety valves provide protection from the Appendix G limits (Reference 2). 411 degF is reduced to 380 degF.

Methodology

The primary source for the generation of these curves and text amendments is Reference 2, which re-evaluates the heatup and cooldown curves based on ASME Code Case N-640 (Reference 3). The Westinghouse WCAP explains the methodology of ASME Code Case N-640 and applies it to the IP3 model. The intent of the analysis was to determine new heatup and cooldown curves that would be bounded by the curves in current use at IP3. Using the new methodology, Westinghouse determined that curves for a service lifetime of 34.7 EFPY would be no more limiting than the current curves, across the entire Reactor Coolant System (RCS) temperature range. As it happens, a burnup of this magnitude falls well beyond the expected plant lifetime burnup at license expiration.

In order to implement this analysis, one exemption is tacitly assumed, and one is formally required. The former is the re-use of an exemption that has been previously requested and granted. This is for the use of the Westinghouse methodology (formerly the Combustion Engineering methodology) by which the curves were derived. Entergy (NYPA at the time) provided the Commission with a generic report (Reference 5) describing the CE methodology in 1998. It should be noted that the W-CE methodology has been the basis of the Indian Point Unit 3 heatup-cooldown-OPS curve derivation since the initial OPS license amendment (Amendment No. 67) was issued in 1986.

The latter is for the use of ASME Code Case N-640, which has been routinely accepted as the new standard methodology for the preparation of Pressure-Temperature curves.

Finally, it should be noted that Entergy is no longer requesting an exemption for ASME Code Case N-514, which had been included in previous submittals. The 110% multiplier provided by the code case is no longer applied to the curves. Furthermore, the Code Case reduced the penalty on OPS enable temperature from the traditional value of 90 degF down to 50 degF. This change to the original penalty on OPS enable temperature has been incorporated into the ASME Code in its 1992-1995 Edition and Reg Guide 1.147 Rev 12.

Effective Service Life for Curve Applicability

The Westinghouse WCAP provides curves suitable for a service life of 34.7 EFPY, but it also notes that the criterion for pressurized thermal shock (PTS) would be exceeded after a service life of 31.4 EFPY. This is the point at which the limiting baseplate reaches a surface RT-PTS of 270 degF (IP3, unlike most plants, is baseplate-limited rather than weld-limited). Therefore, in order to provide reasonable bounds for operation, Entergy will retain the 34.7 EFPY curves, but reduce the expiration date to **no greater than** 31.4 EFPY. This is a conservative position, since calculated curves for 31.4 EFPY would be less restrictive than for 34.7 EFPY.

The Expiration Date was reduced even further (to 20 EFPY), in order to support Operations' request to retain the existing OPS Enable Temperature of 319 degF. Attachment A of the supporting Entergy calculation (Reference 2) describes the technical relationship between Enable Temperature and Expiration Date and explicitly shows how the original controlling parameters of 34.7 EFPY and 340 degF could be revised to 20 EFPY and 319 degF, respectively.

As observed above, in the section labeled "Methodology," a lifetime burnup of 34.7 EFPY is well in excess of the expected lifetime burnup at license expiration. This is also true for a lifetime burnup of 31.4 EFPY. To wit: Even if the plant were to operate at 100% power continuously between now and license expiration, the lifetime service burnup would be about 28.2 EFPY, which is well below 31.4 EFPY. Allowing for 98% capability factor and refueling outages reduces the expected lifetime burnup even further. All of this confirms that a burnup of 31.4 EFPY would not be reached before license expiration, which provides extra margin in the P/T limits.

It is extremely important to note that the 20 EFPY expiration date is based on retention of the 319 degF Enable Temperature, but the curves themselves support operation through an anticipated service life of 34.7 EFPY. This means that, for future amendment submittals, the exact same curves may be used for a revised OPS Enable Temperature and Expiration Date.

Fluence

As the IP3 core model has undergone considerable revision in light of the recent Appendix K power uprate, it can be stated that the neutron fluence models and cross-section library provided by Westinghouse are the most up-to-date. This was approved by the Commission in 2002, prior to the issuance of the Appendix K Power Uprate Technical Specification Amendment.

Surveillance Data Credibility

In previous submittals, there has been debate regarding the credibility of the IP3 surveillance program. Entergy has maintained that the data collected in the surveillance program to date is acceptable within allowable statistical variations, and the WCAP reports this in Section 2.4. The Commission has questioned this in the past, based on its evaluation of the longitudinal vs. the transverse capsule analyses. Westinghouse has evaluated the Chemistry Factor (CF) when determined both ways (i.e., a statistically determined CF of 170 degF plus a reduced penalty of 17 degF versus a tabular-determined CF of 160 degF plus a standard penalty of 34 degF). In spite of the previous position that the IP3 surveillance data is statistically credible, Entergy will take the more conservative position of retaining the more restrictive of the two CF/penalty combinations, and will therefore base the P/T curve analysis on a CF of 160 degF with a penalty of 34 degF.

Range for OPS Setpoint Curve

It should be noted that the range of the OPS Setpoint Curve (TS Figure 3.4.12-1) is narrower than in the current TS figure. This is because the original OPS curve covered operation beyond the OPS operating range, up to the point at which the Appendix G limits were protected by the safety valves (411 degF in the current TS, 380 degF in the proposed amendment).

Protection beyond the OPS enable range has been handled by Section 3.4.A of the Technical Requirements Manual (TRM) ever since implementation of the Improved Technical Specifications at IP3. Accordingly, the OPS pressure limitations for temperatures above the OPS enable temperature are no longer required and are being removed from the TS. Note: the setpoint curve includes pressures up to 330 degF (i.e.,11 degF above the enable temperature) to permit calibration of the equipment. For similar reasons, Figures 3.4.12-2 and 3.4.12-3 extend no farther than 330 degF.

The current TS limit for OPS setpoint pressure levels off at a maximum "ceiling" of 1851 psig. Based on the current analysis (Reference 2), the ceiling for OPS pressure at an OPS Enable Temperature of 319 degF is 2030 psig. This pressure does not appear on Figure 3.4.12-1, as it is higher than any pressure along the entire range of the curve.

Reference 1: WCAP 16037, Rev 1, "Final Report on Pressure-Temperature Limits for Indian Point Unit 3 NPP," Westinghouse Electric Co, May 2003

Reference 2: Entergy Calculation IP3-CALC-RCS-02444, Rev 2, "Generation of Pressure/Temperature Curves in the Technical Specifications," May 2003

Reference 3: ASME Boiler and Pressure Vessel Code, Case N-640, "Alternative Reference Fracture Toughness for Development of P/T Limit Curves," Section XI, Division 1, 2/26/99

Reference 4: ASME Boiler and Pressure Vessel Code, 1995 Edition and addenda through the 1996 Addenda, Section XI, Appendices A and G

Reference 5: CE Document 063-PENG-ER-096, Rev 1, "Technical Methodology Paper Comparing ABB/CE PT Curve to ASME Section III, Appendix G" ABB-Combustion Engineering, 1/22/98

ATTACHMENT V

ENTERGY NUCLEAR OPERATIONS, INC. CALCULATION

"CALCULATION IP3-CALC-RCS-02444 REV 2-

GENERATION OF PRESSURE/TEMPERATURE CURVES

IN THE TECHNICAL SPECIFICATIONS"

ENTERGY NUCLEAR OPERATIONS, INC,
INDIAN POINT NUCLEAR GENERATING UNIT NO. 3
DOCKET NO. 50-286

CALCULATION COVER PAGE

☐IP-2	☒IP-3	☐JAF	☐PNPS

Calculation No. IP3-CALC-RCS-02444	Revision 2	Sheet 1 of 45
Title: Generation of Pressure / Temperature Curves in the Technical Specifications		☒ QR ☐ NQR
Discipline: WPO Nuclear Engineering Analysis		Design Basis Calculation? ☒ Yes ☐ No (IP3-DBD-314)
This calculation supercedes/voids calculation: supersedes IP3-CALC-RCS-00884 Rev 0 and IP3-CALC-RCS-02444 Rev 1		
Modification No./Task No/ER No: N/A		
☒ No software used ☐ Software used and filed separately (Include Computer Run Summary Sheet) ☐ Software used and filed with this calculation		
System No./Name: Reactor Coolant System Component No./Name: Reactor Vessel (Attached additional pages if necessary)		

Print / Sign

REV #	STATUS (Prel. Pend, A, V, S)	PREPARER	REVIEWER/DESIGN VERIFIER	OTHER REVIEWER/ DESIGN VERIFIER	APPROVER	DATE
2	Pend	Floyd Gumble Floyd Gumble 5/27/03	GERALD CANNON Gerald Cannon 5/27/03	—	JERALD HEAD Jerald Head	5/27/03

CALCULATION SUMMARY PAGE

Calculation No. IP3-CALC-RCS-02444 Revision No. 2

CALCULATION OBJECTIVE: Prepare Heatup / Cooldown / OPS Curves as needed to support proposed Technical Specifications Amendment for plant operation through a service life of 20 EFPY
CONCLUSIONS: Curves provided as required (Figures 1, 2, 3, 4, 5, 6 and 7 in this document)
ASSUMPTIONS: See Section 5 for all assumptions.
DESIGN INPUT DOCUMENTS: As noted in the document, the primary sources of information are the recent Westinghouse-CE report on Pressure-Temperature curves (Reference 7.1) abd the original OPS analysis (Reference 7.4). Numerous other documents and publications supporting the conclusions of this calculation are listed in Section 7.
AFFECTED DOCUMENTS: Indian Point 3 Technical Specifications Indian Point 3 Graphs Book Curves, RCS-1 Series Design Basis Document DBD-314 (Reactor Coolant System)
METHODOLOGY: See Section 8 for details

RECORD OF REVISIONS

Calculation Number: IP3-CALC-RCS-02444 Page 3 of 45

Revision No.	Description of Change	Reason For Change
0	New calculation	N/A
1	Added uncertainties to curves	NRC request
1	Revised methodology for generation of OPS curve per NRC recommendations	NRC request
2	Updates curves for new expiration service lifetime of 20 EFPY	Supports proposed Tech Spec amendment
2	Incorporates new Westinghouse-CE analysis using ASME Code Case N-640	Supports proposed Tech Spec amendment
2	Changed title to remove reference to Pressure-Temperature Limits Report	Entergy is no longer pursuing addition of PTLR to license
2	Updated instrument uncertainties to be consistent with current uncertainty calcs	Supports proposed Tech Spec amendment

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Appendix A: Variation of OPS Enable Temperature versus Expiration Date 44

1. BACKGROUND

There are seven curves in the Indian Point Unit 3 Technical Specifications (TS) that are associated with Reactor Coolant System (RCS) pressure and temperature limits for plant operations in Modes 3, 4 and 5. These curves are associated with plant service life and have an expiration date in effective Full-Power Years (EFPY) of service. Accordingly, as the plant ages, these curves must be formally updated via license amendment.

2. PURPOSE

This calculation uses the most recent analytical methodology to revise the pressure-temperature (P/T) curves, which are listed below:

Figure #	Title
3.4.3-1	Heatup Limitations for the Reactor Coolant System
3.4.3-2	Cooldown Limitations for the Reactor Coolant System
3.4.3-3	Hydrostatic and Inservice Leak Testing Limitations for the Reactor Coolant System
3.4.12-1	Maximum Allowable Nominal PORV Setpoint for LTOPS (OPS)
3.4.12-2	Pressurizer Limitations for OPS Inoperable, 20 EFPY (Up to one charging pump capable of feeding the RCS)
3.4.12-3	Pressurizer Limitations for OPS Inoperable, 20 EFPY (Up to three charging pumps and/or one safety injection pump capable of feeding the RCS)
3.4.12-4	Secondary Side Limitations for RCP Start with Secondary Side Hotter than Primary Side, 20 EFPY

Titles have been revised to reflect the new expiration dates provided by this calculation.

These curves replace those prepared under previous revisions of this calculation, and are based on the Combustion Engineering/Westinghouse (CE/W) methodology, which has been used for P/T curve generation since 1989. The current set of curves expires after a plant service life of 16.17 EFPY. This calculation generates new curves with an expiration date of 20 EFPY.

The calculation is based primarily on a new report (Reference 7.1) issued by W/CE, who are the manufacturer of the reactor vessel. The report uses the standard Combustion Engineering methodology, which has been approved by the NRC in past TS amendments. The report also incorporates adjustments from ASME Code Case N-514 (Reference 7.2), which has been approved for previous submittals and ASME

Code Case N-640 (Reference 7.3), which has been approved for other plants but not yet for IP3.

3. METHOD OF ANALYSIS

The methodology by which these curves are derived is described in detail in each sub-section of Section 8. The root of this calculation comes from the uncorrected heatup, cooldown and hydrostatic test curves provided by Westinghouse-CE in Reference 7.1. From this report, the seven curves are developed using the same methodology as in Revision 1 of this calculation, with the following exception:

> The previous methodology under ASME Code Case N-514 allowed a multiplier of 1.1 to be applied to the OPS curve. Under the new Code Case N-640, this multiplier has been removed. However, the revised assumptions for isothermal cooldown calculation (upon which the OPS curve is based) compensate for this penalty.

4. LIST OF SYMBOLS

ASME = American Society of Mechanical Engineers
EFPY = Effective Full-Power Years
PORV = Power-Operated Relief Valves
OPS or LTOPS = Overpressure Protection System
P/T Curves = Pressure vs. Temperature Curves
Psi = Differential pounds per square inch
Psia = Pounds per square inch absolute
Psig = Pounds per square inch gauge
RCP = Reactor Coolant Pump
RCS = Reactor Coolant System
RHR = Residual Heat Removal
TRM = IP3 Technical Requirements Manual
TS or Tech Specs= IP3 Technical Specifications

Also, in this document, the terms "Service Life" and "Expiration Date" in units of EFPY, are used interchangeably, as applied to the applicability of the curves generated herein.

5. ASSUMPTIONS

All calculations are based on approved documents and standards. However, in order to implement these curves into the IP3 licensing documents and graphs book, one exemption is required:

- An exemption is required for the use of ASME Code Case N-640, which revises the methodology by which the crack initiation stress intensity factor is defined, which directly affects the derivation of the curves in Reference 7.1. The NRC has approved this Code Case for use in other plants. This will be the first time this Code Case is applied to IP3.
- An exemption was formally approved in 1998 for the use of the Westinghouse-CE methodology (Reference 7.6). This methodology has been in place since 1989 and has been used for every revision to the P/T curves since that time (Tech Spec Amendments Nos 121, 179 and 202). At the NRC's request, a formal exemption for the use of this methodology was submitted in 1998 and approved in April of that year. Since the exemption as approved does not include an upper bound for burnup applicability, it is not required for implementation of this calculation.
- Note that the previous revision of this calculation took an exemption for the use of ASME Code Case N-514 (Reference 7.2), which provided both a reduced penalty on OPS enable temperature (90°F reduced to 50°F) and a 10% margin on OPS setpoint pressure. The methodology of Code Case N-640 disallows use of the 10% margin term, and the 50°F penalty has been incorporated into the NRC Standard (Reference 7.14). Therefore, it is **not** necessary to require an exemption for Code Case N-514.

The heatup-cooldown analysis in Reference 7.1 assumes isothermal conditions in the RCS. For conservative purposes, all references to temperature in this calculation will refer to Average T-inlet. This is slightly lower than Tavg and is therefore conservative for low-temperature pressure calculations.

Except for the OPS setpoint curve, all of the curves calculated in this document include allowance for instrument uncertainties. The uncertainties used in this calculation, along with the curves to which they apply, are shown on the table that follows. **For future revisions to these curves, it is important to note and reverify the applicability of instrument uncertainties assumed in the calculation of the curves.**

SUMMARY OF INSTRUMENT UNCERTAINTIES USED IN THIS DOCUMENT

Parameter and Affected Instruments	Uncertainty assumed in this Calculation
Wide Range RCS Temperature	30°F (See Note 4 below)
RCS Pressure: Lower Narrow Range (PT-413, 433, 443)	37 psi (See Note 1 below)
RCS Pressure: Upper Narrow Range (PT-455, 456, 457, 474)	30 psi (See Note 3 below)
RCS Pressure: Wide Range (PT-402, 403)	108 psi (See Note 2 below)
OPS Enable Temperature	14.4°F (from Reference 7.7)
Pressurizer Level	7% (from Reference 7.16)
Primary-to-Secondary ΔT	36°F (See Note 5 below)

Notes:

1. The RCS Lower Narrow Range pressure uncertainty is based upon a 64 psi instrument uncertainty (Reference 7.7) reduced by the square root of three (i.e., 1.73), which allows for multiple indication from the three independent pressure instruments PT-413, 433 and 443. Because all three measure RCS pressure, which should be the same value for all, it is acceptable statistically to reduce the uncertainty by a factor of $\sqrt{N}$, where N is the number of instruments.

2. By the same token, the RCS Wide Range pressure uncertainty is based on a 153 psi uncertainty (Reference 7.8) reduced by the square root of two (i.e., 1.414), allowing for multiple indication from PT-402 and PT-403. Similar to the case of RCS Lower Narrow Range pressure, the uncertainty can be reduced statistically from 153 psi to 108 psi.

3. The four RCS Upper Range pressure uncertainty instruments have an uncertainty of about 35 psi (Reference 7.9), which could similarly be reduced by $\sqrt{4}$ to 17.5 psi, using the arguments presented in Notes 1 and 2. However, since 30 psi is historically the minimum allowance permitted for pressure uncertainty, it shall be retained here.

4. Multiple indication for temperature measurement cannot be credited, as it is for pressure in Notes 1-3, since temperature may vary throughout the RCS. One cannot expect all temperature indicators to be reading the same value. According to Reference 7.5, the uncertainties for the four wide range temperature indicators are +24.6, +30.3, +23.1 and +22.1°F, respectively. The use of 30°F as an uncertainty for T-Cold is bounding in the case of the lowest three, and nearly identical to the highest (the difference between 30.3°F and 30°F is within the thickness of the line on the curves). Given the other conservatisms in this calculation, such as the use of T-Cold for T-avg, it is a reasonable assumption to round the uncertainty to 30°F.

5. This parameter is based upon the extremely rare case in which secondary side temperature exceeds primary side temperature prior to RCP start. Assuming an uncertainty of 30°F for RCS temperature as noted in Note 1 and an uncertainty in SG temperature of 20°F for SG temperature (instruments TE-SG31, SG32, SG33, SG34, which have a range of 400°F and an uncertainty of 20°F). Combining 20°F and 30°F by root-mean-square methodology results in 36.056°F, or approximately 36°F.

This document refers to T-inlet as the temperature of water entering the reactor vessel. For purposes of application to the Tech Spec amendments, T-Inlet is considered equivalent to T-Cold.

6 INPUT

Inputs are defined for each curve in the sections where they are derived.

7 REFERENCES

7.1 WCAP 16037 Rev 1, "Final Report on Pressure-Temperature Limits for Indian Point Unit 3 Nuclear Power Plant," Westinghouse Electric Co, May 2003

7.2 ASME Code Case N-514

7.3 ASME Code Case N-640

7.4 "Indian Point Unit 3 Low Temperature Overpressurization Protection System Analysis, Final Report," D. Speyer and M. Feltus, 8/24/84

7.5 Calculation IP3-CALC-RCS-02952 Rev 0

7.6 CE Document 063-PENG-ER-096, Rev 1, "Technical Methodology Paper Comparing ABB/CE PT Curve to ASME Section III, Appendix G" ABB-Combustion Engineering, 1/22/98

7.7 Calculation IP3-CALC-RCS-00404, Rev 4

7.8 Report IP3-RPT-UNSPEC-02006, Rev 3

7.9 Calculation IP3-CALC-RPS-00288 Rev 3

7.10 Code of Federal Regulations 10CFR50 Appendix G, "Fracture Toughness Requirements," January 1988

7.11 "Evaluation of Indian Point Unit 3 LTOPS," Agreement S-90-09811, D. Speyer, October 28, 1992

7.12 Pressurizer Outline Drawing 9321-05-2292 Rev 0

7.13 SECL-92-131, "High Head Safety Injection Flow Changes Safety Analysis," Westinghouse Electric Co, June 1992

7.14 Regulatory Guide 1.99 Rev 2, USNRC

7.15 IP3 Reactor Coolant System Design Basis Document IP3-DBD-314, Rev 1

7.16 Calculation IP3-CALC-RPC-00318 Rev 1

8 CALCULATIONS

The seven curves in the Technical Specifications are:

Limitations for RCS Heatup (TS Fig. 3.4.3-1)
Limitations for RCS Cooldown (TS Fig. 3.4.3-2)
RCS Pressure Limitations for Hydrostatic Testing (TS Fig. 3.4.3-3)
OPS Setpoint (TS Fig. 3.4.12-1)
Pressurizer Limitations for OPS Inoperable (Up to 1 Charging Pump Capable of Injection into RCS) (TS Fig 3.4.12-2)
Pressurizer Limitations for OPS Inoperable (Up to 3 Charging Pumps and/or 1 SI Pump Capable of Injection into RCS) (TS Fig. 3.4.12-3)
Secondary Side Limitations for RCP Start with Secondary Side Hotter than Primary (TS Fig 3.4.12-4)

The values for these curves are developed one at a time in the sections that follow.

IMPORTANT NOTE: All curves in this calculation are based on the data found in Reference 7.1, which was prepared assuming an applicable plant service life of 34.7 EFPY. However, as noted in Section 1.0 of Reference 7.1, the Pressurized Thermal Shock screening criterion (RT_{PTS}) of 270°F for baseplate materials will be exceeded at a plant service life of 31.4 EFPY. Therefore, the expiration date of all curves CANNOT exceed 31.4 EFPY.

The applicable Service Life is FURTHER reduced to 20 EFPY, in order to support Operations' request to retain the existing OPS Enable Temperature of 319°F (See Appendix A for details on the relationship between Enable Temperature and Service Life). THEREFORE, the official expiration date is changed to 20 EFPY, and the RT_{NDT} temperatures (at the ¼ and ¾ reactor vessel depths) labeling the curves have been revised to those for 20 EFPY. This is a CONSERVATIVE position, since the curves themselves were derived for a service life of 34.7 EFPY.

8.1 Application of Uncertainties and Pressure Penalties

The P/T curves in Reference 7.1 include no allowance for instrument uncertainties. Therefore, before they can be added to the Tech Specs or Graphs Book, certain adjustments must be made as noted on Page 5.

The application of uncertainties and other penalties is a complicated process, due to the different instruments used, the limitations on pump head at different temperatures, the fact that some curves are operator limits versus automatic instrument setpoints, and so on. The purpose of this section is to provide a series of penalties that can be applied in later sections to establish the various curves. Therefore:

Temperature (P/T Curves): As noted in Section 5, temperature uncertainty for operator limit curves is 30°F.

Temperature (OPS Curve): The exception to the above statement is the OPS curve, which uses a penalty of 50°F. This allows for the temperature lag between the reactor vessel and the OPS instrumentation as established in the original OPS analysis (Reference 7.4). 50°F has been used historically as a temperature penalty on OPS, and the analysis assumptions remain valid for this application.

Pressure (Instrumentation Uncertainty): The pressure uncertainty varies with the instrumentation used. Plant procedures require specific instruments to be used during different ranges, in order to minimize the uncertainty penalty. Logically, the wide range instruments have the highest uncertainty, while the upper and lower narrow range instruments have smaller uncertainties. Therefore, the P/T curves specify which instruments to use, and the uncertainties will be applied as follows:

37 psi for 0 < RCS pressure < 1500 psig, using PT-413, 433, 443
108 psi for 1500 psig < RCS pressure < 1700 psig, using PT-402, 403
30 psi for RCS pressure > 1700 psig, using PT-455, 456, 457, 474

Note: All instrument uncertainties are unchanged from the previous revision, **except** low range RCS pressure. For these instruments, the uncertainty is reduced from 43 psi to 37 psi, due to improvements in the uncertainty analysis (Ref. 7.7).

Limitations for RCP and RHR Pump Operation

The operation of Reactor Coolant Pumps (RCP's) and Residual Heat Removal (RHR) Pumps adds a pressure penalty to the RCS, which is caused by static head from elevation differences and dynamic head from pump operation. For the RCP's, this effect has been evaluated in the original OPS design (Reference 7.4), and these penalties are:

Number of Operating RCP's	Static / Dynamic Pressure Head
0	3.2 psi
1	8.0 psi
2	13.0 psi
3	21.4 psi
4	30.3 psi

The pressure head from the two RHR pumps (which have significantly lower flow than the RCP's) is bounded by that of two operating RCP's. Therefore, the presence of two operating RHR pumps is assumed to add a total of 13.0 psi to the reactor vessel.

For ease of calculation, penalty fractions have been rounded up (i.e., 21.4 becomes 22 psi, and 30.3 becomes 31 psi).

At lower temperatures, fewer RCP's are in operation, per plant procedures and the Graphs Book. Therefore, it is permissible to credit fewer pumps in service when calculating pressure penalties. Operating procedures at IP3 restrict RCP operation as follows:

Number of RCP's in Operation	Minimum Required Temperature
1	90°F
2	100°F
3	110°F
4	120°F

There is no procedural restriction for RHR pump operation. Therefore, penalties for pump head are applied to the P/T curves as follows: RCP penalties are added to the temperatures to which they apply, and an additional 13 psi is added to allow for RHR pumps. These penalties are summarized below:

Condition	Instrument Uncertainty Penalty (psi)	RCP Penalty (psi)	RHR Penalty (psi)	Total Pressure Penalty (psi)
Low Press. T ≤ 90°F	37	8	13	**58**
Low Press T ≤ 100°F	37	13	13	**63**
Low Press T ≤ 110°F	37	22	13	**72**
Low Press T > 110°F	37	31	13	**81**
Intermediate Pressure (1500 psig < P<1700 psig)	108	31	13	**152**
High Pressure P > 1700 psig	30	31	13	**74**

These penalties are applied to the P/T curves as noted in the sections that follow. Because these penalties are irregular, some "smoothing" of the curves will be applied for ease of operator use. In all cases, the curves will be equal to or more restrictive than those calculated.

8.2 Limitations for Heatup

The heatup curves for 20 EFPY are taken directly from Table 1 of Reference 7.1for heatup rates of 20°F/hr, 40°F/hr and 60°F/hr. These data are shown on Table 1 of this calculation.

The table in Reference 7.1 includes no allowance for instrument uncertainty. Therefore, in order to create a figure applicable for Tech Specs and the IP3 Graphs Book, the temperature and pressure penalties as defined in Section 8.1 are applied.

Finally, an upper limit is added at very low temperatures to restrict pressure under all conditions to no greater than the minimum service pressure. This pressure is defined in References 7.1 (Westinghouse-CE Report) and 7.10 (Appendix G) as 20% of the pre-service hydrostatic test pressure, or 621 psig. Allowing for instrument uncertainty reduces this limit by 37 psi to 584 psig. In accordance with the requirements of Appendix G, this limit applies from the boltup temperature of 60°F to a temperature of 158°F (increased by 30°F to 188°F and rounded up to 190°F for ease of plotting).

It should be noted that this 621 psig limit has always been in existence but has never been visible before, due to the low pressures required by the previous P/T curve methodology. The revised methodology under Code Case N-640 raises the maximum pressure limits sufficiently that the service pressure limit is visible for the first time.

8.3 Limitations for RCS Cooldown

The cooldown curves are established using the same methodology as the heatup curves in Section 8.1.

The cooldown curves for 20 EFPY are taken directly from Table 1 of Reference 7.1 for cooldown rates of 0°F/hr (isothermal), 20°F/hr, 50°F/hr, 80°F/hr and 100°F/hr. These data are shown on Table 2 of this calculation.

The table in Reference 7.1 includes no allowance for instrument uncertainty. Therefore, in order to create a figure applicable for Tech Specs and the IP3 Graphs Book, the temperature and pressure penalties as defined in Section 8.1 are applied.

Similar to the case of the heatup curves, an upper limit is added at very low temperatures to restrict pressure under all conditions to no greater than the minimum service pressure. This pressure is defined in References 7.1 (Westinghouse-CE Report) and 7.10 (Appendix G) as 20% of the pre-service hydrostatic test pressure, or 621 psig. Allowing for instrument uncertainty reduces this limit by 37 psi to 584 psig. In accordance with the requirements of Appendix G, this limit applies from the boltup temperature of 60°F to a temperature of 158°F (increased by 30°F to 188°F and rounded up to 190°F for ease of plotting).

8.4 OPS Setpoint Curve

This figure provides several pieces of information:

- The limiting pressure as a function of temperature for OPS actuation (i.e., the OPS setpoint); and
- The OPS enable temperature.

The intent and function of the OPS (Low Temperature Overpressure Protection System, also known as the LTOPS) is tom prevent potential damage to the reactor vessel that might occur during RCS pressure excursions at low temperatures.

The OPS setpoint is determined (per ASME Code Case N-640, Reference 7.3, and the OPS analysis, Reference 7.4) by:

- Starting with the 10CFR50 Appendix G P/T curve for isothermal cooldown,
- Adding a 50°F penalty on temperature to allow for differences between the reactor vessel and the RCS instrumentation (this is also used to support RCP start with the secondary side hotter than the primary);
- Reducing the allowable pressure by 44 psi to allow for pressure overshoot;
- Applying an additional penalty (as noted in Section 8.1) to allow for RCP and RHR pump pressure head(s); and
- Identifying an absolute upper limit for the OPS setpoint, regardless of RCS temperature.

In summary, the OPS curve is a basic pressure-temperature limit curve modeled on the Appendix G Isothermal P/T Curve and adjusted to allow for the design basis mass and heat input events.

The complex calculational process that generates this curve is shown in detail in Sections 8.4.1 through 8.4.8, which follow.

8.4.1 Establishment of the Appendix G Curve

The Appendix G curve upon which the OPS curve is based is found on Table 2 and consists of the isothermal cooldown curve (i.e., 0°F/hr). This curve is then adjusted to incorporate pressure and temperature penalties as identified below.

NOTE: The lowest RCS temperature used in this analysis is 50°F. This is because of the limitation in

Reference 7.1 requiring a minimum boltup temperature of 60°F. The 50°F temperature limit bounds the boltup temperature requirement and is therefore valid for all conditions at which the RCS could be at pressure.

8.4.2 Overshoot and Temperature Lag Penalties

A pressure penalty of 44 psi is now applied to the curve, since 44 psi is the maximum amount of "overshoot" (i.e., pressure surge subsequent to the initiating event and prior to relief via the PORV's) that would be encountered (Reference 7.4).

In addition to the overshoot penalty, a temperature penalty of 50°F is applied to allow for temperature lag between vessel metal temperature and RCS fluid temperature. This is applied by increasing all temperatures on the OPS curve by 50°F.

These steps are shown in Tabular fashion on Table 3.

8.4.3 Limitations for RCP and RHR Pump Operation

The operation of RCP and RHR pumps has already been discussed in Section 8.1. The same penalties shown on Page 14 for pump head must be applied to the OPS curve (i.e., 13+13=26 psi for an assumed vessel temperature of 100°F, and so on). This is shown on Table 3.

However, the penalties for instrument uncertainty, which were applied to heatup and cooldown curves, are not applied here. This is because the OPS limit is an instrument setpoint, not a guide for the operators. The curve generated in this procedure is an analytical limit, which will be noted as such in the Tech Specs. Instrument uncertainty will be applied by Design Electrical Engineering via a Setpoint Change Request. The resultant curve, which will represent the actual OPS trip setpoint in the field, will be incorporated into the Operators' Graphs Book.

8.4.4 OPS Enable Temperature

For the first 11 EFPY of service life, the OPS enable temperature was defined as the limiting RT_{NDT} for heatup or cooldown plus 90°F, in accordance with the requirements of Reg Guide 1.99 Rev 2.

The Tech Specs currently include an OPS enable temperature based on RT_{NDT} plus 50°F, as established in ASME Code Case N-514 (Reference 7.2) and approved by the NRC for use at IP3.

Since that time, the 50°F penalty has been incorporated into the ASME standards circa 1995. Other benefits provided by Code Case N-514, such as a 10% increase in allowable pressure limits, have been superseded by the methodology of Code Case N-640 (Reference 7.3), which is being applied to generate the heatup and cooldown curves in Reference 7.1.

Therefore, the OPS analysis no longer utilizes Code Case N-514, and no exemption is required. But because the 50°F penalty has replaced the 90°F penalty for OPS enable temperature in the ASME standards and the USRNC requirements, the 50°F may be retained for the analysis.

Reference 7.1 defines the limiting OPS enable temperature for 34.7 EFPY of service to be no lower than 324.8°F. Adding an allowance for instrument error of 14.4°F (from Reference 7.7) increases this to 339.2°F. For the purposes of this calculation and the associated Tech Spec amendment submittal, the existing enable temperature of 319°F (i.e., 304.6°F + 14.4°F uncertainty) will be applied. Details on the derivation of the revised expiration date to support this enable temperature can be found in Appendix A.

8.4.5 Absolute Maximum for OPS Pressure

ASME Code Case N-640 allows for establishment of higher OPS setpoints than have been used in the past. Because of this, it is worth evaluating whether there is an absolute maximum or a "ceiling" for OPS setpoints. In other words, is there a pressure that the OPS setpoint can never exceed, regardless of temperature?

In fact, such a maximum exists, and it stems from the heat-input scenario. As noted in Reference 7.4, the heat-input analysis of record assumes a maximum ΔT of 100°F between primary and secondary systems. For a heat-input scenario, the most limiting case comes, logically enough, at the highest temperature and pressure. For OPS, this is the enable temperature (which we have just defined as 319°F, including temperature uncertainty). The maximum allowable OPS pressure is that which limits the overshoot on a heat-input event to 44 psi, which is the design basis for the original OPS (Reference 7.4 and Section 8.4.2 of this calculation). A supplemental report (Reference 7.11) prepared by TM Engineering (the authors of the original OPS analysis) calculates maximum OPS pressure as a function of enable temperature. That curve is shown on Figure 3A.

Review of this figure establishes a maximum OPS pressure of 2030 psig, for an OPS enable temperature of 319°F. This is higher than any pressure along the entire range of the curve and therefore has no impact on the OPS setpoint.

Author's Note: The curve in Reference 7.11 as prepared assuming a different OPS methodology than that currently under review. Therefore, the individual OPS enable temperatures selected for evaluation are different than the ones identified in Reference 7.11 The curve, however, is quite linear across the range of enable temperatures and is therefore valid for all analytical OPS enable temperatures between 308°F and 352°F.

8.4.6 Final OPS Curve

The OPS Curve, as defined in the sections above, is derived on Table 3 and shown on Figure 3. Note that the curve has been "leveled off" at the low temperature end to ensure that its slope is always zero or positive. The curve ends at

350°F, which is 31°F greater than the revised enable temperature for the OPS. This provides Design Electrical Engineering and I&C with overscale information, if needed, and allows for future revision of the OPS curve in Tech Specs, without having to revise this calculation..

At no point does the curve exceed the limiting maximum pressure of 2030 psig.

It should also be noted that the limitation of 621 psi for temperatures below 158°F, as applied to the heatup and cooldown curves, is met by the OPS curve as well. For this application, instrument uncertainties used in Tables 1 and 2 are not applied, since OPS is an automatic system, which will have its uncertainties applied downstream of this calc.

8.4.7 Verification of RHR Piping Overpressure Protection

In most cases, no SI pumps are available to inject into the RCS below a temperature of 350°F, per Tech Specs requirements. However, in Mode 5, it is possible to have one or two SI pumps in service to support testing, accident response or mid-loop operation. Therefore, it is necessary to demonstrate that under these conditions, the OPS will protect the RHR piping as well as the reactor vessel.

According to Table 3, the OPS limits the maximum RCS pressure to 625 psig at 230°F (i.e., 200°F + 30°F uncertainty). Adding 44 psi overshoot gives us 669 psig. The design basis RHR pressure is 737 psig. Therefore, the OPS will protect the RHR System from overpressurization in Mode 5.

8.4.8 Pressurizer Safety Valve Protection

Technical Requirements Manual (TRM) Section 3.4.A deals specifically with the point above the OPS enable temperature at which the Appendix G curves are protected by the pressurizer safety valves.

According to the RCS design basis document (Reference 7.15), the pressurizer safety valves open at a pressure of no greater than 2485 psig. Allowing a 4% tolerance on valve setting raises this pressure to 2585 psig. This pressure corresponds to a temperature of 350°F on the 60°F/hr heatup curve (Table 1). An additional 30°F is added for instrument uncertainty.

Therefore, Section 3.4.1 of the TRM shall be revised to support "low temperature operation from 319°F to 380°F."

8.5 Curve for RCP Start with Secondary Side Hotter than Primary Side

For cases in which the secondary side is hotter than the primary side, certain restrictions are applied by Tech Specs before an RCP can be started. For example, the operators are required to maintain a pressurizer level of no greater than 73% (i.e., 80% less 7% for instrument uncertainty). This allows for an anticipated surge when the RCS is heated by the secondary side subsequent to RCP start.

The Tech Specs also impose a limitation on maximum T-Cold as a function of the ΔT between primary and secondary sides. This is to prevent the heat input resulting from RCP start increasing the RCS temperature to the extent that OPS enable temperature is exceeded and the system automatically disabled.

This is most easily explained by example. In the steps that follow, the derivation of the Secondary Side Temperature Limitations (SSTL) Curve is established.

a. For a service life of 20 EFPY, we have identified the OPS enable temperature as 319°F, which includes a 14.4°F allowance for instrument uncertainty.

b. The original OPS analysis (Reference 7.4 is based on a maximum error of 36°F in ΔT measurement. In other words, an indicated primary-to-secondary ΔT of 64°F could be as great as 100°F. Similarly, an indicated primary-to-secondary ΔT of 0°F (isothermal) could be as great as 36°F.

Note: The above assumption is made for the purpose of creating the graph, and is not directly applied to the procedures. A typical pump start will be done with the primary and secondary sides at the same temperature, or with the primary side a bit hotter. Good engineering judgment does NOT require the operators to assume a ΔT of 36°F when the primary and secondary side temperatures are the same. HOWEVER, for those rare cases in which the RCS has been cooled more rapidly than the steam generators, the assumptions above form bounding limits that would be applied to pump start.

c. The OPS is analyzed for a maximum actual primary-to-secondary ΔT of 100°F.

d. The SSTL Curve consists of two lines, defined by three points (P1, P2 and P3)

e. P1 is the maximum allowable indicated ΔT between primary and secondary sides. This is equal to 100°F (ΔT limit) - 36°F (uncertainty) = 64°F.

f. P2 is the T-Cold for "isothermal" primary-to-secondary conditions. In other words, for an indicated ΔT of 0°F, the analysis assumes a "true" primary-to-secondary ΔT of 36°F. Therefore, when the RCP is started, the RCS will heat up by half that amount, or 18°F. Therefore, P2 is 319°F - 18°F = 301°F.

g. P3 is just like P2, only it applies to an indicated ΔT of 64°F, which corresponds to a "true" ΔT of 100°F. So the start of an RCP would result in an RCS heatup of no more than one-half of 100°F, or 50°F. The OPS enable temperature less 50°F is 269°F, so P3 is set at 269°F for an indicated ΔT of 64°F.

The locations of the 3 points (and the completed curve) are shown on Figure 4.

It should be recognized that most RCP starts will be done with the primary side temperature equal to or hotter than the secondary side. A hotter secondary side is a rare case, only occurring for pump starts which closely follow rapid cooldowns (such as an emergency plant shutdown for equipment repair in Mode 5). For this reason, the operators are not required to assume that the secondary side is 36°F hotter when the two sides are indicating identical temperatures. That is merely the basis by which the curve is generated.

8.6 Pressurizer Limitations for OPS Inoperable (Up to One Charging Pump Operable)

The curves derived in this section (Figure 5) and the next (Figure 6) refer to another operator action allowed by the Tech Specs. This one is in response to OPS inoperability. It protects the RCS from overpressure by establishing a bubble in the pressurizer (as per Reference 7.4. This bubble provides a cushion to keep RCS pressure below the OPS setpoint for a full ten minutes. Ten minutes is defined in Reference 7.4 as a reasonable time for operator response in the event of a mass injection scenario, and this has been the basis for OPS Tech Specs since the OPS was added to the IP3 license.

The only difference between Figures 5 and 6 is the magnitude of the potential mass input. If only a single charging pump is capable of feeding the RCS, then the maximum mass input to the RCS on an inadvertent pump start is about 80 gpm (the analysis conservatively assumes 100 gpm). On the other hand, if all three charging pumps are capable of delivering mass to the RCS, or if one SI pump is capable of feeding the RCS, the mass input is much greater, and a larger pressurizer bubble is required.

There is no credible scenario that credits simultaneous start of an SI pump and one or more charging pumps.

8.6.1 Calculation of Curves

As noted above, this figure consists of a series of curves which define a pressurizer bubble adequately large to compensate for ten minutes of mass injection without exceeding OPS setpoints. This is done by defining maximum pressurizer level as a function of T-Cold for a series of limiting RCS pressures.

The applicable assumptions are as follows:

- Maximum mass input = 100 gpm, which equals 13.37 ft^3/min (or 133.7 ft^3 in ten minutes);
- Initial pressures used: ≤400, ≤450, ≤500 and ≤550 psig;
- Pressurizer level uncertainty of 7%;
- Pressure uncertainty of 37 psi (See Section 5).
- No extra uncertainty is included for temperature, since the OPS curve already includes a 50°F allowance. That is appropriate, since Figures 5 and 6 are operator guides, not instrument setpoints. Therefore, the conservative parameters in the OPS setpoint, such as overshoot and pipe/vessel ΔT more than compensate for the 30°F uncertainty applied to Tables 1 and 2.

The equations that generate these curves are taken directly from Reference 7.4, which was originally submitted to the NRC and approved via Tech Spec amendment 67:

$L(PZR) = (1730.65\ ft^3 - V_g(0)) / 16.613$, where

- $L(PZR)$ = the limiting pressurizer level
- 1730.65 ft^3 = available pressurizer volume
- 16.613 = ft^3 / percent PZR level

$V_g(0) = \Delta V / [1 - P_0 / P_f]^{(1/1.4)}$ where

- ΔV = Increase in liquid volume due to 10 minute mass input
- P_0 = Initial RCS pressure in psia (e.g., if the initial RCS pressure is ≤100 psig and the instrument uncertainty is 37 psi, then P_0 = 100+14.7+37=151.7 psig
- P_f = OPS allowable maximum pressure at the chosen RCS temperature
- 1/1.4 = the inverse gamma expansion term for the steam space in the pressurizer (which is conservative for a nitrogen atmosphere in lieu of steam)

The final pressurizer level is reduced by 7% to allow for instrument uncertainty, and the maximum pressurizer level under ANY circumstances is no greater than 73% (i.e., 80% analytical less 7%).

For illustrative purposes, here is a sample calculation for a single point:

At an indicated RCS temperature of 250°F and indicated pressure no greater than 450 psig:

$$V_g(0) = 133.7\ ft^3 / [1-(450+37+14.7)/(671+14.7)]^{\wedge}1/1.4$$
$$= 342.14\ ft^3$$

where 133.7 ft^3 is the maximum mass input in ten minutes, as defined on page 23.

L(PZR) = (1730.65 – 342.14) / 16.613 – 7% = 76.5%

By comparison, an indicated RCS temperature of 150°F and indicated pressure no greater than 500 psig results in $V_g(0) > 1730.65$, and therefore off the curve.

Table 5 presents the results of the calculations required to create the curve, which is shown on Figure 5.

8.7 Pressurizer Limitations for OPS Inoperable (Up to Three Charging Pumps and/or One SI Pump Operable)

This is essentially the same as Section 8.6, with the following changed assumptions:

- The initial limiting pressures used are 100, 200, 300, 400 and 500 psig;
- The limiting mass input is all three charging pumps or one safety injection pump;
- Instrument uncertainties remain the same

The single failure associated with mass-input accident initiation here is either inadvertent start of one SI pump (the other two must be incapable of feeding the RCS when OPS is required to be operational) or an Appendix R fire in the charging pump room control box that causes all three charging pumps to start. The analysis does **not** assume simultaneous injection from one SI pump and 3 charging pumps. It **does**, however, consider inadvertent SI pump start while normal charging is in service, since RCS pressure would be maintained using the normal letdown path.

The original OPS analysis (Reference 7.4) used the following values for SI pump injection against RCS pressure:

RCS Pressure (psig)	SI Pump Flow (gpm)	ΔV after 10 Minutes (ft^3)
100	630	842.2
200	608	812.8
300	583	779.4
400	558	745.9
500	533	712.5

These flows were calculated using the degraded pump curve in FSAR Figure 6.2-2 (1985 edition), and increased by 5%. In the current version of the FSAR, this curve is presented as a min-max performance curve, in which case these flows would fall exactly between the minimum and maximum flows.

Table 6 presents the results of the calculations required to create the curve, which appears on Figure 6.

8.8 RCS Pressure Limits for Hydrostatic Testing

Hydrostatic test pressure limits are taken directly from Tables 1 and 3 of Reference 7.1. The philosophy behind the generation of the hydrostatic pressure limits is that the normal heatup curves shall be used up to the minimum allowable temperature for testing (this is defined in Reference 7.1 as 308.5°F, which we will round up to 310°F and increase by 30°F to 340°F), at which point the curve steps up to the limits calculated for hydrostatic testing. The peak allowable testing pressure, per plant procedures, is 2485 psig.

Portions of the curve are shown in Table 7, and the curve appears in Figure 7.

8.9 Verification of Pressurizer Bubble for Two SI Pumps in Service

Finally, verification is provided for the special case in which two SI pumps are capable of feeding the RCS. This is the case in which pressurizer level is at zero (indicated), with the reactor vessel head in place (if the head bolts are detensioned, as in Mode 6, then no overpressure is possible under any circumstances, and there is no need for restrictions).

The available volume in the pressurizer, assuming 7% level uncertainty, is:

$[(1471.8\ ft^3 \times 0.93) + (0.5 \times (1800 - 1471.8))] \times 7.45\ gal/ft^3$
$= 11{,}420$ gal

where 1471.8 is the volume of the pressurizer between the instrument taps, and the total volume is 1800 ft^3. Therefore, the above equation represents the span of pressurizer level instruments plus the dome at the top, with no credit taken for displacement due to heaters and sprays, or piping volume between the pressurizer and the PORV's (See Reference 7.12 for details).

According to Reference 7.13, the maximum expected flow of two SI pumps against zero pressure is 1060 gpm. Increasing this by 7% for conservatism gives us 1134 gpm. Multiplying the result by 10 gives us 11,340 gallons in ten minutes which is less than the available 11,420 gallons. Therefore, two SI pumps starting inadvertently will not fill the pressurizer in ten minutes, which is an adequate time for operators to respond.

9 CONCLUSION

The required curves needed to update the TS for 20 EFPY are listed in Tables 1 through 7 and shown graphically on Figures 1 through 7 (excluding Fig 3A).

For future reference, these same curves are valid through a Service Life of 34.7 EFPY, at a Rated Thermal Power of 3067.4 MWth, **provided** that the OPS enable temperature is adjusted to match the chosen expiration date in accordance with the rules established in Appendix A **and further provided** that the expiration date does not exceed 31.4 EFPY until such time as the NRC relaxes the screening criteria on RT_{PTS}.

Table 1
Data for Heatup Curves, 20 EFPY
All pressures are in units of psig

Temperatures / Pressures penalized per Section 8.1 shown **in bold font**

Temp (°F)	Temp +30°F	20 °F/hr	20 °F/hr	40 °F/hr	40 °F/hr	60 °F/hr	60 °F/hr
50	**≤80**	625	**567**	625	**567**	625	**567**
60	**90**	627	**569**	627	**569**	627	**569**
70	**100**	629	**566**	622	**559**	620	**557**
80	**110**	631	**559**	604	**532**	594	**522**
90	**120**	634	**553**	594	**513**	575	**494**
100	**130**	637	**556**	589	**508**	561	**480**
110	**140**	641	**560**	588	**507**	552	**471**
120	**150**	646	**565**	591	**510**	548	**467**
130	**160**	653	**572**	597	**516**	547	**466**
140	**170**	660	**579**	606	**525**	549	**468**
150	**180**	670	**584***	618	**537**	554	**473**
160	**190**	681	**584***	634	**553**	563	**482**
170	**200**	695	**614**	654	**573**	575	**494**
180	**210**	713	**632**	678	**597**	592	**511**
190	**220**	733	**652**	708	**627**	613	**532**
200	**230**	759	**678**	745	**664**	639	**558**
210	**240**	790	**709**	790	**709**	672	**591**
220	**250**	828	**747**	828	**747**	712	**631**
230	**260**	875	**794**	875	**794**	762	**681**
240	**270**	932	**851**	932	**851**	824	**743**
250	**280**	1001	**920**	1001	**920**	899	**818**
260	**290**	1086	**1005**	1086	**1005**	991	**910**
270	**300**	1182	**1101**	1187	**1106**	1103	**1022**
280	**310**	1289	**1208**	1279	**1198**	1241	**1160**
290	**320**	1421	**1340**	1390	**1309**	1376	**1295**
300	**330**	1581	**1429**	1526	**1374**	1492	**1340**
310	**340**	1777	**1625**	1693	**1541**	1633	**1481**
320	**350**	2016	**1942**	1896	**1822**	1806	**1733**
330	**360**	2309	**2235**	2145	**2071**	2017	**1943**
340	**370**	2665	**2591**	2448	**2374**	2275	**2201**
350	**380**	3101	**3027**	2818	**2744**	2590	**2516**

Notes: 1. Headings in units of °F/hr represent various heatup rates
2. Penalty on Temperature is +30°F
3. Penalty on Pressure is as per Section 8.1
4. Maximum pressure at low temperatures (for T≤190 degF) = 584 psig (indicated by as asterisk)

Table 2
Data for Cooldown Curves, 20 EFPY
All pressures are in units of psig

Temperatures / Pressures penalized per Section 8.1 shown in **bold font**

Temp (°F)	Temp +30°F	0 °F/hr	0 °F/hr	20 °F/hr	20 °F/hr	50 °F/hr	50 °F/hr	80 °F/hr	80 °F/hr	100 °F/hr	100 °F/hr
50	**≤80**	625	**567**	548	**490**	433	**375**	318	**260**	243	**185**
60	**90**	627	**569**	550	**492**	435	**372**	321	**263**	246	**188**
70	**100**	629	**566**	552	**489**	438	**375**	325	**262**	250	**187**
80	**110**	631	**559**	555	**483**	441	**369**	329	**257**	256	**184**
90	**120**	634	**553**	558	**477**	446	**365**	335	**254**	262	**181**
100	**130**	637	**556**	562	**481**	451	**370**	341	**260**	270	**189**
110	**140**	641	**560**	567	**486**	457	**376**	350	**269**	279	**198**
120	**150**	646	**565**	573	**492**	465	**384**	359	**278**	291	**210**
130	**160**	653	**572**	581	**500**	474	**393**	372	**291**	305	**224**
140	**170**	660	**579**	590	**509**	486	**405**	386	**305**	323	**242**
150	**180**	670	**584***	601	**520**	500	**419**	404	**323**	344	**263**
160	**190**	681	**584***	614	**533**	517	**436**	426	**345**	370	**289**
170	**200**	695	**614**	631	**550**	538	**457**	453	**372**	402	**321**
180	**210**	713	**632**	651	**570**	564	**483**	486	**405**	440	**359**
190	**220**	733	**652**	676	**595**	596	**515**	526	**445**	488	**407**
200	**230**	759	**678**	706	**625**	634	**553**	575	**494**	545	**464**
210	**240**	790	**709**	742	**661**	681	**600**	635	**554**	616	**535**
220	**250**	828	**747**	787	**706**	738	**657**	708	**627**	701	**620**
230	**260**	875	**794**	842	**761**	808	**727**	797	**716**	806	**725†**
240	**270**	932	**851**	909	**828**	893	**812**	906	**825†**	932	**851†**
250	**280**	1001	**920**	991	**910**	998	**917†**	1001	**920†**	1001	**920†**
260	**290**	1086	**1005**	1086	**1005**	1086	**1005**	1086	**1005**	1086	**1005**
270	**300**	1189	**1108**	1189	**1108**	1189	**1108**	1189	**1108**	1189	**1108**
280	**310**	1316	**1235**	1316	**1235**	1316	**1235**	1316	**1235**	1316	**1235**
290	**320**	1471	**1390**	1471	**1390**	1471	**1390**	1471	**1390**	1471	**1390**
300	**330**	1659	**1507**	1659	**1507**	1659	**1507**	1659	**1507**	1659	**1507**
310	**340**	1890	**1816**	1890	**1816**	1890	**1816**	1890	**1816**	1890	**1813**
320	**350**	2171	**2097**	2171	**2097**	2171	**2097**	2171	**2097**	2171	**2097**
330	**360**	2515	**2441**	2515	**2441**	2515	**2441**	2515	**2441**	2515	**2441**

Notes: 1. Headings in units of °F/hr represent various cooldown rates
2. Penalty on Temperature is +30°F
3. Penalty on Pressure is as per Section 8.1
4. Maximum pressure at low temperatures (for T≤190°F) = 584 psig (indicated by an asterisk)
5. Pressures marked with a cross (†) will be reduced slightly on Figure 2. This is a conservative direction and enhances the readability of the curve.

Table 3
Determination of OPS Setpoint Curve

Note: Data is provided up through an adjusted temperature of 350°F to accommodate future revisions of the Tech Spec OPS curve for an expiration date up to 34.7 EFPY

Temp (°F)	Temp + 50°F	Appendix G Isothermal Limit (psig)	App. G Pressure Reduced by 44 psi overshoot	Penalty due to RCP/RHR Pump Ops (psi)	OPS Setpoint Curve (App G Pressure Reduced by Pump Penalty and 44 psi Overshoot)
50	≤100	625	581	26	555 (use 541*)
60	110	627	583	35	548 (use 541*)
70	120	629	585	44	541
80	130	631	587	44	543
90	140	634	590	44	546
100	150	637	593	44	549
110	160	641	597	44	553
120	170	646	602	44	558
130	180	653	609	44	565
140	190	660	616	44	572
150	200	670	626	44	582
160	210	681	637	44	593
170	220	695	651	44	607
180	230	713	669	44	625
190	240	733	689	44	645
200	250	759	715	44	671
210	260	790	746	44	702
220	270	828	784	44	740
230	280	875	831	44	787
240	290	932	888	44	844
250	300	1001	957	44	913
260	310	1086	1042	44	998
270	320	1189	1145	44	1101
280	330	1316	1272	44	1228
290	340	1471	1427	44	1383
300	350	1659	1615	44	1571

*OPS setpoint values lowered to maintain zero or positive slope throughout range of operating curve.

Table 4

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Table 5
Pressurizer Level and RCS Pressure Restrictions for OPS Inoperable And up to One Charging Pump Operable

Note: Data is provided up through an adjusted temperature of 350°F to accommodate future revisions of the Tech Spec OPS curve for an expiration date up to 34.7 EFPY

		Max PZR Level (%) for RCS Indicated Pressure of:			
RCS Temp (°F)	**OPS Max Pressure (psig)**	**RCS P = 400 psig**	**RCS P = 450 psig**	**RCS P = 500 psig**	**RCS P = 550 psig**
≤100	541	70.5	54.6	-	-
110	541	70.5	54.6	-	-
130	543	70.8	55.6	-	-
150	549	71.6	58.2	<0 (-28.7)	-
170	558	72.7	61.4	11.8	-
190	572	74.2	65.2	36.9	-
210	593	75.9	69.2	53.0	<0 (-120.7)
230	625	77.9	73.1	64.0	36.7
250	671	79.8	76.6	71.3	61.1
270	470	81.7	79.6	76.6	72.0
290	844	83.5	82.1	80.4	78.1
310	998	84.9	84.1	83.1	81.8
330	1228	86.1	85.5	84.9	84.3
≥350	1571	86.9	86.6	86.3	85.9

Note: All Pressurizer levels >735 will be truncated to 73% on Figure 5

Table 6
Pressurizer Level and RCS Pressure Restrictions for OPS Inoperable And up to Three Charging Pumps and/or One SI Pump Operable

Note: Data is provided up through an adjusted temperature of 350°F to accommodate future revisions of the Tech Spec OPS curve for an expiration date up to 34.7 EFPY

RCS Temp (°F)	OPS Max Pressure (psig)	Maximum PZR Level (%) for RCS Indicated Pressure of: RCS P = 100 psig	RCS P = 200 psig	RCS P = 300 psig	RCS P = 400 psig	RCS P = 500 psig
		ΔV=842.2	ΔV=812.8	ΔV=779.4	ΔV=745.9	ΔV=712.5
≤100	541	33.5	21.9	1.2	-	-
110	541	33.5	21.9	1.2	-	-
130	543	33.6	22.1	1.6	-	-
150	549	33.8	22.5	2.8	-	-
170	558	34.0	23.2	4.6	-	-
190	572	34.4	24.2	7.0	-	-
210	593	34.9	25.5	10.2	-	-
230	625	35.7	27.3	14.2	<0 (-10.5)	-
250	671	36.6	29.3	18.8	0.4	-
270	740	37.7	31.8	23.7	11.0	<0 (-12.4)
290	844	38.9	34.5	28.8	20.6	7.8
310	998	40.2	37.0	33.5	28.7	21.9
330	1228	41.5	39.7	37.7	35.2	32.0
≥350	1571	42.7	41.8	41.1	40.1	39.0

Table 7
RCS Temperature / Pressure Restrictions for Hydrostatic Testing

RCS Temp (°F)	RCS Temp + 30°F	Heatup Curve Less Instrument Error (psig)	Hydrostatic Pressure (psig)	Hydrostatic Pressure – 30 psig
260	290	910	1448	1418
270	300	1022	1586	1556
280	310	1160	1755	1725
290	320	1295	1961	1931
300	330	1340	2212	2182
310	340	1481	2520	2490
320	350	1732	2895	2865
330	360	1943	3354	3324
340	370	2201	3914	3884
350	380	2516	4598	4568

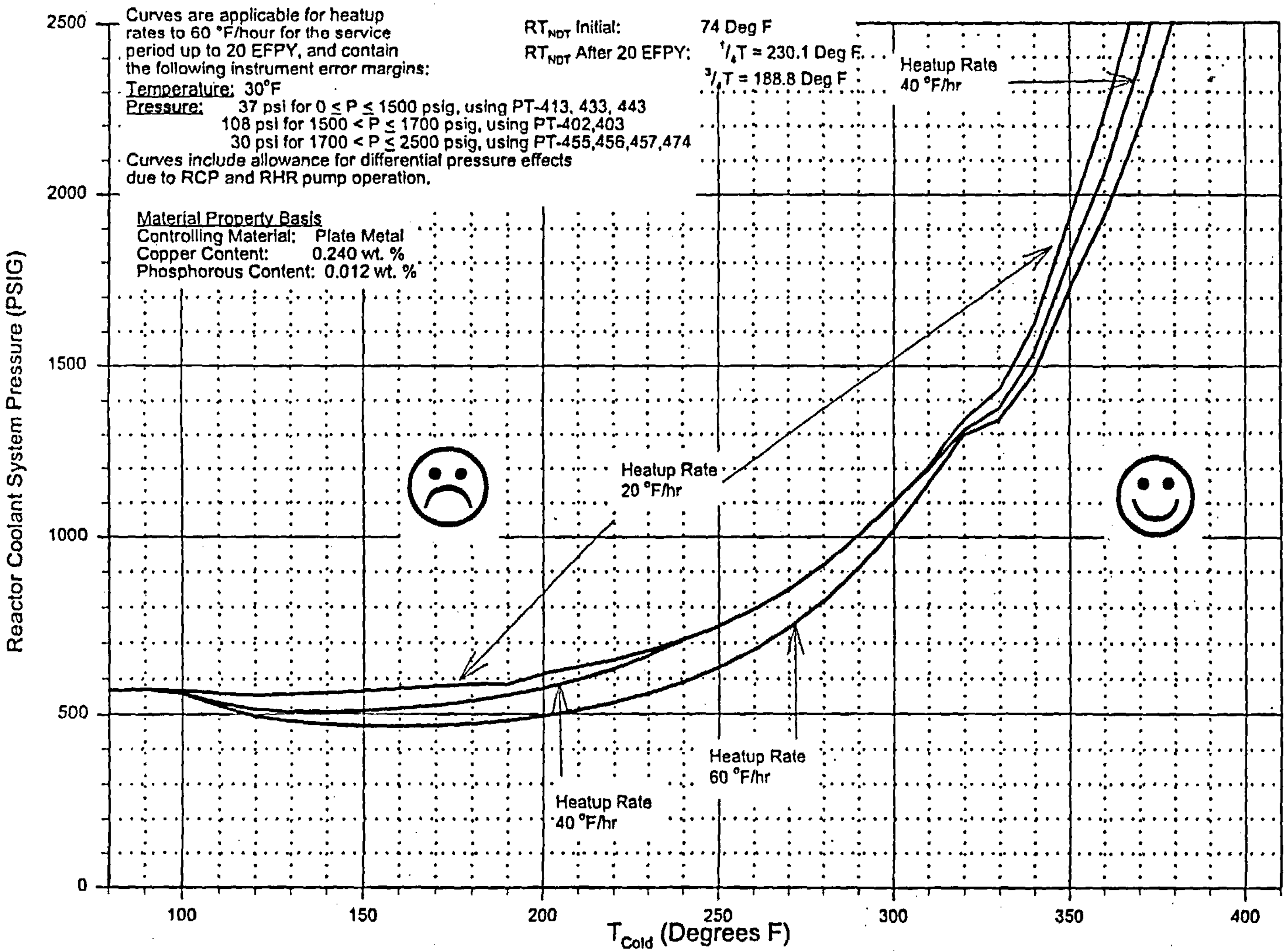


Figure 1
Reactor Coolant System Heatup Limitations, 20 EFPY
Including Limiting Temperatures for RCP Operation

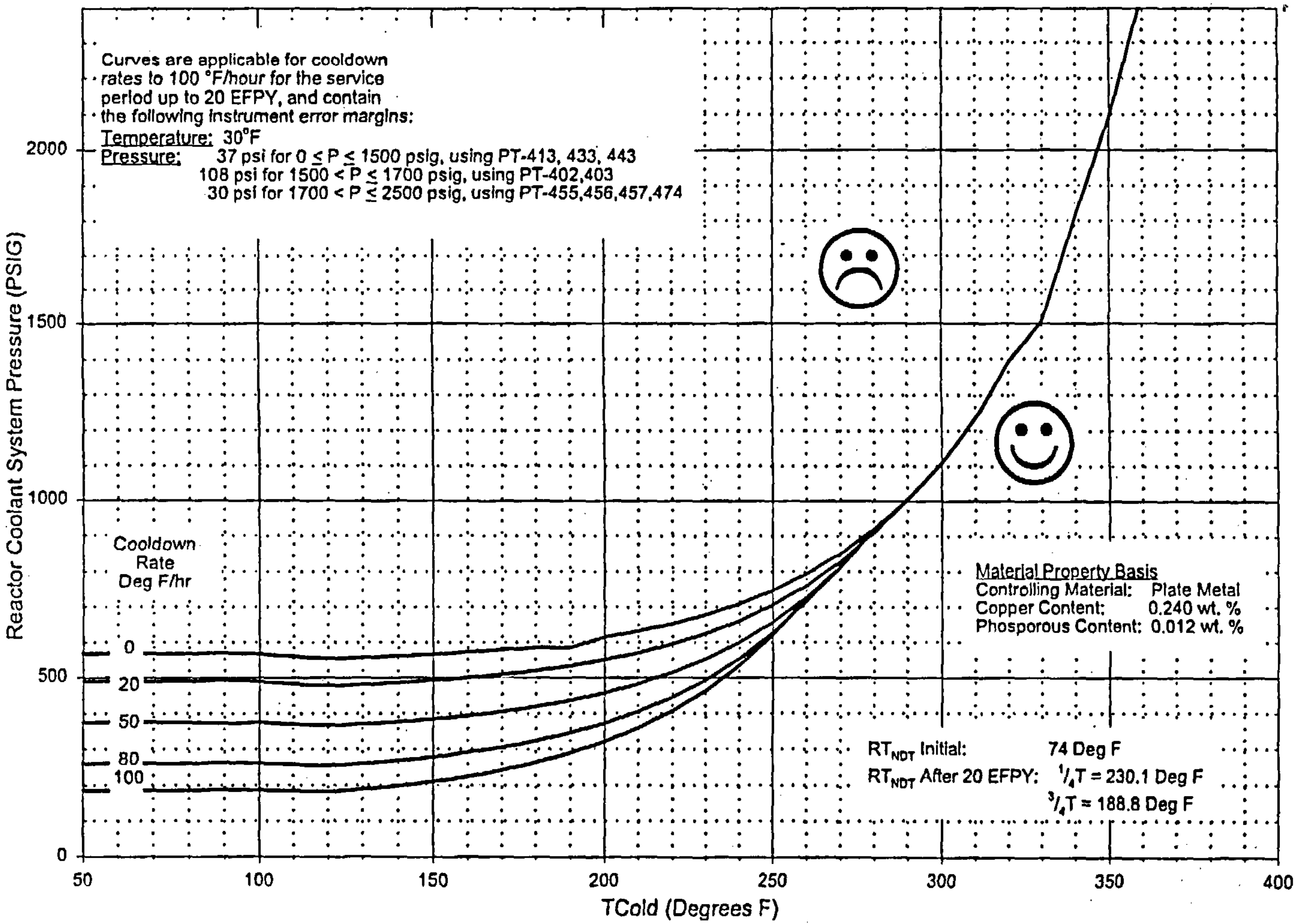
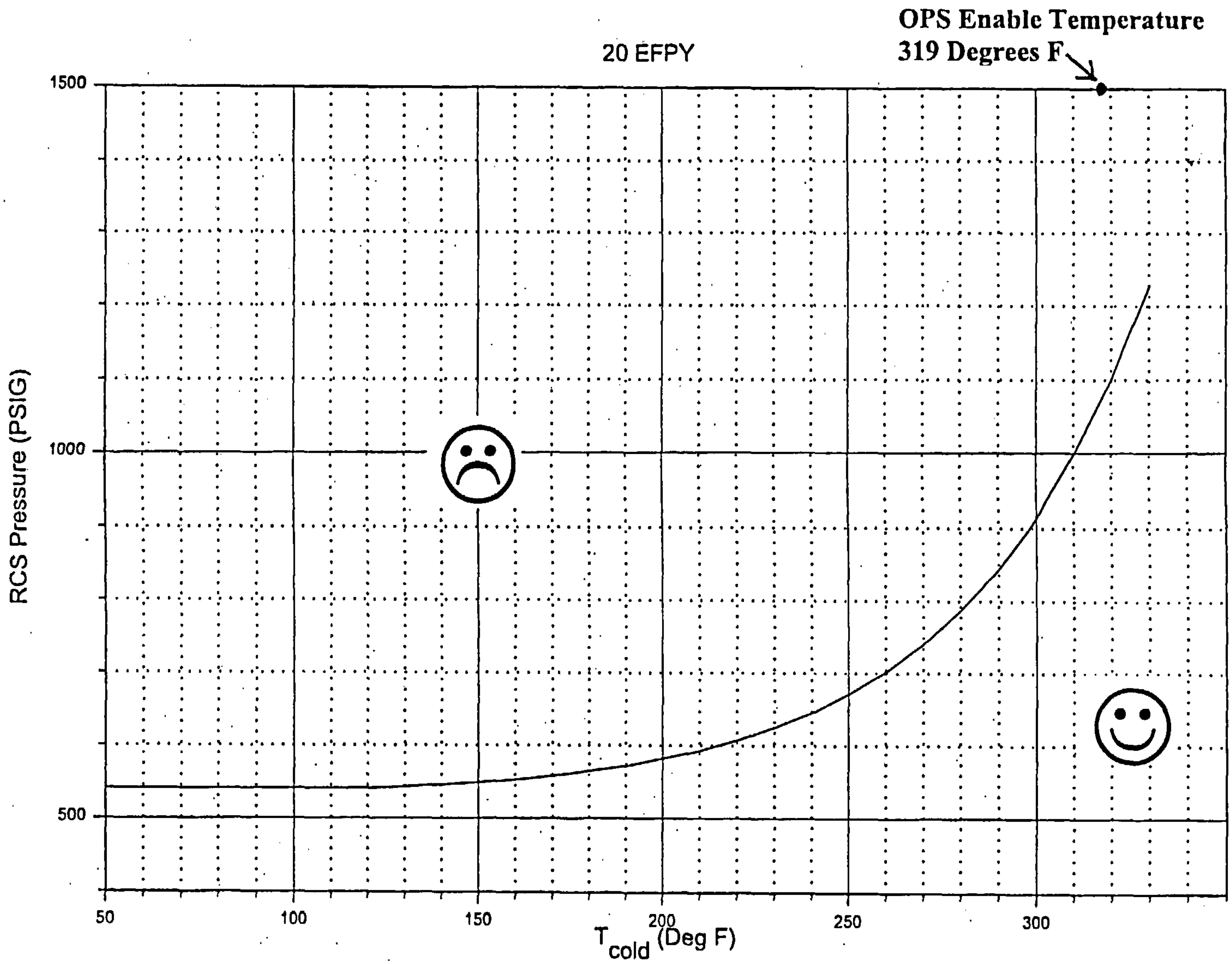


Figure 2
Reactor System Cooldown Limitations, 20 EFPY
Including Limiting Temperatures for RCP Operation

Maximum Permissible Analytic OPS Pressure for an
Enable Temperature of 319°F = 2030 psig



Note: OPS Enable Temperature includes an allowance of 14.4 degF for instrument uncertainty and margin.

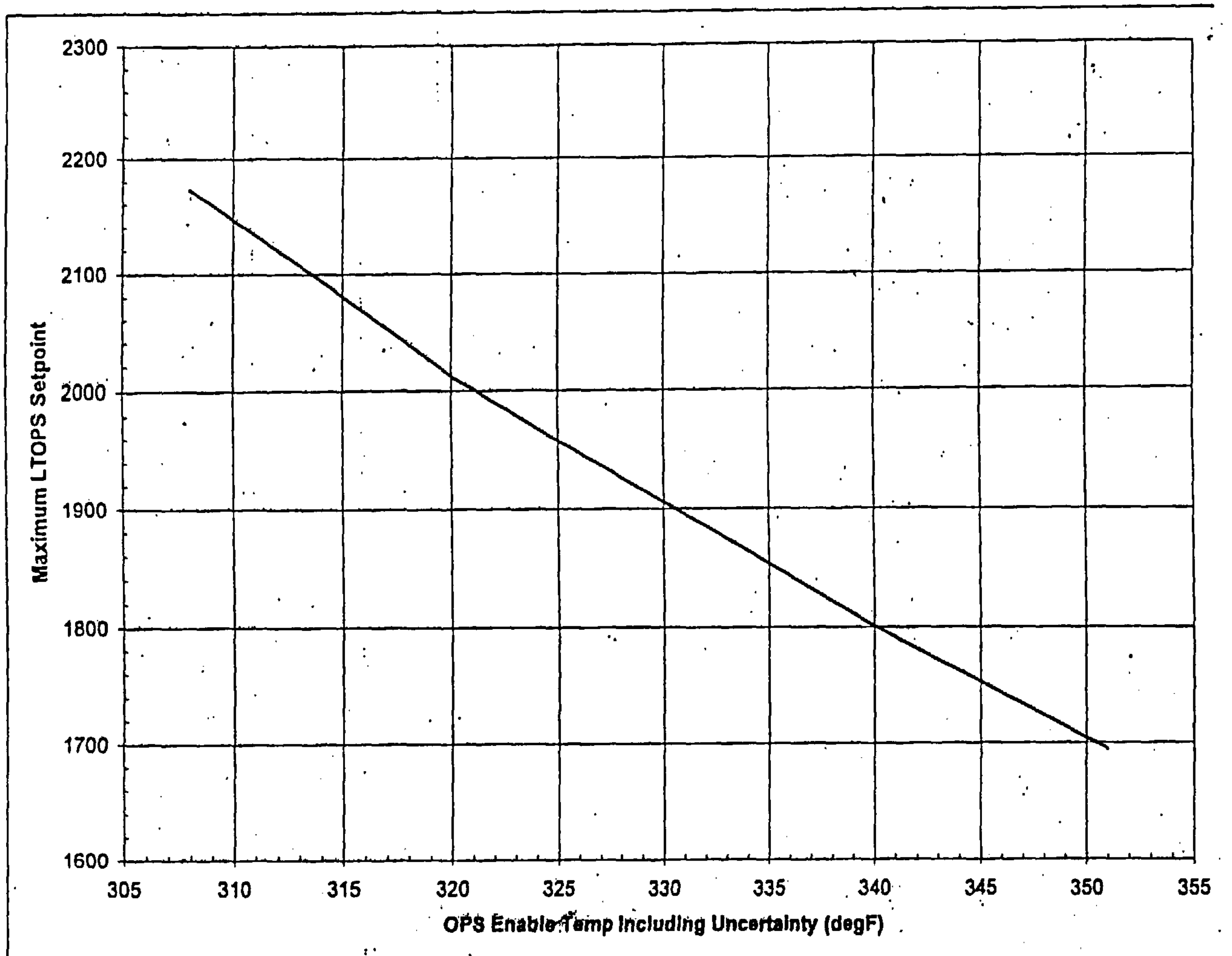
Analytical Curve

Figure 3
OPS Setpoint (Analytic Curve), Including Arming Temperature
20 EFPY

LTOP
3.4.12

Figure 3A
Maximum Permissible RCS Pressure vs. OPS Enable Temperature
(from Reference 7.11)

Based on 1 RCP start with 100 degF delta-T



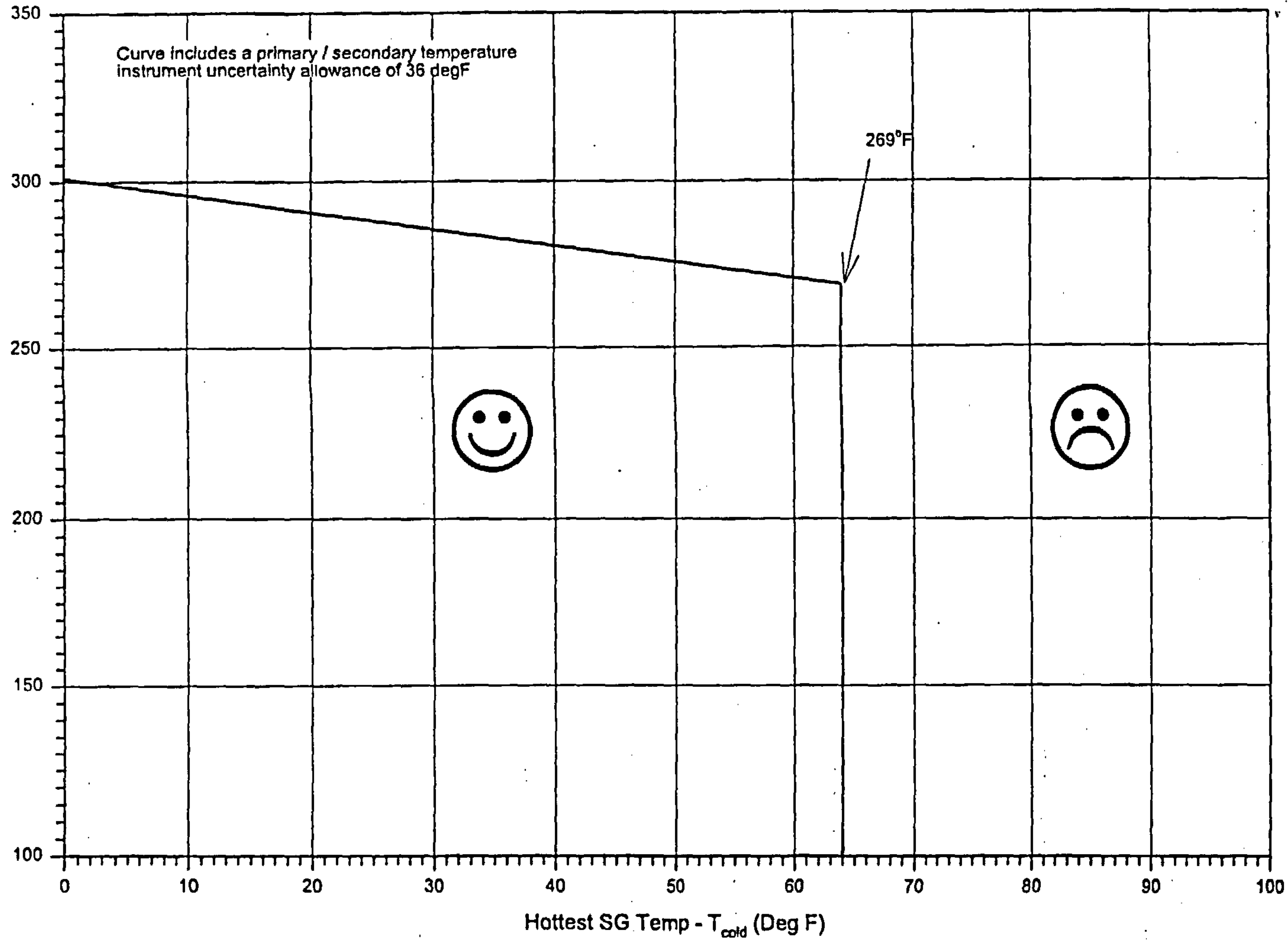
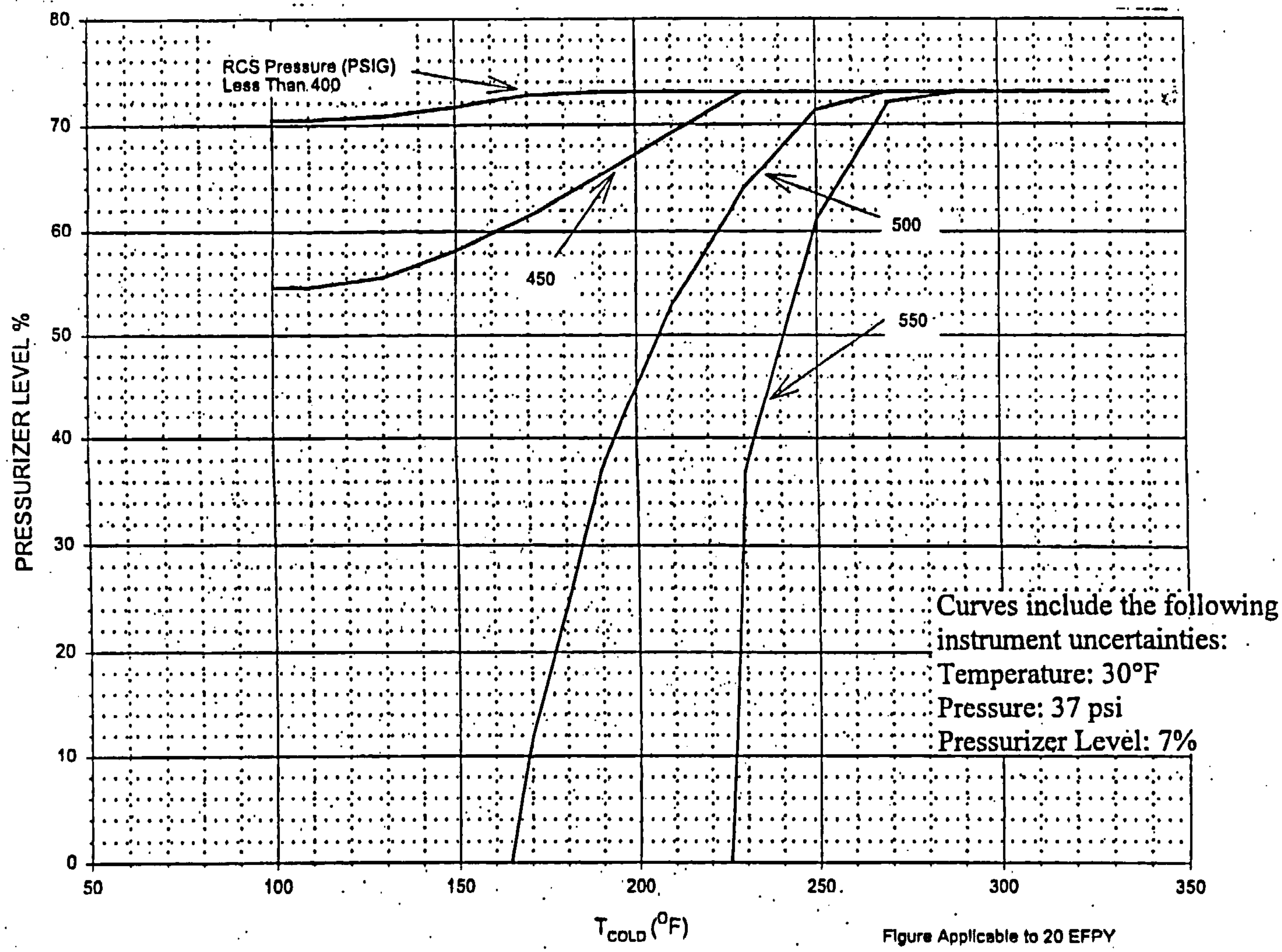


Figure 4
Secondary Side Limitations for RCP Start with Secondary Side Hotter Than Primary
20 EFPY

Figure 5
Pressurizer Limitations for OPS Inoperable
(Up to One Charging Pump Capable of Feeding RCS)
20 EFPY



Curves represent maximum allowable pressurizer levels for the conditions defined

Figure 6
Pressurizer Limitations for OPS Inoperable
(Up to Three Charging Pumps and/or One Safety Injection Pump Capable of Feeding RCS)
20 EFPY

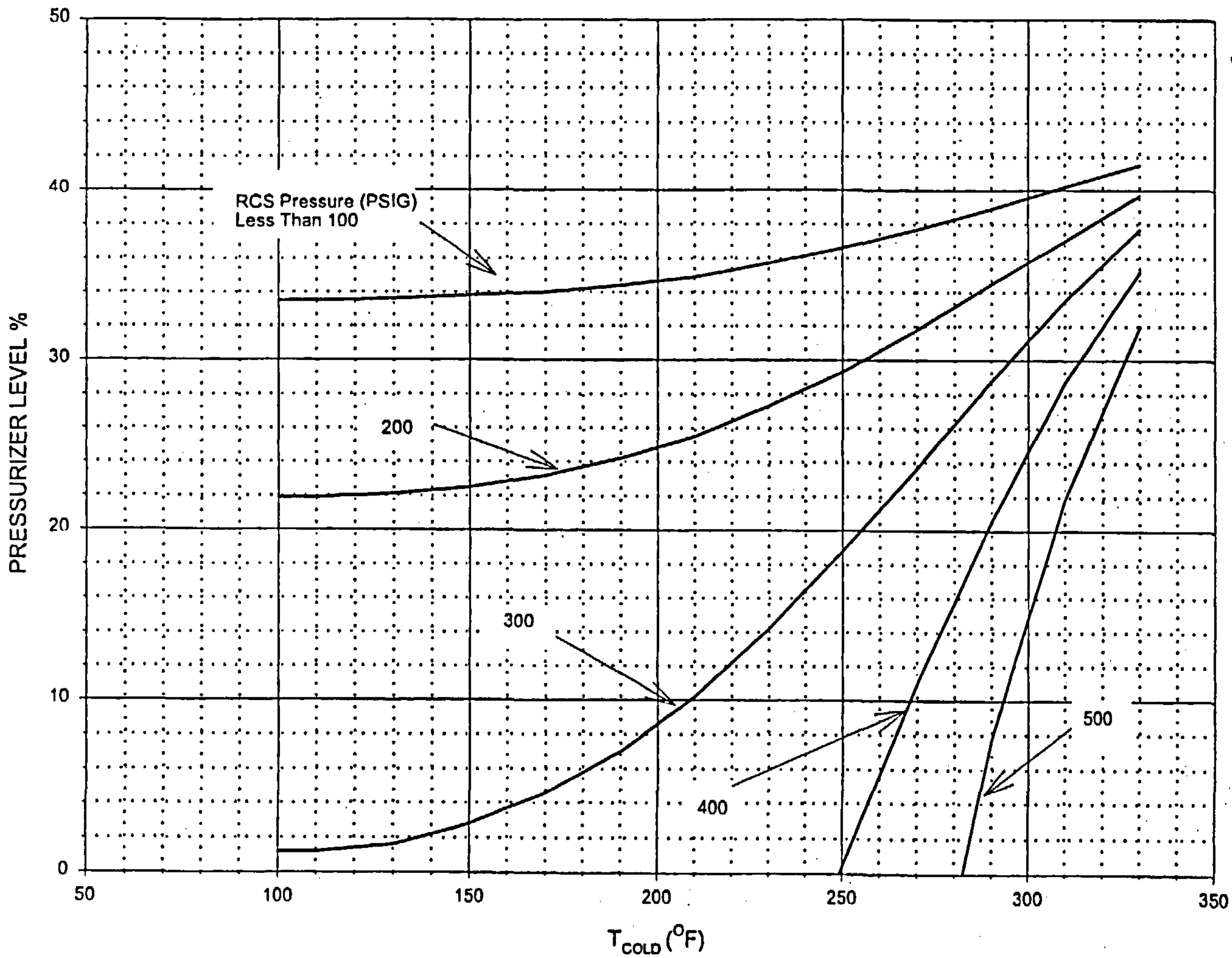


Figure Applicable to 20 EFPY

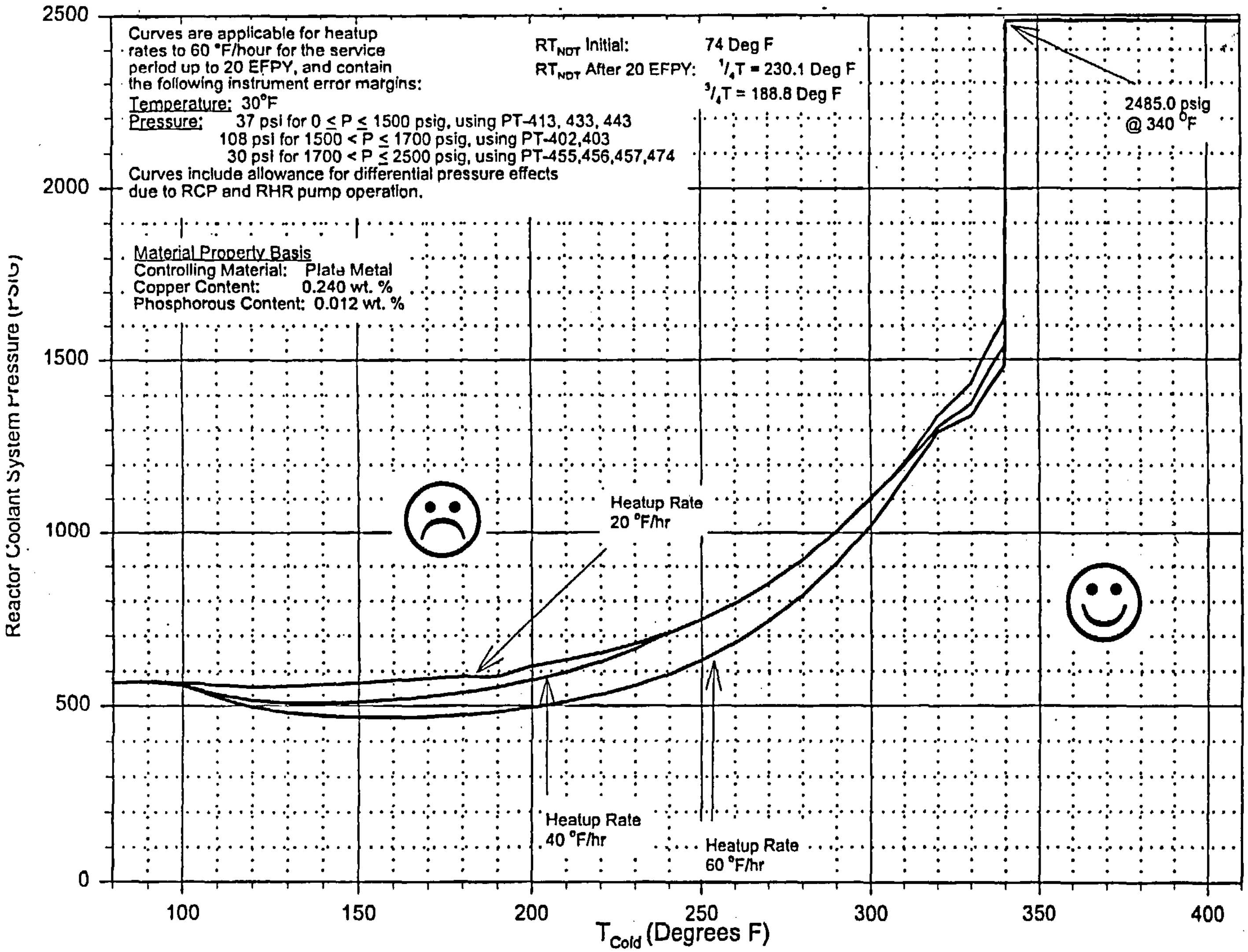


Figure 7
RCS Pressure Limitations for Hydrostatic Testing
20 EFPY

Appendix A
Variation of OPS Enable Temperature versus Expiration Date

Reference 7.1 provides adequate information to calculate the limiting expiration date in EFPY for any chosen OPS Enable Temperature, or vice versa. For the case specifically identified in this calculation, we would like to define the expiration date for a Tech Spec OPS Enable Temperature of 319°F. The procedure is as follows:

1) First, determine the enable temperature with no allowance for instrument error. In this case, that is 319°F – 14.4°F = 304.6°F.

2) Second, identify the baseline points upon which we will base our variation. These specific base points are defined in Section 10 of Reference 7.1 as 324.80°F and 34.7 EFPY. Note that limiting (i.e., highest) OPS Enable Temperature is always going to be the Disable Temperature for the highest heatup rate (the terms "enable temperature" and "disable temperature" are used interchangeably here, since there is only one actual setpoint, which is used for both heatup and cooldown). The third baseline point is the RT_{NDT} at the 1/4T location, which is defined in Section 10 of Reference 7.1 as 250.38°F.

3) Now identify a new desired OPS Enable Temperature. For this example, it is 304.6°F, which is lower than the baseline temperature by 20.2°F.

4) Reduce the base point 1/4T RT_{NDT} by the same amount. For this example, 250.38°F – 20.2°F = 230.18°F.

5) Next, go to Table 2-3 of Reference 7.1. Use the columns "Operating Time" and "1/4T for CF=160; Margin=°F." By interpolation, find the Operating Time associated with 230.18°F. This is 20.053 EFPY, which we will conservatively reduce to 20 EFPY.

6) **Important Note:** As noted in Section 10 of Reference 7.1, ASME Boiler and Pressure Vessel Code Section XI, Appendix G, imposes a 50°F penalty on the OPS Enable Temperature. The base point RT_{NDT} of 250.38°F **already includes** the 50°F penalty, as incorporated via the Westinghouse-CE program PTCURVE. Therefore, it is not necessary to add another 50°F penalty when deriving the applicable expiration date.

7) Repeat Steps 1 through 5 for as many points as desired, in order to calculate Expiration Dates for other possible OPS Enable Temperatures. The table below shows some examples. These can be used for future Tech Spec submittals, since the curves themselves are applicable up through 34.7 EFPY.

8) **Sanity Check:** The value of RT_{NDT} @ 1/4T is very nearly linear between burnups of 20 and 35 EFPY, as shown on the figure below, which is taken from Table 2-3 of Reference 7.1. This means that the error introduced by linear interpolation between points (and also by the methodology of working backwards from the base points) will be negligible.

Additional points correlating Enable Temperature with Expiration Date appear below:

Desired OPS Enable Temperature (°F)	Applicable Expiration Date (EFPY)		Desired OPS Enable Temperature (°F)	Applicable Expiration Date (EFPY)
324	23.1		333	29.5
327	25.1		336	31.9

Note: EFPY values rounded DOWN to next 0.1 EFPY

The figure below represents the change in RT_{NDT} @ 1/4T with burnup: