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50-366

HL-5932

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Edwin I. Hatch Nuclear Plant
Request to Revise Technical Specifications:
Pressure and Temperature Limits

Ladies and Gentlemen:

In accordance with the provisions of 10 CFR 50.90, as required by 10 CFR 50.59(c)(1), Southern Nuclear Operating Company (SNC) is proposing changes to the Plant Hatch Unit 1 and Unit 2 Technical Specifications, Appendix A to Operating Licenses DPR-57 and NPF-5, respectively. The proposed changes revise the vessel pressure and temperature (P/T) limit curves. In addition, SNC is requesting an exemption from the requirements of 10 CFR 50, Appendix G, to allow the use of ASME Code Cases N-588 and N-640 as the basis for the revised P/T curves.

The proposed P/T curves were developed in accordance with 1989 ASME Code, Section XI, Appendix G; 10 CFR 50, Appendix G; and ASME Code Cases N-588 and N-640. The use of the code cases as the basis for the proposed P/T curves constitutes an alternative to the requirements of 10 CFR 50, Appendix G. 10 CFR 50.60 (b) provides that the NRC may grant an alternative to these requirements using the procedures for exemption specified in 10 CFR 50.12. It is noteworthy that an exemption for these same code cases was granted to Commonwealth Edison Nuclear Stations Quad Cities one and two on February 4, 2000.

The Plant Hatch License Renewal Application submitted to the NRC on February 29, 2000, contained a set of revised Unit 1 and Unit 2 P/T curves. The Application extended the curves to 54 effective full-power years; however, no credit for the allowances of ASME Code Cases N-588 and N-640 was taken. Once the proposed Technical Specifications changes related to this submittal are approved, SNC will delete the P/T curves from the License Renewal Application in a future update.

Enclosure 1 provides a description of the proposed changes, an explanation of and justification for the changes, and the circumstances necessitating the changes. Enclosure 2 describes SNC's determination that the proposed changes do not involve a significant hazards consideration. Enclosure 3 provides page change instructions for incorporating the proposed Technical Specifications pages, the revised Technical Specifications pages, and the associated markups of the current Technical Specifications pages. Enclosure 4 contains the Request for Exemption from the Requirements of 10 CFR 50, Appendix G.

A047

RGN-001

cc: Southern Nuclear Operating Company
Mr. P. H. Wells, Nuclear Plant General Manager
Document Management - A2.001

U.S. Nuclear Regulatory Commission, Washington, D.C.
Mr. L. N. Olshan, Project Manager - Hatch

U.S. Nuclear Regulatory Commission, Region II
Mr. L. A. Reyes, Regional Administrator
Mr. J. T. Munday, Senior Resident Inspector - Hatch

State of Georgia
Mr. L. C. Barrett, Commissioner - Department of Natural Resources

For information purposes, copies of ASME Code Cases N-588 and N-640; Structural Integrity Report SIR-00-037, "Revised Pressure-Temperature Curves for Plant Hatch"; and General Electric Report GE-NE-B1100827-00-01 are provided in Attachments 1, 2, and 3 respectively.

To support the upcoming Unit 1 refueling outage, SNC requests the NRC review and approve the amendments no later than September 30, 2000. SNC also requests that, once the amendments are approved, they be issued with an immediate effective date, with implementation no later than 30 days after issuance.

In accordance with the requirements of 10 CFR 50.91, a copy of this letter and all applicable enclosures will be sent to the designated State official of the Environmental Protection Division of the Georgia Department of Natural Resources.

Mr. H. L. Sumner, Jr. states he is Vice President of Southern Nuclear Operating Company and is authorized to execute this oath on behalf of Southern Nuclear Operating Company, and to the best of his knowledge and belief, the facts set forth in this letter are true.

Respectfully submitted,

Lewis Sumner

H. L. Sumner, Jr.

Sworn to and subscribed before me this 1st *day of* June *, 2000.*

Jamie O. Davis
Notary Public

MY COMMISSION EXPIRES SEPTEMBER 17, 2000

OCV/sp

Enclosures:
1. Description of and Justification for Proposed Changes.
2. 10 CFR 50.92 No Significant Hazards Evaluation and Environmental Assessment.
3. Page Change Instructions, Revised Technical Specifications Pages, and Associated Marked-Up Pages.
4. Request for Exemption from the Requirements of 10 CFR 50, Appendix G.

Attachments:
1. ASME Code Cases N-588 and N-640.
2. Structural Integrity Report SIR-00-037, "Revised Pressure-Temperature Curves for Plant Hatch," Revision 0.
3. General Electric Report GE-NE-B1100827-00-01.

Enclosure 1

Edwin I. Hatch Nuclear Plant
Request to Revise Technical Specifications:
Pressure and Temperature Limits

Description of and Justification for Proposed Changes

Description of Proposed Changes

Southern Nuclear Operating Company (SNC) proposes to revise the Plant Hatch Unit 1 and Unit 2 Technical Specifications requirements for reactor pressure vessel (RPV) pressure and temperature (P/T) limits. Changes are proposed to Units 1 and 2 Figures 3.4.9-1, 3.4.9-2, and 3.4.9-3, which show the P/T limit curves for inservice leakage and hydrostatic testing, non-nuclear heatup and cooldown, and criticality, respectively. No changes to the Limiting Condition for Operation or any Surveillance Requirements of Technical Specification 3.4.9 are proposed.

The P/T curves are being revised to:

1. Make use of ASME Code Cases N-588 and N-640.

2. Extend the validity of the curves to 54 effective full-power years (EFPYs). The purpose of the extension is to account for the possibility of an extended license for Plant Hatch. In addition, intermediate curves for 36, 40, 44, and 48 EFPYs are included due to the expected irradiation shift for the Unit 1 RPV. (These intermediate curves are included only in the Unit 1 pressure test curve.)

The P/T limit curves included in this submittal were prepared by Structural Integrity Associates Inc., using the allowances of the two code cases. Their report is included as an attachment to this submittal. Also attached is the General Electric report which provides the basis for the extension of the curves for license renewal purposes.

Justification for Proposed Changes

A. Code Case N-640

This code case (Attachment 1) allows use of the K_{1c} fracture toughness curve shown on ASME Code, Section XI, Appendix A, Figure G-2200-1, in lieu of the K_{1a} fracture toughness curve of ASME Code, Section XI, Appendix G, Figure G-2210-1, as the lower bound for fracture toughness in the development of the P/T limit curves. The other margins involved with the ASME Code, Section XI, Appendix G, process of determining P/T limits remain the same.

Use of Code Case N-640 is justified based upon the knowledge gained in the industry since the fracture toughness curve was created in 1974. Since that time, additional knowledge of the fracture toughness of materials and their response to applied loads has been acquired. This additional knowledge demonstrates the lower bound fracture toughness provided by the K_{1a} curve is well beyond the margin of safety required to protect against potential RPV failure. The K_{1c} curve provides an adequate margin of safety as discussed below.

Use of the K_{1c} fracture toughness curve in developing P/T limits provides additional operating margin for the P/T curves, thus realizing significant benefits primarily for the pressure test. For example, the lower temperature requirement significantly lowers the duration of the pressure test. Additionally, a personnel safety benefit is provided while conducting inspections of the primary containment at elevated temperatures. (Further justification for Code Case N-640 is provided in Enclosure 4.)

B. Code Case N-588

This code case (Attachment 1) provides relief from the specific requirement of 10 CFR 50, Appendix G, that Article G-2120 of ASME Code, Section XI, Appendix G, be used to determine the maximum postulated defects in the RPV for the determination of P/T limits. Article G-2120 specifies that the postulated defect be in the surface of the material and normal to the direction of maximum stress. Appendix G also provides a methodology for determining the stress intensity factors for this maximum postulated defect. The purpose of the article is to ensure the prevention of nonductile fractures by providing procedures to identify the most limiting postulated fractures considered in developing the P/T limits.

Code Case N-588 revises the Article G-2120 reference flaw orientation for circumferential welds in RPVs by eliminating certain unrealistic and overly conservative assumptions. The code case essentially recognizes existing procedures and controls in the fabrication process of reactor vessels designed to minimize defects that can be introduced into the weld during the fabrication process. Also, industry experience with the repair weld indications found during preservice inspection and data taken from nondestructive and destructive examinations were considered in developing Code Case N-588. (Further justification for Code Case N-588 is provided in Enclosure 4.)

C. Extension to 54 EFPYs

The Units 1 and 2 P/T limit curves are being extended to 54 EFPYs to account for the possibility of an extended license for Plant Hatch. One of the major considerations for extended life of the RPV is irradiation of the core region, or beltline. The effect of irradiation is to shift the reference nil-ductility transition temperature (RT_{ndt}) of the beltline materials. This shift must be evaluated to meet the requirements of 10 CFR 50, Appendix G. To encompass the effect of irradiation for extended operation, a maximum lifetime of 54 EFPYs was used to determine the effect of irradiation and develop the P/T curves.

GE's evaluation of the effect of an additional 20 years of operation on the P/T limits is provided in GE-NE-B1100827-00-01 (Attachment 3). New curves incorporating the effect of the renewal term were generated. The three P/T curves; i.e., pressure test, non-nuclear heatup and cooldown, and core critical operation, were updated for the extended operation. The extended curves ensure the P/T limits are not exceeded during the renewal period.

The code case allowance for all curves has of course been applied to all the curves up to and including the 54 EFPY curves.

Enclosure 2

Edwin I. Hatch Nuclear Plant
Request to Revise Technical Specifications:
Pressure and Temperature Limits

<u>10 CFR 50.92 No Significant Hazards Evaluation and Environmental Assessment</u>

In 10 CFR 50.92(c), the NRC provides the following standards to be used in determining the existence of a significant hazards consideration:

> ...a proposed amendment to an operating license for a facility licensed under 50.21(b) or 50.22 for a testing facility involves no significant hazards consideration if operation of the facility in accordance with the proposed amendment would not: (1) Involve a significant increase in the probability or consequences of an accident previously evaluated; or (2) Create the possibility of an accident of a new or different kind from any previously evaluated; or (3) Involve a significant reduction in the margin of safety.

Southern Nuclear Operating Company has reviewed the proposed license amendment request and determined its adoption does not involve a significant hazards consideration based upon the following discussion.

Basis for no significant hazards consideration determination

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

   The changes to the calculational methodology for the pressure and temperature (P/T) limits based upon Code Cases N-640 and N-588 continue to provide adequate margin in the prevention of a non-ductile type fracture of the reactor pressure vessel (RPV). The code cases were developed based upon the knowledge gained through years of industry experience. P/T curves developed using the allowances of Code Cases N-640 and N-588 indeed yield more operating margin. However, the experience gained in the areas of fracture toughness of materials and pre-existing undetected defects show that some of the existing assumptions used for the calculation of P/T limits are unnecessarily conservative and unrealistic. Therefore, providing the allowances of the subject code cases in developing the P/T limit curves will continue to provide adequate protection against nonductile-type fractures of the RPV.

   The evaluation for extending the Unit 1 and Unit 2 P/T limit curves to 54 EFPYs was performed using the approved methodologies of 10 CFR 50, Appendix G, and with the allowances of code cases N-588 and N-640. The curves generated from these methods ensure the P/T limits will not be exceeded during any phase of reactor operation. Therefore, the probability of occurrence and the consequences of a previously analyzed event are not significantly increased. Finally, the proposed changes will not affect any other system or piece of equipment designed for the prevention or mitigation of previously analyzed events.

Thus, the probability of occurrence and the consequences of any previously analyzed event are not significantly increased as the result of the proposed changes.

2. *Do the proposed changes create the possibility of a new or different type of accident from any previously evaluated.*

   The proposed changes provide more operating margin in the P/T limit curves for inservice leakage and hydrostatic pressure testing, non-nuclear heatup and cooldown, and criticality, with the benefits being primarily realizable during the pressure tests. The revised curves also extend the P/T limit curves to 54 EFPYs. However, operation in the "new" regions of the curves have been analyzed with the new P/T curves providing adequate protection against a nonductile-type fracture of the RPV. Otherwise, the proposed changes do not result in any new or unanalyzed operation of any system or piece of equipment important to safety, and as a result, the possibility of a new type event is not created.

3. *Do the proposed changes involve a significant reduction in the margin of safety?*

   As mentioned previously, the revised P/T curves provide more operating margin and thus, more operational flexibility than the current P/T curves. With the increased operational margin, a reduction in the safety margin results with respect to the existing curves. However, the industry experience since the inception of the P/T limits in 1974 confirms that some of the existing methodologies used to develop P/T curves are unrealistic and unnecessarily conservative. Accordingly, ASME Code Cases N-640 and N-588 take advantage of the acquired knowledge by establishing more realistic methodologies for the development of P/T curves. Therefore, operational flexibility is gained and an acceptable margin of safety to RPV non-ductile type fracture is maintained.

   The extension of the P/T curves to 54 EFPYs was performed per the guidelines of 10 CFR 50, and using code cases N-640 and N-588 and thus, the margin of safety is not significantly reduced as the result of the proposed changes.

Environmental Assessment

10 CFR 51.22(c) (9) provides criterion for identification of licensing and regulatory actions eligible for categorical exclusion from performing an environmental assessment. A proposed amendment to an operating license for a facility requires no environmental assessment if operation of the facility in accordance with the proposed license amendment would not:

1. Involve a significant hazards consideration;

2. Result in a significant change in the types or significant increase in the amounts of any effluents that may be released off-site;

3. Result in a significant increase individual or cumulative occupational radiation exposure.

Southern Nuclear Operating Company (SNC) has determined that the proposed Technical Specifications changes described in Enclosure 1 meet the eligibility criteria for categorical exclusion set forth in 10 CFR 51.229(c) (9). Accordingly, pursuant to 10 CFR 51.22, no environmental impact statement needs to be prepared in connection with the issuance of the license amendment for the proposed changes. The basis for this determination using the above criteria follows:

1. As demonstrated in this enclosure, the proposed changes do not involve a significant hazards consideration.

2. The proposed changes do not result in a significant change to the types of effluents or in the amounts of effluents released offsite. These proposed changes involve the reactor vessel pressure-temperature limits. They do not involve changes to the radioactive waste processing systems or to radioactive waste effluent monitors. Accordingly, the changes do not require the radioactive waste processing systems to perform any different function than they are designed to perform nor do they change the operation or testing of any such system.

3. The proposed changes do not result in a significant increase in occupational radiation exposure. Inspections of primary containment during pressure tests will continue to be done in accordance with as low as reasonably achievable (ALARA) principles. As discussed in Enclosure 4, the changes will result in lower temperatures in the primary containment for the inspectors, but will not result in additional time for inspection. In that respect, their exposure time will not be increased.

Enclosure 3

Edwin I. Hatch Nuclear Plant
Request to Revise Technical Specifications:
Pressure and Temperature Limits

Page Change Instructions

Unit 1

Page	Instruction
3.4-25	Replace
3.4-26	Replace
3.4-27	Replace

Unit 2

Page	Instruction
3.4-25	Replace
3.4-26	Replace
3.4-27	Replace

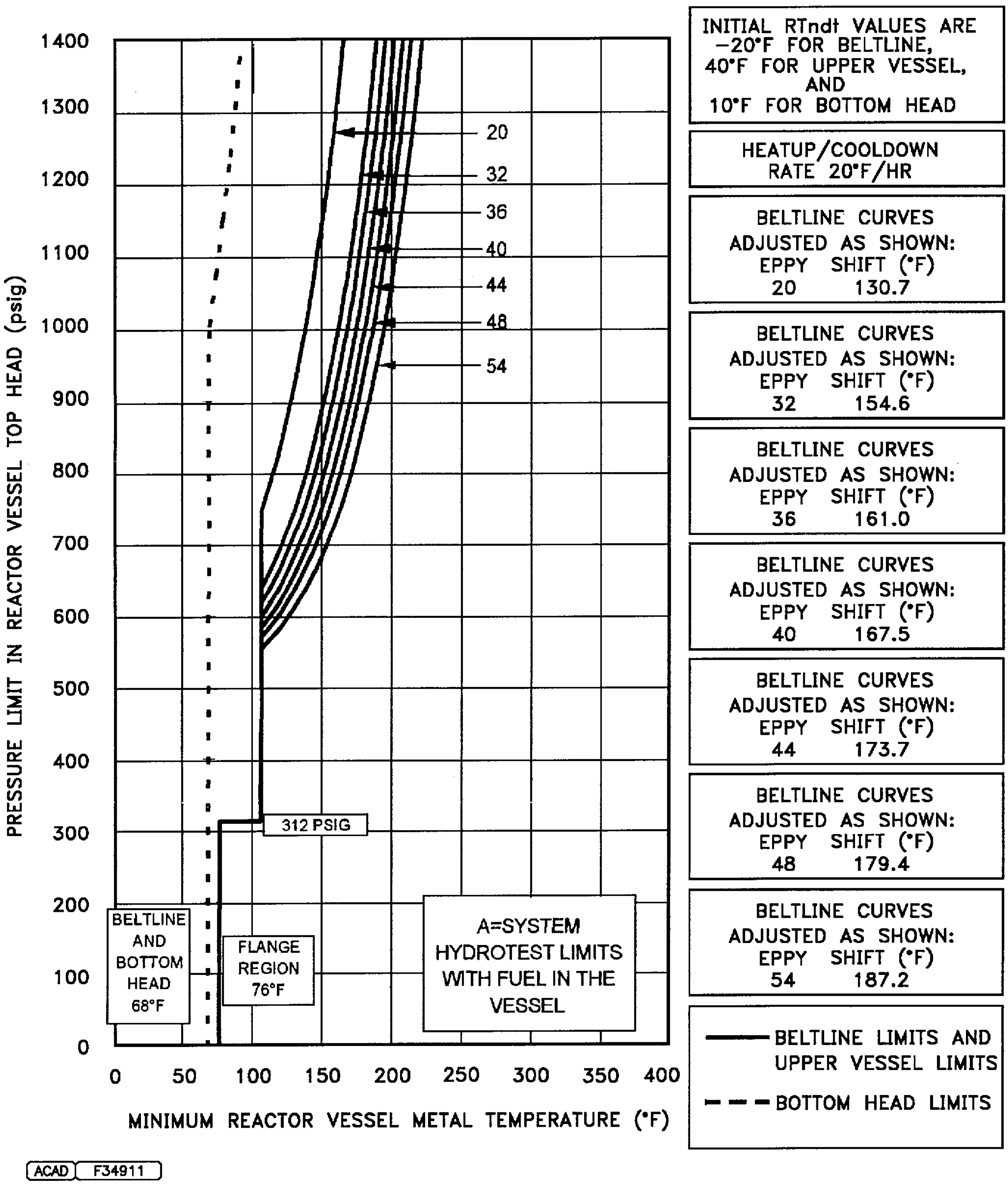
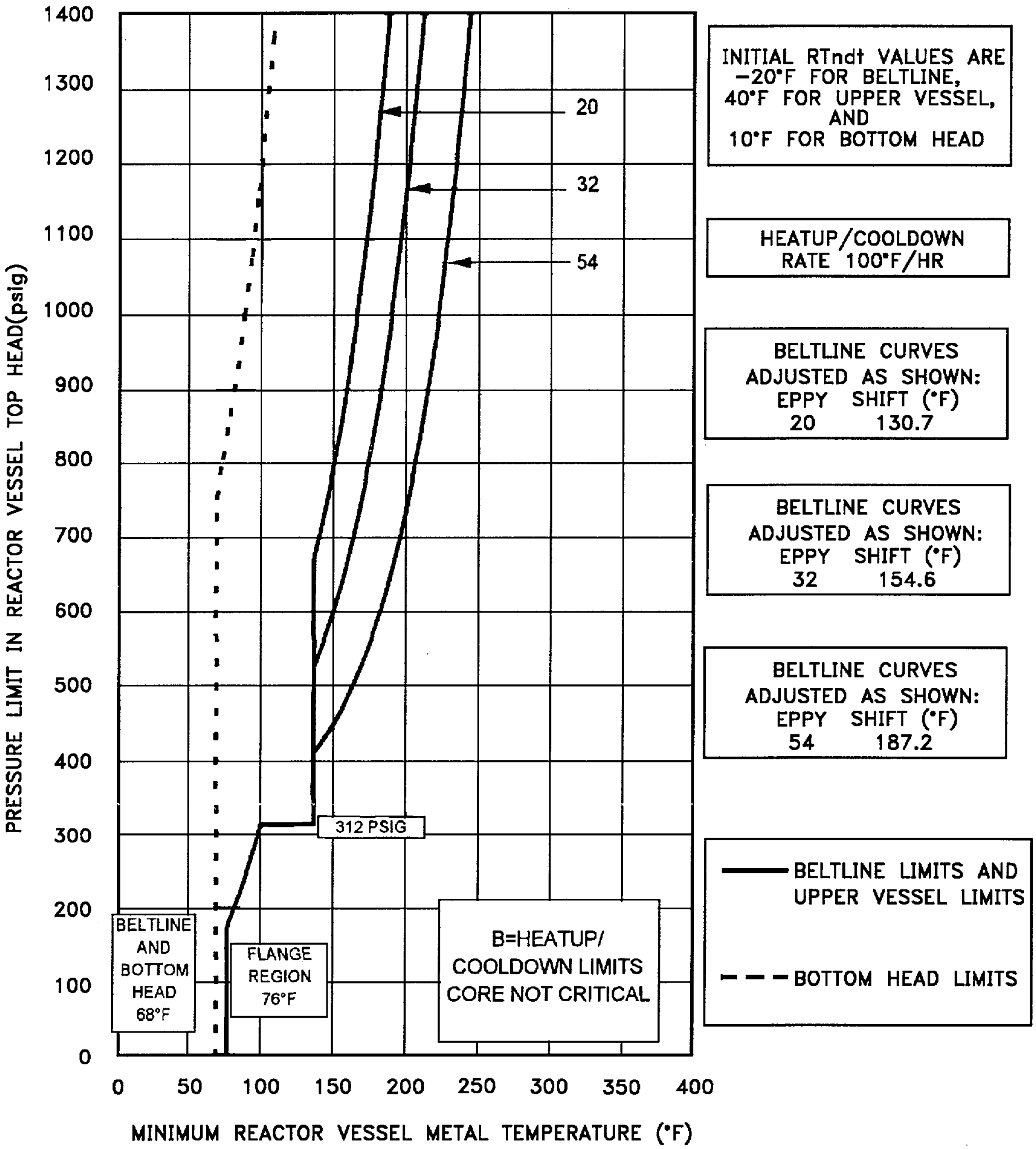


Figure 3.4.9-1 (page 1 of 1)
Pressure/Temperature Limits for
Inservice Hydrostatic and Inservice Leakage Tests



ACAD F34921

Figure 3.4.9−2 (page 1 of 1)
Pressure/Temperature Limits for Non−Nuclear Heatup,
Low Power Physics Tests, and Cooldown Following a Shutdown

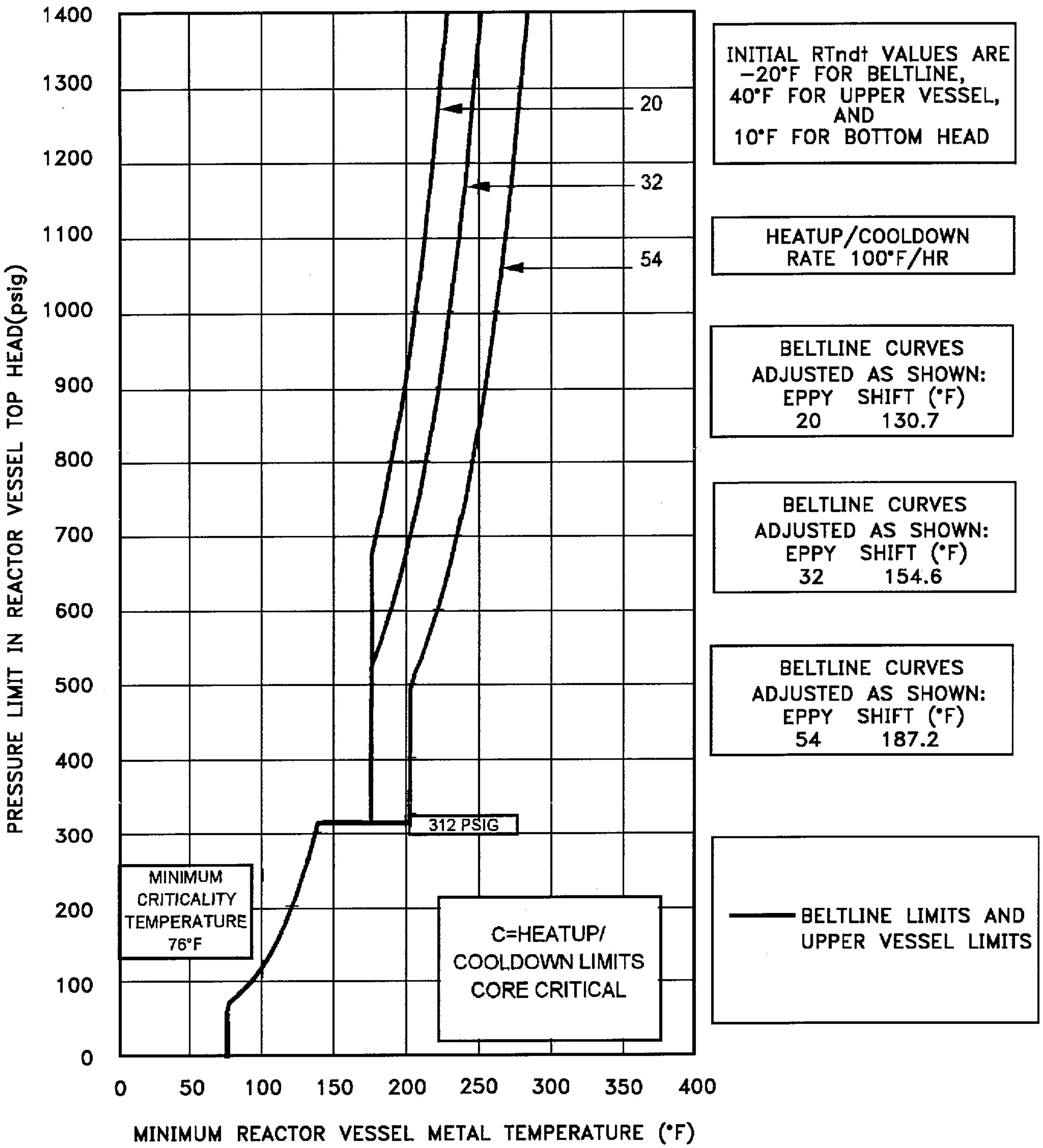


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Figure 3.4.9−3 (Page 1 of 1)
Pressure/Temperature Limits for Criticality

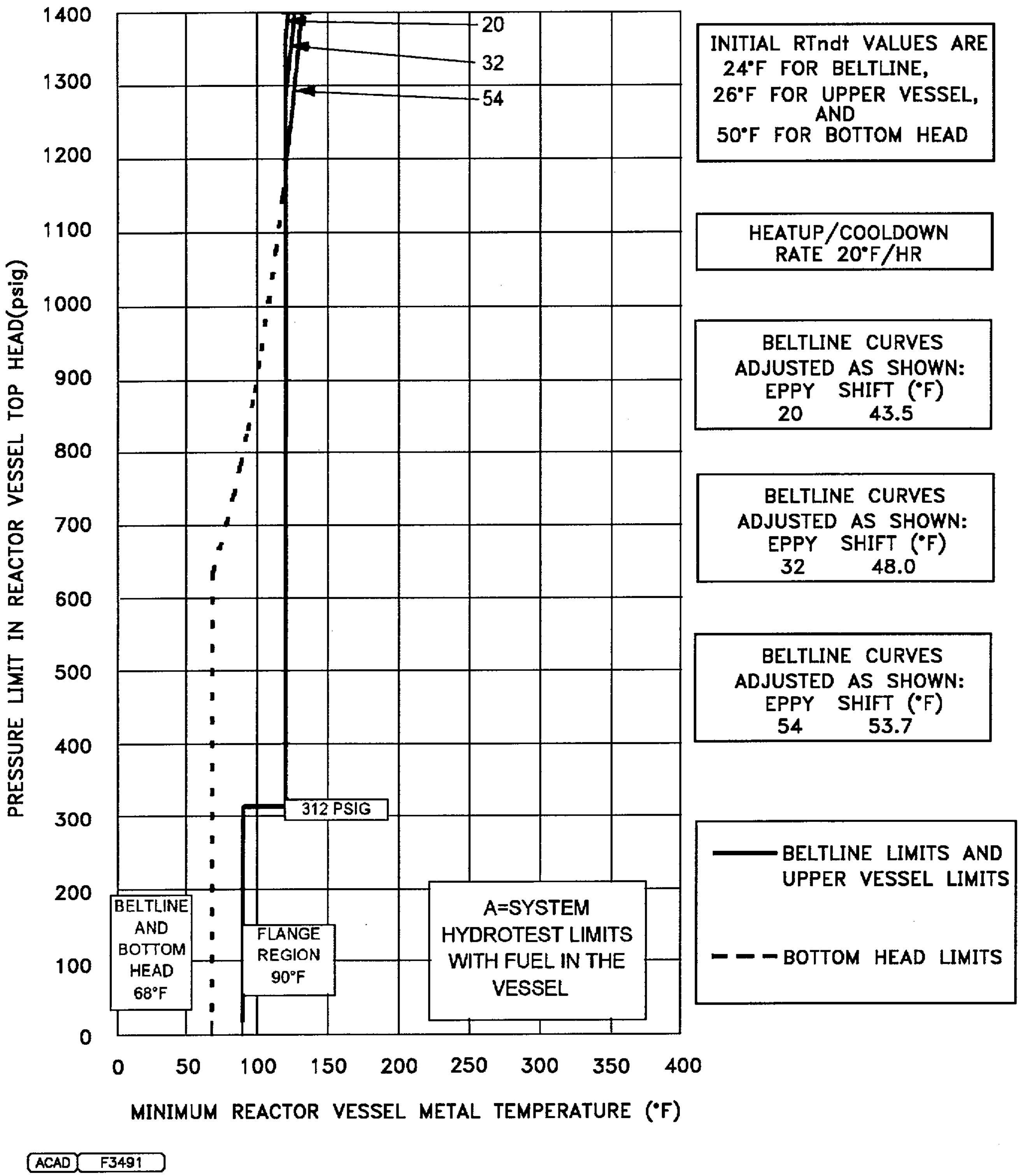


Figure 3.4.9-1 (page 1 of 1)
Pressure/Temperature Limits for
Inservice Hydrostatic and Inservice Leakage Tests

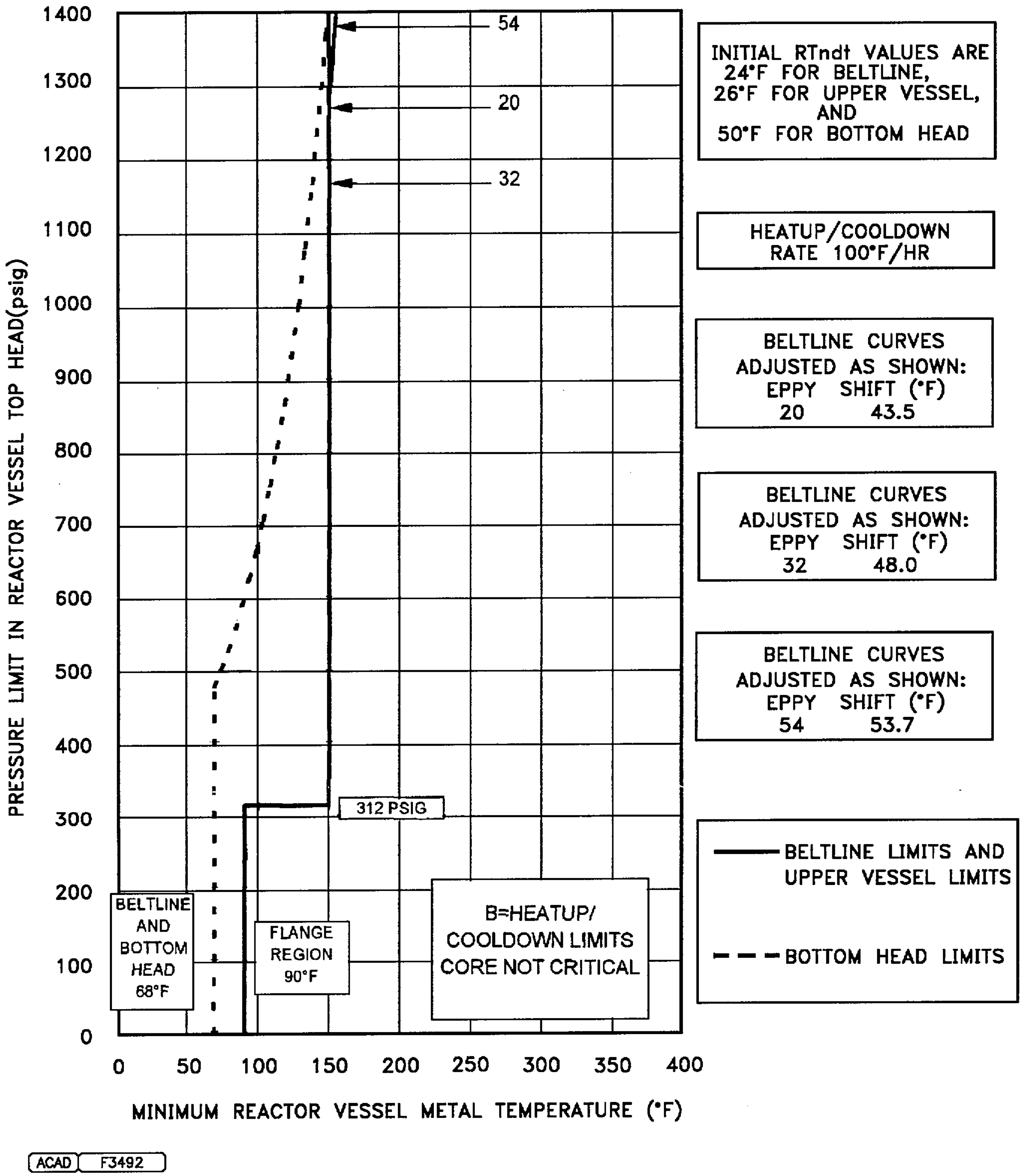
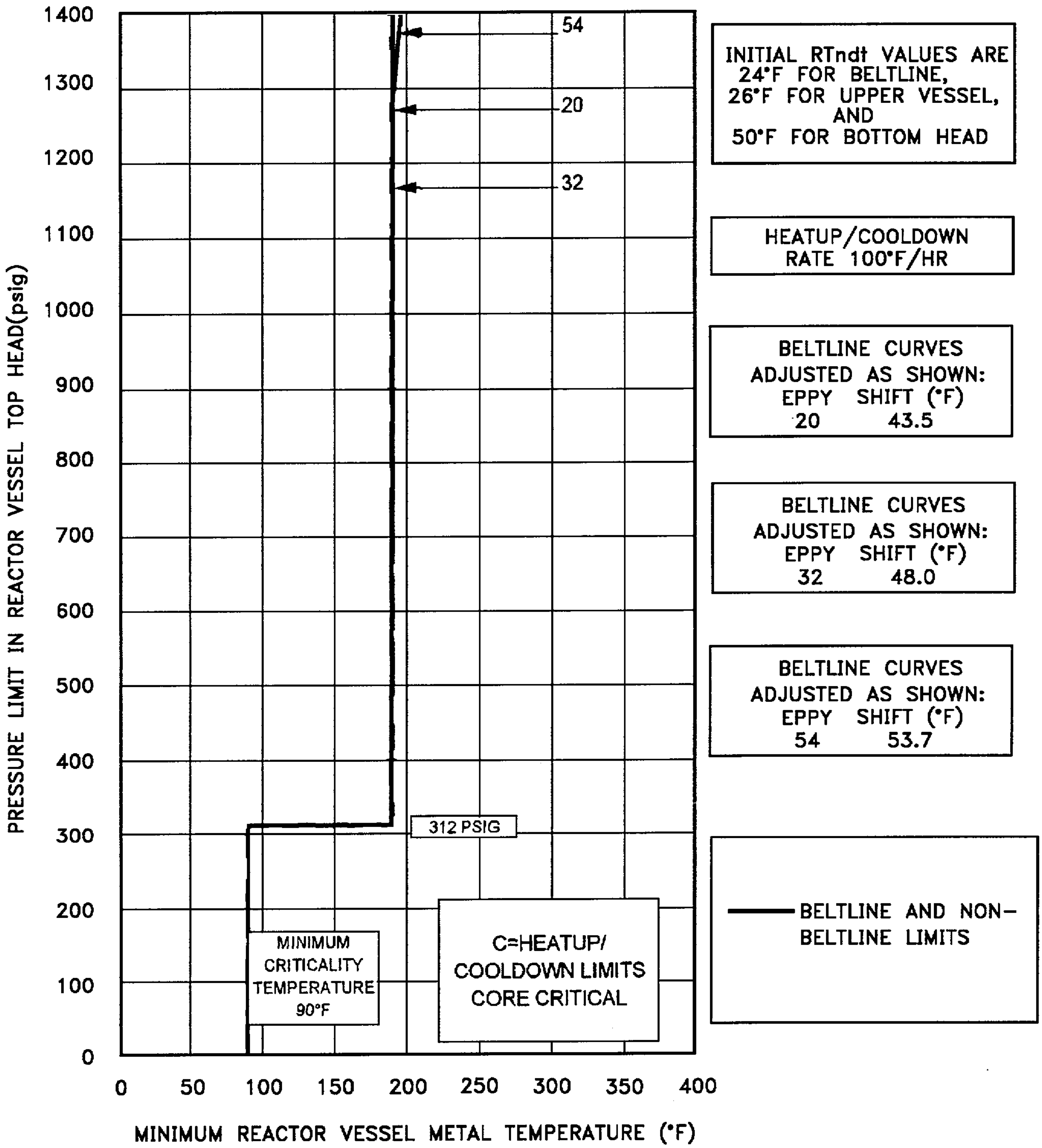


Figure 3.4.9-2 (page 1 of 1)
Pressure/Temperature Limits for Non-Nuclear Heatup,
Low Power Physics Tests, and Cooldown Following a Shutdown



ACAD F3493

Figure 3.4.9-3 (page 1 of 1)
Pressure/Temperature Limits for Criticality

Enclosure 4

Edwin I. Hatch Nuclear Plant
Request to Revise Technical Specifications:
Pressure and Temperature Limits

Request for Exemption from the Requirements of
<u>10 CFR 50, Appendix G</u>

In accordance with 10 CFR 50.12, Southern Nuclear Operating Company (SNC) is requesting an exemption from the requirements of 10 CFR 50.60(a) for Edwin I. Hatch Nuclear Plant (HNP) Unit 1 and Unit 2. The exemption permits the use of ASME Section XI Code Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Limit Curves, Section XI, Division 1," and ASME Section XI Code Case N-588, "Alternative to Reference Flaw Orientation of Appendix G for Circumferential Welds in Reactor Vessels, Section XI, Division 1," in lieu of 10 CFR 50, Appendix G, paragraph IV.A.2.b.

Justification for Use of Code Case N-640
(Code Case N-640 is provided in Attachment 1.)

10 CFR 50.12(a) Requirements

The requested exemption to allow use of ASME Code Case N-640 in conjunction with ASME Code, Section XI, Appendix G, to determine the pressure and temperature (P/T) limits meets the criteria of 10 CFR 50.12 as discussed below.

10 CFR 50.12 states that the Commission may grant an exemption from requirements contained in 10 CFR 50 provided:

1. *The requested exemption is authorized by law*: No law precludes the activities covered by this exemption request. 10 CFR 50.60(b) allows the use of alternatives to 10 CFR 50, Appendices G and H when the NRC grants an exemption under 10 CFR 50.12.

2. *The requested exemption does not present an undue risk to the public health and safety*: The proposed revision to the P/T limits rely, in part, on the requested exemption. The revised P/T limits were developed using the K_{Ic} fracture toughness curve shown on ASME XI, Appendix A, Figure A-2200-1, in lieu of the K_{Ia} fracture toughness curve of ASME XI, Appendix G, Figure G-2210-1, as the lower bound for fracture toughness. The other margins involved with the ASME XI, Appendix G process of determining P/T limit curves remain unchanged.

   Use of the K_{Ic} curve in determining the lower bound fracture toughness in the development of P/T operating limits curve is more technically correct than the K_{Ia} curve. The K_{Ic} curve models the slow heatup and cooldown process of a reactor vessel. Use of this approach is justified by the initial conservatism of the K_{Ia} curve when the curve was codified in 1974. This initial conservatism was necessary due to limited knowledge of reactor pressure vessel (RPV) material fracture toughness.

Since 1974, additional knowledge about the fracture toughness of vessel materials and their fracture response to applied loads has been gained. The additional knowledge demonstrates the lower bound fracture toughness provided by the K_{Ia} curve is well beyond the margin of safety required to protect against potential RPV failure. The lower bound K_{Ic} fracture toughness provides an adequate margin of safety to protect against potential RPV failure and does not present an undue risk to public health and safety.

There are two primary benefits of P/T curves based on the K_{Ic} limits. They occur during the pressure test and are: 1) a reduction in the duration of the pressure test and 2) personnel safety while conducting inspections in primary containment at elevated temperatures.

3. *The requested exemption will not endanger the common defense and security*: The common defense and security are not endangered by this exemption request.

4. *Special circumstances are present which necessitate the request for an exemption to the regulations of 10 CFR 50.60*: In accordance with 10 CFR 50.12(a)(2), the NRC will consider granting an exemption to the regulations if special circumstances are present. This exemption meets the special circumstances of the following paragraphs:

   - (2)(ii) - Demonstrates the underlying purpose of the regulation will continue to be achieved.
   - (2)(iii) - Will result in undue hardship or other cost that are significant if the regulation is enforced.

   (10 CFR 50.12(a)(2)(ii): ASME XI, Appendix G, provides procedures for determining allowable loading on the RPV and is approved for that purpose by 10 CFR 50, Appendix G. Application of these procedures in the determination of P/T operating and test curves satisfies the underlying requirement that:

   1) The reactor coolant pressure boundary be operated in a regime having sufficient margin to ensure, when stressed, the vessel boundary behaves in a ductile manner and the probability of a rapidly propagating fracture is minimized; And

   2) P/T operating and test limit curves provide adequate margin in consideration of uncertainties in determining the effects of irradiation on material properties.

The ASME XI, Appendix G, procedure was conservatively developed based upon the level of knowledge existing in 1974 concerning RPV materials and the estimated effects of operation. Since 1974, the level of knowledge concerning these topics has greatly expanded. This increased knowledge permits relaxation of the ASME XI, Appendix G, requirements via application of ASME Code Case N-640, while maintaining the underlying purpose of the ASME Code and NRC regulations to ensure an acceptable margin of safety.

10 CFR 50.12(a)(2) iii): The reactor coolant system (RCS) pressure-temperature operating window is defined by the P/T operating and test limit curves developed in accordance with the ASME XI, Appendix G procedure. Continued operation of HNP Units 1 and 2 with these P/T curves without the relief provided by ASME Code Case N-640 would unnecessarily restrict the P/T operating window. This restriction requires the Operations staff to maintain a high temperature during pressure tests and also subjects inspection personnel to increased safety hazards while conducting inspections of systems with the potential for steam leaks in a primary containment at elevated temperatures.

This constitutes an unnecessary burden that can be alleviated by the application of ASME Code Case N-640 in the development of the proposed P/T curves. Implementation of the proposed P/T curves, as allowed by ASME Code Case N-640, does not significantly reduce the margin of safety.

Code Case N-640, Conclusion for Exemption Acceptability

Compliance with the specified requirement of 10 CFR 50.60(a) will result in hardship and unusual difficulty without a compensating increase in the level of quality and safety. ASME Code Case N-640 allows a reduction in the lower bound fracture toughness used by ASME XI, Appendix G, in the determination of reactor coolant P/T limits. This proposed alternative is acceptable, because the ASME Code case maintains the relative margin of safety commensurate with the margin of safety that existed at the time ASME XI, Appendix G, was approved in 1974. Therefore, application of ASME Code Case N-640 for HNP Units 1 and 2 ensures an acceptable margin of safety and does not present an undue risk to the public health and safety.

Justification for the Use of Code Case N-588
(Code Case N-588 is provided in Attachment 1.)

10 CFR 50.12(a) Requirements:

The requested exemption to allow use of ASME Code Case N-588 to determine stress intensity factors for postulated flaws and postulated flaw orientation for circumferential welds meets the criteria of 10 CFR 50.12 as discussed below. 10 CFR 50.12 states that the Commission may grant an exemption from requirements contained in 10 CFR 50 provided that:

1. *The requested exemption is authorized by law*: No law precludes the activities covered by this exemption request. 10 CFR 50.60(b) allows the use of alternatives to 10 CFR 50, Appendices G and H, when the NRC grants an exemption under 10 CFR 50.12.

2. *The requested exemption does not present an undue risk to the public health and safety*: 10 CFR 50, Appendix G, requires that Article G-2120 of ASME XI, Appendix G, be used to determine the maximum postulated defects in RPVs for the vessel P/T limits. These limits are determined for normal operation and pressure/leak test conditions. Article G-2120 specifies, in part, that the postulated defect be in the surface of the vessel material and normal (perpendicular in the plane of the material) to the direction of maximum stress. ASME XI, Appendix G, also provides methodology for determining the stress intensity factors for a maximum postulated defect normal to the maximum stress. The purpose of this article is, in part, to ensure the prevention of nonductile fractures by providing

procedures to identify the most limiting postulated fractures to be considered in the development of pressure-temperature limits.

Code Case N-588 provides benefits in terms of calculating P/T limits by revising the Article G-2120 reference flaw orientation for circumferential welds in reactor vessels. The reference flaw is a postulated flaw that accounts for the possibility of a prior existing defect that may have gone undetected during the fabrication process. Thus, the intended application of a reference flaw is to account for defects that could physically exist within the geometry of the weldment. The current ASME Section XI, Appendix G approach mandates the consideration of an axial reference flaw in circumferential welds for purposes of calculating the P/T limits. Postulating the Appendix G reference flaw in a circumferential weld is physically unrealistic and overly conservative, because the length of the flaw is 1.5 times the vessel wall thickness, which is much longer than the width of circumferential welds. The possibility that an axial flaw may extend from a circumferential weld into a plate/forging or axial weld is already adequately covered by the requirement that defects be postulated in plates/forgings and axial welds. The fabrication of RPVs for nuclear power plant operation involved precise welding procedures and controls designed to optimize the resulting weld microstructure and provide the required material properties.

These controls are also designed to minimize defects that could be introduced into the weld during the fabrication process. Industry experience with the repair of weld indications found during preservice inspection, inservice nondestructive examinations, and data taken from destructive examination of actual vessel welds confirms that any remaining defects are small, laminar in nature, and do not cross transverse to the weld bead. Therefore, any postulated defects introduced during the fabrication process and not detected during subsequent nondestructive examinations would only be expected to be oriented in the direction of weld fabrication. For circumferential welds, this indicates a postulated defect with a circumferential orientation.

ASME Code Case N-588 addresses this issue by allowing consideration of maximum postulated defects oriented circumferentially in circumferential welds. ASME Code Case N-588 also provides appropriate procedures for determining the stress intensity factors for use in developing reactor pressure vessel P/T limits per ASME XI, Appendix G procedures. The procedures allowed by ASME Code Case N-588 are conservative and provide a margin of safety in the development of RPV P/T operating and pressure test limits that will prevent nonductile fracture of the vessel.

The proposed P/T limits include restrictions on allowable operating conditions and equipment operability requirements to ensure operating conditions are consistent with the assumptions of the accident analysis. Specifically, RCS pressure and temperature must be maintained within the heatup and cooldown P/T limits specified in Technical Specification 3.4.9. Therefore, this exemption does not present an undue risk to the public health and safety.

3. *The requested exemption will not endanger the common defense and security*: The common defense and security are not endangered by this exemption request.

4. *Special circumstances are present which necessitate the request for an exemption to the regulations of 10 CFR 50.60*: In accordance with 10 CFR 50.12(a)(2), the NRC will consider granting an exemption to the regulations if special circumstances are present. This exemption meets the special circumstances of the following paragraphs:

   - (a)(2)(ii) - Demonstrates that the underlying purpose of the regulation will continue to be achieved;
   - (a)(2)(iii) - Will result in undue hardship or other costs that are significant if the regulation is enforced and;

   10 CFR 50.12(a)(2)(ii): The underlying purpose of 10 CFR 50, Appendix G and ASME XI, Appendix G, is to satisfy the underlying requirement that:

   1) The reactor coolant pressure boundary be operated in a regime having sufficient margin to ensure that when stressed the vessel boundary behaves in a non-brittle manner and the probability of a rapidly propagating fracture is minimized; And

   2) P/T operating and test curves provide margin in consideration of uncertainties in determining the effects of irradiation on material properties.

Application of ASME Code Case N-588 when determining P/T operating and test limit curves per ASME XI, Appendix G, provides appropriate procedures for determining limiting maximum postulated defects and considering those defects in the P/T limits. This application of the code case maintains the margin of safety originally contemplated when ASME XI, Appendix G was developed. Therefore, use of ASME Code Case N-588, as described above, satisfies the underlying purpose of the ASME Code and the NRC regulations to ensure an acceptable level of safety.

10 CFR 50.12(a)(2)(iii): The RCS P/T operating window is defined by the P/T operating and test curves developed in accordance with the ASME XI, Appendix G procedure. Continued operation with these P/T curves without the relief provided by ASME Code Case N-588 will unnecessarily restrict the P/T operating window for Units 1 and 2. This restriction requires the Operations staff to maintain a high temperature during pressure tests and also subjects inspection personnel to increased safety hazards while conducting inspections of systems with the potential for steam leaks in a primary containment at elevated temperatures.

This constitutes an unnecessary burden that can be alleviated by the application of ASME Code Case N-588 in the development the proposed P/T curves. Implementation of the proposed P/T curves as allowed by ASME Code Case N-588 maintains an acceptable margin of safety.

ASME Code Case N-588, Conclusion for Exemption Acceptability

Compliance with the specified requirements of 10 CFR 50.60 will result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. ASME Code Case N-588 allows postulation of a circumferential defect in circumferential welds to be considered in lieu of requiring the defect to be oriented across the weld from one plate or forging to the adjoining plate or forging. This circumstance was not considered at the time ASME XI, Appendix G was developed and imposes restrictions on P/T operating limits beyond those originally contemplated.

This proposed alternative is acceptable, because the Code Case N-588 maintains the relative margin of safety commensurate with the margin of safety that existed at the time ASME XI, Appendix G, was approved in 1974. Therefore, application of ASME Code Case N-588 will ensure an acceptable margin of safety. The approach is justified by consideration of the overpressurization design basis events and the resulting margin to RPV failure.

Restrictions on allowable operating conditions and equipment operability requirements are established to ensure operating conditions are consistent with the assumptions of the accident analysis. Specifically, RCS pressure and temperature must be maintained within the heatup and cooldown rate-dependent P/T limits specified in Technical Specification 3.4.9. Therefore, this exemption does not present an undue risk to the public health and safety.

ATTACHMENT 1

<u>ASME CODE CASE N-588</u>
Alternative to Reference Flaw Orientation of Appendix G for Circumferential Welds in Reactor Vessels

and

<u>ASME CODE CASE N-640</u>
Alternative Reference Fracture Toughness for Development of P-T Limit Curves

Approval Date: December 12, 1997
See Numeric Index for expiration and any reaffirmation dates.

Case N-588
Alternative to Reference Flaw Orientation of Appendix G for Circumferential Welds in Reactor Vessels
Section XI, Division 1

Inquiry: Paragraph G-2120 specifies that postulated reference defects should be sharp, surface defects oriented normal to the direction of maximum stress. What alternative rules may be used for postulating a reference defect in a circumferential welds?

Reply: It is the opinion of the Committee that, as an alternative to the procedure for assuming axially oriented reference defects in all welds and base metal per G-2120, a circumferential orientation may be used specifically for circumferential welds.

CONTENTS

-1000 INTRODUCTION

-1100 Scope

This Case presents an alternative procedure for calculating applied stress intensity factors during normal operation and pressure test conditions. The procedure is based upon the principles of linear elastic fracture mechanics. At each location being investigated a maximum postulated defect is assumed, and the *mode I stress intensity factor* K_I is produced by each of the specified pressure and thermal loadings. Different procedures are recommended for axial and circumferential weld orientations.

-2100 GENERAL REQUIREMENTS

-2120 Maximum Postulated Defects

The postulated defect used in this recommended procedure are sharp, surface defects oriented axially for plates, forgings and axial welds, and oriented circumferentially for circumferential welds. For section thicknesses of 4 in. to 12 in. The postulated defects have a depth of one-fourth of the section thickness and a length of 11/2 times the section thickness. Defects are postulated at both the inside and outside surfaces. For sections greater than 12 in. thick, the postulated defect for the 12 in. section is used. For sections less than 4 in. thick, the 1 in. deep defect is conservatively postulated. Smaller defect sizes[1] may be used on an individual case basis if a smaller size of maximum postulated defect can be ensured. Due to the safety factors recommended here, the prevention of nonductile fracture is ensured for some of the most important situations even if the defects were to be about twice as large in linear dimensions as this postulated maximum defect.

-2200 Level A and Level B Service Limits

-2210 Shells and Heads Remote from Discontinuities

-2211 Recommendations

The assumptions of this Subarticle are recommended for shell and head regions during Level A and B Service Limits.

[1]WRCB 175 (Welding Research Council Bulletin 175) "PVRC Recommendations on Toughness Requirements for Ferritic Materials" provides procedures in para. 5(c)(2) for considering maximum postulated defects smaller than those described.

-2212 Material Fracture Toughness

-2212.1 Reference Critical Stress Intensity Factor for Material. The K_{Ia} values of Fig. G-2210-1 are recommended.

-2212.2 Irradiation Effects. Subarticle A-4400 of Appendix A is recommended to define the change in reference critical stress intensity factor due to irradiation.

-2213 Maximum Postulated Defects

The recommended maximum postulated defects are described in -2120.

-2214 Calculated Stress Intensity Factors

-2214.1 Membrane Tension. The K_I corresponding to membrane tension for the postulated axial defect of -2120 is K_{Im} = $\mathbf{M}_m$ x (pR_i/t), where M_m for an inside axial surface flaw is given by

$M_m = 1.85$ for $\sqrt{t} < 2$

$M_m = 0.926\sqrt{t}$ for $2 \le \sqrt{t} \le 3.464$

$M_m = 3.21$ for $\sqrt{t} > 3.464$

Similarly, M_m for an outside axial surface flaw is given by

$M_m = 1.77$ for $\sqrt{t} < 2$

$M_m = 0.893\sqrt{t}$ for $2 \le \sqrt{t} \le 3.464$

$M_m = 3.09$ for $\sqrt{t} \le 3.464$

where

p = internal pressure (ksi)

R_i = vessel inner radius (in.)

t = vessel wall thickness (in.)

The K_I corresponding to membrane tension for the postulated circumferential defect of -2120 is K_{IM} = M_m *x* (pR_i/t), where M_m for an inside circumferential surface defect is given by

$M_m = 0.89$ for $\sqrt{t} < 2$

$M_m = 0.443\sqrt{t}$ for $2 \le \sqrt{t} \le 3.464$

$M_m = 1.53$ for $\sqrt{t} > 3.464$

Similarly, M_m for an outside circumferential surface defect is given by

$M_m = 0.89$ for $\sqrt{t} < 2$

$M_m = 0.443\sqrt{t}$ for $2 \le \sqrt{t} \le 3.464$

$M_m = 1.53$ for $\sqrt{t} > 3.464$

-2214.2 **Bending Stress.** The K_I corresponding to bending stress for postulated axial or circumferential defects of -2120 is $K_{Ib} = M_b$ *x* maximum bending stress, where M_b *is* two-thirds of M_m.

-2214.3 **Radial Thermal Gradient.** The maximum K_I produced by a radial thermal gradient for a postulated axial or circumferential inside surface defect of

-2120 is $K_{It} = 0.953 \times 10^{-3} \times CR \times t^{2.5}$ where CR is the cooldown rate in F/hr., or, for a postulated axial or circumferential outside surface defect, $K_{It} = 0.753 \times 10^{-3} \times HU \times t^{2.5}$,where HU is the heatup rate in F/hr.

The through-wall temperature difference associated with the maximum thermal K_I can be determined from Fig. G-2214-1. The temperature at any radial distance from the vessel surface can be determined from Fig. G-2214-2 for the maximum thermal K_I.

(a) The maximum thermal K_I and the temperature relationship in Fig. G-2214-1 are applicable only for the conditions in -2214.3(a)(1) and (2).

(1) An assumed shape of the temperature gradient is approximately as shown in Fig. G-2214-2.

(2) The temperature change starts from a steady state condition and has a rate, associated with startup and shutdown, less than about 100°F/hr. The results would be overly conservative if applied to rapid temperature changes.

(b) Alternatively, the K_I for radial thermal gradient can be calculated for any thermal stress distribution at any specified time during cooldown for a ¼-thickness axial or circumferential surface defect.

For an inside surface defect during cooldown

$$K_{It} = (1.0359C_0 + 0.6322C_1 + 0.4753C_2 + 0.3855C_3)\sqrt{\pi a}$$

For an outside surface defect during heatup

$$K_{It} = (1.043C_0 + 0.630C_1 + 0.481C_2 + 0.401C_3)\sqrt{\pi a}$$

The coefficients C_0, C_1, C_2 and C_3 are determined from the thermal stress distribution at any specified time during the heatup or cooldown using

$$\sigma(x) = C_0 + C_1\,(x/a) + C_2\,(x/a)^2 + C_3\,(x/a)^3$$

where x is a dummy variable that represents the radial distance, in., from the appropriate (i.e., inside or outside) surface and a is the maximum crack depth, in.

(c) For the startup condition, the allowable pressure vs. temperature relationship is the minimum pressure at any temperature, determined from (1) the calculated steady state results for the ¼-thickness inside surface defect, (2) the calculated steady state results for the ¼-thickness outside surface defect, and (3) the calculated results for the maximum allowable heatup rate using a ¼-thickness outside surface defect.

-2215 Allowable Pressure

The equations given in this Subarticle provide the basis for determination of the allowable pressure at any temperature at the depth of the postulated defect during Service Conditions for which Level A and Level B Service Limits are specified. In addition to the conservatism of these assumptions, it is recommended that a factor of 2 be applied to the calculated K_I values produced by primary stresses. In shell and head regions remote from discontinuities, the only significant loadings are: (1) general primary membrane stress due to pressure; and (2) thermal stress due to thermal gradient through the thickness during startup and shutdown. Therefore, the requirement to be satisfied and from which the allowable pressure for any assumed rate of temperature change can be determined is:

$$2K_{Im} + K_{It} < K_{Ia}$$

throughout the life of the component at each temperature with K_{Im} from -2214.1, K_{It} from -2214.3, and K_{Ia} from Fig. G-2210-1.

The allowable pressure at any temperature shall be determined by the following procedure:

(a) For the startup condition, consider postulated defects in accordance with -2120, perform calculations for thermal stress intensity factors due to the specified range of heatup rates from -2214.3, calculate the *Kja* toughness for all vessel beltline materials from -2212 using temperatures and RT_{NDT} values for the corresponding locations of interest, and calculate the pressure as a function of coolant inlet temperature for each material and location. The allowable pressure vs. temperature relationship is the minimum pressure at any temperature determined from (1) the calculated steady-state (K_{It} = 0) results for the ¼ thickness inside surface postulated defects using the equation:

$$P = (K_{Ia}/2M_m) * (t/R_i)$$

and (2) the calculated results from all vessel beltline materials for the heatup stress intensity factors using

(1)

the corresponding ¼ thickness outside surface postulated defects and the equation

$$P = [(K_{Ia} - K_{It})/2M_m] * (t/R_i)$$

(b) For the cooldown condition, consider postulated defects in accordance with -2120, perform calculations for thermal stress intensity factors due to the specified range of cooldown rates from -2214.3, calculate the K_{Ia} toughness for all vessel belthne materials from -2212 using temperatures and RT_{NDT} values for the corresponding locations of interest, and calculate the pressure as a function of coolant inlet temperature for each material and location using the equation:

$$P = [(K_{Ia} - K_{It})/2M_m] * (t/R_i)$$

The allowable pressure vs temperature relationship is the minimum pressure at any temperature, determined from all vessel beltline materials for the cooldown stress intensity factors using the corresponding 1/4 thickness inside surface postulated defects.

Approval Date: February 26, 1999
See Numeric Index for expiration and any reaffirmation dates.

Case N-640
Alternative Reference Fracture Toughness for Development of P-T Limit Curves
Section X1, Division 1

Inquiry: May the reference fracture toughness curve K_{IC}, as found in Appendix A of Section XI, be used in lieu of Fig. G-2210-1 in Appendix G for the development of P-T Limit Curves?

Reply: It is the opinion of the Committee that the reference fracture toughness K_{IC} of Fig. A-4200-1 of Appendix A may be used in lieu of Fig. G-2210-1 in Appendix G for the development of P-T Limit Curves. When this Case is employed, LTOP Systems shall limit the maximum pressure in the vessel to 100% of the pressure allowed by the P-T Limit Curves.

ATTACHMENT 2

Structural Integrity Report SIR-00-037
Revised Pressure-Temperature Curves for Plant Hatch

Structural Integrity Associates, Inc.

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March 31, 2000
GLS-00-017
SIR-00-037, Rev. 0

Mr. Marty Sims
Southern Nuclear Operating Co.
P.O. Box 1295
40 Inverness Center Parkway
Bin B052
Birmingham, Alabama 35201

Subject: Revised Pressure-Temperature Curves for Hatch

Reference: Southern Nuclear P.O. No. 6043370, Req. No. HPBH-000281, BOWA #00-03

Dear Marty:

The attachment to this letter documents the revised set of pressure-temperature (P-T) curves developed for Hatch Units 1 and 2. This work was performed in accordance with the referenced contract, and includes a full set of updated P-T curves (i.e., pressure test, core not critical, and core critical conditions) for both Hatch units for 20, 32, and 54 effective full power years (EFPY). The curves were developed in accordance with the 1989 ASME Code, Section XI, Appendix G, U.S. 10CFR 50 Appendix G, and ASME Code Cases N-588 and N-640.

The inputs, methodology, and results for this effort are summarized in the attachment. The calculations for this work (SNOC-22Q-301, -302, and –303) are also attached.

This transmittal completes the work associated with this effort. Thank you for providing SI with the opportunity to provide these services to Southern Nuclear. I hope you find the work to be satisfactory and that it meets your needs and expectations.

Prepared By: *Gary L. Stevens 3/31/00*
Gary L. Stevens, P. E.
Associate

Reviewed By: *[signature]*
H. L. Gustin, P. E.
Associate

Approved By: *Gary L. Stevens 3/31/00*
Gary L. Stevens, P. E.
Associate

jj
Attachment
cc: SNOC-22Q-106, -401

ATTACHMENT

REVISED P-T CURVES FOR HATCH

1.0 Introduction

This attachment documents the revised set of pressure-temperature (P-T) curves developed for Hatch Units 1 and 2. This work includes a full set of updated P-T curves (i.e., pressure test, core not critical, and core critical conditions) for both Hatch units for 20, 32, and 54 effective full power years (EFPY). The curves were developed using the same methodology described in the Reference [1] report, modified to incorporate the methodology specified in ASME Code Cases N-588 [2] and N-640 [3]. The Reference [1] report developed curves in accordance with the 1989 ASME Code, Section XI, Appendix G [4], 10CFR50 Appendix G [5], and WRC-175 [6]. The improvement realized from these modified curves is as much as 60°F, and is primarily obtained from using the arrest fracture toughness, K_{IC}, in accordance with Code Case N-640.

2.0 RT_{NDT} Determination

RT_{NDT} estimates were developed for the Hatch reactor pressure vessel (RPV) materials in accordance with Regulatory Guide 1.99, Revision 2 (RG 1.99) [7] for the different EFPY levels required for this work, and are shown in Table 1 for Hatch Unit 1 and Table 2 for Hatch Unit 2. The inputs used for the calculations were based on the data documented in Reference [1]. The fluence estimates used in Tables 1 and 2 account for power uprate conditions.

3.0 P-T Curve Methodology

The P-T curve methodology is based on the requirements of References [2] through [5]. The approach taken is identical to that documented in Reference [1], except for the incorporation of Code Case N-588 [2] and N-640 [3]. This revised approach includes the following:

- K_{IC} was used in place of K_{IA} in accordance with Code Case N-640 [3]:

$$K_{IC} = 20.734\, e^{[0.02(T - ART_{NDT})]} + 33.2$$

where: T = metal temperature at assumed flaw tip (°F)
= conservatively set equal to the fluid temperature
ART_{NDT} = adjusted reference temperature for location under consideration and desired EFPY (°F)
K_{IC} = critical stress intensity factor (ksi√inch)
Note that a maximum value of 200 ksi√inch is allowed, per Ref. [4].

- For the beltline region, the thermal stress intensity factor, K_{IT}, was calculated for a cooldown transient in accordance with Code Case N-588 [2]:

$$K_{IT} = 9.53\times10^{-4}\ CR\ t^{2.5}$$

where:
K_{IT} = thermal stress intensity factor (ksi$\sqrt{\text{inch}}$)
CR = transient cooldown rate (°F/hr)
t = vessel wall thickness (inches)

- For the beltline region, the allowable pressure, P, was calculated in accordance with Code Case N-588 [2] for an inside surface axial flaw:

$$K_{IP} = M_m\ \sigma_m$$

where:
M_m = membrane stress correction factor
σ_m = membrane stress due to pressure (ksi)
= PR/t
P = pressure (ksi)
R = vessel radius (inches)
t = vessel wall thickness (inches)

Thus, $P = K_{IP}t/(RM_m)$

Note that Code Case N-588 is not applicable for the bottom head or upper vessel regions, as the stress intensity factor relationships are for shells and heads remote from discontinuities.

All other aspects of the methodology detailed in Reference [1] was maintained for the revised P-T curves. The supporting calculations for the curves are contained in References [8] through [10]. The resulting P-T curves relate the minimum required reactor metal temperature to the reactor pressure.

4.0 P-T Curves

The resulting P-T curves are shown in Figures 1 through 9 for Hatch Unit 1, and in Figures 10 through 18 for Hatch Unit 2. Tabulated values of pressure and temperature for these figures can be found in supporting References [8] through [10].

Combined P-T curves and tabulated values for Hatch Operations personnel to use are included in Appendix A for Unit 1 and Appendix B for Unit 2.

5.0 References

1. GE Report No. GE-NE-B1100827-00-01, "Plant Hatch Units 1 & 2 RPV Pressure Temperature Limits License Renewal Evaluation," Class II, March 1999, SI File No. SNOC-22Q-201.

2. ASME Boiler and Pressure Vessel Code, Code Case N-588, "Attenuation to Reference Flow [sic] Orientation of Appendix G for Circumferential Welds in Reactor Vessels," Section XI, Division 1, Approved December 12, 1997, SI File No. SNOC-22Q-202.

3. ASME Boiler and Pressure Vessel Code, Code Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Limit Curves," Section XI, Division 1, Approved February 26, 1999, SI File No. SNOC-22Q-202.

4. ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Nonmandatory Appendix G, "Fracture Toughness Criteria for Protection Against Failure," 1989 Edition, No Addenda.

5. U. S. Code of Federal Regulations, Title 10, Part 50, Appendix G, "Fracture Toughness Requirements," December 1995.

6. WRC Bulletin 175, "PVRC Recommendations on Toughness Requirements for Ferritic Materials," PVRC Ad Hoc Group on Toughness Requirements, Welding Research Council, August 1972.

7. USNRC Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, (Task ME 305-4), May 1988.

8. Structural Associates Calculation No. SNOC-22Q-301, Revision 0, "Development of Unit 2 Pressure Test P-T Curves," 3/6/2000.

9. Structural Associates Calculation No. SNOC-22Q-302, Revision 0, "Development of Remaining Unit 2 P-T Curves," 3/28/2000.

10. Structural Associates Calculation No. SNOC-22Q-303, Revision 0, "Development of Hatch Unit 1 P-T Curves," 3/28/2000.

Table 1
RT_{NDT} Estimates for Hatch Unit 1

Hatch Unit 1 Limiting RPV Material ART_{NDT} Calculations (1)

Part Name & Material	Heat No.	Initial RT_{NDT} (°F)	Chemistry		Chemistry Factor (°F)	EFPY	Adjustments For 1/4t			
			Cu (wt %)	Ni (wt %)			ΔRT_{NDT} (°F)	Margin Terms		ART_{NDT} (°F)
								σ_Δ (°F)	σ_I (°F)	
BELTLINE (Lower Int. Shell)	C4114-2	-20	0.13	0.70	245	20.0	96.7	17.0	0.0	110.7
						24.0	105.6	17.0	0.0	119.6
						28.0	113.4	17.0	0.0	127.4
						32.0	120.6	17.0	0.0	134.6
						36.0	127.0	17.0	0.0	141.0
						40.0	133.5	17.0	0.0	147.5
						44.0	139.7	17.0	0.0	153.7
						48.0	145.4	17.0	0.0	159.4
						54.0	153.2	17.0	0.0	167.2

Location	Wall Thickness (inches)		EFPY	Fluence at ID (n/cm^2)	Attenuation @ 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28-0.10\log f)}$	Comment
	Full	1/4t						
BELTLINE (Lower Int. Shell)	5.380	1.345	20.0	1.23E+18	0.724	8.93E+17	0.395	The fluence was linearly interpolated based on 36 EFPY.
			24.0	1.48E+18	0.724	1.07E+18	0.431	The fluence was linearly interpolated based on 36 EFPY.
			28.0	1.73E+18	0.724	1.25E+18	0.463	The fluence was linearly interpolated based on 36 EFPY.
			32.0	1.97E+18	0.724	1.43E+18	0.492	The fluence was linearly interpolated based on 36 EFPY.
			36.0	2.22E+18	0.724	1.61E+18	0.518	The fluence was assumed such that the resulting ART matched that given in [1].
			40.0	2.49E+18	0.724	1.80E+18	0.545	The fluence was assumed such that the resulting ART matched that given in [1].
			44.0	2.77E+18	0.724	2.01E+18	0.570	The fluence was assumed such that the resulting ART matched that given in [1].
			48.0	3.05E+18	0.724	2.21E+18	0.593	The fluence was assumed such that the resulting ART matched that given in [1].
			54.0	3.47E+18	0.724	2.51E+18	0.625	The fluence for this EFPY was given in [1].

Note: 1. Data obtained from Table 3-1 (page 8) of [1].

Table 2
RT_{NDT} Estimates for Hatch Unit 2

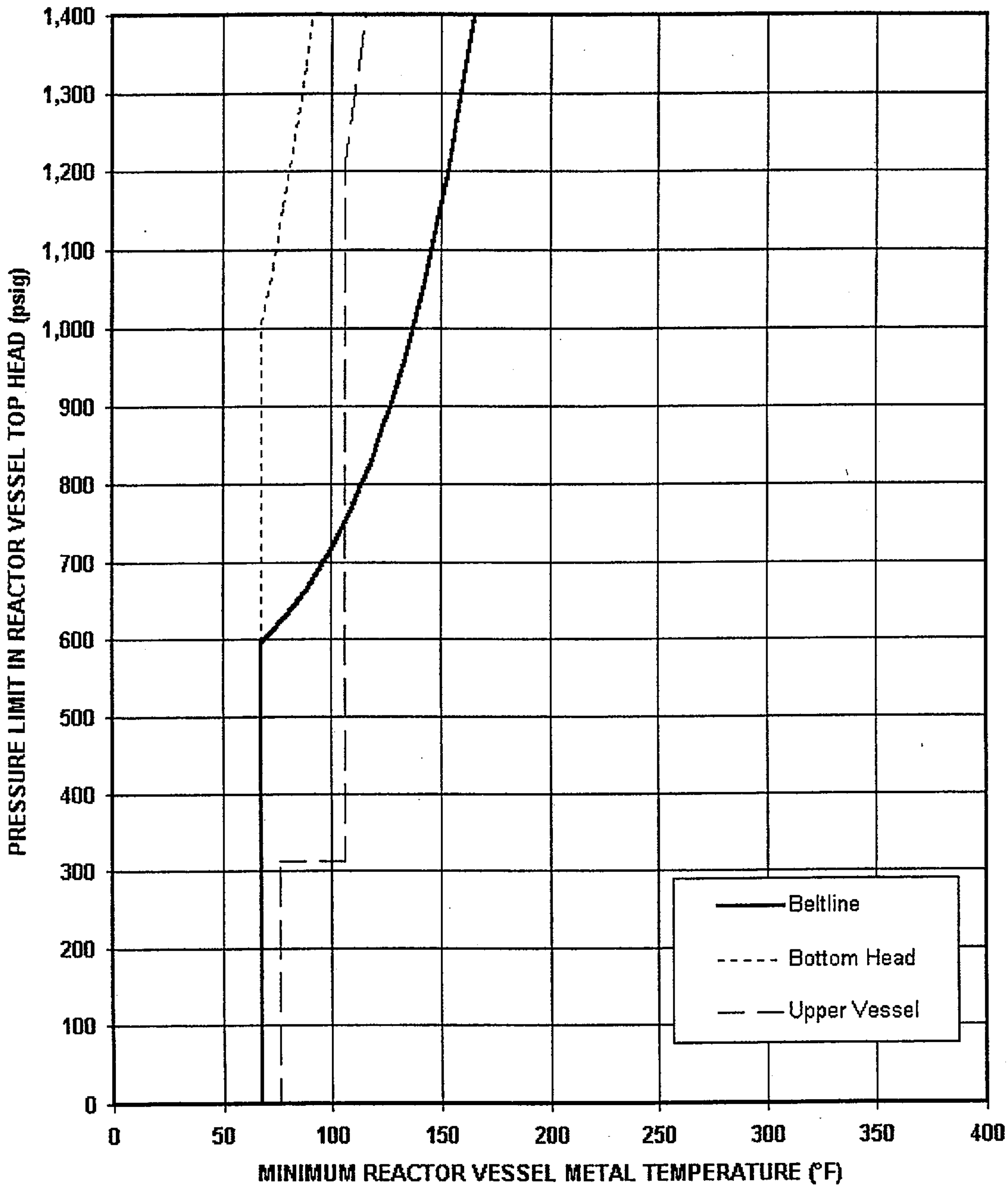
Hatch Unit 2 Limiting RPV Material ART_{NDT} Calculations (1)

Part Name & Material	Heat No.	Initial RT_{NDT} (°F)	Chemistry		Chemistry Factor (°F)	EFPY	Adjustments For 1/4t			
			Cu (wt %)	Ni (wt %)			ΔRT_{NDT} (°F)	Margin Terms σ_Δ (°F)	σ_I (°F)	ART_{NDT} (°F)
BELTLINE (Lower Plate)	C8553-1	24	0.08	0.58	51	20.0	16.7	13.4	0.0	67.5
						24.0	18.4	13.4	0.0	69.2
						28.0	19.8	13.4	0.0	70.6
						32.0	21.2	13.4	0.0	72.0
						36.0	22.4	13.4	0.0	73.2
						40.0	23.5	13.4	0.0	74.3
						44.0	24.6	13.4	0.0	75.4
						48.0	25.5	13.4	0.0	76.3
						54.0	26.9	13.4	0.0	77.7

Location	Wall Thickness (inches) Full	1/4t	EFPY	Fluence at ID (n/cm^2)	Attenuation @ 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28-0.10\log f)}$	Comment
BELTLINE (Lower Plate)	5.380 (see Note 2)	1.345	20.0	8.56E+17	0.724	6.20E+17	0.328	The fluence was linearly interpolated based on 54 EFPY.
			24.0	1.03E+18	0.724	7.43E+17	0.360	The fluence was linearly interpolated based on 54 EFPY.
			28.0	1.20E+18	0.724	8.67E+17	0.389	The fluence was linearly interpolated based on 54 EFPY.
			32.0	1.37E+18	0.724	9.91E+17	0.415	The fluence was linearly interpolated based on 54 EFPY.
			36.0	1.54E+18	0.724	1.12E+18	0.439	The fluence was linearly interpolated based on 54 EFPY.
			40.0	1.71E+18	0.724	1.24E+18	0.461	The fluence was linearly interpolated based on 54 EFPY.
			44.0	1.88E+18	0.724	1.36E+18	0.482	The fluence was linearly interpolated based on 54 EFPY.
			48.0	2.05E+18	0.724	1.49E+18	0.501	The fluence was linearly interpolated based on 54 EFPY.
			54.0	2.31E+18	0.724	1.67E+18	0.528	See Note 2.

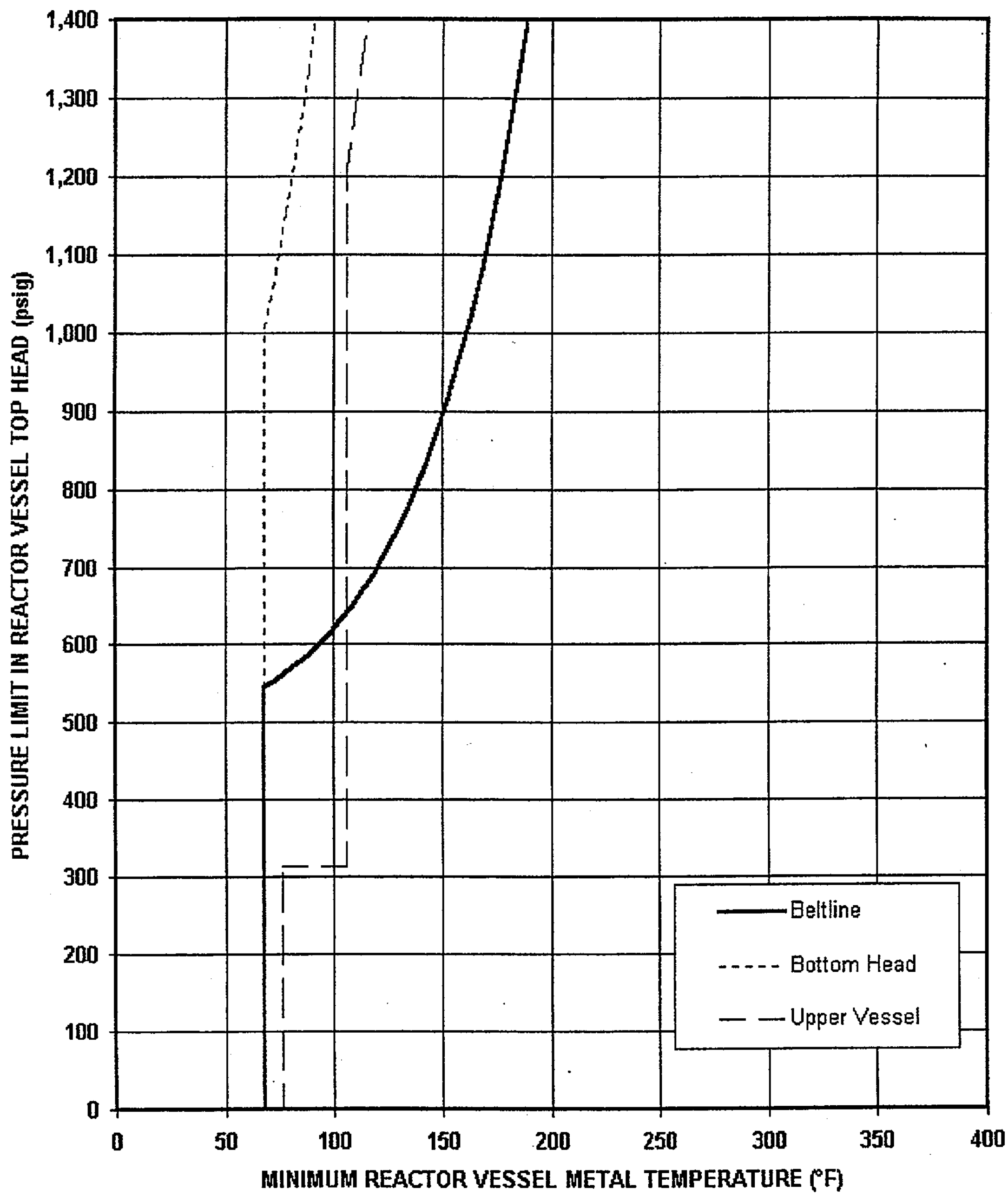
Note: 1. Data obtained from Table 3-2 (page 9) of [1].
2. The Reference [1] report developed a bounding P-T curve by using the smaller lower weld thickness, combined with the thicker lower plate material properties. For this analysis, the smaller thickness is shown (since the P-T curves are based on this thickness), but the ID fluence was adjusted to yield a 1/4t fluence that matched the value in Table 3-2 of Reference [1] for the limiting thicker plate. Therefore, the ID fluence value for 54 EFPY was iterated until the appropriate calculated value at 1/4t was obtained. In effect, the values shown in this table reconcile the analysis case with the bounding case documented in Reference [1].

Figure 1
Pressure Test Curve for Hatch Unit 1 for 20 EFPY



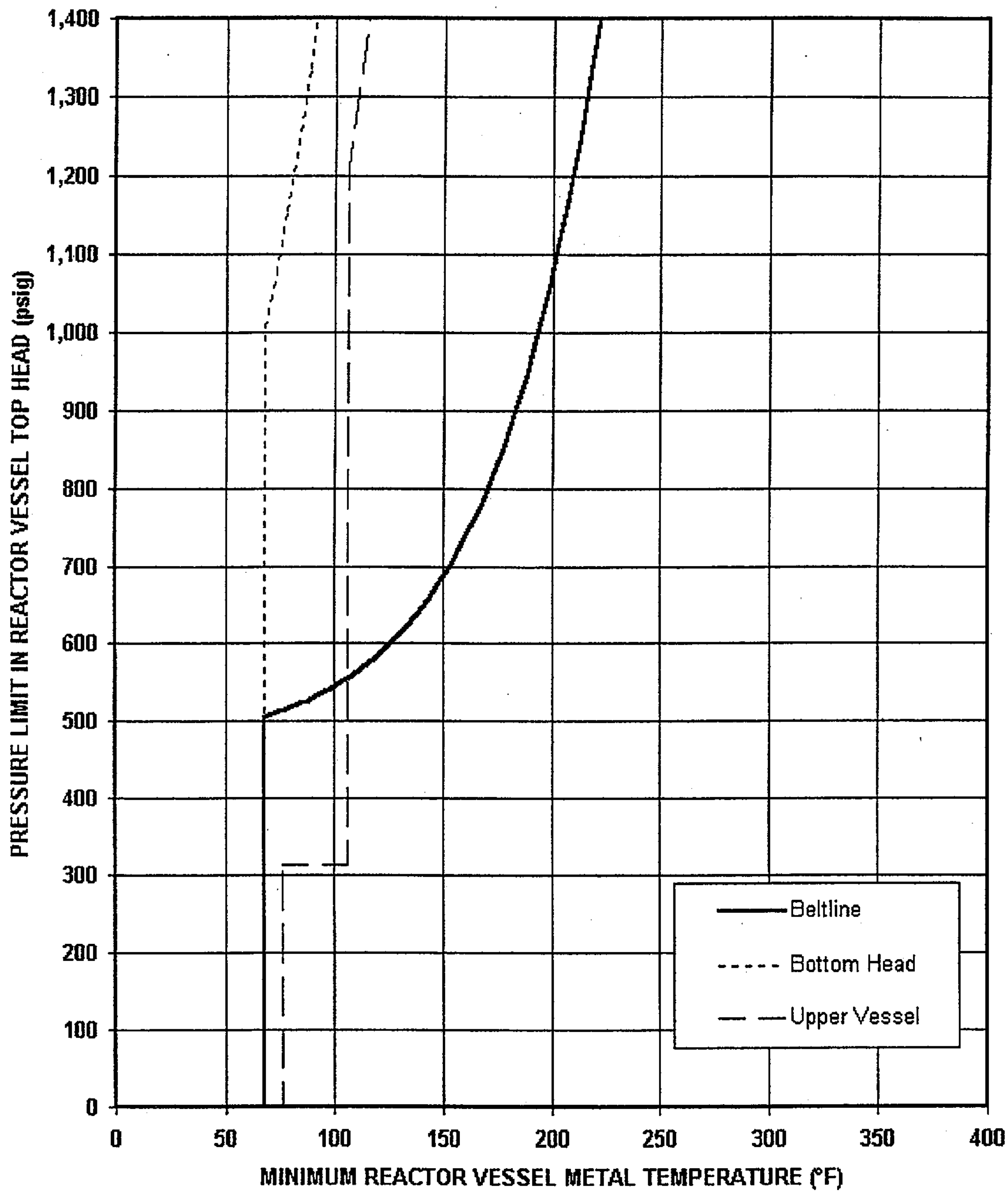
USING CODE CASES
Unit 1 Pressure Test Curve (Curve A), 20 EFPY

Figure 2
Pressure Test Curve for Hatch Unit 1 for 32 EFPY



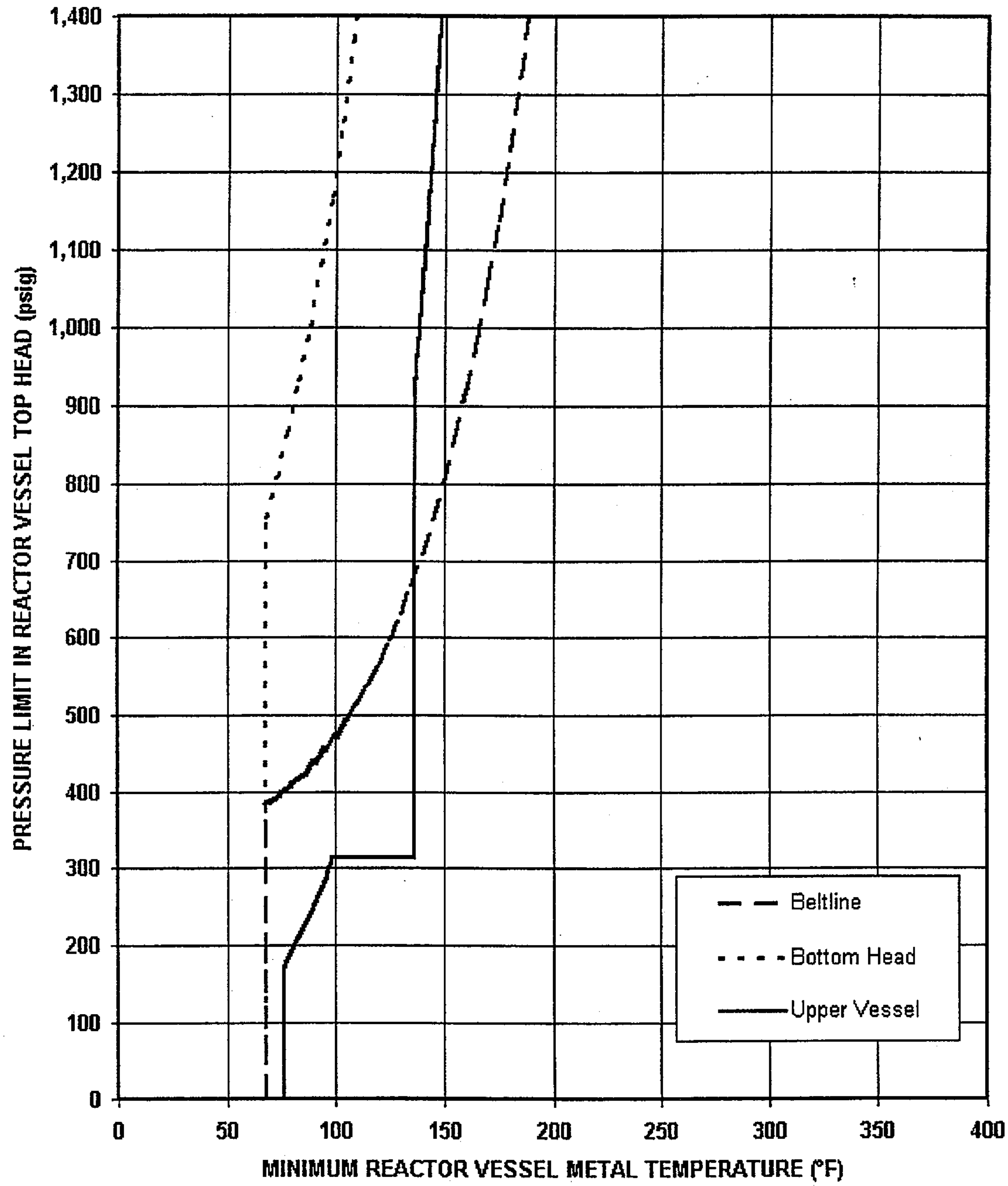
Unit 1 Pressure Test Curve (Curve A), 32 EFPY

Figure 3
Pressure Test Curve for Hatch Unit 1 for 54 EFPY



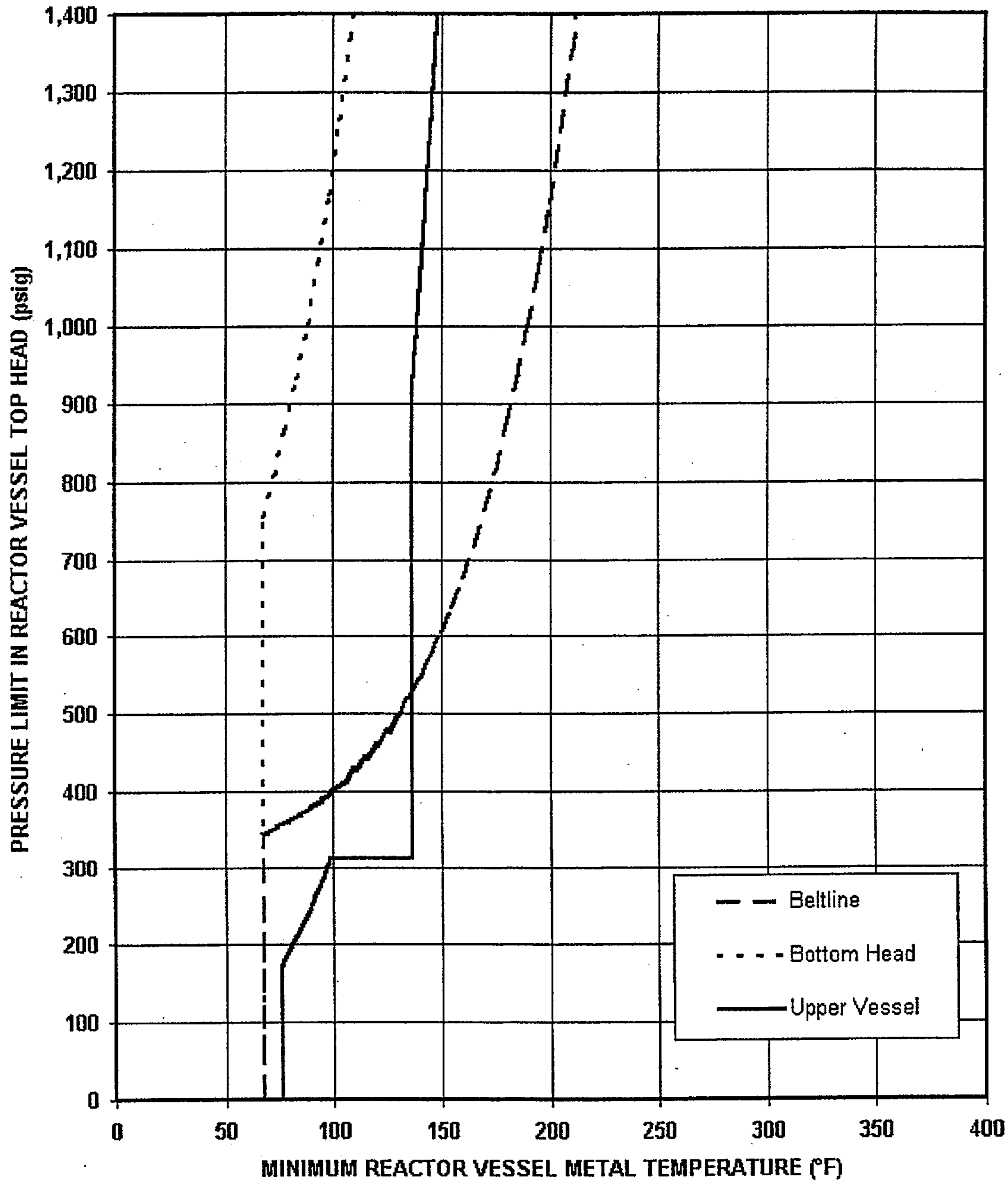
Unit 1 Pressure Test Curve (Curve A), 54 EFPY

Figure 4
Core Not Critical Curve for Hatch Unit 1 for 20 EFPY



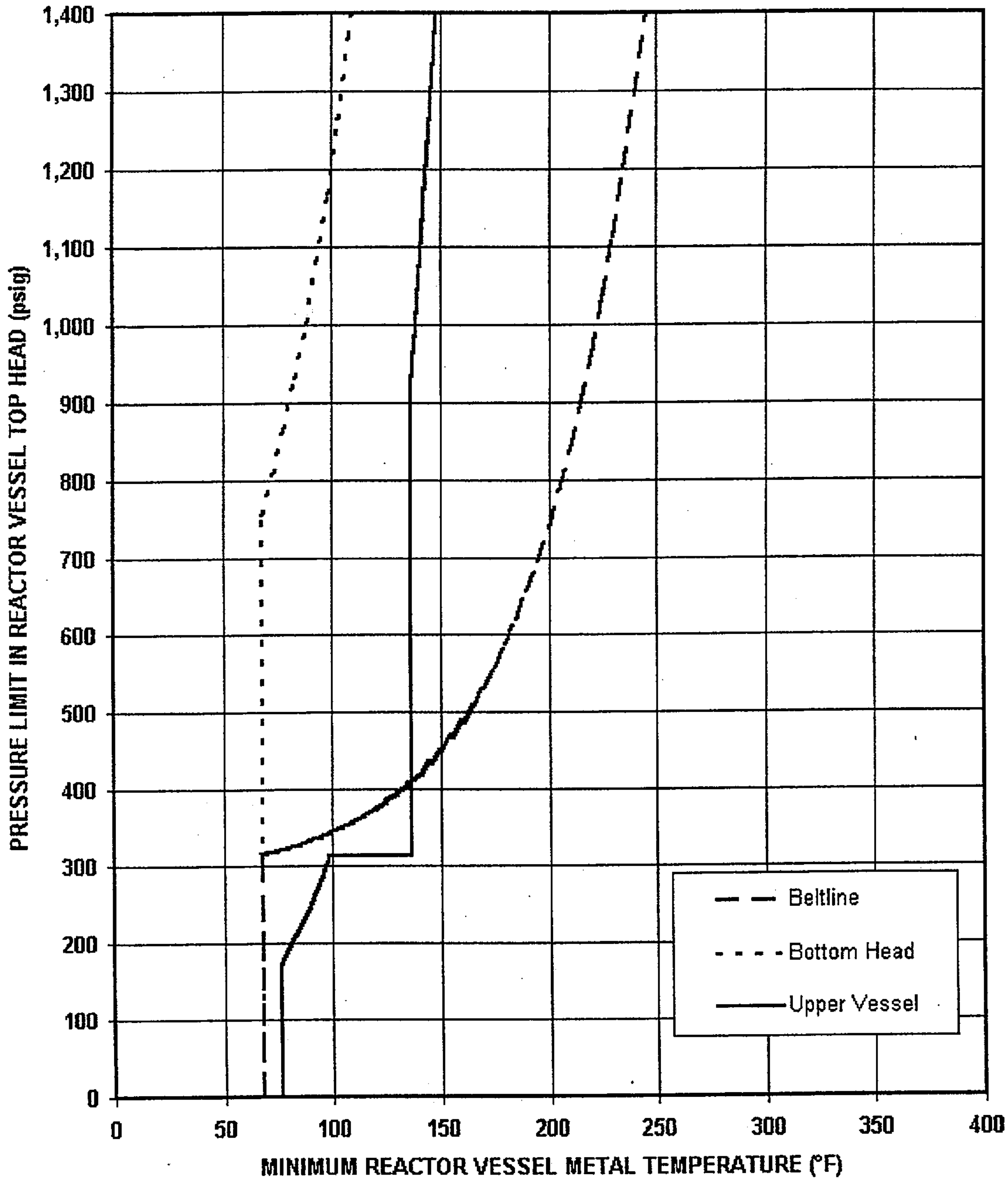
Unit 1 Core Not Critical Curve (Curve B), 20 EFPY

Figure 5
Core Not Critical Curve for Hatch Unit 1 for 32 EFPY



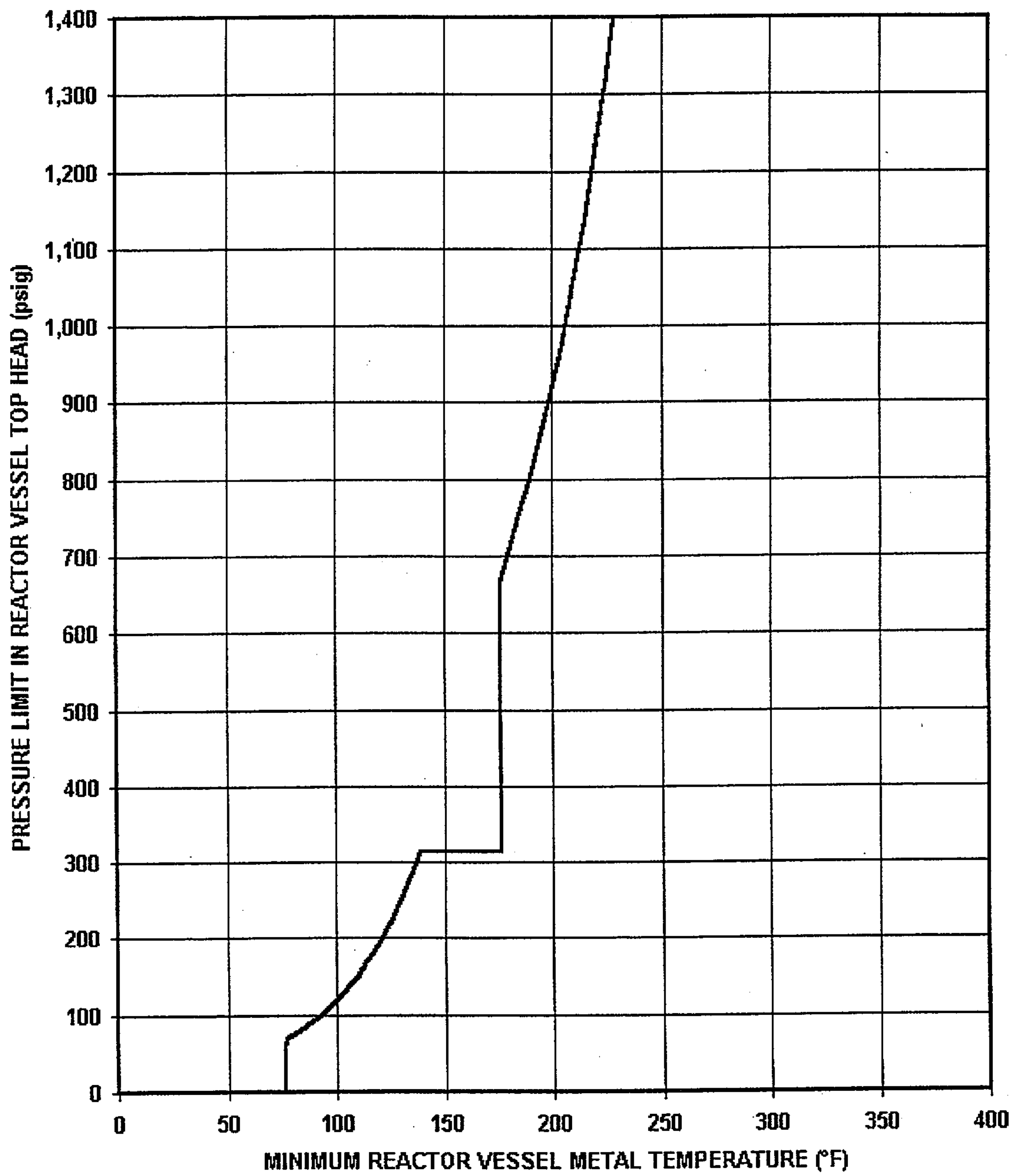
Unit 1 Core Not Critical Curve (Curve B), 32 EFPY

Figure 6
Core Not Critical Curve for Hatch Unit 1 for 54 EFPY



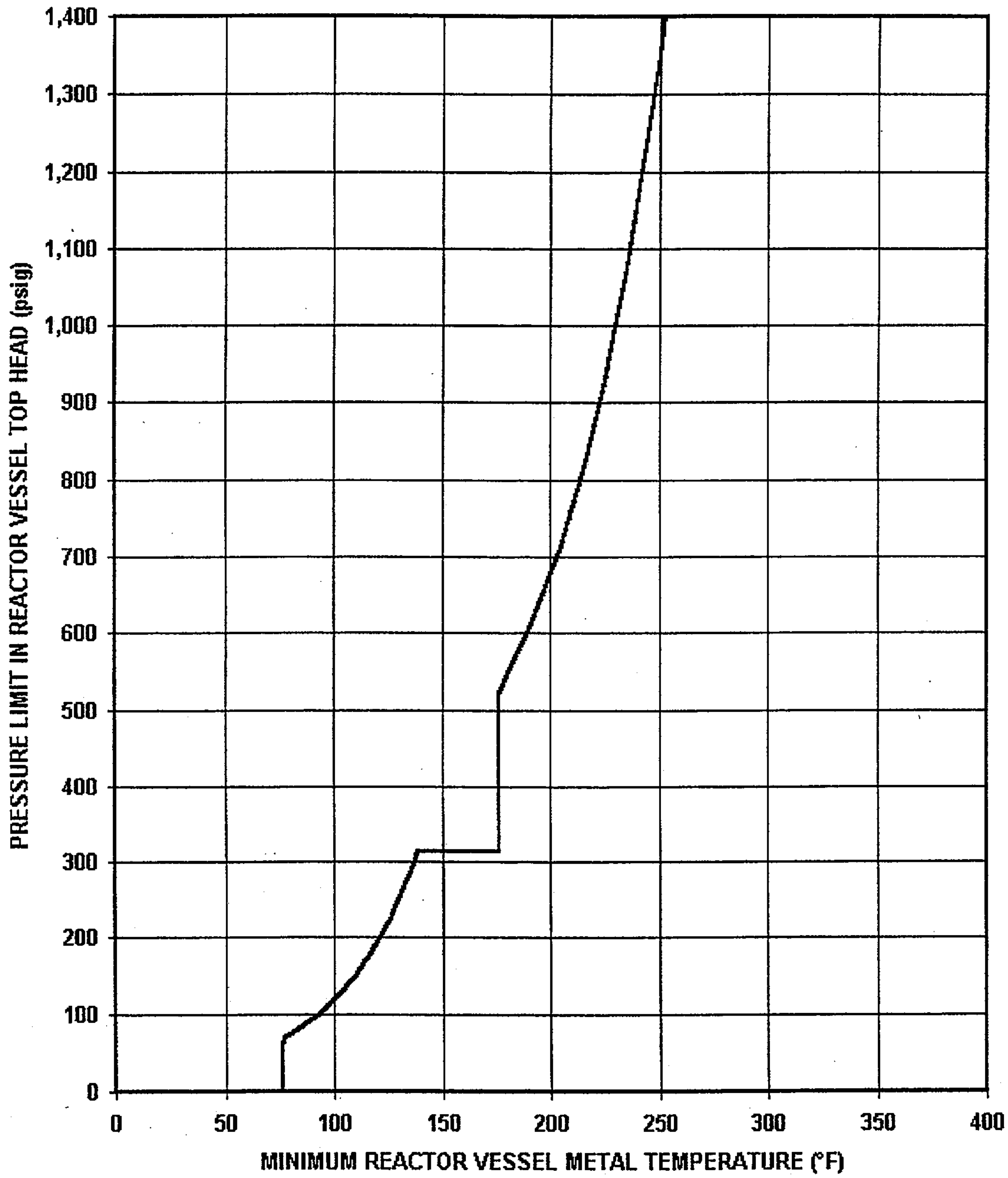
Unit 1 Core Not Critical Curve (Curve B), 54 EFPY

Figure 7
Core Critical Curve for Hatch Unit 1 for 20 EFPY



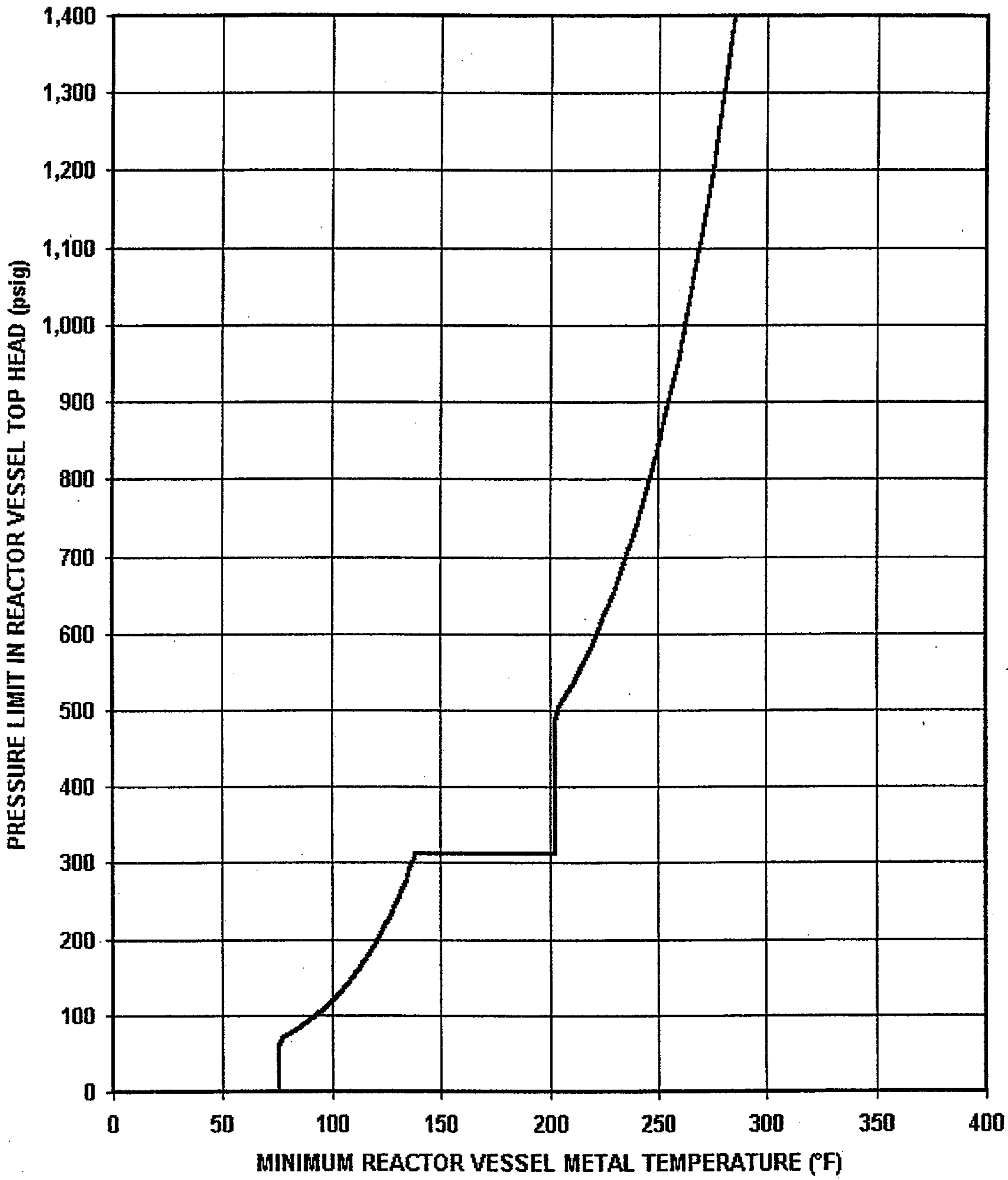
Unit 1 Core Critical Curve (Curve C), 20 EFPY

Figure 8
Core Critical Curve for Hatch Unit 1 for 32 EFPY



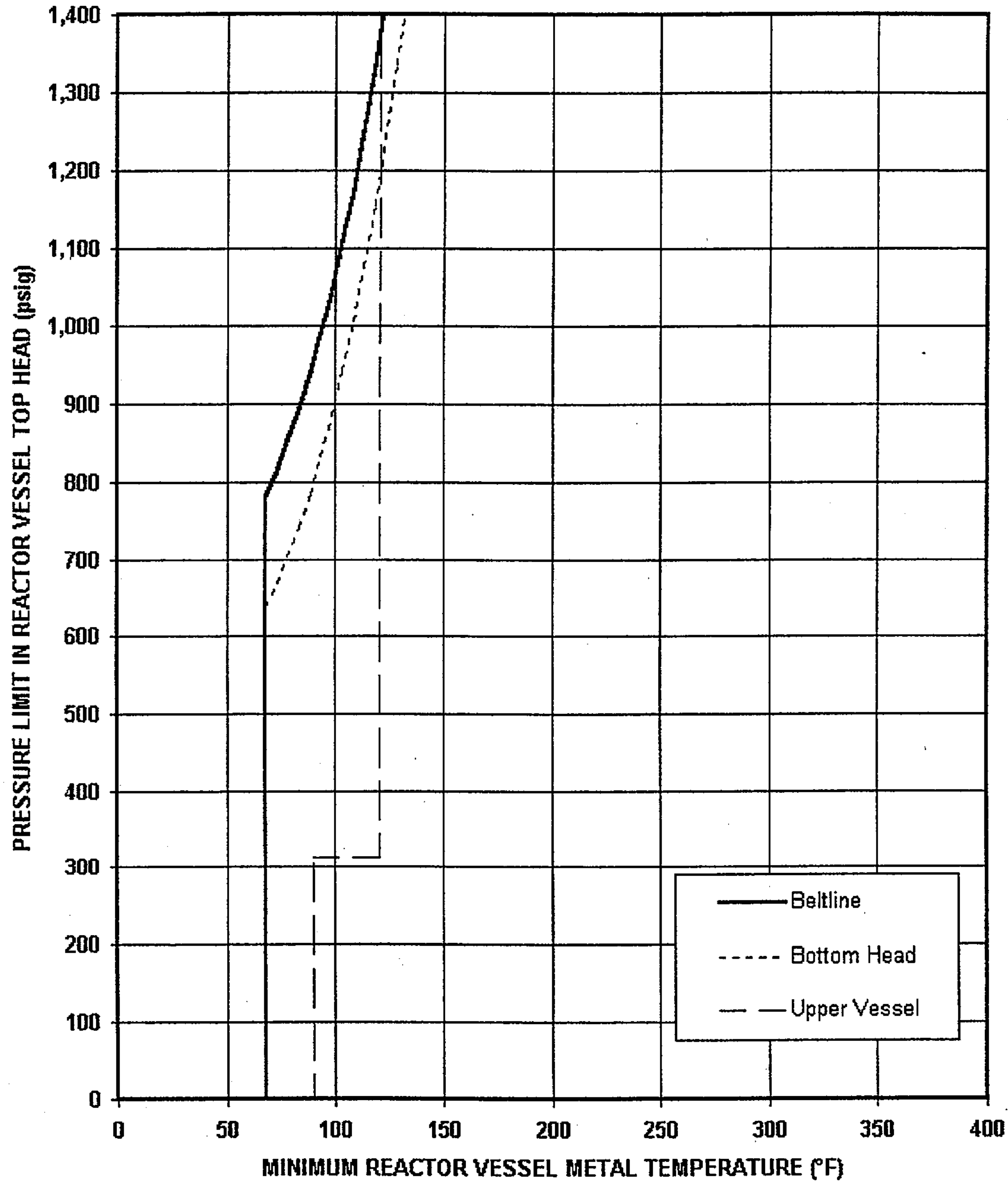
Unit 1 Core Critical Curve (Curve C), 32 EFPY

Figure 9
Core Critical Curve for Hatch Unit 1 for 54 EFPY



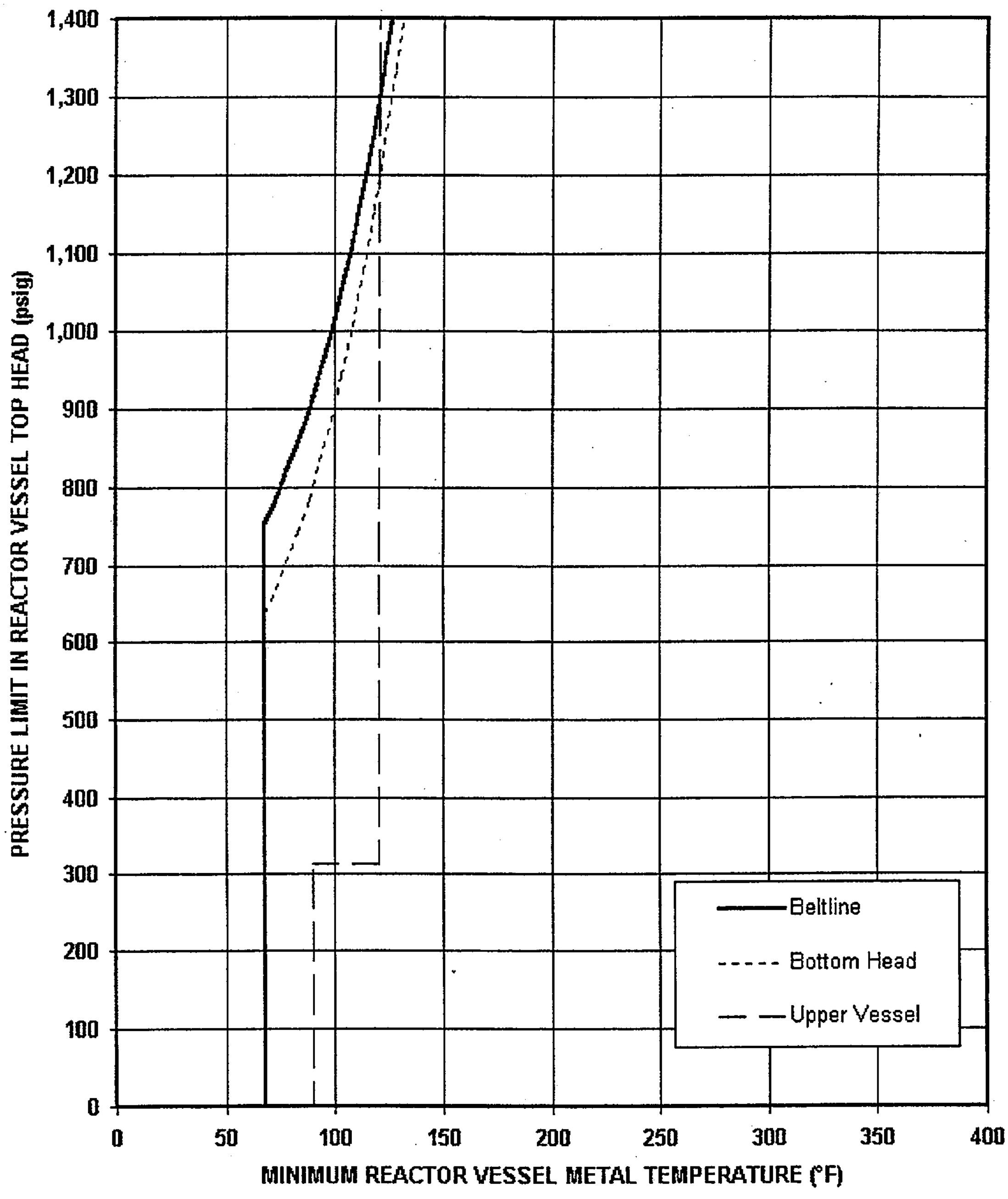
Unit 1 Core Critical Curve (Curve C), 54 EFPY

Figure 10
Pressure Test Curve for Hatch Unit 2 for 20 EFPY



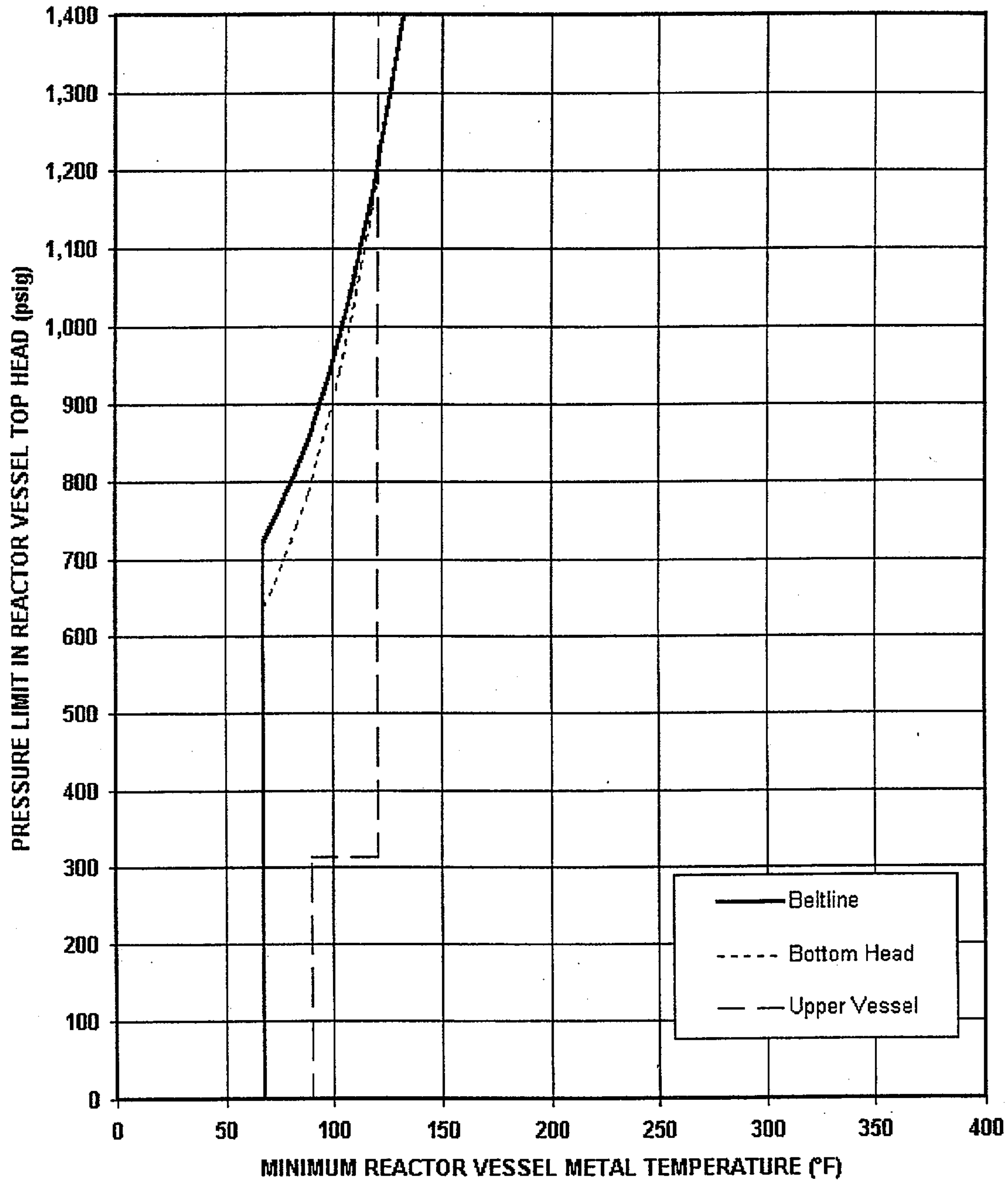
USING CODE CASES
Unit 2 Pressure Test Curve (Curve A), 20 EFPY

Figure 11
Pressure Test Curve for Hatch Unit 2 for 32 EFPY



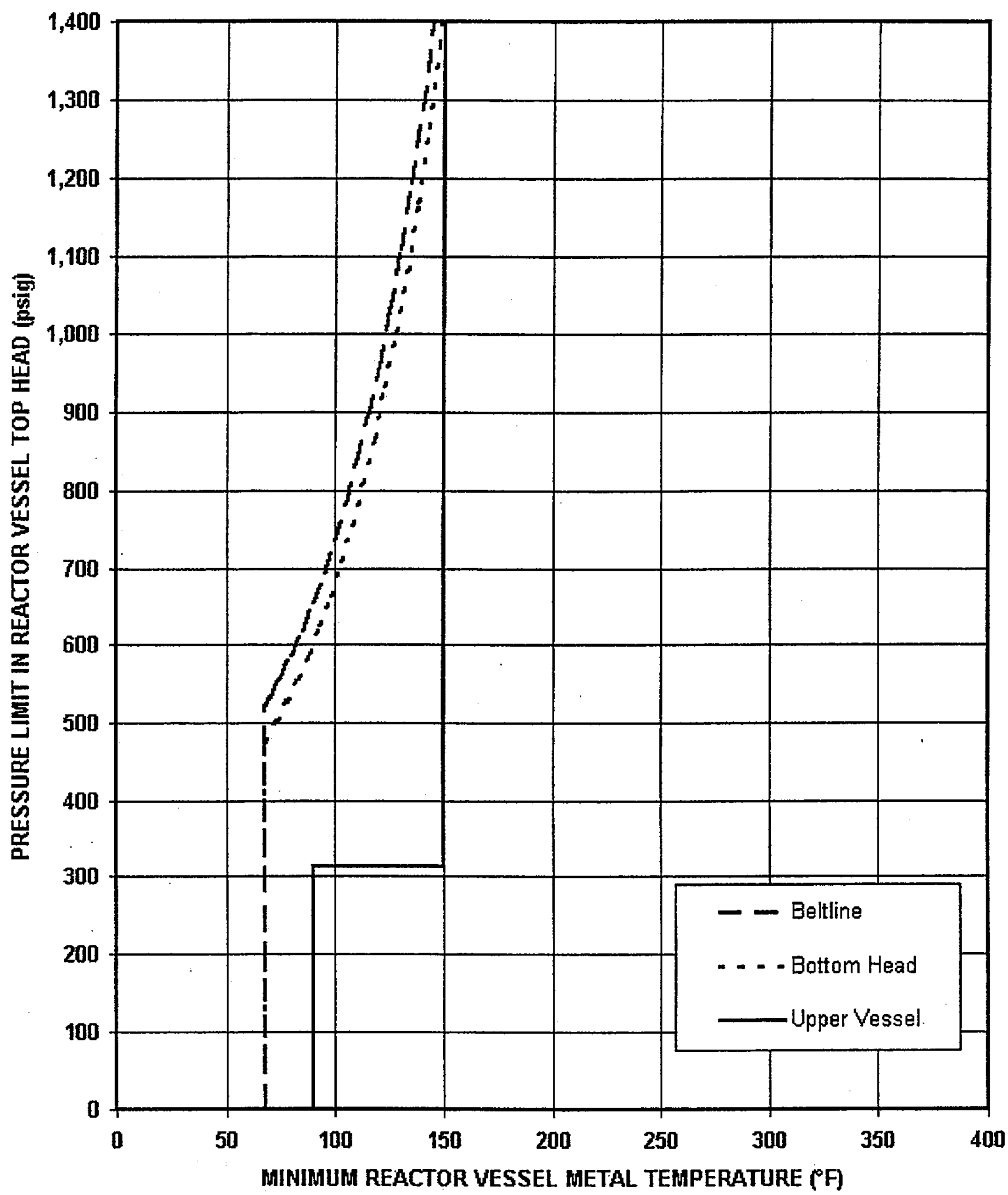
Unit 2 Pressure Test Curve (Curve A), 32 EFPY

Figure 12
Pressure Test Curve for Hatch Unit 2 for 54 EFPY



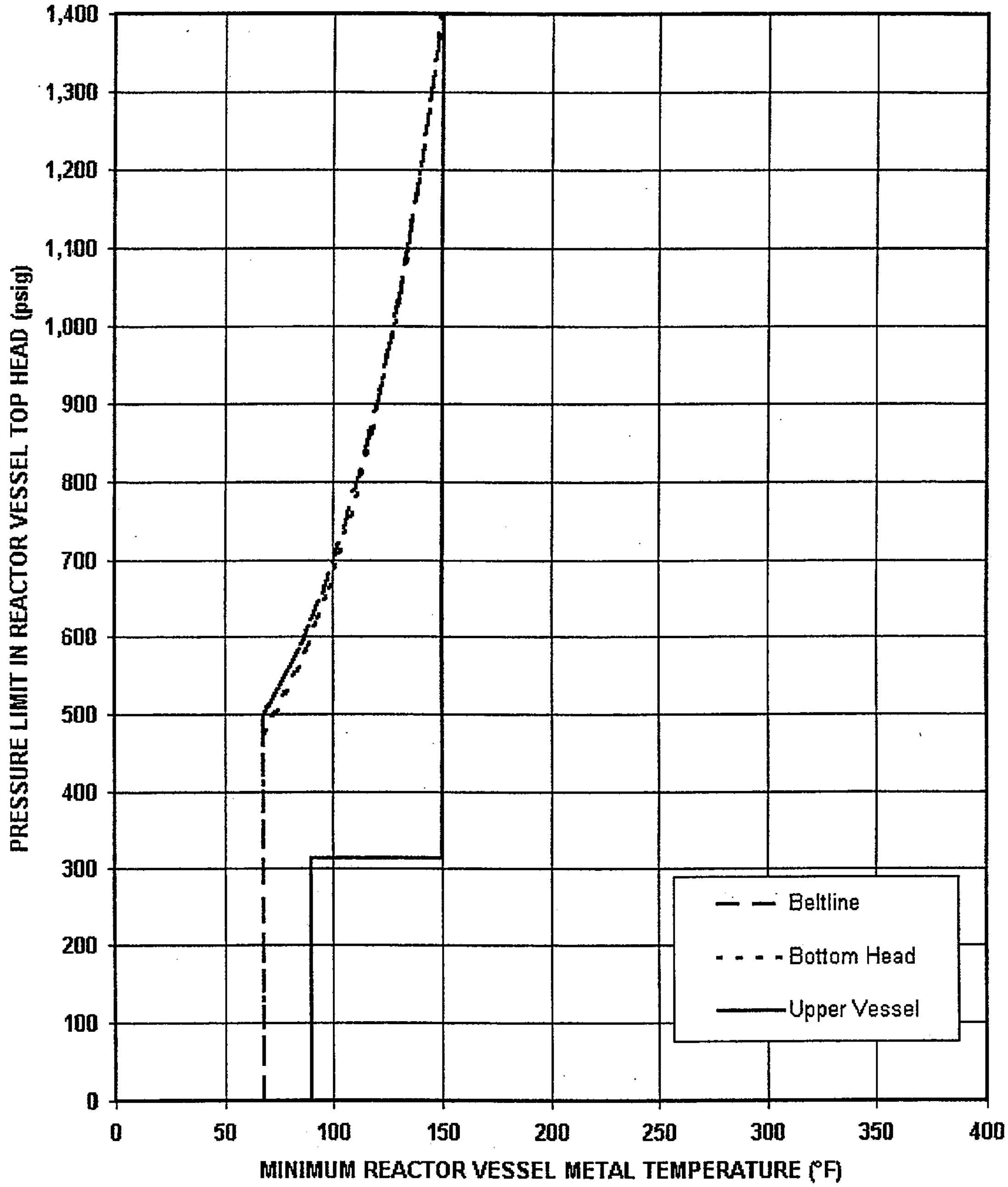
Unit 2 Pressure Test Curve (Curve A), 54 EFPY

Figure 13
Core Not Critical Curve for Hatch Unit 2 for 20 EFPY



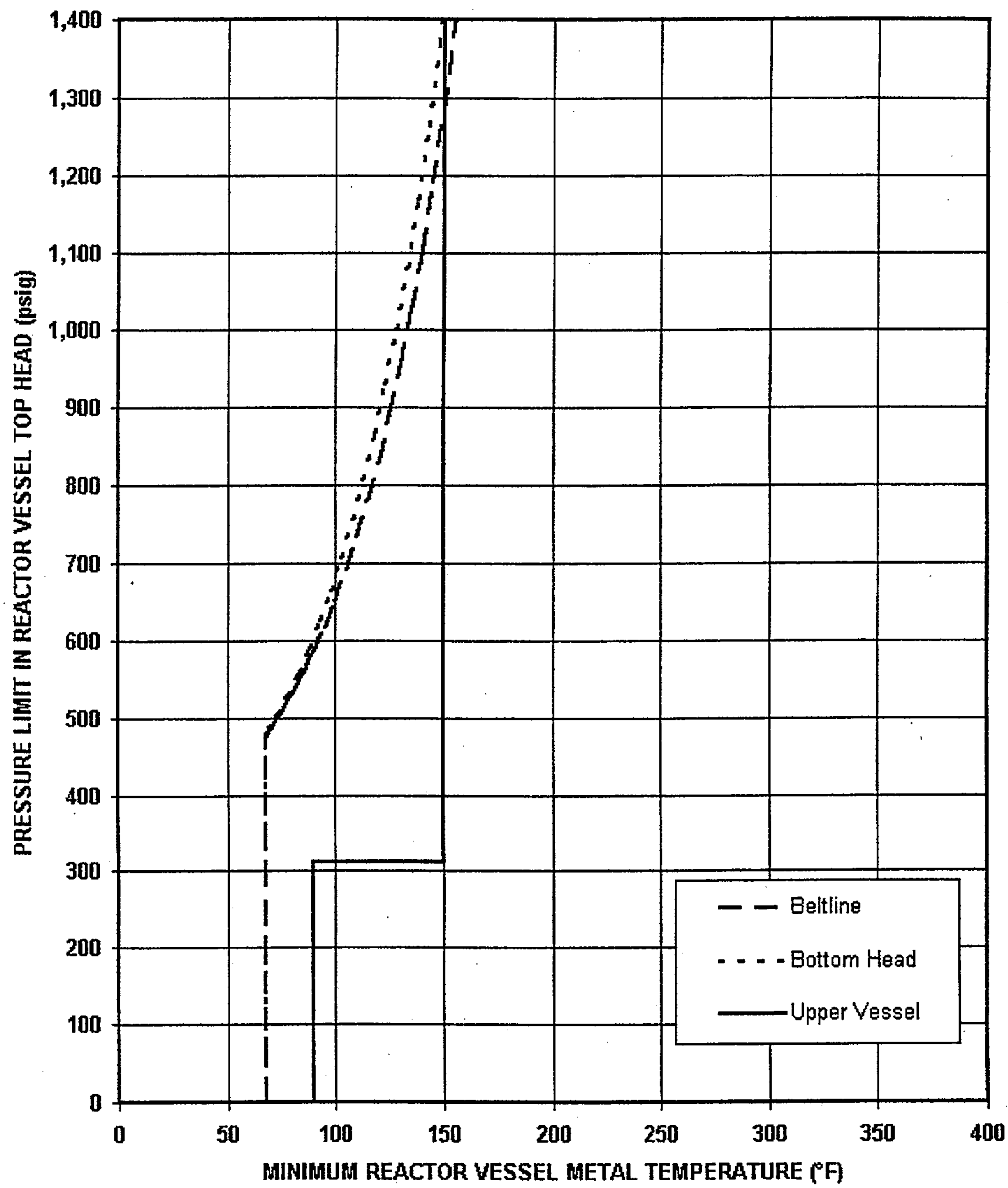
Unit 2 Core Not Critical Curve (Curve B), 20 EFPY

Figure 14
Core Not Critical Curve for Hatch Unit 2 for 32 EFPY



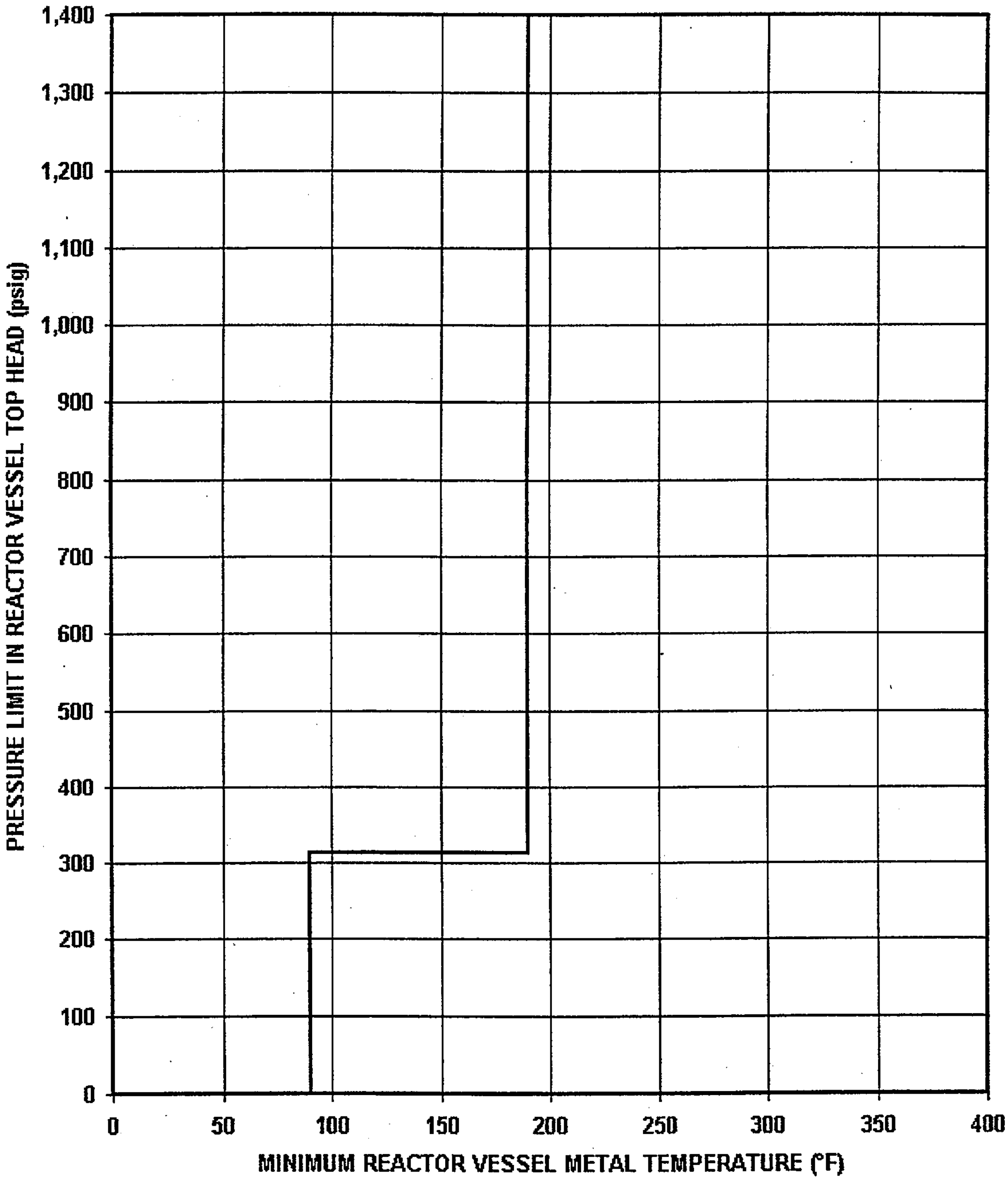
Unit 2 Core Not Critical Curve (Curve B), 32 EFPY

Figure 15
Core Not Critical Curve for Hatch Unit 2 for 54 EFPY



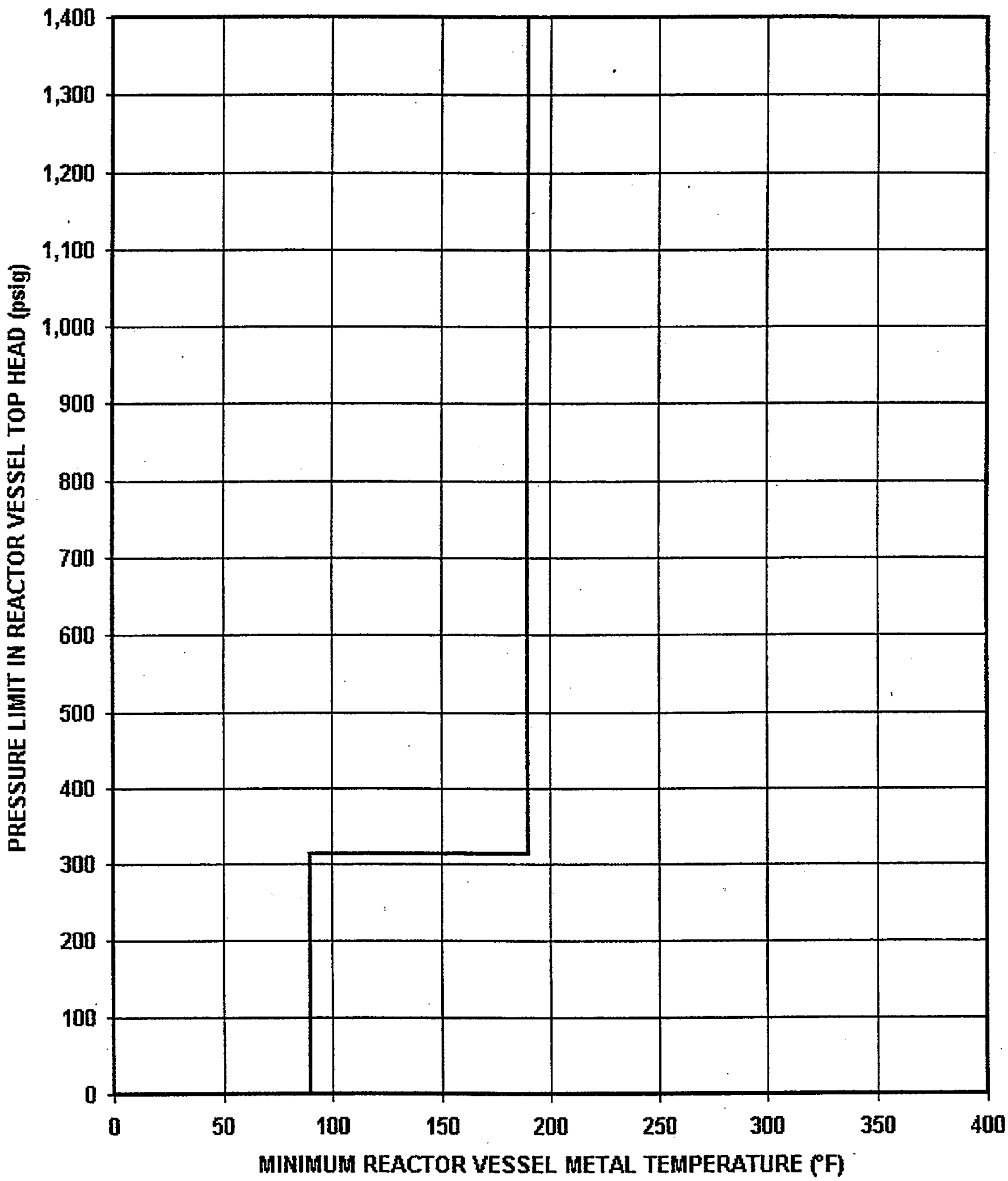
Unit 2 Core Not Critical Curve (Curve B), 54 EFPY

Figure 16
Core Critical Curve for Hatch Unit 2 for 20 EFPY



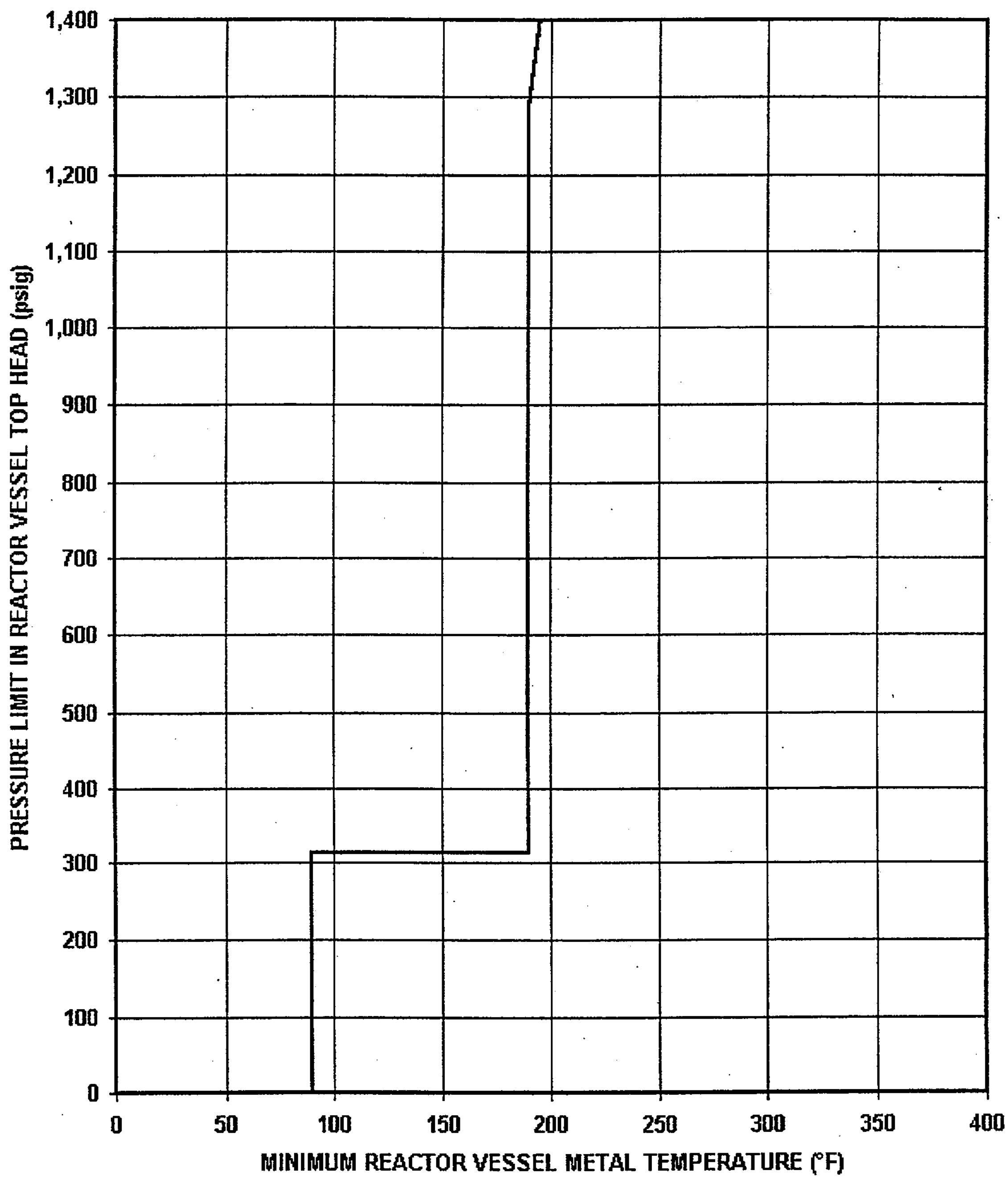
Unit 2 Core Critical Curve (Curve C), 20 EFPY

Figure 17
Core Critical Curve for Hatch Unit 2 for 32 EFPY



Unit 2 Core Critical Curve (Curve C), 32 EFPY

Figure 18
Core Critical Curve for Hatch Unit 2 for 54 EFPY



Unit 2 Core Critical Curve (Curve C), 54 EFPY

Appendix A

Combined P-T Curves and Tabulated Values
For
Hatch Unit 1

Table A-1
Tabulated Pressure Test P-T Curves for Hatch Unit 1

UNIT 1, CURVE A

Bottom Head		20 EFPY Upper Vessel and Beltline		32 EFPY Upper Vessel and Beltline		54 EFPY Upper Vessel and Beltline	
Temperature (°F)	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**
68.0	0.0	76.0	0.0	76.0	0.0	76.0	0.0
68.0	1006.0	76.0	312.5	76.0	312.5	76.0	312.5
73.0	1076.4	106.0	312.5	106.0	312.5	106.0	312.5
78.0	1154.2	106.0	749.0	106.0	640.0	106.0	555.0
83.0	1240.3	108.0	760.8	108.0	647.5	108.0	558.9
88.0	1335.4	113.0	792.2	113.0	666.9	113.0	569.0
93.0	1440.4	118.0	826.8	118.0	688.4	118.0	580.2
98.0	1556.6	123.0	865.1	123.0	712.2	123.0	592.6
		128.0	907.5	128.0	738.4	128.0	606.3
		133.0	954.2	133.0	767.4	133.0	621.4
		138.0	1006.0	138.0	799.5	138.0	638.1
		143.0	1063.1	143.0	834.9	143.0	656.6
		148.0	1126.3	148.0	874.1	148.0	677.0
		153.0	1196.1	153.0	917.4	153.0	699.5
		158.0	1273.2	158.0	965.2	158.0	724.4
		163.0	1358.5	163.0	1018.0	163.0	752.0
		168.0	1452.7	168.0	1076.5	168.0	782.4
		173.0	1556.8	173.0	1141.0	173.0	816.1
				178.0	1212.4	178.0	853.2
				183.0	1291.2	183.0	894.3
				188.0	1378.4	188.0	939.7
				193.0	1474.7	193.0	989.9
				198.0	1581.2	198.0	1045.4
						203.0	1106.7
						208.0	1174.4
						213.0	1249.2
						218.0	1332.0
						223.0	1423.4
						228.0	1524.5

Table A-2
Tabulated Core Not Critical P-T Curves for Hatch Unit 1

UNIT 1, CURVE B

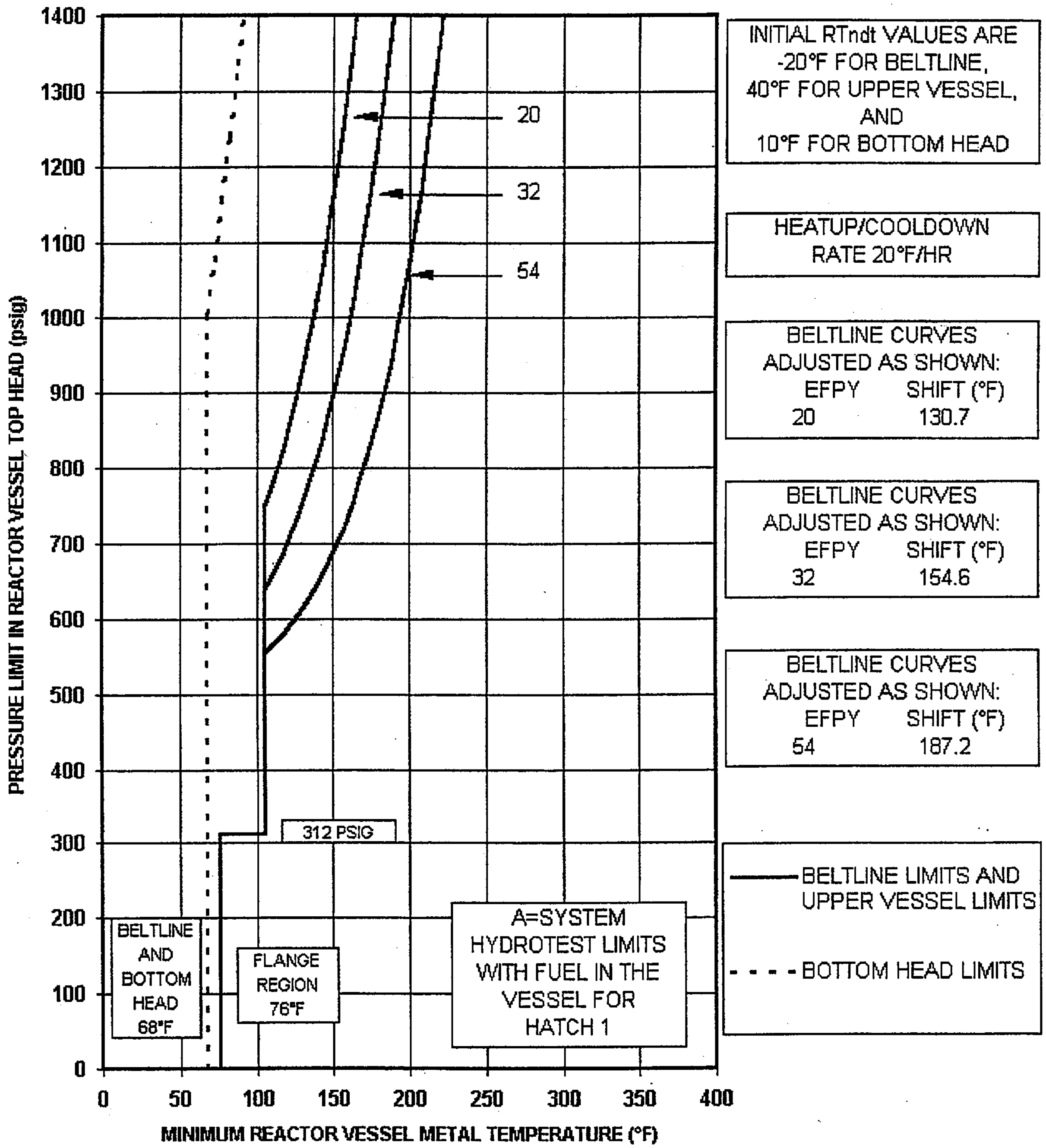
Bottom Head		20 EFPY Upper Vessel and Beltline		32 EFPY Upper Vessel and Beltline		54 EFPY Upper Vessel and Beltline	
Temperature (°F)	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**
68.0	0.0	76.0	0.0	76.0	0.0	76.0	0.0
68.0	754.5	76.0	170.0	76.0	170.0	76.0	170.0
73.0	807.3	76.9	180.0	76.9	180.0	76.9	180.0
78.0	865.7	79.0	190.0	79.0	190.0	79.0	190.0
83.0	930.2	81.1	200.0	81.1	200.0	81.1	200.0
88.0	1001.5	83.0	210.0	83.0	210.0	83.0	210.0
93.0	1080.3	84.8	220.0	84.8	220.0	84.8	220.0
98.0	1167.4	86.6	230.0	86.6	230.0	86.6	230.0
103.0	1263.7	88.3	240.0	88.3	240.0	88.3	240.0
108.0	1370.1	89.9	250.0	89.9	250.0	89.9	250.0
113.0	1487.7	91.4	260.0	91.4	260.0	91.4	260.0
118.0	1519.0	92.9	270.0	92.9	270.0	92.9	270.0
		94.3	280.0	94.3	280.0	94.3	280.0
		95.7	290.0	95.7	290.0	95.7	290.0
		97.0	300.0	97.0	300.0	97.0	300.0
		98.3	310.0	98.3	310.0	98.3	310.0
		98.7	312.5	98.7	312.5	98.7	312.5
		136.0	312.5	136.0	312.5	136.0	312.5
		136.0	675.0	136.0	526.0	136.0	320.0
		140.0	707.3	141.0	551.5	136.0	330.0
		145.0	751.9	146.0	579.7	136.0	340.0
		150.0	801.2	151.0	610.9	136.0	350.0
		155.0	855.7	156.0	645.3	136.0	360.0
		160.0	915.9	161.0	683.4	136.0	370.0
		165.0	982.5	166.0	725.5	136.0	380.0
		170.0	1056.0	171.0	772.0	136.0	390.0
		175.0	1137.3	176.0	823.5	136.0	400.0
		180.0	1227.2	181.0	880.3	136.0	410.0
		185.0	1326.4	186.0	943.1	140.0	420.2
		190.0	1436.2	191.0	1012.5	145.0	434.6
		195.0	1557.4	196.0	1089.2	150.0	450.5
				201.0	1174.0	155.0	468.1
				206.0	1267.7	160.0	487.6
				211.0	1371.2	165.0	509.1
				216.0	1485.6	170.0	532.8
				221.0	1612.1	175.0	559.1
						180.0	588.1
						185.0	620.2
						190.0	655.6
						195.0	694.8
						200.0	738.1
						205.0	785.9
						210.0	838.8
						215.0	897.2
						220.0	961.8
						225.0	1033.2
						230.0	1112.1
						235.0	1199.3
						240.0	1295.6
						245.0	1402.1
						250.0	1519.8

Table A-3
Tabulated Core Critical P-T Curves for Hatch Unit 1

UNIT 1, CURVE C

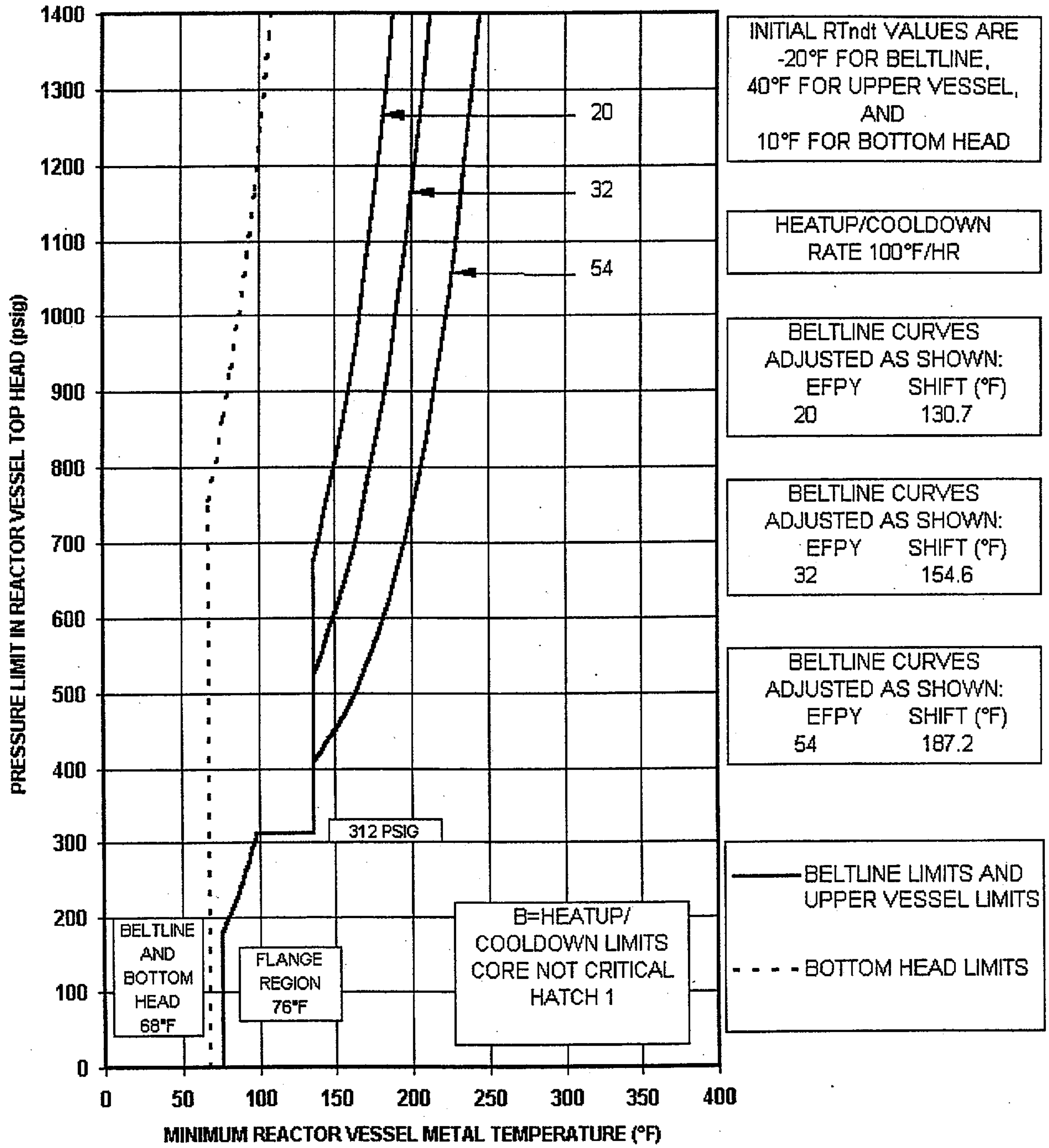
20 EFPY Upper Vessel and Beltline		32 EFPY Upper Vessel and Beltline		54 EFPY Upper Vessel and Beltline	
Temperature (°F)	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**
76.0	0.0	76.0	0.0	76.0	0.0
76.0	60.0	76.0	60.0	76.0	60.0
77.2	70.0	77.2	70.0	77.2	70.0
83.2	80.0	83.2	80.0	83.2	80.0
88.4	90.0	88.4	90.0	88.4	90.0
92.9	100.0	92.9	100.0	92.9	100.0
96.9	110.0	96.9	110.0	96.9	110.0
100.5	120.0	100.5	120.0	100.5	120.0
103.8	130.0	103.8	130.0	103.8	130.0
106.8	140.0	106.8	140.0	106.8	140.0
109.6	150.0	109.6	150.0	109.6	150.0
112.2	160.0	112.2	160.0	112.2	160.0
114.6	170.0	114.6	170.0	114.6	170.0
116.9	180.0	116.9	180.0	116.9	180.0
119.0	190.0	119.0	190.0	119.0	190.0
121.1	200.0	121.1	200.0	121.1	200.0
123.0	210.0	123.0	210.0	123.0	210.0
124.8	220.0	124.8	220.0	124.8	220.0
126.6	230.0	126.6	230.0	126.6	230.0
128.3	240.0	128.3	240.0	128.3	240.0
129.9	250.0	129.9	250.0	129.9	250.0
131.4	260.0	131.4	260.0	131.4	260.0
132.9	270.0	132.9	270.0	132.9	270.0
134.3	280.0	134.3	280.0	134.3	280.0
135.7	290.0	135.7	290.0	135.7	290.0
137.0	300.0	137.0	300.0	137.0	300.0
138.3	310.0	138.3	310.0	138.3	310.0
138.7	312.5	138.7	312.5	138.7	312.5
176.0	312.5	176.0	312.5	203.0	312.5
176.0	674.7	176.0	525.9	203.0	491.7
181.0	715.9	181.0	551.5	206.0	513.6
186.0	761.4	186.0	579.7	211.0	537.9
191.0	811.7	191.0	610.9	216.0	564.7
196.0	867.3	196.0	645.3	221.0	594.3
201.0	928.7	201.0	683.4	226.0	627.0
206.0	996.6	206.0	725.5	231.0	663.1
211.0	1071.7	211.0	772.0	236.0	703.1
216.0	1154.6	216.0	823.5	241.0	747.3
221.0	1246.2	221.0	880.3	246.0	796.1
226.0	1347.5	226.0	943.1	251.0	850.0
231.0	1459.5	231.0	1012.5	256.0	909.6
236.0	1583.2	236.0	1089.2	261.0	975.5
		241.0	1174.0	266.0	1048.4
		246.0	1267.7	271.0	1128.8
		251.0	1371.2	276.0	1217.8
		256.0	1485.6	281.0	1316.1
		261.0	1612.1	286.0	1424.7
				291.0	1544.7

Figure A-1
Pressure Test Curves for Hatch Unit 1



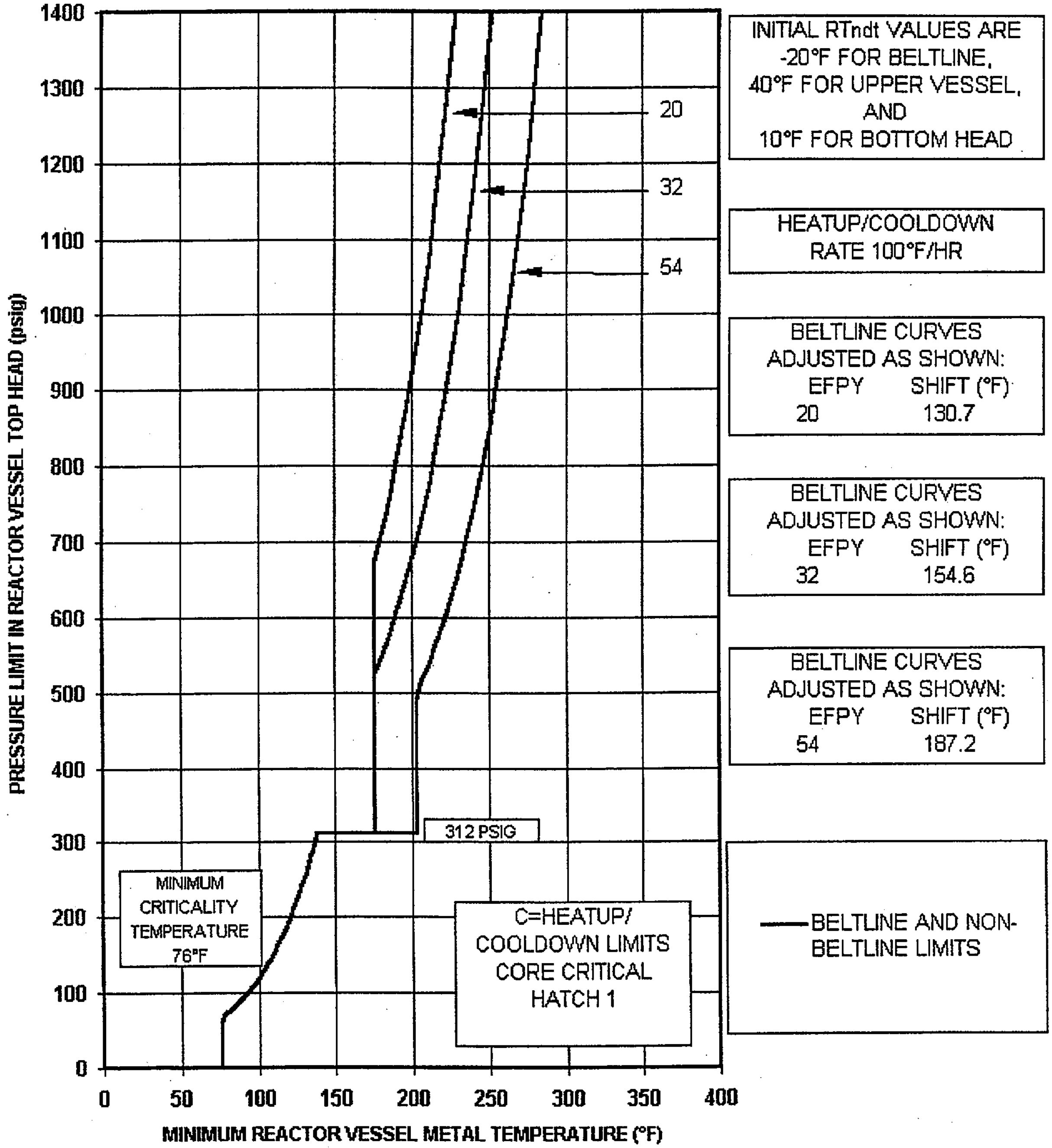
Hatch Unit 1
Pressure/Temperature Limits for
Inservice Hydrostatic and Inservice Leakage Tests

Figure A-2
Core Not Critical Curves for Hatch Unit 1



Hatch Unit 1
Pressure/Temperature Limits for
Heatup/Cooldown Conditions, Core Not Critical

Figure A-3
Core Critical Curves for Hatch Unit 1



Hatch Unit 1
Pressure/Temperature Limits for
Heatup/Cooldown Conditions, Core Critical

Appendix B

Combined P-T Curves and Tabulated Values
For
Hatch Unit 2

Table B-1
Tabulated Pressure Test P-T Curves for Hatch Unit 2

UNIT 2, CURVE A

Bottom Head		20 EFPY Upper Vessel and Beltline		32 EFPY Upper Vessel and Beltline		54 EFPY Upper Vessel and Beltline	
Temperature (°F)	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**
68.0	0.0	90.0	0.0	90.0	0.0	90.0	0.0
68.0	637.1	90.0	312.5	90.0	312.5	90.0	312.5
73.0	668.8	120.0	312.5	120.0	312.5	120.0	312.5
78.0	703.8	120.0	1362.0	120.0	1285.0	120.0	1196.0
83.0	742.4	123.0	1417.7	125.0	1371.1	125.0	1273.2
88.0	785.1	128.0	1518.1	130.0	1466.6	130.0	1358.5
93.0	832.4			135.0	1572.2	135.0	1452.7
98.0	884.5						
103.0	942.2						
108.0	1006.0						
113.0	1076.4						
118.0	1154.2						
123.0	1240.3						
128.0	1335.4						
133.0	1440.4						
138.0	1556.6						

Table B-2
Tabulated Core Not Critical P-T Curves for Hatch Unit 2

UNIT 2, CURVE B

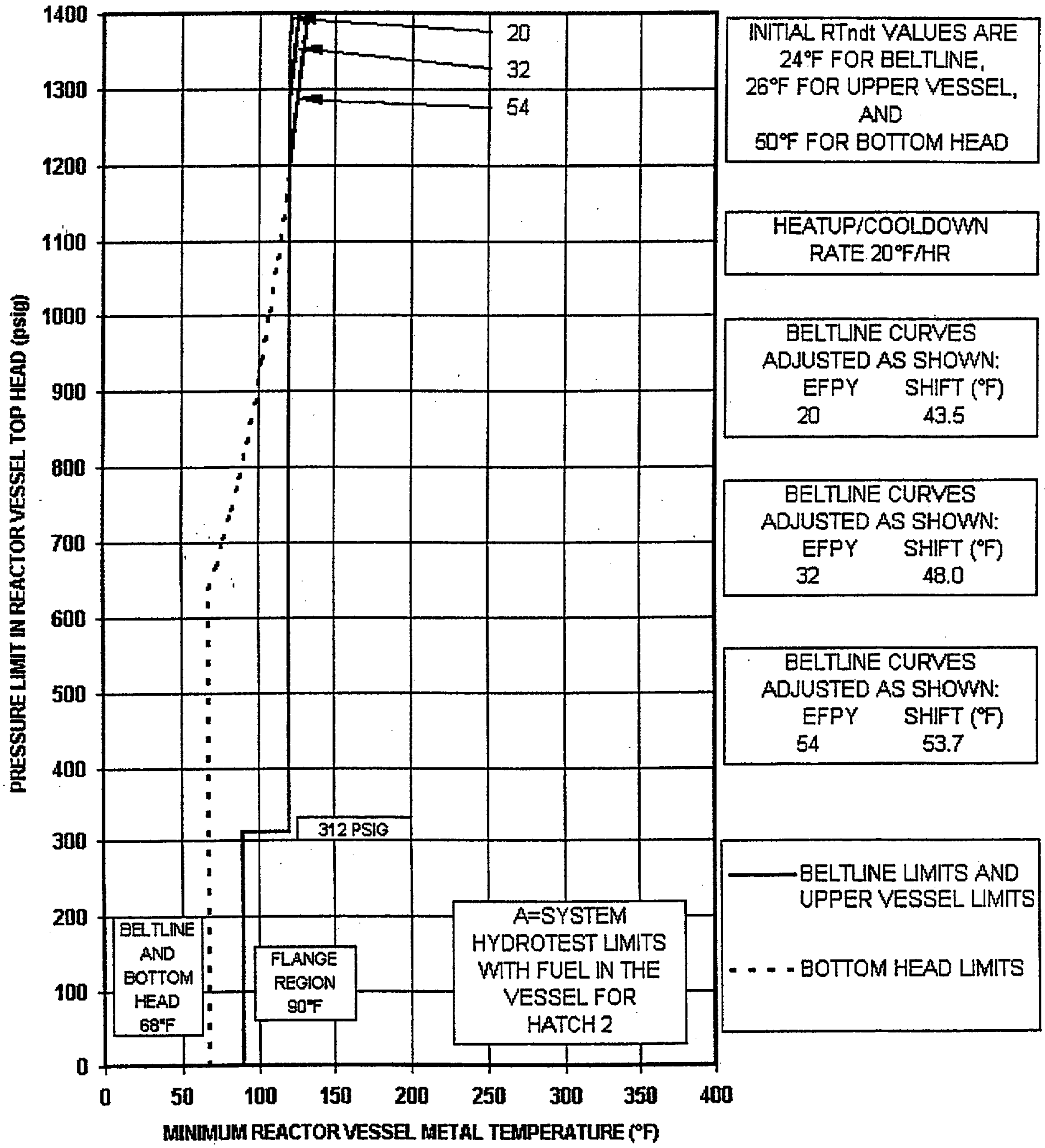
Bottom Head		20 EFPY Upper Vessel and Beltline		32 EFPY Upper Vessel and Beltline		54 EFPY Upper Vessel and Beltline	
Temperature (°F)	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**
68.0	0.0	90.0	0.0	90.0	0.0	90.0	0.0
68.0	477.9	90.0	312.5	90.0	312.5	90.0	312.5
73.0	501.6	150.0	312.5	150.0	312.5	150.0	312.5
78.0	527.8	150.0	320.0	150.0	320.0	150.0	320.0
83.0	556.8	150	1512	150.0	1406.6	150.0	1285.5
88.0	588.9	155	1642	155.0	1524.7	155.0	1391.0
93.0	624.3	160	1785	160.0	1655.3	160.0	1507.5
98.0	663.4						
103.0	706.7						
108.0	754.5						
113.0	807.3						
118.0	865.7						
123.0	930.2						
128.0	1001.5						
133.0	1080.3						
138.0	1167.4						
143.0	1263.7						
148.0	1370.1						
153.0	1487.7						
158.0	1519.0						

Table B-3
Tabulated Core Critical P-T Curves for Hatch Unit 2

UNIT 2, CURVE C

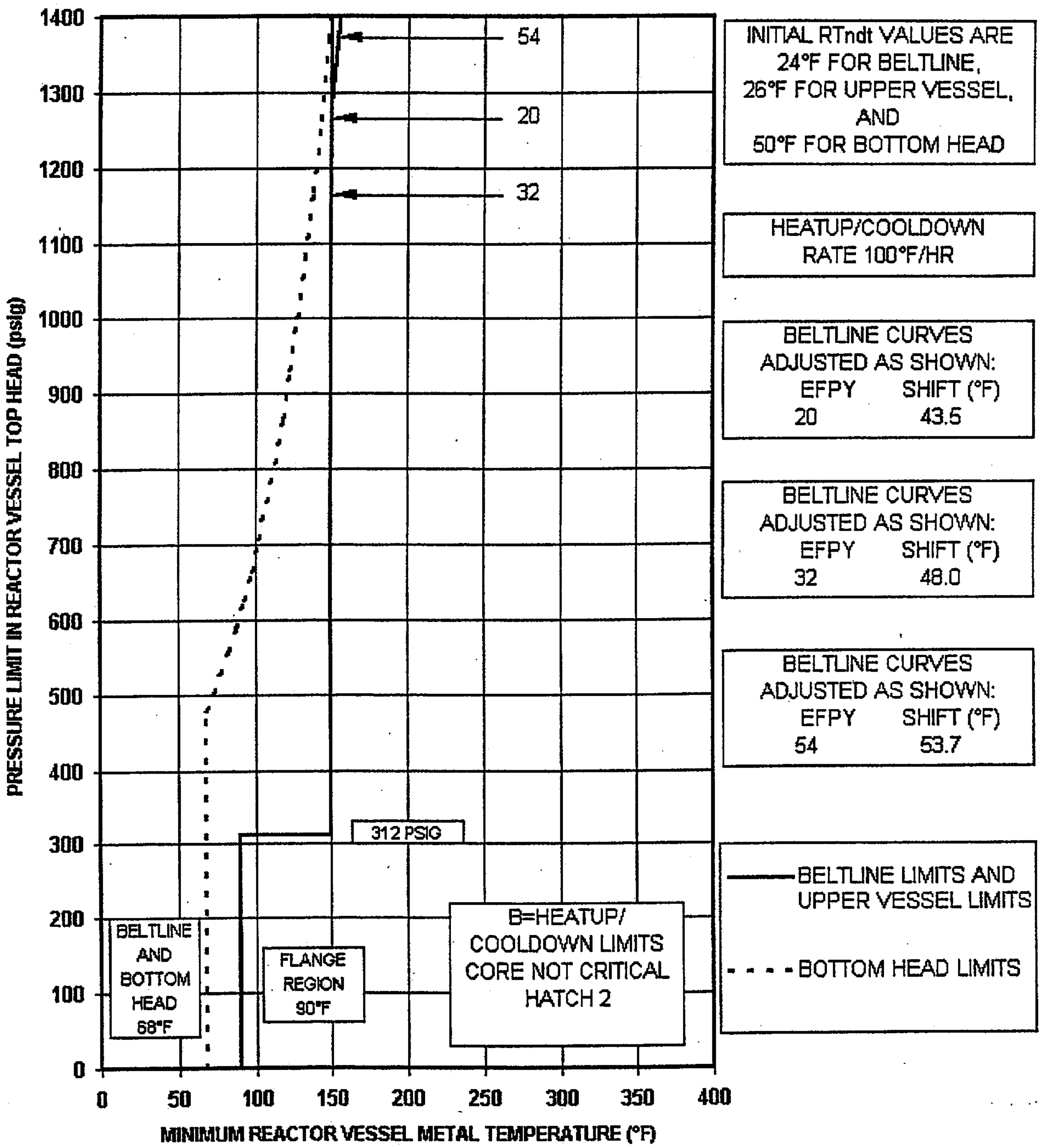
20 EFPY Upper Vessel and Beltline		32 EFPY Upper Vessel and Beltline		54 EFPY Upper Vessel and Beltline	
Temperature (°F)	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**	**Temperature (°F)**	**Pressure (psig)**
90.0	0.0	90.0	0.0	90.0	0.0
90.0	312.5	90.0	312.5	90.0	312.5
190.0	312.5	190.0	312.5	190.0	312.5
190.0	1400.0	190.0	1400.0	190.0	1285.5
				195.0	1391.0
				200.0	1507.5

Figure B-1
Pressure Test Curves for Hatch Unit 2



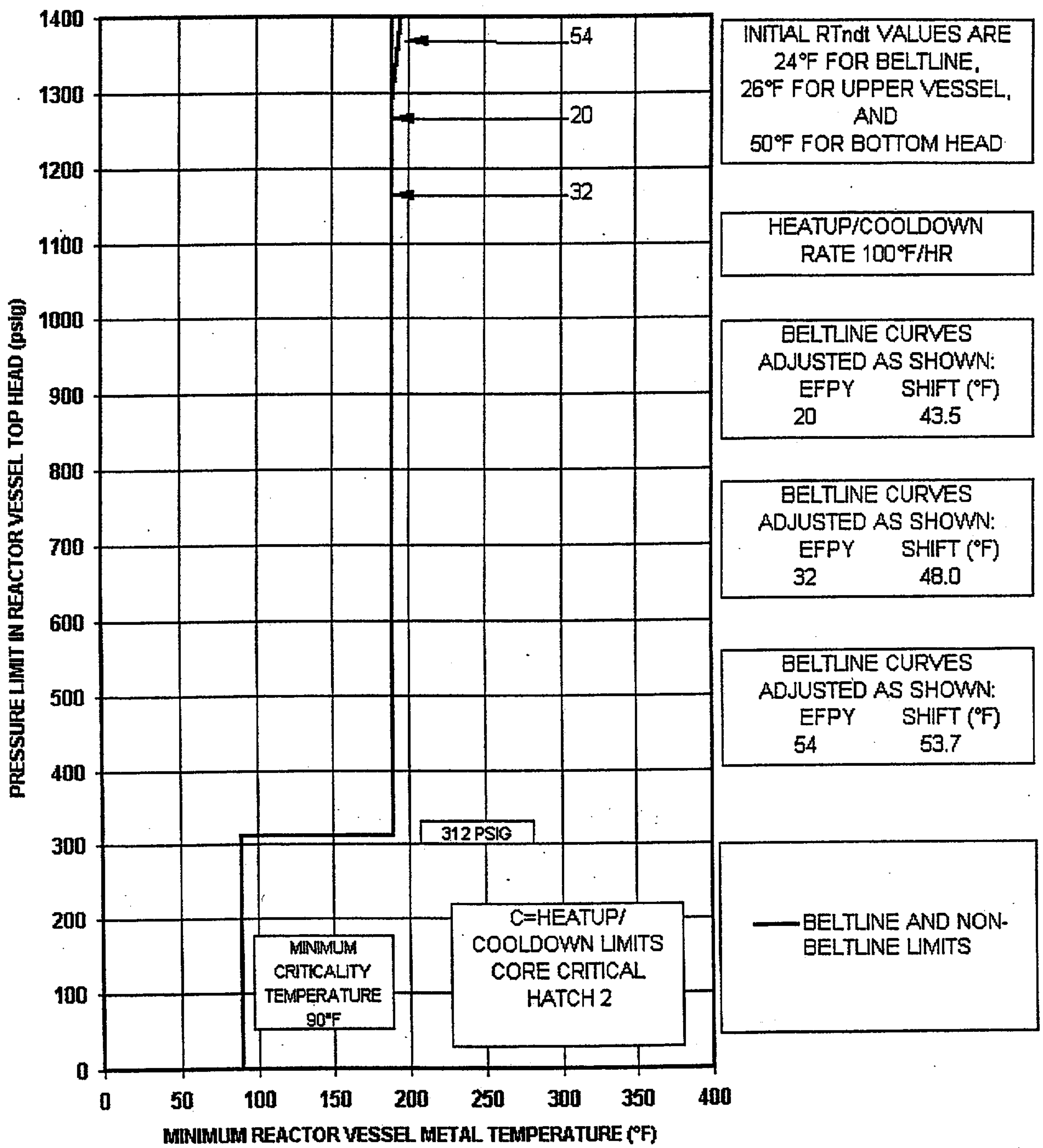
Hatch Unit 2
Pressure/Temperature Limits for
Inservice Hydrostatic and Inservice Leakage Tests

Figure B-2
Core Not Critical Curves for Hatch Unit 2



Hatch Unit 2
Pressure/Temperature Limits for
Heatup/Cooldown Conditions, Core Not Critical

Figure B-3
Core Critical Curves for Hatch Unit 2



Hatch Unit 2
Pressure/Temperature Limits for
Heatup/Cooldown Conditions, Core Critical

ATTACHMENT 3

General Electric Report GE-NE-B1100827-00-01

GE Nuclear Energy

Structural Assessment and Mitigation
General Electric Company
175 Curtner Avenue, San Jose, CA 95125

GE-NE-B1100827-00-01
Class II

March 1999

PLANT HATCH UNITS 1 & 2
RPV PRESSURE TEMPERATURE LIMITS
LICENSE RENEWAL EVALUATION

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CONTENTS OF THIS REPORT
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

As part of the effort to evaluate the reactor pressure vessel (for both Hatch 1 and 2) for the license renewal term, the effects of irradiation on the core beltline region have been evaluated. The purpose of this evaluation was to provide input to the pressure-temperature operating limits, as required by 10CFR50, Appendix G [1].

The evaluation (incorporating Extended Power Uprate at 17 Effective Full Power Years (EFPY) [2]) has been performed for a lifetime of 54 EFPY for both Units. This input was used to generate pressure-temperature curves for 54 EFPY for both Units. In addition, intermediate curves for 36, 40, 44, and 48 EFPY for Unit 1 have been provided, due to the expected irradiation shift for the Hatch 1 vessel.

1. INTRODUCTION

One of the major considerations for extended life of the Reactor Pressure Vessel is irradiation of the core region, or beltline. The effect of irradiation is to shift the reference nil-ductility transition temperature (RT_{NDT}) of the beltline materials. This shift must be evaluated in order to conform to the requirements of 10CFR50, Appendix G [1]. To encompass the effects of irradiation for the license renewal term, a maximum lifetime of 54 EFPY was used to determine the effects of irradiation (see Section 3), and to develop the pressure-temperature (P-T) curves (Section 4).

The (P-T) curves included in this report have been developed to present steam dome pressure versus minimum vessel metal temperature incorporating appropriate non-beltline limits and irradiation embrittlement effects in the beltline. Complete P-T curves were developed for 54 effective full power years (EFPY) for both Hatch 1 and 2; in addition, intermediate P-T curves for Hatch Unit 1 have been included for 36, 40, 44 and 48 EFPY, due to the expected irradiation shift for the Hatch 1 vessel. The methodology used to generate the P-T curves in this report is the same as the methodology used to generate the P-T curves for extended power uprate [2]. The pressure-temperature (P-T) curves are established to the requirements of 10CFR50, Appendix G [1] to assure that brittle fracture of the reactor vessel is prevented. The method used to account for irradiation embrittlement is described in Regulatory Guide 1.99, Revision 2 [3], or Rev 2.

In addition to beltline considerations, there are non-beltline discontinuity limits such as nozzles, penetrations, and flanges which affect the P-T curves. The non-beltline limits are based on generic analyses which are adjusted to the maximum reference temperature of nil ductility transition (RT_{NDT}) for the applicable Hatch 1 or 2 vessel components. The non-beltline limits are also governed by requirements in [1].

Furthermore, curves are included to allow monitoring of the bottom head regions of the vessel separate from the beltline region and upper vessel. This refinement could minimize heating requirements prior to pressure testing.

2. RESULTS AND CONCLUSIONS

Based on the results of the evaluation, the following results and conclusions were determined:

- For Unit 1, the 54 EFPY RPV peak fluence prediction is 3.47×10^{18} n/cm^2 at the vessel wall, based on extended power uprate. The 54 EFPY fluence prediction is 2.51×10^{18} n/cm^2 at 1/4 T. (See Section 3). For Unit 2, the 54 EFPY RPV peak fluence prediction is 3.82×10^{18} n/cm^2 at the vessel wall, based on extended power uprate. The 54 EFPY fluence prediction is 2.77×10^{18} n/cm^2 at 1/4 T. (See Section 3)

- The adjusted reference temperature (ART = Initial RT_{NDT} + ΔRT_{NDT} + Margin) was predicted for each beltline material, based on the methods of Regulatory Guide 1.99, Rev 2. The ART for the limiting material for Unit 1, Plate G-4804-2, Heat C4114-2, at 54 EFPY is 167.2°F. For Unit 2, the limiting ART at 54 EFPY is 77.7°F (Plate G-6603-2, Heat C8553-1). Both plates are lower than the 200°F requirement of 10CFR50 Appendix G [1] and Rev 2 [3].

- An update of the beltline material USE values at 54 EFPY was performed using the Reg. Guide 1.99, Rev. 2 methodology. The Equivalent Margin Analyses demonstrate that the 10CFR50 Appendix G [1] safety requirements are met.

- P-T curves were developed for three reactor conditions: pressure test (Curve A), non-nuclear heatup and cooldown (Curve B), and core critical operation (Curve C) which are valid for up to 54 EFPY of operation. For Unit 1, the beltline curve is more limiting for Curve A at pressures above approximately 410 psig. For Curves B and C, the beltline curves are limiting for pressures above approximately 300 psig. The P-T curves for 54 EFPY are shown in Figures 4-1 through 4-3 [The intermediate curves for 36, 40, 44, and 48 EFPY are located in Appendices A-D]. For Unit 2, the bottom head curve is more limiting for Curve A at pressures above approximately 610 psig. For Curve B, the Feedwater nozzle limits are applicable in the range 90-960 psig. For Curves B and C, the beltline curves are limiting for pressures above approximately 960 psig. The P-T curves for 54 EFPY are shown in Figures 4-4 through 4-6.

3. ADJUSTED REFERENCE TEMPERATURE AND UPPER SHELF ENERGY

The 54 EFPY peak fluence values of 3.47×10^{18} n/cm^2 and 3.82×10^{18} n/cm^2 for Hatch Unit 1 and Hatch Unit 2, respectively, are used to calculate the 54 EFPY 1/4T fluence values of 2.51×10^{18} n/cm^2 and 2.77×10^{18} n/cm^2 (Tables 3-1 and 3-2, for Units 1 and 2, respectively). The 54 EFPY 1/4T fluence is used in this section to calculate adjusted reference temperatures (ARTs) and upper shelf energy (USE) decrease for the beltline materials.

3.1 ADJUSTED REFERENCE TEMPERATURE AT 54 EFPY

The effect on adjusted reference temperature (ART) due to irradiation in the beltline materials is determined according to the methods in Reg. Guide 1.99, Rev. 2 [3], as a function of neutron fluence and the element contents of copper (Cu) and nickel (Ni). The specific relationship from Reg. Guide 1.99, Rev. 2 [3] is:

$$ART = \text{Initial } RT_{NDT} + \Delta RT_{NDT} + \text{Margin} \quad (3-1)$$

where:

$$\Delta RT_{NDT} = CF \cdot f^{(0.28-0.10\log f)} \quad (3-2)$$

$$\text{Margin} = 2\sqrt{\sigma_I^2 + \sigma_\Delta^2} \quad (3-3)$$

CF = chemistry factor from Table 1 or Table 2 of Reg. Guide 1.99, Rev. 2 [3]

f = 1/4T fluence (n/cm^2) divided by 10^{19}

σ_I = standard deviation on initial RT_{NDT} which is taken to be 0°F

σ_Δ = standard deviation on ΔRT_{NDT}, 28°F for welds and 17°F for base material, except that σ_Δ need not exceed 0.50 times the ΔRT_{NDT} value

The ART values for 54 EFPY are calculated based upon chemistry data as described in Table 3-1 and 3-2 for Hatch Unit 1 and Hatch Unit 2, respectively.

3.2 ART VS. EFPY

Each beltline plate and weld ΔRT_{NDT} value is determined by multiplying the CF from Reg. Guide 1.99, Rev. 2 [3] determined for the Cu-Ni content of the material, by the fluence factor for the EFPY being evaluated. The Initial RT_{NDT}, ΔRT_{NDT} and Margin are added to get the ART of the material. The 54 EFPY ART values for all of the beltline plates and welds are shown in Tables 3-1 and 3-2. The ART for the limiting beltline material in Hatch Unit 1, plate Heat C4114-2, at 54 EFPY is 167.2°F. The ART for the limiting beltline material in Hatch Unit 2, plate Heat C8553-1, at 54 EFPY is 77.7°F.

3.3 UPPER SHELF ENERGY AT 54 EFPY

Unirradiated Upper Shelf data were not available for all of the material heats. Due to the lack of specific pre-operational USE data, Hatch 1 and 2 have been evaluated to verify that the BWR Owners' Group Equivalent Margin Analyses are applicable. The calculations in Tables 3-3 through 3-6 show that the equivalent margin analyses are applicable. The Equivalent Margin Analyses demonstrate that the 10 CFR 50, Appendix G safety requirements are satisfactorily met for Hatch Units 1 and 2. The Owners' Group Program Report [4] was submitted to the NRC in December 1993 and approved by SER on December 8, 1993.

BELTLINE ART VALUES FOR Hatch 1

Lower-Intermediate
Thickness = 5.38 inches

Lower-Intermediate
54 EFPY Peak I.D. fluence = 3.47E+18 n/cm^2
54 EFPY Peak 1/4 T fluence = 2.51E+18 n/cm^2

Lower
Weld Thickness = 5.38 inches (Girth)
Plate Thickness = 6.375 inches (and Long Welds)

Lower
54 EFPY Peak I.D. fluence = 2.36E+18 n/cm^2
54 EFPY Peak 1/4 T weld fluence = 1.71E+18 n/cm^2
54 EFPY Peak 1/4 T plate fluence = 1.61E+18 n/cm^2

COMPONENT	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Fluence Level n/cm^2	Initial RTndt °F	54 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	54 EFPY Shift °F	54 EFPY ART °F
PLATES:												
Lower												
G-4805-1	C4112-1	0.13	0.64	92	1.61E+18	8	47.7	0.0	17.0	34.0	81.7	89.7
G-4805-2	C4112-2	0.13	0.64	92	1.61E+18	10	47.7	0.0	17.0	34.0	81.7	91.7
G-4805-3	C4149-1	0.14	0.57	99	1.61E+18	-10	51.4	0.0	17.0	34.0	85.4	75.4
Lower-Intmed												
G-4803-7	C4337-1	0.17	0.62	128	2.51E+18	-20	80.0	0.0	17.0	34.0	114.0	94.0
G-4804-1	C3985-2	0.13	0.58	90	2.51E+18	-20	56.3	0.0	17.0	34.0	90.3	70.3
G-4804-2*	C4114-2	0.13	0.70	245	2.51E+18	-20	153.2	0.0	17.0	34.0	187.2	167.2
WELDS:												
Lower Long												
1-307	13253/1092 Flux 3791	0.221	0.732	189	1.61E+18	-50	98.0	0.0	28.0	56.0	154.0	104.0
Lower-Intmed Long.												
1-308	IP2809/1092 Flux 3854	0.22	0.735	189	2.51E+18	-50	118.2	0.0	28.0	56.0	174.2	124.2
1-308	IP2815/1092 Flux 3854	0.316	0.724	219	2.51E+18	-50	136.9	0.0	28.0	56.0	192.9	142.9
Girth												
Lower to Lower-Int Girth												
1-313	90099/0091 Flux 3977	0.197	0.060	91	1.71E+18	-10	48.5	0.0	24.2	48.5	96.9	86.9
1-313	33A277/0091 Flux 3977	0.258	0.165	126	1.71E+18	-50	67.1	0.0	28.0	56.0	123.1	73.1

* CF Adjusted by a factor of 2.62

Table 3-1: Hatch 1 ART Values (54 EFPY)

BELTLINE ART VALUES FOR Hatch 2

Lower-Intermediate
Thickness = 5.38 inches

Lower
Weld Thickness = 5.38 inches (Girth)
Plate Thickness = 6.375 inches (and Long Weld)

Lower-Intermediate
54 EFPY Peak I.D. fluence = 3.82E+18 n/cm^2
54 EFPY Peak 1/4 T fluence = 2.77E+18 n/cm^2

Lower
54 EFPY Peak I.D. fluence = 2.44E+18 n/cm^2
54 EFPY Peak 1/4 T weld fluence = 1.77E+18 n/cm^2
54 EFPY Peak 1/4 T plate fluence = 1.67E+18 n/cm^2

COMPONENT	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Fluence Level n/cm^2	Initial RTndt °F	54 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	54 EFPY Shift °F	54 EFPY ART °F
PLATES:												
Lower												
G-6603-1	C8553-2	0.08	0.58	51	1.67E+18	-20	26.9	0.0	13.4	26.9	53.7	33.7
G-6603-2	C8553-1	0.08	0.58	51	1.67E+18	24	26.9	0.0	13.4	26.9	53.7	77.7
G-6603-3	C8571-1	0.08	0.53	51	1.67E+18	0	26.9	0.0	13.4	26.9	53.7	53.7
Lower-Intmed												
G-6602-2	C8554-1	0.08	0.57	51	2.77E+18	-20	33.1	0.0	16.6	33.1	66.2	46.2
G-6602-1	C8554-2	0.08	0.58	51	2.77E+18	-10	33.1	0.0	16.6	33.1	66.2	56.2
G-6601-4	C8579-2	0.11	0.48	73	2.77E+18	-4	47.4	0.0	17.0	34.0	81.4	77.4
WELDS:												
Lower Long 101-842	10137, LINDE 0091	0.216	0.043	98	1.67E+18	-50	51.6	0.0	25.8	51.6	103.3	53.3
Lower-Intmed Long. 101-834	51874, LINDE 0091 / Flux Lot 3458	0.147	0.037	68	2.77E+18	-50	44.2	0.0	22.1	44.2	88.3	38.3
Girth Lower to Lower-Int Girth 301-871	4P6052, LINDE 0091 / Flux Lot 0145	0.047	0.049	31	1.77E+18	-50	16.8	0.0	8.4	16.8	33.5	-16.5

Table 3-2: Hatch 2 ART Values (54 EFPY)

Table 3-3: Hatch 1 Plate Equivalent Margin Analysis

PLANT APPLICABILITY VERIFICATION FORM
FOR HATCH UNIT 1 - BWR 4/MK I - Including Extended Power Uprate

BWR/3-6 PLATE

Surveillance Plate USE:

%Cu = 0.12

1st Capsule Fluence = 2.4×10^{17} n/cm^2
2nd Capsule Fluence = 4.6×10^{17} n/cm^2

Unirradiated to 1st Capsule Measured % Decrease = 4 (Charpy Curves)
Unirradiated to 2nd Capsule Measured % Decrease = -5 (Charpy Curves)

1st Rev 2 Predicted % Decrease = 9 (Rev 2, Figure 2)
2nd Rev 2 Predicted % Decrease = 10 (Rev 2, Figure 2)

Limiting Beltline Plate USE:

%Cu = 0.17

54 EFPY ¼ T Fluence = 2.51×10^{18} n/cm^2

Rev 2 Predicted % Decrease = 19 (Rev 2, Figure 2)

Adjusted % Decrease = N/A (Rev 2, Position 2.2)

19 % $\leq$ 21%, so vessel plates are bounded by equivalent margin analysis

Table 3-4: Hatch 1 Weld Equivalent Margin Analysis

PLANT APPLICABILITY VERIFICATION FORM

FOR HATCH UNIT 1 - BWR 4/MK I - Including Extended Power Uprate

BWR/2-6 WELD

Surveillance Weld USE:

%Cu = 0.30

1st Capsule Fluence = 2.4×10^{17} n/cm^2
2nd Capsule Fluence = 4.6×10^{17} n/cm^2

Unirradiated to 1st or 2nd Capsule Measured % Decrease = Unknown
1st to 2nd Capsule Measured % Decrease = -16 (Charpy Curves)

1st Rev 2 Predicted % Decrease = 19 (Rev 2, Figure 2)
2nd Rev 2 Predicted % Decrease = 22 (Rev 2, Figure 2)

Limiting Beltline Weld USE:

%Cu = 0.316

54 EFPY ¼ T Fluence = 2.51×10^{18} n/cm^2

Rev 2 Predicted % Decrease = 33 (Rev 2, Figure 2)

Adjusted % Decrease = N/A (Rev 2, Position 2.2)

33 % ≤ 34%, so vessel welds are bounded by equivalent margin analysis

Table 3-5: Hatch 2 Plate Equivalent Margin Analysis

PLANT APPLICABILITY VERIFICATION FORM

FOR HATCH UNIT 2 - BWR 4/MK I - Including Extended Power Uprate

BWR/3-6 PLATE

Surveillance Plate USE:

%Cu = 0.08

1st Capsule Fluence = 2.3×10^{17} n/cm^2

Measured % Decrease = 0 (Charpy Curves)

Reg. Guide Rev 2 Predicted % Decrease = 7 (Rev 2, Figure 2)

Limiting Beltline Plate USE:

%Cu = 0.11

54 EFPY ¼ T Fluence = 2.77×10^{18} n/cm^2

Rev 2 Predicted % Decrease = 15 (Rev 2, Figure 2)

Adjusted % Decrease = N/A (Rev 2, Position 2.2)

15 % $\leq$ 21%, so vessel plates are bounded by equivalent margin analysis

Table 3-6: Hatch 2 Weld Equivalent Margin Analysis

PLANT APPLICABILITY VERIFICATION FORM
FOR HATCH UNIT 2 - BWR 4/MK I - Including Extended Power Uprate

BWR/2-6 WELD

Surveillance Weld USE:

%Cu = 0.13

Capsule Fluence = 2.3×10^{17} n/cm^2

Capsule Measured % Decrease = -1 (Charpy Curves)

Rev 2 Predicted % Decrease = 11 (Rev 2, Figure 2)

Limiting Beltline Weld USE:

%Cu = 0.216

54 EFPY ¼ T Fluence = 1.77×10^{18} n/cm^2

Rev 2 Predicted % Decrease = 24 (Rev 2, Figure 2)

Adjusted % Decrease = N/A (Rev 2, Position 2.2)

24 % ≤ 34%, so vessel welds are bounded by equivalent margin analysis

4. PRESSURE-TEMPERATURE CURVES

4.1 BACKGROUND

Nuclear Regulatory Commission (NRC) 10CFR50 Appendix G [1] specifies fracture toughness requirements to provide adequate margins of safety during the operating conditions to which a pressure-retaining component may be subjected over its service lifetime. The ASME Code (Appendix G of Section XI [8]) forms the basis for the requirements of 10CFR50 Appendix G. The limits for pressure and temperature are required by 10CFR50 Appendix G for three categories of operation: (a) hydrostatic pressure tests and leak tests, (b) core not critical heatup/cooldown, and (c) core critical operation. The heat transfer characteristics for these three categories are: (a) isothermal conditions for the hydrotest, and (b and c) insulated outside surface and metal temperature equaling the fluid temperature for 100°F/hr heatup/cooldown thermal rate. Heat transfer characteristics for the other transient conditions were based on flow and temperature conditions in the thermal cycle diagrams. The condition that results in the highest required temperature for the limiting material determines the minimum allowable temperature for the vessel.

There are four vessel regions defined in the thermal cycle diagram that should be monitored against the Pressure-Temperature (P-T) curve operating limits:

- Closure flange region (Region A)
- Core beltline region (Region B)
- Upper vessel (Regions A & B)
- Lower vessel (Regions B & C)

The closure flange region includes the bolts, top head flange, vessel flange, and adjacent plates and welds. The core beltline is the vessel location adjacent to the active fuel, such that the neutron fluence is sufficient to cause a significant shift of RT_{NDT}. The remaining portion of the vessel (i.e., upper vessel, lower vessel) includes shells, components like the nozzles, the support skirt, and stabilizer brackets; these regions will be called the non-beltline region.

Under certain conditions, the minimum bottom head temperature can be significantly cooler than the beltline or closure flange region. These conditions can occur when the recirculation pumps are operating at low speed (or are off), and during water injection through the control rod drives. To account for these circumstances, individual temperature limits for the bottom head were established. Bottom head curves are not provided for the core critical curve, since during core critical operation the entire RPV follows the steam saturation curve that is well to the right of the core critical curve.

The P-T curves for the heatup and cooldown operating condition at a given EFPY apply for both the 1/4T and 3/4T locations. When combining pressure and thermal stresses, it is usually necessary to evaluate stresses at the 1/4T location (inside surface flaw) and the 3/4T location (outside surface flaw). This is because the thermal gradient tensile stress of interest is in the inner wall during cooldown and is in the outer wall during heatup. However, as a conservative simplification, the thermal gradient stress at 1/4T is assumed to be tensile for both heatup and cooldown. This results in the approach of applying the maximum tensile stress at the 1/4T location. This approach is conservative for two reasons: 1) the maximum stress is used regardless of flaw location, and 2) the irradiation effects cause the allowable toughness, K_{IR}, at 1/4T to be less than that at 3/4T for a given metal temperature. This approach causes no operational difficulties, since the BWR vessel metal temperature is at steam saturation conditions during normal operation, satisfying the heatup/cooldown curve limits.

Except for the independent bottom head curve, the applicable temperature is the greater of the 10CFR50 Appendix G minimum temperature requirement and the ASME Appendix G limits. A summary of the requirements is provided in Table 4-1.

There are three vessel regions that affect the operating limits: the non-beltline regions, the core beltline region, and the closure flange. The closure flange region limits are controlling at lower pressures primarily because of

10CFR50, Appendix G requirements as indicated in Table 4-1. The non-beltline and beltline region operating limits are evaluated according to procedures in 10CFR50, Appendix G [1], ASME Boiler and Pressure Vessel Code, Section XI, Appendix G [8], and Welding Research Council (WRC) Bulletin 175 [5]. The beltline region minimum temperature limits are adjusted to account for vessel irradiation.

Limiting composite curves are applicable for (a) hydrostatic pressure tests and leak tests, (b) core not critical heatup/cooldown, and (c) core critical operation. The individual curves used to construct the limiting curves are described in Tables 4-2 and 4-3, for Units 1 and 2, respectively. Tables 4-2 and 4-3 show the pressure range over which each curve used to construct the composite P-T curves is limiting. The curves consist of the 10CFR50 Appendix G bolt-up limits (limits for the closure flange region that are highly stressed by the bolt preload), the non-beltline bottom head curve, the non-beltline feedwater nozzle curve, and the beltline curve. During core critical operation the entire RPV follows the saturation curve that is well to the right of the core critical curve.

4.2 NON-BELTLINE REGIONS

Non-beltline regions are defined as the vessel locations that are remote from the active fuel and where the neutron fluence is not sufficient to cause any significant shift of RT_{NDT}. Non-beltline components include most nozzles, the closure flanges, some shell plates, the top and bottom head plates and the control rod drive (CRD) penetrations.

Detailed stress analyses of the non-beltline components were performed for the BWR/6 specifically for the purpose of fracture toughness analysis. The analyses took into account all mechanical loading and anticipated thermal transients. Transients considered include 100°F/hr start-up and shutdown, SCRAM, loss of feedwater heaters or flow, loss of recirculation pump flow, and all transients involving emergency core cooling injections. Primary membrane and bending stresses and secondary membrane and bending stresses due to the most severe of these transients were used according to the ASME Code [8] to develop plots of allowable pressure (P) versus temperature relative to the reference temperature (T - RT_{NDT}). Plots were developed for the limiting BWR/4 components: the feedwater nozzle (FW) and the CRD penetration (bottom head). All other components in the non-beltline regions are categorized under one of these two components.

The P-T curves for the non-beltline region were conservatively developed for a large BWR/6 (nominal inside diameter of 251 inches). The analysis is considered appropriate for Hatch Unit 1 and Hatch Unit 2 as the plant specific geometric values are bounded by the generic analysis for a large BWR/6, as determined from Equations 4-2 and 4-3. The generic value was adapted to the conditions at Hatch Unit 1 and Hatch Unit 2 by using plant specific RT_{NDT} values for the reactor pressure vessel (RPV). The presence of nozzles and CRD penetration holes of the upper vessel and bottom head, respectively, has made the analysis different from a shell analysis such as the beltline. This was the result of the stress concentrations and higher thermal stresses for certain transient conditions experienced by the upper vessel and the bottom head.

The non-beltline curves are based on the most limiting (conservative) properties of either the upper vessel region or the bottom head. The non-beltline curves are shifted based on the most limiting initial RT_{NDT} values for the appropriate non-beltline components; the initial RT_{NDT} values were obtained from [6,7]. The individual bottom head curve is based on the non-beltline bottom head curve described in the next section. A detailed description of the construction of each non-beltline curve is included in the following sections.

4.2.1 PRESSURE TEST - NON-BELTLINE, CURVE A (USING BOTTOM HEAD)

In a BWR/6 finite element analysis, the CRD penetration region was modeled to compute the local stresses for determination of the stress intensity factor, K_I. The results of that computation were K_I = 154.3 ksi-in$^{1/2}$ for an applied pressure of 1593 psig (1563 psig preservice hydrotest pressure at the top of the vessel plus 30 psig hydrostatic pressure at the bottom of the vessel). The computed value of (T - RT_{NDT}) was 161°F; the limit for the temperature change rate is 20°F/hr.

The CRD penetration region limits were established primarily for consideration of bottom head discontinuity stresses during pressure testing.

The CRD penetration stresses were obtained from finite element analysis. These stresses, and other inputs used in the generic calculations, are shown below:

$_{pm}$ = 35.87 ksi	$_{sm}$ = 0.30 ksi	$_{ys}$ = 47.68 ksi
$_{pb}$ = -0.30 ksi	$_{sb}$ = 1.50 ksi	t = 8.0 inch

The value of M_m from Figure G-2214-1 [8] was based on a thickness of 8.0 inches; hence, $t^{1/2}$ = 2.83. The stress to yield ratio, $/ \ _{ys}$, was calculated to be 0.78. The resulting value obtained was:

$$M_m = 2.83$$

K_{Im} is calculated from the equation in Paragraph G-2214.1 [8]:

$$K_{Im} = M_m{}^* \sigma_{pm} = 101.5 \text{ ksi-in}^{1/2}$$

K_{Ib} is calculated from the equation in Paragraph G-2214.2 [8]:

$$K_{Ib} = (2/3)\ M_m{}^* \sigma_{pb} = -0.60 \text{ ksi-in}^{1/2}$$

The total K_I is therefore:

$$K_I = 1.5\,(K_{Im} + K_{Ib}) + M_m * (\sigma_{sm} + (2/3) * \sigma_{sb}) = 154.3 \text{ ksi-in}^{1/2}$$

This equation includes a safety factor of 1.5 on primary stress.

The method to solve for $(T - RT_{NDT})$ for a specific K_I is based on the curve in Figure G-2210-1 in ASME Appendix G [8]:

$$(T - RT_{NDT}) = \ln [(K_I - 26.78) / 1.223] / 0.0145 - 160$$
$$(T - RT_{NDT}) = \ln [(154.3 - 26.78) / 1.223] / 0.0145 - 160$$
$$(T - RT_{NDT}) = 161°F$$

The generic curve was generated by scaling 154.3 ksi-in$^{1/2}$ by the nominal pressures and calculating the associated $(T - RT_{NDT})$:

Pressure Test CRD Penetration K_I and $(T - RT_{NDT})$ as a Function Of Pressure

Nominal Pressure (psig)	K_I (ksi-in$^{1/2}$)	$T - RT_{NDT}$ (°F)
1563	154.3	161
1400	138.2	151
1200	118.5	138
1000	98.7	121
800	79.0	99
600	59.2	66
400	39.5	1

The highest RT_{NDT} values for the bottom head plates and welds are 10°F and 50°F, for Hatch 1 and 2, respectively [6,7]. The generic P-T curve is shifted by these values.

The P-T curve is dependent on the K_I value calculated, which is proportional to the stress and the crack depth according to the relationship:

$$K_I \quad (\quad a)^{1/2}$$
(4-1)

The stress is proportional to R/t and, for the P-T curves, crack depth, *a*, is t/4. Thus, K_I is proportional to $R/(t)^{1/2}$. The generic curve value of $R/(t)^{1/2}$, based on the generic BWR/6 bottom head dimensions, is:

Generic: $$R / (t)^{1/2} = 138 / (8)^{1/2} = 49 \text{ inch}^{1/2} \quad (4\text{-}2)$$

The Hatch Unit 1 and Hatch Unit 2 specific bottom head dimensions are R = 110 inches and t = 5.38 inches minimum, resulting in:

Hatch Unit 1 and Unit 2 specific:

$$R / (t)^{1/2} = 110/ (5.38)^{1/2} = 47 \text{ inch}^{1/2} \quad (4\text{-}3)$$

Since the generic value of $R/(t)^{1/2}$ is larger than that for Hatch Unit 1 and Hatch Unit 2, the generic P-T curve is conservative when applied to the Hatch Unit 1 and Hatch Unit 2 bottom heads.

4.2.2 CORE NOT CRITICAL HEATUP/COOLDOWN - NON-BELTLINE CURVE B (USING BOTTOM HEAD)

As discussed previously, the CRD penetration region limits were established primarily for consideration of bottom head discontinuity stresses during pressure testing. Heatup/cooldown limits were calculated by increasing the safety factor in Section 4.2.1 from 1.5 to 2.0, on the assumption that the conservative factor of 3.0 on bottom head pressure stress bounds the thermal stresses occurring during heatup/cooldown.

Subsequent analysis examined CRD penetration region limits for several emergency conditions involving severe bottom head thermal conditions. The transients with the most severe bottom head conditions were sudden start of an idle recirculation loop (cooldown) and improper start-up, or black start, from a hot standby condition with bottom head drain closed (heatup). The sudden start causes a step-change cooldown of 178°F. The improper start-up sequence involves a step-change heatup of 348°F. The result of CRD penetration region fracture toughness analysis for these conditions showed comparable P-T limits to those established assuming 3.0 times nominal pressure stress. Therefore, the CRD penetration region limits are adequate to assure structural integrity for heatup/cooldown step-changes in excess of 100°F.

The calculated value of K_I for pressure test is multiplied by a safety factor (SF) of 1.5, per ASME Appendix G [8] for comparison with K_{IR}, the material fracture toughness. A safety factor of 2.0 is used for the core not critical. Therefore, the K_I value for the core not critical condition is $(154.3 / 1.5)^* 2.0 = 205.7$ ksi-in$^{1/2}$.

Therefore, the method to solve for $(T - RT_{NDT})$ for a specific K_I is also based on the curve in Figure G-2210-1 in ASME Appendix G [8] for the core not critical:

$$(T - RT_{NDT}) = \ln [(K_I - 26.78) / 1.223] / 0.0145 - 160$$
$$(T - RT_{NDT}) = \ln [(205.7 - 26.78) / 1.223] / 0.0145 - 160$$
$$(T - RT_{NDT}) = 184°F$$

The generic curve was generated by scaling 205.7 ksi-in$^{1/2}$ by the nominal pressures and calculating the associated (T - RT_{NDT}):

Core Not Critical CRD Penetration K_I and (T - RT_{NDT}) as a Function of Pressure

Nominal Pressure (psig)	K_I (ksi-in$^{1/2}$)	T - RT_{NDT} (°F)
1563	205.7	184
1400	184.2	175
1200	157.9	162
1000	131.6	147
800	105.3	127
600	79.0	99
400	52.6	50

The highest RT_{NDT} values for the bottom head plates and welds is 10°F and 50°F,for Hatch 1 and 2, respectively. The generic P-T curve is shifted by these values.

4.2.3 PRESSURE TEST - NON-BELTLINE CURVE A (USING FEEDWATER NOZZLE/UPPER VESSEL REGION)

CBI Nuclear (CBIN) modeled the 251-inch BWR/6 feedwater nozzles to compute local stresses for determination of the stress intensity factor, K_I. The result of that computation was K_I = 143.1 ksi-in$^{1/2}$ for an applied pressure of 1563 psig preservice hydrotest pressure. The computed value of (T - RT_{NDT}) was 154°F. The respective flaw depth and orientation used in this calculation is perpendicular to the maximum stress (hoop) at a depth of 1/4T through the corner thickness.

To evaluate the CBIN result, K_I is calculated for the upper vessel nominal stress, PR/t, according to the methods in ASME Code Appendix G (Section III or XI). The result is compared to that determined by CBIN in order to quantify the K magnification associated with the stress concentration created by the feedwater nozzles.

A calculation of K_I is shown below using the BWR/6, 251-inch dimensions:

Vessel Radius, R	126.7 inches
Vessel Thickness, t	6.5 inches
Vessel Pressure, P	1563 psig

Pressure stress: σ = PR/t = 1563 psig 126.7 inches / (6.5 inches) = 30,466 psi

The factor F (a/r_n) from Figure A5-1 of WRC-175 [5] is 1.6 where :

a =	lesser of 1/4 t_n or 1/4 t_v	
t_n =	thickness of nozzle	= 7.13 inches
t_v =	thickness of vessel	= 6.5 inches
r_n =	apparent radius of nozzle	= r_i + 0.29 r_c
r_i =	actual inner radius of nozzle	= 6 inches
r_c =	nozzle radius (nozzle corner radius)	= 4.0 inches

Thus, a/r_n = 1.63 / 6.94 = 0.23 and the ratio of K_I around the feedwater nozzle to the membrane stress · ($a)^{1/2}$ at places with no geometric discontinuity is 1.6.

Including the safety factor of 1.3, the stress intensity factor, K_I, is $1.3*\sigma*(\pi a)^{1/2}*F(a/r_n)$:

$$\text{Nominal } K_I = 1.3 \cdot 30.466 \cdot (\pi \cdot 1.63)^{1/2} \cdot 1.6 = 143 \text{ ksi-in}^{1/2}$$

The method to solve for (T - RT_{NDT}) for a specific K_I is based on the curve in Figure G-2210-1 in ASME Appendix G [8]:

$$(T - RT_{NDT}) = \ln [(K_I - 26.78) / 1.223] / 0.0145 - 160$$
$$(T - RT_{NDT}) = 1n [(143 - 26.78) / 1.223] / 0.0145 - 160$$
$$(T - RT_{NDT}) = 154°F$$

The generic pressure test P-T curve was generated by scaling 143 ksi-in$^{1/2}$ by the nominal pressures and calculating the associated (T - RT_{NDT}):

Pressure Test Feedwater Nozzle K_I and (T - RT_{NDT}) as a Function of Pressure

Nominal Pressure (psig)	K_I (ksi-in$^{1/2}$)	(T - RT_{NDT}) (°F)
1563	143	154
1400	128	145
1200	110	131
1000	92	114
800	73	91
600	55	56
400	37	-16

The P-T curve is dependent on the K_I value calculated, which is proportional to the stress and the crack depth according to the relationship:

$$K_I \propto \sigma (\pi a)^{1/2}$$

The stress is proportional to R/t and, for the P-T curves, crack depth, *a*, is t/4. Thus, K_I is proportional to $R/(t)^{1/2}$.

The generic curve value of $R/(t)^{1/2}$, based on the BWR/6, 251-inch feedwater nozzle dimensions is:

Generic: $R/(t)^{1/2} = 126.7 / (6.5)^{1/2} = 49.7 \text{ inch}^{1/2}$

where t is the nominal vessel thickness. The Hatch Unit 1 and Hatch Unit 2 specific vessel shell dimensions applicable to the feedwater nozzle location are R = 110 inches and t = 5.38 inches nominal.

Hatch Unit 1 and Unit 2 specific: $R/(t)^{1/2} = 110 / (5.38)^{1/2} = 47.4 \text{ inch}^{1/2}$

Since the generic value of $R/(t)^{1/2}$ is greater than that for Hatch Unit 1 and Hatch Unit 2, the generic P-T curve is conservative when applied to the Hatch Unit 1 and Hatch Unit 2 feedwater nozzles.

As discussed below, the highest RT_{NDT} values for the nozzle materials are 40°F and 26°F, for Hatch 1 and 2, respectively. The generic pressure test P-T curve is applied to the Hatch Unit 1 and Hatch Unit 2 feedwater nozzle curves by shifting the P vs. (T - RT_{NDT}) values above to reflect the RT_{NDT} values of 40°F and 26°F.

4.2.4 CORE NOT CRITICAL HEATUP/COOLDOWN - NON-BELTLINE CURVE B (USING FEEDWATER NOZZLE/UPPER VESSEL REGION)

The feedwater nozzle was selected to represent non-beltline components for fracture toughness analyses because the stress conditions are the most severe experienced in the vessel. In addition to the more severe pressure and piping load stresses resulting from the nozzle discontinuity, the feedwater nozzle region experiences relatively cold feedwater flow in hotter vessel coolant.

Stresses are taken from finite element analysis done specifically for fracture toughness analysis purposes. Analyses were performed for all feedwater nozzle transients that involve rapid temperature changes. The most severe of these was normal operation with cold 40°F feedwater injection, which is equivalent to hot standby.

The non-beltline curves based on feedwater nozzle limits were calculated according to the methods for nozzles in Appendix 5 of the Welding Research Council (WRC) Bulletin 175 [5].

The stress intensity factor for a nozzle flaw under primary stress conditions (K_{IP}) is given in WRC Bulletin 175 Appendix 5 [5] by the expression for a flaw at a hole in a flat plate:

$$K_{IP} = SF \cdot (\quad a)^{1/2} \cdot F(a/r_n) \qquad (4\text{-}4)$$

where SF is the safety factor applied per WRC Bulletin 175 [5] recommended ranges, and $F(a/r_n)$ is the shape correction factor.

Finite element analysis of a nozzle corner flaw was performed to determine appropriate values of $F(a/r_n)$ for Equation 4-4. These values are shown in Figure A5-1 of WRC Bulletin 175 [5].

The stresses used in Equation 4-4 were taken from BWR/6 design stress reports for the feedwater nozzle. The stresses considered are primary membrane, $_{pm}$, and primary bending, $_{pb}$. Secondary membrane, $_{sm}$, and secondary bending, $_{sb}$, stresses are included in the total K_I by using ASME Appendix G [8] methods for secondary portion, K_{Is}:

$$K_{Is} = M_m (\; _{sm} + (2/3) \cdot \; _{sb}) \quad (4\text{-}5)$$

In the case where the total stress exceeded yield stress, a plasticity correction factor was applied based on the recommendations of WRC Bulletin 175 Section 5.C.3 [5]. However, the correction was not applied to primary membrane stresses because stresses that are based on equilibrium considerations (i.e., primary membrane) are not displacement controlled and are not reduced or changed by deformation of the component. K_{IP} and K_{Is} are added to obtain the total value of stress intensity factor, K_I. A safety factor of 1.6 is applied to primary stresses for core not critical heatup/cooldown conditions.

Once K_I was calculated, the following relationship was used to determine ($T - RT_{NDT}$). The highest RT_{NDT} for the appropriate non-beltline components was then used to establish the P-T curves.

$$(T - RT_{NDT}) = \ln [(K_I - 26.78) / 1.223] / 0.0145 - 160 \quad (4\text{-}6)$$

Example: Core Not Critical Heatup/Cooldown Calculation for Feedwater Nozzle/Upper Vessel Region

The non-beltline core not critical heatup/cooldown curve was based on the feedwater nozzle generic analysis, where feedwater injection of 40°F into the vessel while at operating conditions (551.4°F and 1050 psig) was the limiting normal or upset condition from a brittle fracture perspective. The feedwater nozzle corner stresses were obtained from finite element analysis. These stresses, and other inputs used in the generic calculations, are shown below:

$_{pm}$ = 20.49 ksi	$_{sm}$ = 16.19 ksi	$_{ys}$ = 45.0 ksi	t = 7.5 inch
$_{pb}$ = 0.22 ksi	$_{sb}$ = 19.04 ksi	*a* = 1.88 inch	r_n = 6.94 inch

In this case the total stress, 55.94 ksi, exceeds the yield stress, $_{ys}$, so the correction factor, R, is calculated to consider the nonlinear effects in the plastic region according to the following equation based on the assumptions and recommendation of WRC Bulletin 175 [5]. (The value of specified yield stress is for the material at the temperature under consideration. For conservatism, the temperature assumed for the crack root is the inside surface temperature.)

$$R = [\ _{ys} - \ _{pm} + ((\ _{total} - \ _{ys}) / 30)] / (\ _{total} - \ _{pm})$$
(4-7)

For the stresses given, the ratio, R = 0.70. Therefore, all the stresses are adjusted by the factor 0.70, except for $_{pm}$. The resulting stresses are:

$$_{pm} = 20.49 \text{ ksi} \qquad _{sm} = 11.33 \text{ ksi}$$
$$_{pb} = 0.15 \text{ ksi} \qquad _{sb} = 13.33 \text{ ksi}$$

The value of M_m from Figure G-2214-1 [8] was based on a thickness of 7.5 inches; hence, $t^{1/2} = 2.74$. The stress to yield ratio, $/ \ _{ys}$, was conservatively assumed to be 1.0. The resulting value obtained was: $M_m = 2.84$.

The value $F(a/r_n)$, taken from Figure A5-1 of WRC Bulletin 175 [5] for an a/r_n of 0.27, is 1.5; however, 1.6 is used to be conservative.

$$F\,(a / r_n) = 1.6$$

K_{IP} is calculated from Equation 4-4:

$$K_{IP} = 1.6 \cdot (20.49 + 0.15) \cdot (\ \cdot 1.88)^{1/2} \cdot 1.6$$
$$K_{IP} = 128.4 \text{ ksi-in}^{1/2}$$

K_{Is} is calculated from Equation 4-5:

$$K_{Is} = 2.84 \cdot (11.33 + 2/3 \cdot 13.33)$$
$$K_{Is} = 57.4 \text{ ksi-in}^{1/2}$$

The total K_I is, therefore, 186 ksi-in$^{1/2}$.

The total K_I is substituted into Equation 4-6 to solve for $(T - RT_{NDT})$:

$(T - RT_{NDT}) =$ ln [(186 - 26.78) / 1.223] / 0.0145 - 160
$(T - RT_{NDT}) = 176°F$

The generic curve was generated by scaling the stresses used to determine the K_I; this scaling was performed after the adjustment to stresses above yield. The primary stresses were scaled by the nominal pressures, while the secondary stresses were scaled by the temperature difference of the 40°F water injected into the hot reactor vessel nozzle. In the base case that yielded a K_I value of 186 ksi-in$^{1/2}$, the pressure is 1050 psig and the hot reactor vessel temperature is 551.4°F. Since the reactor vessel temperature follows the saturation temperature curve, the secondary stresses are scaled by $(T_{saturation} - 40) / (551.4 - 40)$. From K_I the associated $(T - RT_{NDT})$ can be calculated:

Core Not Critical Feedwater Nozzle K_I and $(T - RT_{NDT})$ as a Function of Pressure

Nominal Pressure (psig)	Saturation Temp. (°F)	K_I (ksi-in$^{1/2}$)	$(T - RT_{NDT})$ (°F)
1563	604	226	191
1400	588	213	187
1200	557	198	181
1050	551	186	176
1000	546	182	174
800	520	166	167
600	489	146	156
400	448	115	135

The highest non-beltline RT_{NDT} values for the feedwater region components are 40°F and 26°F (steam outlet nozzle) for Hatch Unit 1 and Hatch Unit 2, respectively [6,7]. The generic curve is applied to the Hatch Unit 1 and Hatch Unit 2 upper vessels by shifting the P vs. $(T - RT_{NDT})$ values above to reflect the RT_{NDT} values of 40°F and 26°F.

4.3 CORE BELTLINE REGION

The pressure-temperature (P-T) operating limits for the beltline region are determined according to the ASME Code. As the beltline fluence increases with the increase in operating life, the P-T curves shift to a higher temperature.

The stress intensity factors (K_I), calculated for the beltline region according to ASME Code Appendix G procedures [8], were based on a combination of pressure and thermal stresses for a 1/4T flaw in a flat plate. The pressure stresses were calculated using thin-walled cylinder equations. Thermal stresses were calculated assuming the through-wall temperature distribution of a flat plate; values were calculated for 100°F/hr thermal gradient. The shift value of the most limiting ART material was used to adjust the RT_{NDT} values for the P-T limits.

4.3.1 BELTLINE REGION - PRESSURE TEST

The methods of ASME Code Section XI, Appendix G [8] are used to calculate the pressure test beltline limits. The vessel shell, with an inside radius (R) to minimum thickness (t_{min}) ratio of 15, is treated as a thin-walled cylinder. The maximum stress is the hoop stress, given as:

$$_{m} = PR / t_{min} \qquad (4\text{-}8)$$

The stress intensity factor, K_{Im}, is calculated using Figure G-2214-1 of the ASME Code Section XI, Appendix G [8], accounting for the proper ratio of stress to yield strength. Figure G-2214-1 was taken from Welding Research Council (WRC) Bulletin 175 [5], based on a 1/4T radial flaw with a six-to-one aspect ratio (length of 1.5T). The flaw is oriented normal to the maximum stress direction, in this case a vertically oriented flaw. This orientation is used even in the case where the circumferential weld is the limiting beltline material.

The calculated value of K_{Im} for pressure test is multiplied by a safety factor (SF) of 1.5, per ASME Appendix G [8] for comparison with K_{IR}, the material fracture toughness. A safety factor of 2.0 is used for the core not critical and core critical conditions.

The relationship between K_{IR} and temperature relative to reference temperature ($T - RT_{NDT}$) is shown in Figure G-2210-1 of ASME Section XI Appendix G [8]. represented by the relationship:

$$K_{Im} \cdot SF = K_{IR} = 1.223 \exp[0.0145 (T - RT_{NDT} + 160)] + 26.78 \qquad (4\text{-}9)$$

This relationship is derived in the Welding Research Council (WRC) Bulletin 175 [5] as the lower bound of all dynamic fracture toughness and crack arrest toughness data. This relationship provides values of pressure versus temperature (from K_{IR} and ($T - RT_{NDT}$), respectively).

GE's current practice for the pressure test curve is to add a stress intensity factor, K_{It}, for a heatup/cooldown rate of 20°F/hr to provide operating flexibility. For the core not critical and core critical condition curves, a stress intensity factor is added for a heatup/cooldown rate of 100°F/hr. The K_{It} calculation for a heatup/cooldown rate of 100°F/hr is described in Sections 4.3.3 and 4.3.4.

4.3.2 CALCULATIONS FOR THE BELTLINE REGION - PRESSURE TEST

This sample calculation is for a pressure test pressure of 1105 psig at 54 EFPY for Hatch Unit 1. The following inputs were used in the beltline limit calculation:

Adjusted RT_{NDT} = Initial RT_{NDT} + Shift	A = -20 + 187.2 = 167.2 °F (Based on ART values in Section 3)
Vessel Height	H = 825 inches
Bottom of Active Fuel Height	B = 208.5 inches
Vessel Radius (to inside of clad)	R = 110 inches
Minimum Vessel Thickness (without clad)	t = 5.38 inches
Limiting Beltline Material Yield Strength	$_y$ = 64.4 ksi

Pressure is calculated to include hydrostatic pressure for a full vessel:

$$P = 1105 \text{ psi} + (H - B)\ 0.0361 \text{ psi/inch} = P \text{ psig} \quad (4\text{-}10)$$

$$= 1105 + (825 - 208.5)\ 0.0361 = 1127 \text{ psig}$$

Pressure stress:

$$= PR/t \quad (4\text{-}11)$$
$$= 1.127 \cdot 110 / 5.38 = 23.0 \text{ ksi}$$

The factor M_m (= 2.23) depends on (/ $_y$ = 23.0 / 64.4) and $t^{1/2}$ and is determined from Figure G-2214-1 of the ASME Code Appendix G [8], where t is the minimum vessel thickness without cladding. The stress intensity factor for the pressure stress is $K_{Im} = M_m \cdot$ The stress intensity factor for the thermal stress, K_{It}, is calculated as described in Section 4.3.4 except that the value of "G" is 20°F/hr instead of 100°F/hr.

Equation 4-9 can be rearranged, and 1.5 K_{Im} substituted for K_{IR}, to solve for (T - RT_{NDT}). Using ASME Section XI Appendix G, Fig. G-2210-1 [8], K_{Im}= 51.3, and K_{It}= 1.73 for a 20°F/hr heatup/cooldown rate with a vessel thickness, t, that includes cladding:

$$(T - RT_{NDT}) = \ln[(1.5 \cdot K_{Im} + K_{It} - 26.78) / 1.223] / 0.0145 - 160 \quad (4\text{-}12)$$
$$= \ln[(1.5 \cdot 51.3 + 1.73 - 26.78) / 1.223] / 0.0145 - 160$$
$$= 98.5°F$$

T can be calculated by adding the adjusted RT_{NDT}:

$$T = 98.5 + 167 = 265.5°F \qquad \text{for } P = 1105 \text{ psig}$$

4.3.3 BELTLINE REGION - CORE NOT CRITICAL HEATUP/COOLDOWN

The beltline curves for core not critical heatup/cooldown conditions are influenced by pressure stresses and thermal stresses, according to the relationship in ASME Section XI Appendix G [8]:

$$K_{IR} = 2.0 \cdot K_{Im} + K_{It} \qquad (4\text{-}13)$$

where K_{Im} is primary membrane K due to pressure and K_{It} is radial thermal gradient K due to heatup/cooldown.

The pressure stress intensity factor K_{Im} is calculated by the method described above, the only difference being the larger safety factor applied. The thermal gradient stress intensity factor calculation is described below.

The thermal stresses in the vessel wall are caused by a radial thermal gradient that is created by changes in the adjacent reactor coolant temperature in heatup or cooldown conditions. The stress intensity factor is computed by multiplying the coefficient M_t from Figure G-2214-2 of ASME Appendix G [8] by the through-wall temperature gradient T_w, given that the temperature gradient has a through-wall shape similar to that shown in Figure G-2214-3 of ASME Appendix G [8]. The relationship used to compute the through-wall T_w is based on one-dimensional heat conduction through an insulated flat plate:

$$^2T(x,t) / \quad x^2 = 1 / \quad (\quad (x,t) / \quad t)$$

(4-14)

where T(x,t) is temperature of the plate at depth x and time t, and is the thermal diffusivity.

The maximum stress will occur when the radial thermal gradient reaches a quasi-steady state distribution, so that $T(x,t) / \; t = dT(t) / dt = G$, where G is the heatup/cooldown rate, normally 100°F/hr. The differential equation is integrated over x for the following boundary conditions:

1. Vessel inside surface (x = 0) temperature is the same as coolant temperature, T_0.
2. Vessel outside surface (x = C) is perfectly insulated; the thermal gradient dT/dx = 0.

The integrated solution results in the following relationship for wall temperature:

$$T = Gx^2 / 2 - GCx / \quad + T_0$$
(4-15)

This equation is normalized to plot $(T - T_0) / T_w$ versus x / C.

The resulting through-wall gradient compares very closely with Figure G-2214-3 of ASME Appendix G [8]. Therefore, T_w calculated from Equation 4-14 is used with the appropriate M_t of Figure G-2214-2 of ASME Appendix G [8] to compute K_{It} for heatup and cooldown.

The M_t relationships were derived in the Welding Research Council (WRC) Bulletin 175 [5] for infinitely long cracks of 1/4T and 1/8T. For the flat plate geometry and radial thermal gradient, orientation of the crack is not important.

4.3.4 CALCULATIONS FOR THE BELTLINE REGION CORE NOT CRITICAL HEATUP/COOLDOWN

This sample calculation is for a pressure of 1105 psi for 54 EFPY.

The core not critical heatup/cooldown curve at 1105 psig uses the same K_{Im} as the pressure test curve, but with a safety factor of 2.0 instead of 1.5. The increased safety factor is used because the heatup/cooldown cycle represents an operational rather than test condition that necessitates a higher safety factor. In addition, there is a K_{It} term for the thermal stress. The additional inputs used to calculate K_{It} are:

Heatup/cooldown rate, normally 100°F/hr, G = 100 °F/hr

Minimum vessel thickness, including clad thickness, C = 0.47 ft (5.69 inches)

Thermal diffusivity at 550°F (most conservative value), = 0.354 ft ^{2}/ hr [9]

Equation 4-15 can be solved for the through-wall temperature (x = C), resulting in the absolute value of T for heatup or cooldown of:

$$T = GC \quad {}^2/2 \qquad (4\text{-}16)$$

$$= 100\,(0.47)^2 / (2 \bullet 0.354) = 31.2°F$$

The analyzed case for thermal stress is a 1/4T flaw depth with wall thickness of C. The corresponding value of M_t (=0.2775) can be found from ASME Appendix G, Figure G-2214-2 [8]. Thus the thermal stress intensity factor, $K_{It} = M_t \cdot T = 8.66$, can be calculated.

The pressure and thermal stress terms are substituted into Equation 4-9 to solve for $(T - RT_{NDT})$:

$$(T - RT_{NDT}) = \ln[((2 \cdot K_{Im} + K_{It}) - 26.78) / 1.223] / 0.0145 - 160 \qquad (4\text{-}17)$$

$$= \ln[(2 \cdot 51.3 + 8.66 - 26.78) / 1.223] / 0.0145 - 160$$

$$= 132\ °F$$

T can be calculated by adding the adjusted RT_{NDT}:

$$T = 132 + 167 = 299\ °F \quad \text{for } P = 1105 \text{ psig}$$

4.4 CLOSURE FLANGE REGION

10CFR50 Appendix G [1] sets several minimum requirements for pressure and temperature in addition to those outlined in the ASME Code, based on the closure flange region RT_{NDT}. In some cases, the results of analysis for other regions exceed these requirements and closure flange limits do not affect the shape of the P-T curves. However, some closure flange requirements do impact the curves, as is true with Hatch Unit 1 and Hatch Unit 2 at low pressures.

The original ASME Code requirement for bolt-up was at qualification temperature (T_{30L}) plus 60°F. The Code used for the currently licensed P-T curves is the 1989 ASME Code, no addenda. The ASME Code requirements state in Paragraph G-2222(c) that, for application of full bolt preload and reactor pressure up to 20% of hydrostatic test pressure, the RPV metal temperature must be at RT_{NDT} or greater. The approach used for Hatch Unit 1 and Hatch Unit 2 for the bolt-up temperature was based on a more conservative value of (RT_{NDT} + 60), or the LST of the bolting materials, whichever is greater. The 60°F adder is included by GE for two reasons: 1) the pre-1971 requirements of the ASME Code Section III, Subsection NA, Appendix G included the 60°F adder, and 2) inclusion of the additional 60°F requirement above the RT_{NDT} provides the additional assurance that a flaw size between 0.1 and 0.24 inches is acceptable. The limiting initial RT_{NDT} values for the closure flange region were 16°F for Unit 1 and 30°F for Unit 2 due to the flange, upper vessel and top head plate materials, and the LST of the closure studs was 70°F for both units, so the bolt-up temperature values used were 76°F (Unit 1) and 90°F (Unit 2). This conservatism is appropriate because bolt-up is one of the more limiting operating conditions (high stress and low temperature) for brittle fracture.

10CFR50 Appendix G, paragraph IV.A.2 [1] including Table 1, sets minimum temperature requirements for pressure above 20% hydrotest pressure based on the RT_{NDT} of the closure region. Curve A temperature must be no less than (RT_{NDT} + 90°F) and Curve B temperature no less than (RT_{NDT} + 120°F).

For pressures below 20% of preservice hydrostatic test pressure (312 psig) and with full bolt preload, the closure flange region metal temperature is required to be at RT_{NDT} or greater as described above. At low pressure, the ASME Code [8] allows the beltline and bottom head regions to experience even lower metal temperatures than the flange region RT_{NDT}. However, temperatures should not be permitted to be lower than 68°F for the reason discussed below.

The shutdown margin, provided in the Hatch Unit 1 and Hatch Unit 2 Technical Specification, is calculated for a water temperature of 68°F. Shutdown margin is the quantity of reactivity needed for a reactor core to reach criticality with the strongest-worth control rod fully withdrawn and all other control rods fully inserted. Although it may be possible to safely allow the water temperature to fall below this 68°F limit, further extensive calculations would be required to justify a lower temperature. The 76°F (Unit 1) and 90°F (Unit 2) limits apply when the head is on and tensioned and the 68°F limit when the head is off, while fuel is in the vessel. When the head is not tensioned and fuel is not in the vessel, the requirements of 10CFR50 Appendix G [1] do not apply, and there are no limits on the vessel temperatures.

4.5 CORE CRITICAL OPERATION REQUIREMENTS OF 10CFR50, APPENDIX G

Curve C, the core critical operation curve, is generated from the requirements of 10CFR50 Appendix G [1, Table 1]. Table 1 of [1] requires that core critical P-T limits be 40°F above any Curve A or B limits when pressure exceeds 20% of the pre-service system hydrotest pressure. Curve B is more limiting than Curve A, so limiting Curve C values are at least Curve B plus 40°F for pressures above 312 psig.

Table 1 of 10CFR50 Appendix G [1] indicates that for a BWR with water level within normal range for power operation, the allowed temperature for initial criticality at the closure flange region is (RT_{NDT} + 60°F) at pressures below

312 psig. This requirement makes the minimum criticality temperatures 76°F (Unit 1) and 90°F (Unit 2), based on RT_{NDT} values of 16°F and 30°F for Unit 1 and 2, respectively. In addition, above 312 psig the Curve C temperature must be at least the greater of RT_{NDT} of the closure region + 160°F or the temperature required for the hydrostatic pressure test (Curve A at 1105 psig). Therefore, this requirement causes a temperature shift in Curve C at 312 psig.

Table 4-1: Summary of the 10CFR50 Appendix G Requirements

Operating Condition and Pressure	Minimum Temperature Requirement
I. Hydrostatic Pressure Test & Leak Test (Core is Not Critical) - Curve A	
1. At ≤ 20% of preservice hydrotest pressure	Larger of ASME Limits or of highest closure flange region initial RT_{NDT} + 60°F*
2. At > 20% of preservice hydrotest pressure	Larger of ASME Limits or of highest closure flange region initial RT_{NDT} + 90°F
II. Normal operation (heatup and cooldown), including anticipated operational occurrences	
a. Core not critical - Curve B	
1. At ≤ 20% of preservice hydrotest pressure	Larger of ASME Limits or of highest closure flange region initial RT_{NDT} + 60°F*
2. At > 20% of preservice hydrotest pressure	Larger of ASME Limits or of highest closure flange region initial RT_{NDT} + 120°F
b. Core critical - Curve C	
1. At ≤ 20% of preservice hydrotest pressure, with the water level within the normal range for power operation	Larger of ASME Limits + 40°F or of a.1
2. At > 20% of preservice hydrotest pressure	Larger of ASME Limits + 40°F or of a.2 + 40°F or the minimum permissible temperature for the inservice system hydrostatic pressure test

*60°F adder is included by GE as an additional conservatism as discussed in Section 4.4

Table 4-2: Composite and Individual Curves Used To Construct Composite P-T Curves at 54 EFPY (Unit 1)

Curve	Curve Description	Curve Limiting Over Pressure Range, (Psig)
Curve A	10CFR50 Bolt-up Limits	0 - 410
	Bottom Head Limits (CRD Nozzle)	none
	FW Nozzle Limits	none
	Beltline Limits	410 - 1400
Curve B	10CFR50 Bolt-up Limits	0 - 50
	Bottom Head Limits (CRD Nozzle)	none
	FW Nozzle Limits	50-290
	Beltline Limits	290- 1400
Curve C	10CFR50 Bolt-up Limits	0 - 20
	Bottom Head Limits (CRD Nozzle)	none
	FW Nozzle Limits	20-290
	Beltline Limits	290 - 1400

Note: The core critical operation curve is identical to the core not critical heatup/cooldown curve but shifted by 40°F, as required in 10CFR50, Appendix G [1]. Hence the methods used for determining the core not critical heatup/cooldown curves apply to the core critical curves, as well.

Table 4-3: Composite and Individual Curves Used To Construct Composite P-T Curves at 54 EFPY (Unit 2)

Curve	Curve Description	Curve Limiting Over Pressure Range, (Psig)
Curve A	10CFR50 Bolt-up Limits	0 - 610
	Bottom Head Limits (CRD Nozzle)	610-1400
	FW Nozzle Limits	none
	Beltline Limits	none
Curve B	10CFR50 Bolt-up Limits	0 - 90
	Bottom Head Limits (CRD Nozzle)	none
	FW Nozzle Limits	90-960
	Beltline Limits	960-1400
Curve C	10CFR50 Bolt-up Limits	0 - 30
	Bottom Head Limits (CRD Nozzle)	none
	FW Nozzle Limits	30-960
	Beltline Limits	960 - 1400

Note: The core critical operation curve is identical to the core not critical heatup/cooldown curve but shifted by 40°F, as required in 10CFR50, Appendix G [1]. Hence the methods used for determining the core not critical heatup/cooldown curves apply to the core critical curves, as well.

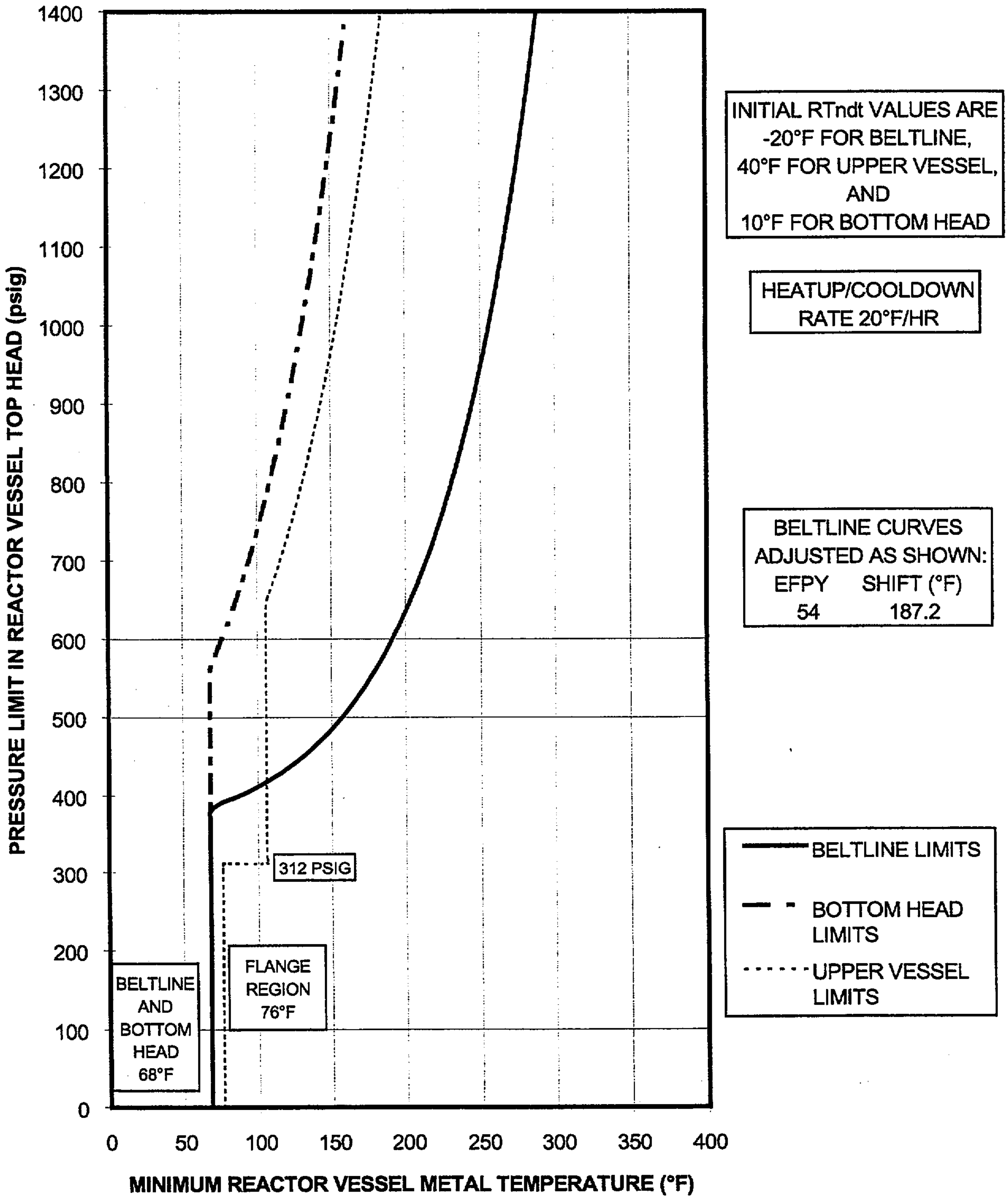

Figure 4-1: Pressure Test Curve (Curve A) [Unit 1]

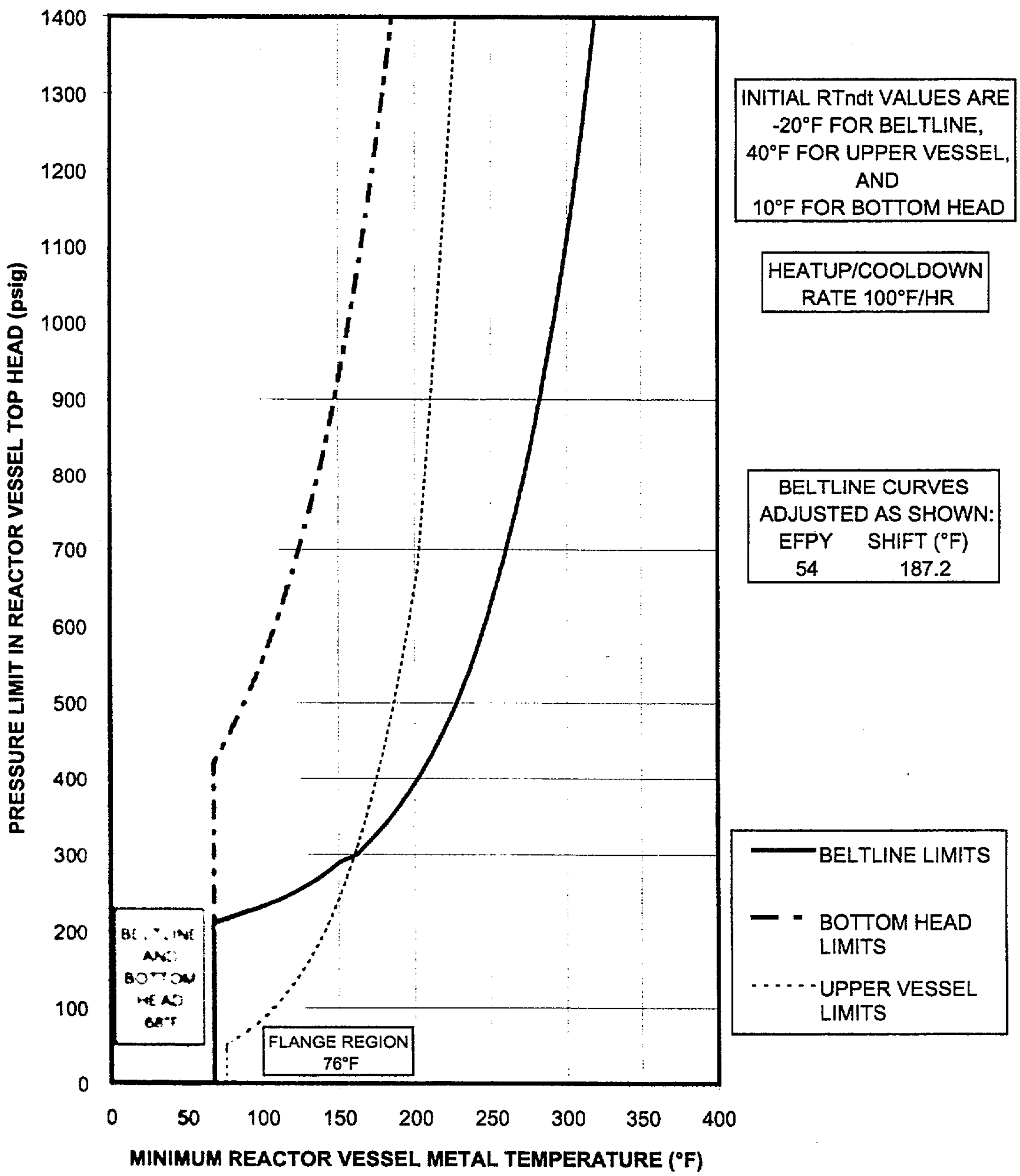

Figure 4-2: Non-Nuclear Heatup/Cooldown (Curve B) [Unit 1]

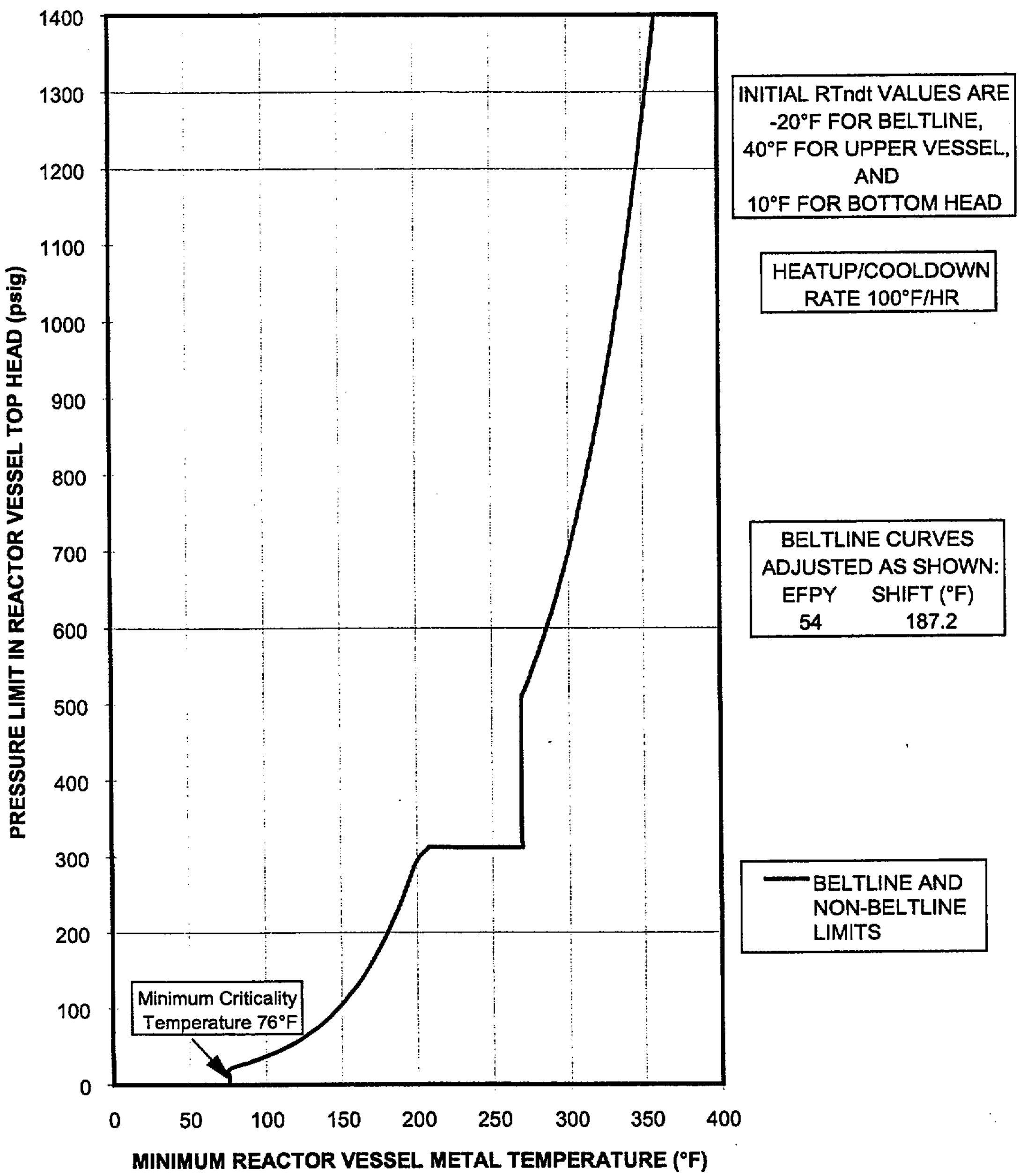

Figure 4-3: Core Critical Curve (Curve C) [Unit 1]

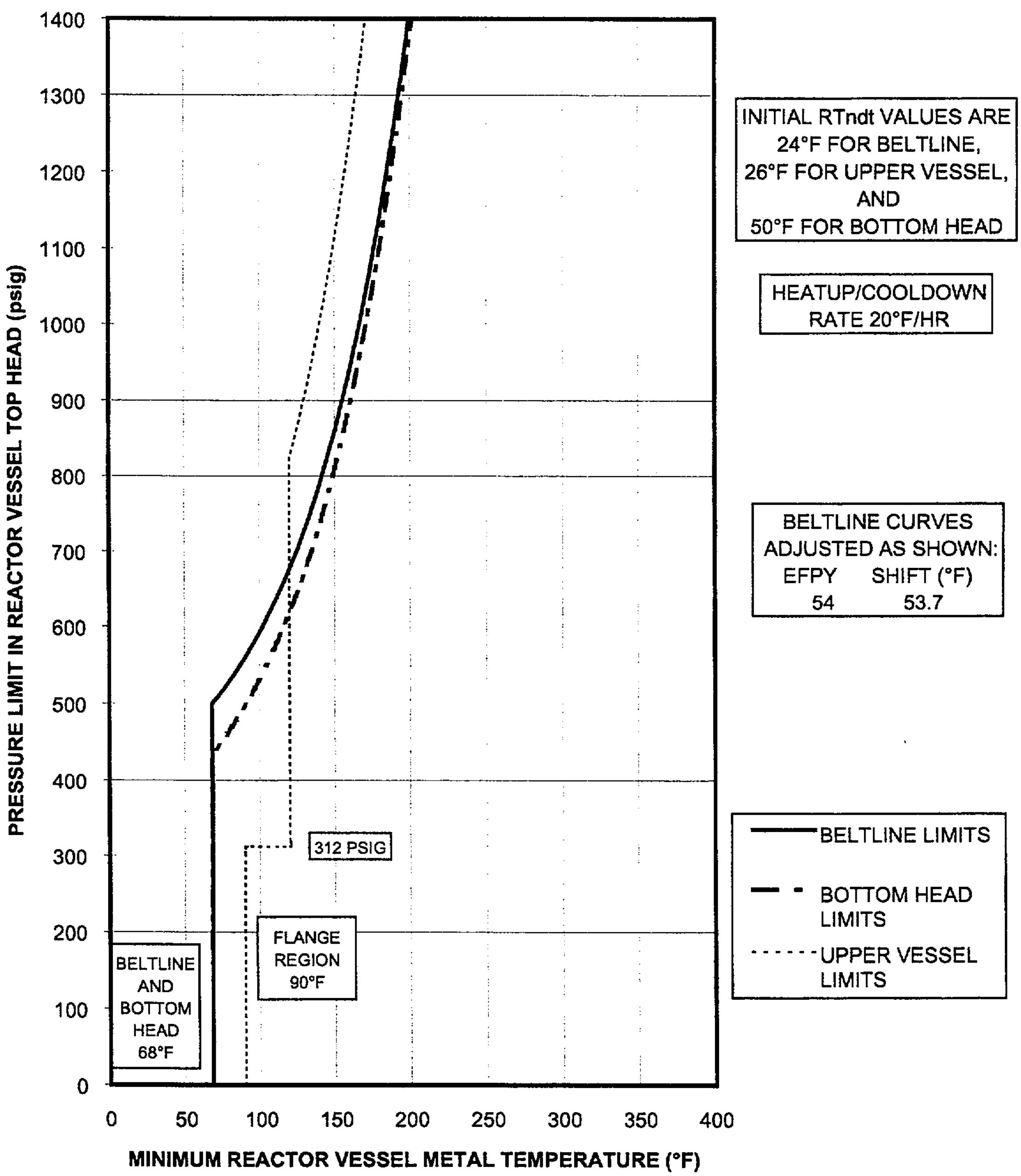

Figure 4-4: Pressure Test Curve (Curve A) [Unit 2]

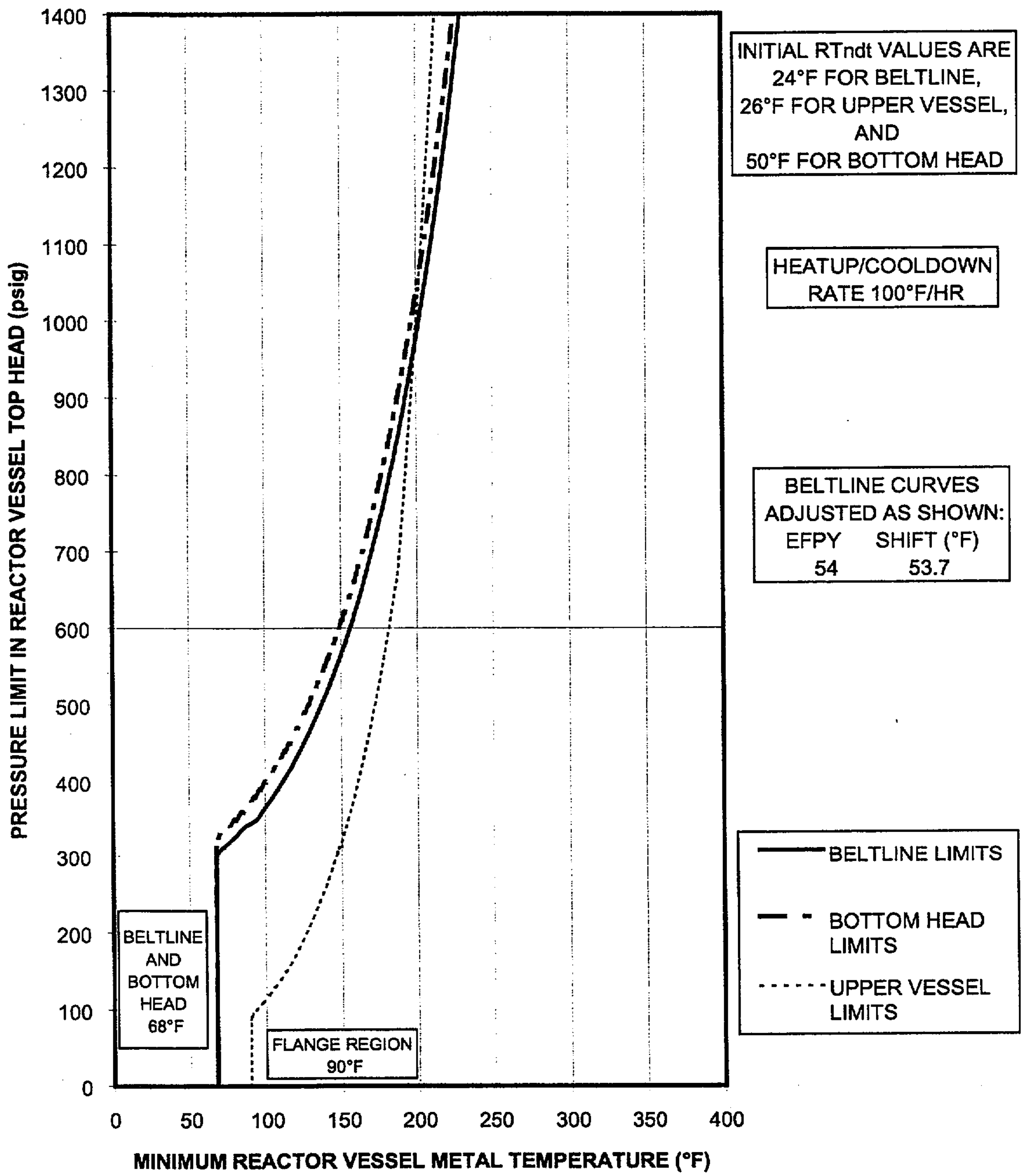

Figure 4-5: Non-Nuclear Heatup/Cooldown (Curve B) [Unit 2]

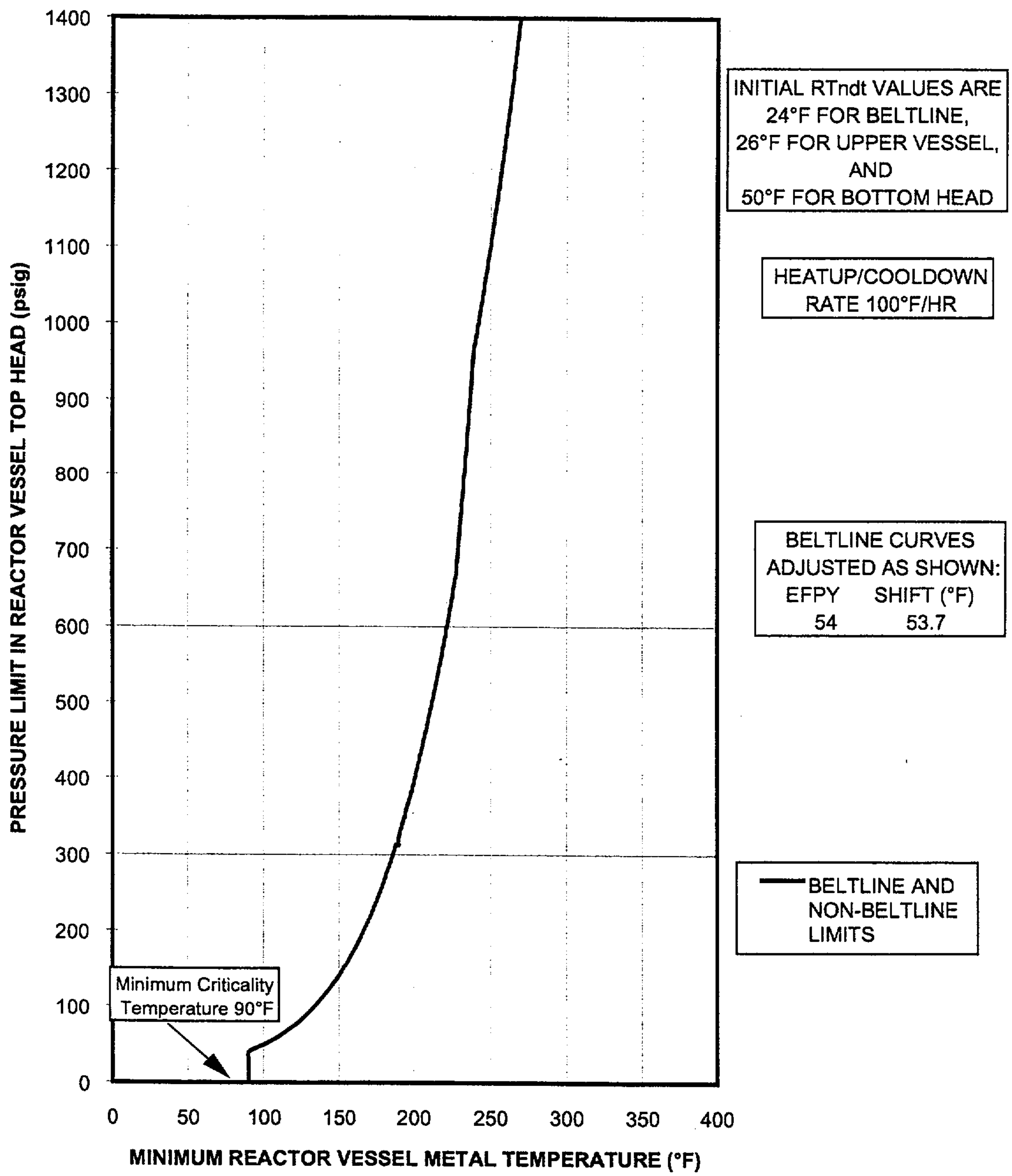

Figure 4-6: Core Critical Curve (Curve C) [Unit 2]

TABLE 4-4. Hatch Unit 1 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-1 THROUGH 4-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
0	68.0	68.0	76.0	68.0	68.0	76.0	76.0
10	68.0	68.0	76.0	68.0	68.0	76.0	76.0
20	68.0	68.0	76.0	68.0	68.0	76.0	76.0
30	68.0	68.0	76.0	68.0	68.0	76.0	90.6
40	68.0	68.0	76.0	68.0	68.0	76.0	104.5
50	68.0	68.0	76.0	68.0	68.0	76.0	115.2
60	68.0	68.0	76.0	68.0	68.0	83.9	123.9
70	68.0	68.0	76.0	68.0	68.0	91.1	131.1
80	68.0	68.0	76.0	68.0	68.0	97.4	137.4
90	68.0	68.0	76.0	68.0	68.0	102.7	142.7
100	68.0	68.0	76.0	68.0	68.0	107.5	147.5
110	68.0	68.0	76.0	68.0	68.0	111.9	151.9
120	68.0	68.0	76.0	68.0	68.0	116.1	156.1
130	68.0	68.0	76.0	68.0	68.0	120.1	160.1
140	68.0	68.0	76.0	68.0	68.0	123.6	163.6
150	68.0	68.0	76.0	68.0	68.0	126.8	166.8
160	68.0	68.0	76.0	68.0	68.0	129.8	169.8
170	68.0	68.0	76.0	68.0	68.0	132.8	172.8
180	68.0	68.0	76.0	68.0	68.0	135.6	175.6
190	68.0	68.0	76.0	68.0	68.0	138.2	178.2
200	68.0	68.0	76.0	68.0	68.0	140.6	180.6
210	68.0	68.0	76.0	68.0	68.0	142.9	182.9
220	68.0	68.0	76.0	68.0	82.2	145.2	185.2
230	68.0	68.0	76.0	68.0	97.4	147.4	187.4
240	68.0	68.0	76.0	68.0	109.8	149.4	189.4

TABLE 4-4. Hatch Unit 1 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-1 THROUGH 4-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
250	68.0	68.0	76.0	68.0	120.3	151.4	191.4
260	68.0	68.0	76.0	68.0	129.4	153.3	193.3
270	68.0	68.0	76.0	68.0	137.5	155.1	195.1
280	68.0	68.0	76.0	68.0	144.7	157.0	197.0
290	68.0	68.0	76.0	68.0	151.2	158.7	198.7
300	68.0	68.0	76.0	68.0	161.5	160.3	201.5
310	68.0	68.0	76.0	68.0	166.8	162.0	206.8
312.5	68.0	68.0	76.0	68.0	168.1	162.3	208.1
312.5	68.0	68.0	106.0	68.0	168.1	162.3	269.2
320	68.0	68.0	106.0	68.0	171.7	163.5	269.2
330	68.0	68.0	106.0	68.0	176.3	165.1	269.2
340	68.0	68.0	106.0	68.0	180.6	166.6	269.2
350	68.0	68.0	106.0	68.0	184.7	168.0	269.2
360	68.0	68.0	106.0	68.0	188.5	169.4	269.2
370	68.0	68.0	106.0	68.0	192.1	170.8	269.2
380	68.0	68.0	106.0	68.0	195.5	172.1	269.2
390	68.0	74.0	106.0	68.0	198.8	173.4	269.2
400	68.0	87.3	106.0	68.0	202.0	174.7	269.2
410	68.0	98.4	106.0	68.0	204.9	176.0	269.2
420	68.0	108.0	106.0	68.0	207.8	177.2	269.2
430	68.0	116.5	106.0	70.3	210.6	178.4	269.2
440	68.0	124.0	106.0	73.2	213.2	179.6	269.2
450	68.0	130.7	106.0	76.1	215.8	180.7	269.2
460	68.0	136.9	106.0	78.8	218.2	181.8	269.2
470	68.0	142.5	106.0	81.5	220.6	182.9	269.2
480	68.0	147.8	106.0	84.0	222.9	184.0	269.2
490	68.0	152.6	106.0	86.5	225.1	185.1	269.2

TABLE 4-4. Hatch Unit 1 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-1 THROUGH 4-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
500	68.0	157.1	106.0	88.8	227.3	186.1	269.2
510	68.0	161.4	106.0	91.1	229.3	187.1	269.3
520	68.0	165.4	106.0	93.3	231.4	188.1	271.4
530	68.0	169.2	106.0	95.5	233.3	189.1	273.3
540	68.0	172.8	106.0	97.6	235.3	190.1	275.3
550	68.0	176.2	106.0	99.6	237.1	191.1	277.1
560	68.0	179.5	106.0	101.5	238.9	192.0	278.9
570	69.5	182.6	106.0	103.5	240.7	192.9	280.7
580	71.8	185.5	106.0	105.3	242.4	193.8	282.4
590	74.0	188.4	106.0	107.1	244.1	194.7	284.1
600	76.1	191.1	106.0	108.9	245.7	195.6	285.7
610	78.2	193.8	106.0	110.6	247.3	196.5	287.3
620	80.2	196.3	106.0	112.3	248.9	197.3	288.9
630	82.1	198.7	106.0	113.9	250.4	198.2	290.4
640	84.0	201.1	106.0	115.5	251.9	199.0	291.9
650	85.9	203.4	106.7	117.1	253.4	199.8	293.4
660	87.7	205.6	108.6	118.6	254.8	200.6	294.8
670	89.4	207.7	110.4	120.1	256.2	201.4	296.2
680	91.1	209.8	112.2	121.6	257.6	201.9	297.6
690	92.8	211.8	114.0	123.0	259.0	202.3	299.0
700	94.4	213.8	115.7	124.4	260.3	202.8	300.3
710	96.0	215.7	117.4	125.8	261.6	203.2	301.6
720	97.6	217.6	119.0	127.1	262.9	203.6	302.9
730	99.1	219.4	120.6	128.4	264.1	204.0	304.1
740	100.6	221.1	122.2	129.7	265.4	204.4	305.4
750	102.0	222.8	123.7	131.0	266.6	204.8	306.6
760	103.5	224.5	125.2	132.3	267.7	205.2	307.7

TABLE 4-4. Hatch Unit 1 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-1 THROUGH 4-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
770	104.8	226.1	126.7	133.5	268.9	205.6	308.9
780	106.2	227.7	128.1	134.7	270.1	206.0	310.1
790	107.6	229.3	129.5	135.9	271.2	206.4	311.2
800	108.9	230.8	130.9	137.0	272.3	206.7	312.3
810	110.2	232.3	132.2	138.2	273.4	207.1	313.4
820	111.4	233.8	133.5	139.3	274.5	207.5	314.5
830	112.7	235.2	134.8	140.4	275.5	207.9	315.5
840	113.9	236.6	136.1	141.5	276.6	208.3	316.6
850	115.1	238.0	137.3	142.6	277.6	208.7	317.6
860	116.3	239.3	138.6	143.6	278.6	209.0	318.6
870	117.5	240.7	139.8	144.7	279.6	209.4	319.6
880	118.6	241.9	140.9	145.7	280.6	209.8	320.6
890	119.7	243.2	142.1	146.7	281.6	210.1	321.6
900	120.8	244.5	143.3	147.7	282.5	210.5	322.5
910	121.9	245.7	144.4	148.7	283.5	210.9	323.5
920	123.0	246.9	145.5	149.7	284.4	211.2	324.4
930	124.0	248.1	146.6	150.6	285.3	211.6	325.3
940	125.1	249.3	147.7	151.6	286.2	212.0	326.2
950	126.1	250.4	148.7	152.5	287.1	212.3	327.1
960	127.1	251.5	149.8	153.4	288.0	212.7	328.0
970	128.1	252.6	150.8	154.3	288.9	213.0	328.9
980	129.1	253.7	151.8	155.2	289.7	213.4	329.7
990	130.0	254.8	152.8	156.1	290.6	213.7	330.6
1000	131.0	255.9	153.8	157.0	291.4	214.1	331.4
1010	131.9	256.9	154.7	157.8	292.3	214.4	332.3
1020	132.9	257.9	155.7	158.7	293.1	214.8	333.1
1030	133.8	258.9	156.6	159.5	293.9	215.1	333.9

TABLE 4-4. Hatch Unit 1 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-1 THROUGH 4-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
1040	134.7	259.9	157.6	160.4	294.7	215.4	334.7
1050	135.6	260.9	158.5	161.2	295.5	215.8	335.5
1060	136.5	261.9	159.4	162.0	296.3	216.1	336.3
1070	137.3	262.8	160.3	162.8	297.1	216.5	337.1
1080	138.2	263.8	161.2	163.6	297.8	216.8	337.8
1090	139.0	264.7	162.0	164.4	298.6	217.1	338.6
1100	139.9	265.6	162.9	165.1	299.3	217.5	339.3
1110	140.7	266.5	163.7	165.9	300.1	217.8	340.1
1120	141.5	267.4	164.6	166.7	300.8	218.1	340.8
1130	142.3	268.3	165.4	167.4	301.5	218.4	341.5
1140	143.1	269.2	166.2	168.1	302.2	218.8	342.2
1150	143.9	270.0	167.0	168.9	303.0	219.1	343.0
1160	144.7	270.9	167.8	169.6	303.7	219.4	343.7
1170	145.5	271.7	168.6	170.3	304.4	219.7	344.4
1180	146.2	272.6	169.4	171.0	305.0	220.0	345.0
1190	147.0	273.4	170.2	171.7	305.7	220.4	345.7
1200	147.7	274.2	170.9	172.4	306.4	220.7	346.4
1210	148.5	275.0	171.7	173.1	307.1	221.0	347.1
1220	149.2	275.8	172.4	173.8	307.7	221.3	347.7
1230	149.9	276.6	173.2	174.5	308.4	221.6	348.4
1240	150.6	277.3	173.9	175.1	309.0	221.9	349.0
1250	151.3	278.1	174.6	175.8	309.7	222.2	349.7
1260	152.0	278.8	175.4	176.5	310.3	222.5	350.3
1270	152.7	279.6	176.1	177.1	311.0	222.8	351.0
1280	153.4	280.3	176.8	177.8	311.6	223.1	351.6
1290	154.1	281.1	177.5	178.4	312.2	223.4	352.2
1300	154.8	281.8	178.1	179.0	312.8	223.7	352.8

TABLE 4-4. Hatch Unit 1 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-1 THROUGH 4-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
1310	155.4	282.5	178.8	179.6	313.4	224.0	353.4
1320	156.1	283.2	179.5	180.3	314.0	224.3	354.0
1330	156.8	283.9	180.2	180.9	314.6	224.6	354.6
1340	157.4	284.6	180.8	181.5	315.2	224.9	355.2
1350	158.1	285.3	181.5	182.1	315.8	225.2	355.8
1360	158.7	286.0	182.1	182.7	316.4	225.5	356.4
1370	159.3	286.7	182.8	183.3	317.0	225.8	357.0
1380	159.9	287.3	183.4	183.9	317.6	226.1	357.6
1390	160.6	288.0	184.0	184.5	318.1	226.4	358.1
1400	161.2	288.6	184.7	185.0	318.7	226.7	358.7

TABLE 4-5. Hatch Unit 2 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-4 THROUGH 4-6)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
0	68.0	68.0	90.0	68.0	68.0	90.0	90.0
10	68.0	68.0	90.0	68.0	68.0	90.0	90.0
20	68.0	68.0	90.0	68.0	68.0	90.0	90.0
30	68.0	68.0	90.0	68.0	68.0	90.0	90.0
40	68.0	68.0	90.0	68.0	68.0	90.0	90.5
50	68.0	68.0	90.0	68.0	68.0	90.0	101.2
60	68.0	68.0	90.0	68.0	68.0	90.0	109.9
70	68.0	68.0	90.0	68.0	68.0	90.0	117.1
80	68.0	68.0	90.0	68.0	68.0	90.0	123.4
90	68.0	68.0	90.0	68.0	68.0	90.0	128.7
100	68.0	68.0	90.0	68.0	68.0	93.5	133.5
110	68.0	68.0	90.0	68.0	68.0	97.9	137.9
120	68.0	68.0	90.0	68.0	68.0	102.1	142.1
130	68.0	68.0	90.0	68.0	68.0	106.1	146.1
140	68.0	68.0	90.0	68.0	68.0	109.6	149.6
150	68.0	68.0	90.0	68.0	68.0	112.8	152.8
160	68.0	68.0	90.0	68.0	68.0	115.8	155.8
170	68.0	68.0	90.0	68.0	68.0	118.8	158.8
180	68.0	68.0	90.0	68.0	68.0	121.6	161.6
190	68.0	68.0	90.0	68.0	68.0	124.2	164.2
200	68.0	68.0	90.0	68.0	68.0	126.6	166.6
210	68.0	68.0	90.0	68.0	68.0	128.9	168.9
220	68.0	68.0	90.0	68.0	68.0	131.2	171.2
230	68.0	68.0	90.0	68.0	68.0	133.4	173.4
240	68.0	68.0	90.0	68.0	68.0	135.4	175.4
250	68.0	68.0	90.0	68.0	68.0	137.4	177.4
260	68.0	68.0	90.0	68.0	68.0	139.3	179.3

TABLE 4-5. Hatch Unit 2 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-4 THROUGH 4-6)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
270	68.0	68.0	90.0	68.0	68.0	141.1	181.1
280	68.0	68.0	90.0	68.0	68.0	143.0	183.0
290	68.0	68.0	90.0	68.0	68.0	144.7	184.7
300	68.0	68.0	90.0	68.0	68.0	146.3	186.3
310	68.0	68.0	90.0	68.0	71.5	148.0	188.0
312.5	68.0	68.0	90.0	68.0	72.9	148.3	188.3
312.5	68.0	68.0	120.0	68.0	72.9	150.0	190.0
320	68.0	68.0	120.0	68.0	76.8	150.0	190.0
330	68.0	68.0	120.0	70.1	81.6	151.1	191.1
340	68.0	68.0	120.0	75.4	86.1	152.6	192.6
350	68.0	68.0	120.0	80.2	94.0	154.0	194.0
360	68.0	68.0	120.0	84.8	97.9	155.4	195.4
370	68.0	68.0	120.0	89.0	101.6	156.8	196.8
380	68.0	68.0	120.0	93.1	105.1	158.1	198.1
390	68.0	68.0	120.0	96.9	108.5	159.4	199.4
400	68.0	68.0	120.0	100.5	111.6	160.7	200.7
410	68.0	68.0	120.0	103.9	114.7	162.0	202.0
420	68.0	68.0	120.0	107.2	117.6	163.2	203.2
430	68.0	68.0	120.0	110.3	120.4	164.4	204.4
440	70.1	68.0	120.0	113.2	123.1	165.6	205.6
450	74.1	68.0	120.0	116.1	125.6	166.7	206.7
460	77.8	68.0	120.0	118.8	128.1	167.8	207.8
470	81.4	68.0	120.0	121.5	130.5	168.9	208.9
480	84.8	68.0	120.0	124.0	132.9	170.0	210.0
490	88.0	68.0	120.0	126.5	135.1	171.1	211.1
500	91.1	68.0	120.0	128.8	137.3	172.1	212.1
510	94.0	72.2	120.0	131.1	139.4	173.1	213.1

TABLE 4-5. Hatch Unit 2 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-4 THROUGH 4-6)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
520	96.9	76.2	120.0	133.3	141.4	174.1	214.1
530	99.6	80.0	120.0	135.5	143.4	175.1	215.1
540	102.2	83.6	120.0	137.6	145.3	176.1	216.1
550	104.7	87.0	120.0	139.6	147.2	177.1	217.1
560	107.2	90.3	120.0	141.5	149.1	178.0	218.0
570	109.5	93.4	120.0	143.5	150.8	178.9	218.9
580	111.8	96.3	120.0	145.3	152.6	179.8	219.8
590	114.0	99.2	120.0	147.1	154.3	180.7	220.7
600	116.1	101.9	120.0	148.9	155.9	181.6	221.6
610	118.2	104.5	120.0	150.6	157.5	182.5	222.5
620	120.2	107.1	120.0	152.3	159.1	183.3	223.3
630	122.1	109.5	120.0	153.9	160.7	184.2	224.2
640	124.0	111.9	120.0	155.5	162.2	185.0	225.0
650	125.9	114.2	120.0	157.1	163.6	185.8	225.8
660	127.7	116.4	120.0	158.6	165.1	186.6	226.6
670	129.4	118.5	120.0	160.1	166.5	187.4	227.4
680	131.1	120.6	120.0	161.6	167.9	187.9	227.9
690	132.8	122.6	120.0	163.0	169.2	188.3	228.3
700	134.4	124.6	120.0	164.4	170.6	188.8	228.8
710	136.0	126.5	120.0	165.8	171.9	189.2	229.2
720	137.6	128.3	120.0	167.1	173.2	189.6	229.6
730	139.1	130.1	120.0	168.4	174.4	190.0	230.0
740	140.6	131.9	120.0	169.7	175.7	190.4	230.4
750	142.0	133.6	120.0	171.0	176.9	190.8	230.8
760	143.5	135.3	120.0	172.3	178.1	191.2	231.2
770	144.8	136.9	120.0	173.5	179.3	191.6	231.6
780	146.2	138.5	120.0	174.7	180.4	192.0	232.0

TABLE 4-5. Hatch Unit 2 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-4 THROUGH 4-6)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
790	147.6	140.1	120.0	175.9	181.5	192.4	232.4
800	148.9	141.6	120.0	177.0	182.7	192.7	232.7
810	150.2	143.1	120.0	178.2	183.8	193.1	233.1
820	151.4	144.5	120.0	179.3	184.8	193.5	233.5
830	152.7	146.0	120.8	180.4	185.9	193.9	233.9
840	153.9	147.4	122.1	181.5	187.0	194.3	234.3
850	155.1	148.7	123.3	182.6	188.0	194.7	234.7
860	156.3	150.1	124.6	183.6	189.0	195.0	235.0
870	157.5	151.4	125.8	184.7	190.0	195.4	235.4
880	158.6	152.7	126.9	185.7	191.0	195.8	235.8
890	159.7	154.0	128.1	186.7	192.0	196.1	236.1
900	160.8	155.2	129.3	187.7	192.9	196.5	236.5
910	161.9	156.5	130.4	188.7	193.9	196.9	236.9
920	163.0	157.7	131.5	189.7	194.8	197.2	237.2
930	164.0	158.8	132.6	190.6	195.8	197.6	237.6
940	165.1	160.0	133.7	191.6	196.7	198.0	238.0
950	166.1	161.2	134.7	192.5	197.6	198.3	238.3
960	167.1	162.3	135.8	193.4	198.5	198.7	238.7
970	168.1	163.4	136.8	194.3	199.3	199.0	239.3
980	169.1	164.5	137.8	195.2	200.2	199.4	240.2
990	170.0	165.6	138.8	196.1	201.0	199.7	241.0
1000	171.0	166.6	139.8	197.0	201.9	200.1	241.9
1010	171.9	167.7	140.7	197.8	202.7	200.4	242.7
1020	172.9	168.7	141.7	198.7	203.5	200.8	243.5
1030	173.8	169.7	142.6	199.5	204.4	201.1	244.4
1040	174.7	170.7	143.6	200.4	205.2	201.4	245.2
1050	175.6	171.7	144.5	201.2	206.0	201.8	246.0

TABLE 4-5. Hatch Unit 2 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-4 THROUGH 4-6)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
1060	176.5	172.6	145.4	202.0	206.7	202.1	246.7
1070	177.3	173.6	146.3	202.8	207.5	202.5	247.5
1080	178.2	174.5	147.2	203.6	208.3	202.8	248.3
1090	179.0	175.5	148.0	204.4	209.1	203.1	249.1
1100	179.9	176.4	148.9	205.1	209.8	203.5	249.8
1110	180.7	177.3	149.7	205.9	210.6	203.8	250.6
1120	181.5	178.2	150.6	206.7	211.3	204.1	251.3
1130	182.3	179.1	151.4	207.4	212.0	204.4	252.0
1140	183.1	179.9	152.2	208.1	212.7	204.8	252.7
1150	183.9	180.8	153.0	208.9	213.4	205.1	253.4
1160	184.7	181.6	153.8	209.6	214.2	205.4	254.2
1170	185.5	182.5	154.6	210.3	214.9	205.7	254.9
1180	186.2	183.3	155.4	211.0	215.5	206.0	255.5
1190	187.0	184.1	156.2	211.7	216.2	206.4	256.2
1200	187.7	184.9	156.9	212.4	216.9	206.7	256.9
1210	188.5	185.7	157.7	213.1	217.6	207.0	257.6
1220	189.2	186.5	158.4	213.8	218.2	207.3	258.2
1230	189.9	187.3	159.2	214.5	218.9	207.6	258.9
1240	190.6	188.1	159.9	215.1	219.6	207.9	259.6
1250	191.3	188.8	160.6	215.8	220.2	208.2	260.2
1260	192.0	189.6	161.4	216.5	220.8	208.5	260.8
1270	192.7	190.3	162.1	217.1	221.5	208.8	261.5
1280	193.4	191.1	162.8	217.8	222.1	209.1	262.1
1290	194.1	191.8	163.5	218.4	222.7	209.4	262.7
1300	194.8	192.5	164.1	219.0	223.3	209.7	263.3
1310	195.4	193.3	164.8	219.6	224.0	210.0	264.0
1320	196.1	194.0	165.5	220.3	224.6	210.3	264.6

TABLE 4-5. Hatch Unit 2 P-T Curve Values for 54 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES 4-4 THROUGH 4-6)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY RPV CURVE C (°F)
1330	196.8	194.7	166.2	220.9	225.2	210.6	265.2
1340	197.4	195.4	166.8	221.5	225.8	210.9	265.8
1350	198.1	196.1	167.5	222.1	226.4	211.2	266.4
1360	198.7	196.7	168.1	222.7	226.9	211.5	266.9
1370	199.3	197.4	168.8	223.3	227.5	211.8	267.5
1380	199.9	198.1	169.4	223.9	228.1	212.1	268.1
1390	200.6	198.7	170.0	224.5	228.7	212.4	268.7
1400	201.2	199.4	170.7	225.0	229.2	212.7	269.2

5. REFERENCES

[1] "Fracture Toughness Requirements", Appendix G to Part 50 of Title 10 of the Code of Federal Regulations, December 1995.

[2] Carey, R. G., "Extended Power Uprate Evaluation Task Report for Edwin I. Hatch Plant Units 1 & 2, Revised Impact on Vessel Fracture Toughness," GE-NE-A13-00402-9, March 1998.

[3] "Radiation Embrittlement of Reactor Vessel Materials", USNRC Regulatory Guide 1.99, Revision 2, May 1988

[4] H. S. Mehta, T. A. Caine, and S. E. Plaxton, "10 CFR 50 Appendix G Equivalent Margin Analysis for Low Upper Shelf Energy in BWR/2 through BWR/6 Vessels, Rev. 1," GENE, San Jose, CA, February, 1994, (NEDO-32205-A).

[5] "PVRC Recommendations on Toughness Requirements for Ferritic Materials", Welding Research Council Bulletin 175, August 1972.

[6] Frew, B. D., "Plant Hatch Unit 1 RPV Surveillance Materials Testing and Analysis", GE-NE-B1100691-01R1, March 1997.

[7] Caine, T. A. "E.I. Hatch Nuclear Power Station Unit 2 Vessel Surveillance Materials Testing and Fracture Toughness Analysis,", SASR 90-104, May 1991.

[8] Protection Against Non-Ductile Failure", Appendix G to Section XI of the 1989 ASME Boiler & Pressure Vessel Code.

[9] Design Stress Intensity Values, Allowable Stresses, Material Properties, and Design Fatigue Curves", Section III Appendix I of the 1989 ASME Boiler and Pressure Vessel Code.

APPENDIX A
HATCH UNIT 1 P-T CURVES
VALID TO 36 EFPY

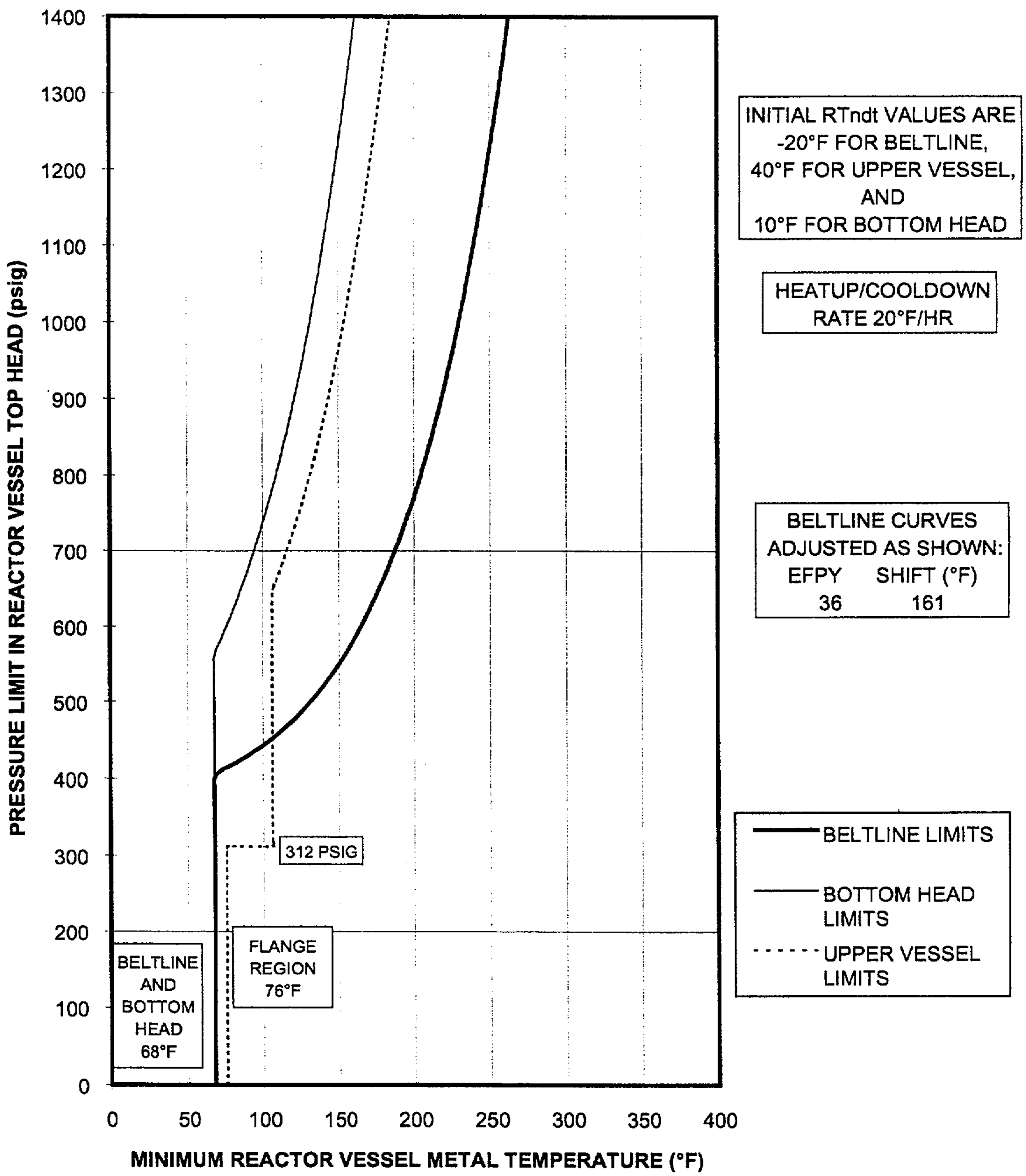

Figure A-1: P-T Curve for Unit 1 (Curve A)

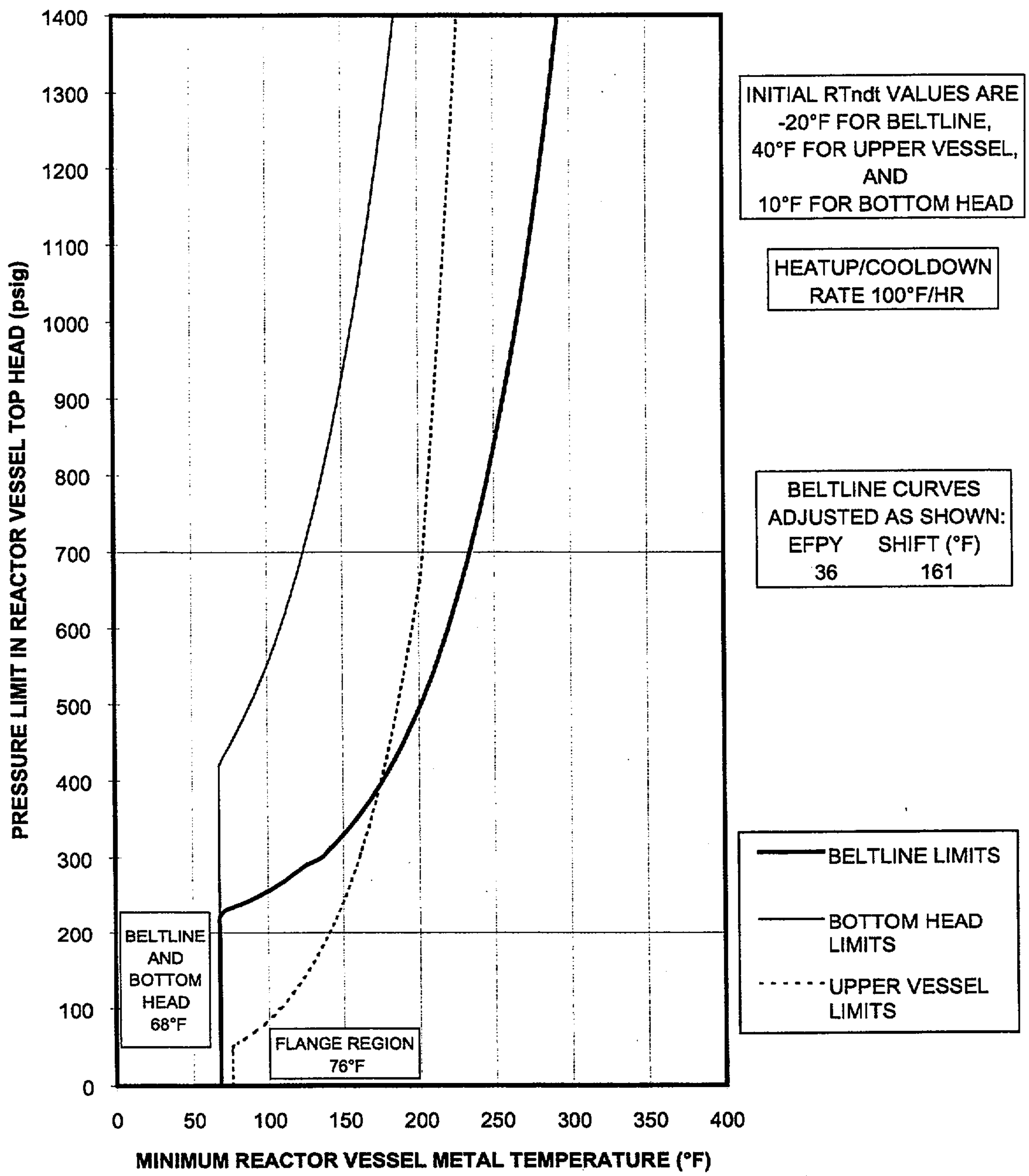

Figure A-2: P-T Curve for Unit 1 (Curve B)

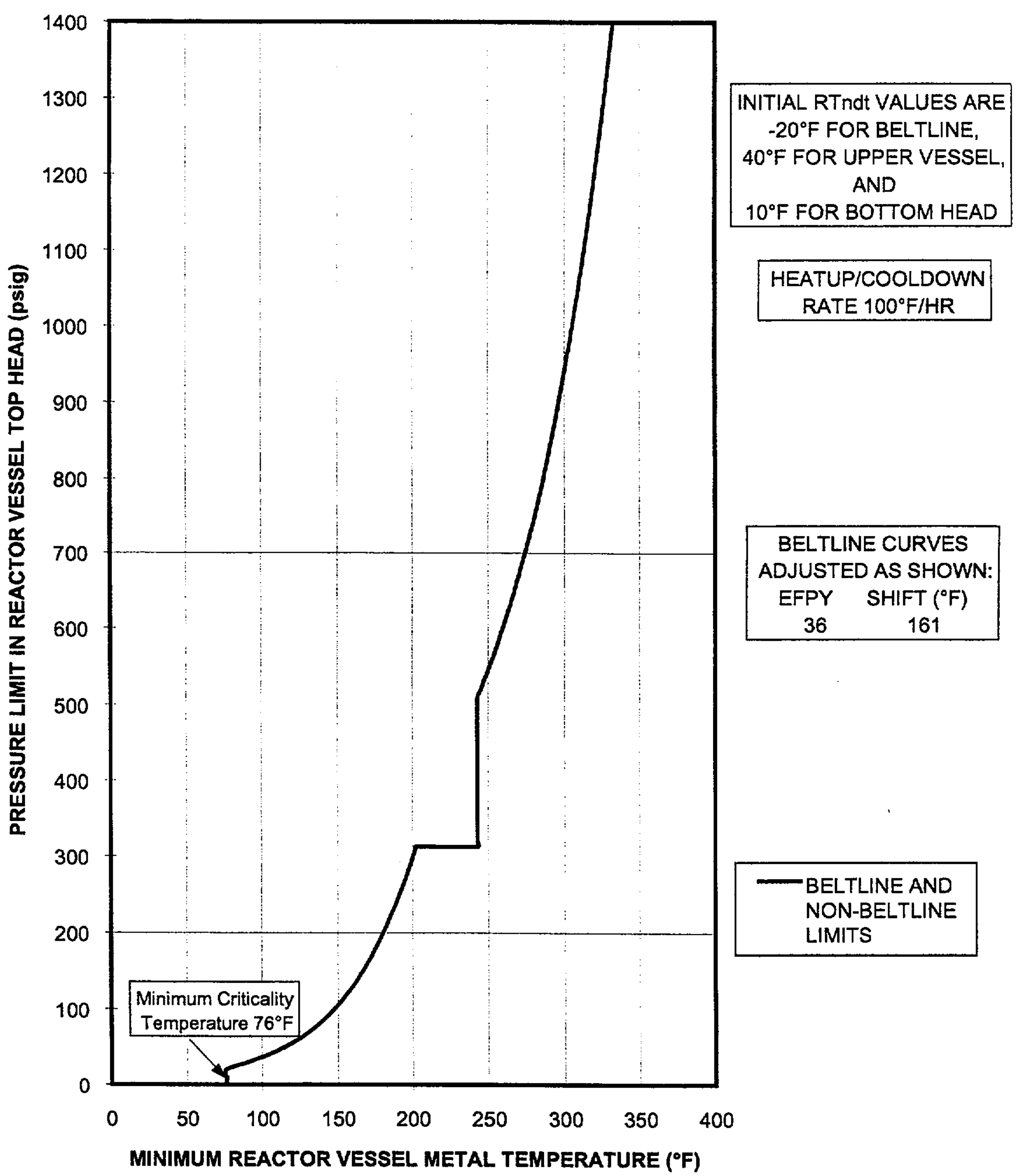

Figure A-3: P-T Curve for Unit 1 (Curve C)

TABLE A-1. Hatch Unit 1 P-T Curve Values for 36 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES A-1 THROUGH A-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	36 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	36 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	36 EFPY RPV CURVE C (°F)
0	68.0	68.0	76.0	68.0	68.0	76.0	76.0
10	68.0	68.0	76.0	68.0	68.0	76.0	76.0
20	68.0	68.0	76.0	68.0	68.0	76.0	76.0
30	68.0	68.0	76.0	68.0	68.0	76.0	90.6
40	68.0	68.0	76.0	68.0	68.0	76.0	104.5
50	68.0	68.0	76.0	68.0	68.0	76.0	115.2
60	68.0	68.0	76.0	68.0	68.0	83.9	123.9
70	68.0	68.0	76.0	68.0	68.0	91.1	131.1
80	68.0	68.0	76.0	68.0	68.0	97.4	137.4
90	68.0	68.0	76.0	68.0	68.0	102.7	142.7
100	68.0	68.0	76.0	68.0	68.0	107.5	147.5
110	68.0	68.0	76.0	68.0	68.0	111.9	151.9
120	68.0	68.0	76.0	68.0	68.0	116.1	156.1
130	68.0	68.0	76.0	68.0	68.0	120.1	160.1
140	68.0	68.0	76.0	68.0	68.0	123.6	163.6
150	68.0	68.0	76.0	68.0	68.0	126.8	166.8
160	68.0	68.0	76.0	68.0	68.0	129.8	169.8
170	68.0	68.0	76.0	68.0	68.0	132.8	172.8
180	68.0	68.0	76.0	68.0	68.0	135.6	175.6
190	68.0	68.0	76.0	68.0	68.0	138.2	178.2
200	68.0	68.0	76.0	68.0	68.0	140.6	180.6
210	68.0	68.0	76.0	68.0	68.0	142.9	182.9
220	68.0	68.0	76.0	68.0	68.0	145.2	185.2
230	68.0	68.0	76.0	68.0	71.2	147.4	187.4
240	68.0	68.0	76.0	68.0	83.6	149.4	189.4
250	68.0	68.0	76.0	68.0	94.1	151.4	191.4
260	68.0	68.0	76.0	68.0	103.2	153.3	193.3

TABLE A-1. Hatch Unit 1 P-T Curve Values for 36 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES A-1 THROUGH A-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	36 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	36 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	36 EFPY RPV CURVE C (°F)
270	68.0	68.0	76.0	68.0	111.3	155.1	195.1
280	68.0	68.0	76.0	68.0	118.5	157.0	197.0
290	68.0	68.0	76.0	68.0	125.0	158.7	198.7
300	68.0	68.0	76.0	68.0	135.3	160.3	200.3
310	68.0	68.0	76.0	68.0	140.6	162.0	202.0
312.5	68.0	68.0	76.0	68.0	141.9	162.3	202.3
312.5	68.0	68.0	106.0	68.0	141.9	162.3	243.0
320	68.0	68.0	106.0	68.0	145.5	163.5	243.0
330	68.0	68.0	106.0	68.0	150.1	165.1	243.0
340	68.0	68.0	106.0	68.0	154.4	166.6	243.0
350	68.0	68.0	106.0	68.0	158.5	168.0	243.0
360	68.0	68.0	106.0	68.0	162.3	169.4	243.0
370	68.0	68.0	106.0	68.0	165.9	170.8	243.0
380	68.0	68.0	106.0	68.0	169.3	172.1	243.0
390	68.0	68.0	106.0	68.0	172.6	173.4	243.0
400	68.0	68.0	106.0	68.0	175.8	174.7	243.0
410	68.0	72.2	106.0	68.0	178.7	176.0	243.0
420	68.0	81.8	106.0	68.0	181.6	177.2	243.0
430	68.0	90.3	106.0	70.3	184.4	178.4	243.0
440	68.0	97.8	106.0	73.2	187.0	179.6	243.0
450	68.0	104.5	106.0	76.1	189.6	180.7	243.0
460	68.0	110.7	106.0	78.8	192.0	181.8	243.0
470	68.0	116.3	106.0	81.5	194.4	182.9	243.0
480	68.0	121.6	106.0	84.0	196.7	184.0	243.0
490	68.0	126.4	106.0	86.5	198.9	185.1	243.0
500	68.0	130.9	106.0	88.8	201.1	186.1	243.0
510	68.0	135.2	106.0	91.1	203.1	187.1	243.1

TABLE A-1. Hatch Unit 1 P-T Curve Values for 36 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES A-1 THROUGH A-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	36 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	36 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	36 EFPY RPV CURVE C (°F)
520	68.0	139.2	106.0	93.3	205.2	188.1	245.2
530	68.0	143.0	106.0	95.5	207.1	189.1	247.1
540	68.0	146.6	106.0	97.6	209.1	190.1	249.1
550	68.0	150.0	106.0	99.6	210.9	191.1	250.9
560	68.0	153.3	106.0	101.5	212.7	192.0	252.7
570	69.5	156.4	106.0	103.5	214.5	192.9	254.5
580	71.8	159.3	106.0	105.3	216.2	193.8	256.2
590	74.0	162.2	106.0	107.1	217.9	194.7	257.9
600	76.1	164.9	106.0	108.9	219.5	195.6	259.5
610	78.2	167.6	106.0	110.6	221.1	196.5	261.1
620	80.2	170.1	106.0	112.3	222.7	197.3	262.7
630	82.1	172.5	106.0	113.9	224.2	198.2	264.2
640	84.0	174.9	106.0	115.5	225.7	199.0	265.7
650	85.9	177.2	106.7	117.1	227.2	199.8	267.2
660	87.7	179.4	108.6	118.6	228.6	200.6	268.6
670	89.4	181.5	110.4	120.1	230.0	201.4	270.0
680	91.1	183.6	112.2	121.6	231.4	201.9	271.4
690	92.8	185.6	114.0	123.0	232.8	202.3	272.8
700	94.4	187.6	115.7	124.4	234.1	202.8	274.1
710	96.0	189.5	117.4	125.8	235.4	203.2	275.4
720	97.6	191.4	119.0	127.1	236.7	203.6	276.7
730	99.1	193.2	120.6	128.4	237.9	204.0	277.9
740	100.6	194.9	122.2	129.7	239.2	204.4	279.2
750	102.0	196.6	123.7	131.0	240.4	204.8	280.4
760	103.5	198.3	125.2	132.3	241.5	205.2	281.5
770	104.8	199.9	126.7	133.5	242.7	205.6	282.7
780	106.2	201.5	128.1	134.7	243.9	206.0	283.9

TABLE A-1. Hatch Unit 1 P-T Curve Values for 36 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES A-1 THROUGH A-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	36 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	36 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	36 EFPY RPV CURVE C (°F)
790	107.6	203.1	129.5	135.9	245.0	206.4	285.0
800	108.9	204.6	130.9	137.0	246.1	206.7	286.1
810	110.2	206.1	132.2	138.2	247.2	207.1	287.2
820	111.4	207.6	133.5	139.3	248.3	207.5	288.3
830	112.7	209.0	134.8	140.4	249.3	207.9	289.3
840	113.9	210.4	136.1	141.5	250.4	208.3	290.4
850	115.1	211.8	137.3	142.6	251.4	208.7	291.4
860	116.3	213.1	138.6	143.6	252.4	209.0	292.4
870	117.5	214.5	139.8	144.7	253.4	209.4	293.4
880	118.6	215.7	140.9	145.7	254.4	209.8	294.4
890	119.7	217.0	142.1	146.7	255.4	210.1	295.4
900	120.8	218.3	143.3	147.7	256.3	210.5	296.3
910	121.9	219.5	144.4	148.7	257.3	210.9	297.3
920	123.0	220.7	145.5	149.7	258.2	211.2	298.2
930	124.0	221.9	146.6	150.6	259.1	211.6	299.1
940	125.1	223.1	147.7	151.6	260.0	212.0	300.0
950	126.1	224.2	148.7	152.5	260.9	212.3	300.9
960	127.1	225.3	149.8	153.4	261.8	212.7	301.8
970	128.1	226.4	150.8	154.3	262.7	213.0	302.7
980	129.1	227.5	151.8	155.2	263.5	213.4	303.5
990	130.0	228.6	152.8	156.1	264.4	213.7	304.4
1000	131.0	229.7	153.8	157.0	265.2	214.1	305.2
1010	131.9	230.7	154.7	157.8	266.1	214.4	306.1
1020	132.9	231.7	155.7	158.7	266.9	214.8	306.9
1030	133.8	232.7	156.6	159.5	267.7	215.1	307.7
1040	134.7	233.7	157.6	160.4	268.5	215.4	308.5
1050	135.6	234.7	158.5	161.2	269.3	215.8	309.3

TABLE A-1. Hatch Unit 1 P-T Curve Values for 36 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES A-1 THROUGH A-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	36 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	36 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	36 EFPY RPV CURVE C (°F)
1060	136.5	235.7	159.4	162.0	270.1	216.1	310.1
1070	137.3	236.6	160.3	162.8	270.9	216.5	310.9
1080	138.2	237.6	161.2	163.6	271.6	216.8	311.6
1090	139.0	238.5	162.0	164.4	272.4	217.1	312.4
1100	139.9	239.4	162.9	165.1	273.1	217.5	313.1
1110	140.7	240.3	163.7	165.9	273.9	217.8	313.9
1120	141.5	241.2	164.6	166.7	274.6	218.1	314.6
1130	142.3	242.1	165.4	167.4	275.3	218.4	315.3
1140	143.1	243.0	166.2	168.1	276.0	218.8	316.0
1150	143.9	243.8	167.0	168.9	276.8	219.1	316.8
1160	144.7	244.7	167.8	169.6	277.5	219.4	317.5
1170	145.5	245.5	168.6	170.3	278.2	219.7	318.2
1180	146.2	246.4	169.4	171.0	278.8	220.0	318.8
1190	147.0	247.2	170.2	171.7	279.5	220.4	319.5
1200	147.7	248.0	170.9	172.4	280.2	220.7	320.2
1210	148.5	248.8	171.7	173.1	280.9	221.0	320.9
1220	149.2	249.6	172.4	173.8	281.5	221.3	321.5
1230	149.9	250.4	173.2	174.5	282.2	221.6	322.2
1240	150.6	251.1	173.9	175.1	282.8	221.9	322.8
1250	151.3	251.9	174.6	175.8	283.5	222.2	323.5
1260	152.0	252.6	175.4	176.5	284.1	222.5	324.1
1270	152.7	253.4	176.1	177.1	284.8	222.8	324.8
1280	153.4	254.1	176.8	177.8	285.4	223.1	325.4
1290	154.1	254.9	177.5	178.4	286.0	223.4	326.0
1300	154.8	255.6	178.1	179.0	286.6	223.7	326.6
1310	155.4	256.3	178.8	179.6	287.2	224.0	327.2
1320	156.1	257.0	179.5	180.3	287.8	224.3	327.8

TABLE A-1. Hatch Unit 1 P-T Curve Values for 36 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES A-1 THROUGH A-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	36 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	36 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	36 EFPY RPV CURVE C (°F)
1330	156.8	257.7	180.2	180.9	288.4	224.6	328.4
1340	157.4	258.4	180.8	181.5	289.0	224.9	329.0
1350	158.1	259.1	181.5	182.1	289.6	225.2	329.6
1360	158.7	259.8	182.1	182.7	290.2	225.5	330.2
1370	159.3	260.5	182.8	183.3	290.8	225.8	330.8
1380	159.9	261.1	183.4	183.9	291.4	226.1	331.4
1390	160.6	261.8	184.0	184.5	291.9	226.4	331.9
1400	161.2	262.4	184.7	185.0	292.5	226.7	332.5

APPENDIX B
HATCH UNIT 1 P-T CURVES
VALID TO 40 EFPY

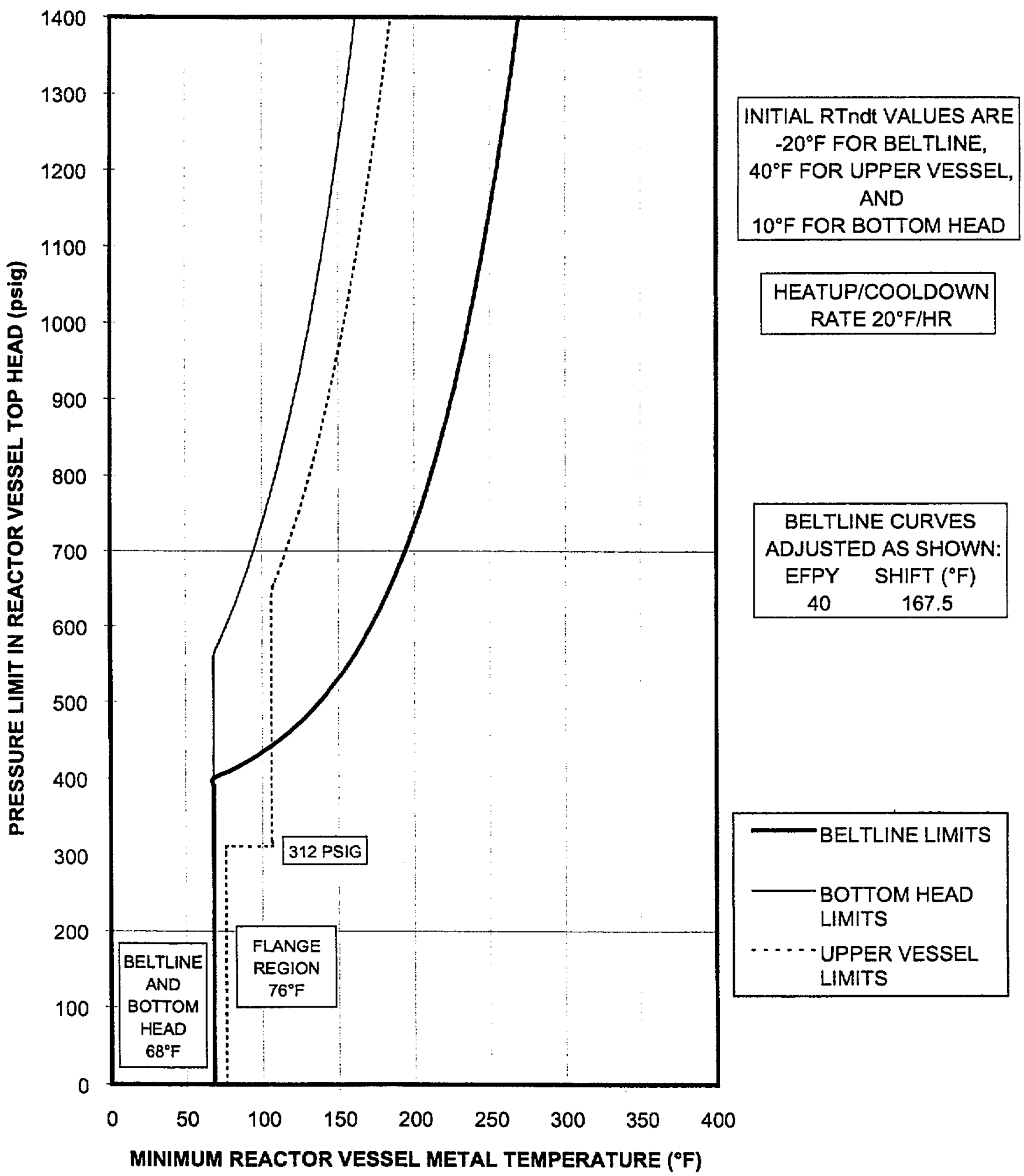

Figure B-1: P-T Curve for Unit 1 (Curve A)

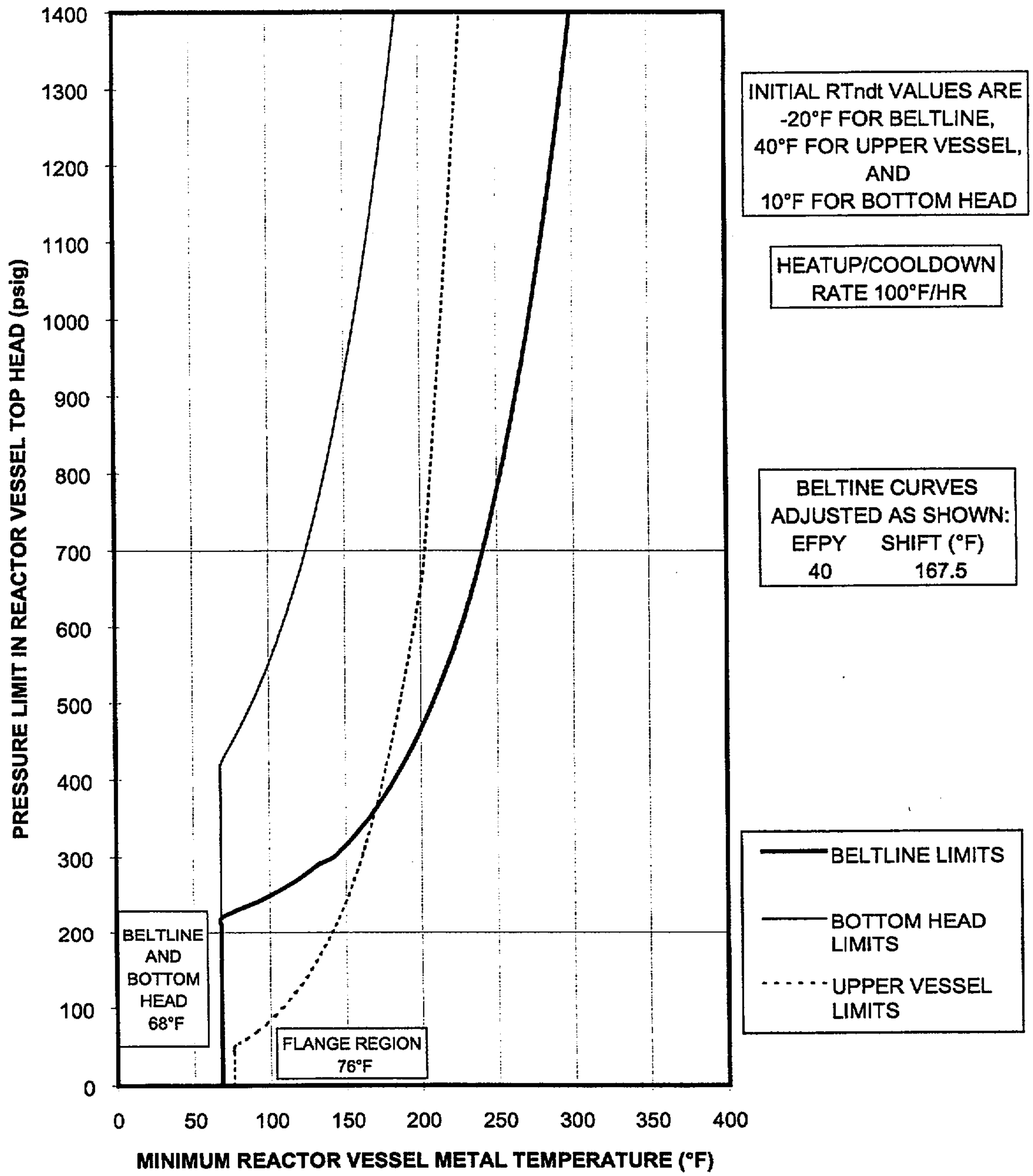

Figure B-2: P-T Curve for Unit 1 (Curve B)

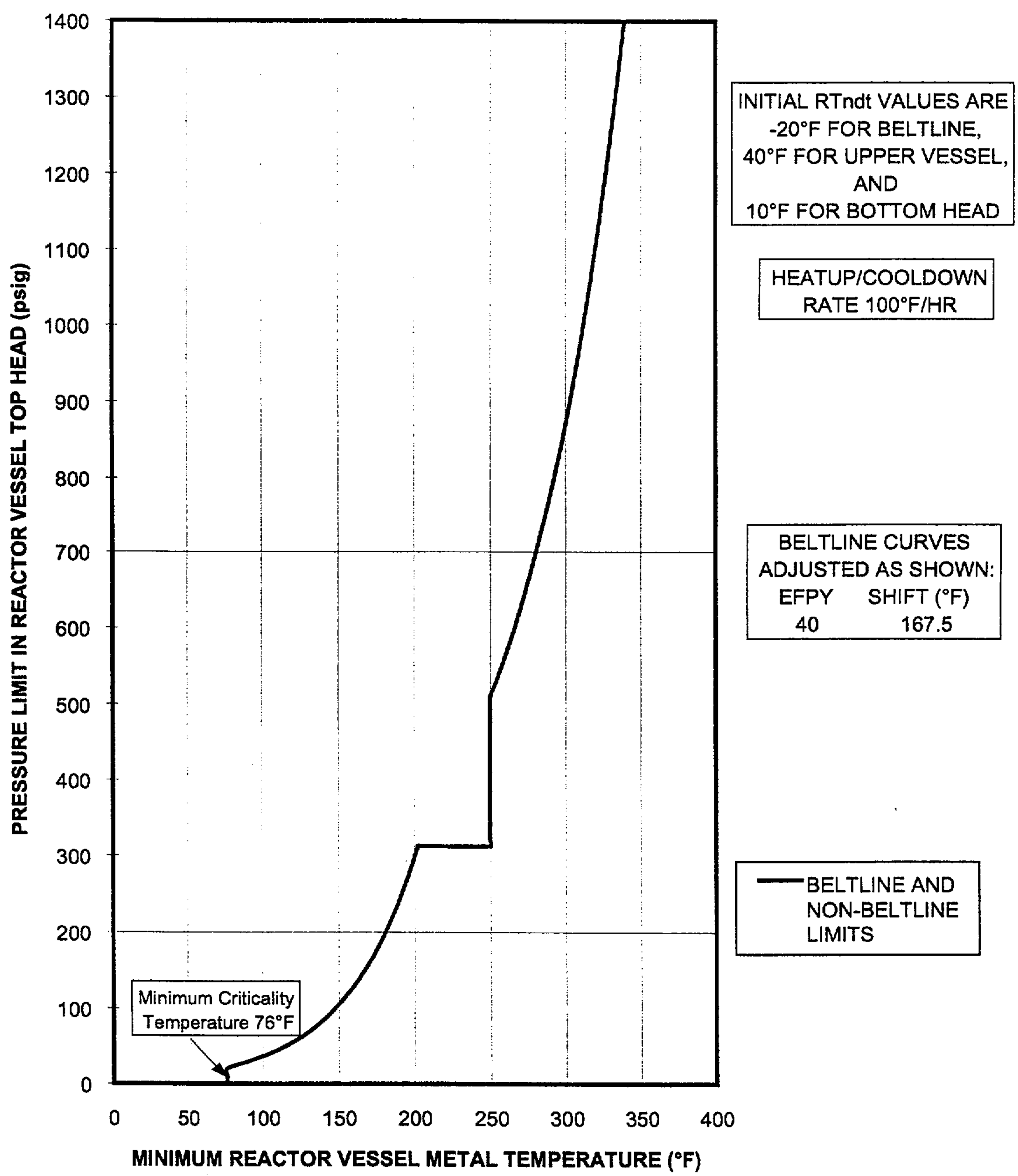

Figure B-3: P-T Curve for Unit 1 (Curve C)

TABLE B-1. Hatch Unit 1 P-T Curve Values for 40 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES B-1 THROUGH B-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	40 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	40 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	40 EFPY RPV CURVE C (°F)
0	68.0	68.0	76.0	68.0	68.0	76.0	76.0
10	68.0	68.0	76.0	68.0	68.0	76.0	76.0
20	68.0	68.0	76.0	68.0	68.0	76.0	76.0
30	68.0	68.0	76.0	68.0	68.0	76.0	90.6
40	68.0	68.0	76.0	68.0	68.0	76.0	104.5
50	68.0	68.0	76.0	68.0	68.0	76.0	115.2
60	68.0	68.0	76.0	68.0	68.0	83.9	123.9
70	68.0	68.0	76.0	68.0	68.0	91.1	131.1
80	68.0	68.0	76.0	68.0	68.0	97.4	137.4
90	68.0	68.0	76.0	68.0	68.0	102.7	142.7
100	68.0	68.0	76.0	68.0	68.0	107.5	147.5
110	68.0	68.0	76.0	68.0	68.0	111.9	151.9
120	68.0	68.0	76.0	68.0	68.0	116.1	156.1
130	68.0	68.0	76.0	68.0	68.0	120.1	160.1
140	68.0	68.0	76.0	68.0	68.0	123.6	163.6
150	68.0	68.0	76.0	68.0	68.0	126.8	166.8
160	68.0	68.0	76.0	68.0	68.0	129.8	169.8
170	68.0	68.0	76.0	68.0	68.0	132.8	172.8
180	68.0	68.0	76.0	68.0	68.0	135.6	175.6
190	68.0	68.0	76.0	68.0	68.0	138.2	178.2
200	68.0	68.0	76.0	68.0	68.0	140.6	180.6
210	68.0	68.0	76.0	68.0	68.0	142.9	182.9
220	68.0	68.0	76.0	68.0	68.0	145.2	185.2
230	68.0	68.0	76.0	68.0	77.7	147.4	187.4
240	68.0	68.0	76.0	68.0	90.1	149.4	189.4
250	68.0	68.0	76.0	68.0	100.6	151.4	191.4

TABLE B-1. Hatch Unit 1 P-T Curve Values for 40 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES B-1 THROUGH B-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	40 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	40 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	40 EFPY RPV CURVE C (°F)
260	68.0	68.0	76.0	68.0	109.7	153.3	193.3
270	68.0	68.0	76.0	68.0	117.8	155.1	195.1
280	68.0	68.0	76.0	68.0	125.0	157.0	197.0
290	68.0	68.0	76.0	68.0	131.5	158.7	198.7
300	68.0	68.0	76.0	68.0	141.8	160.3	200.3
310	68.0	68.0	76.0	68.0	147.1	162.0	202.0
312.5	68.0	68.0	76.0	68.0	148.4	162.3	202.3
312.5	68.0	68.0	106.0	68.0	148.4	162.3	249.5
320	68.0	68.0	106.0	68.0	152.0	163.5	249.5
330	68.0	68.0	106.0	68.0	156.6	165.1	249.5
340	68.0	68.0	106.0	68.0	160.9	166.6	249.5
350	68.0	68.0	106.0	68.0	165.0	168.0	249.5
360	68.0	68.0	106.0	68.0	168.8	169.4	249.5
370	68.0	68.0	106.0	68.0	172.4	170.8	249.5
380	68.0	68.0	106.0	68.0	175.8	172.1	249.5
390	68.0	68.0	106.0	68.0	179.1	173.4	249.5
400	68.0	68.0	106.0	68.0	182.3	174.7	249.5
410	68.0	78.7	106.0	68.0	185.2	176.0	249.5
420	68.0	88.3	106.0	68.0	188.1	177.2	249.5
430	68.0	96.8	106.0	70.3	190.9	178.4	249.5
440	68.0	104.3	106.0	73.2	193.5	179.6	249.5
450	68.0	111.0	106.0	76.1	196.1	180.7	249.5
460	68.0	117.2	106.0	78.8	198.5	181.8	249.5
470	68.0	122.8	106.0	81.5	200.9	182.9	249.5
480	68.0	128.1	106.0	84.0	203.2	184.0	249.5
490	68.0	132.9	106.0	86.5	205.4	185.1	249.5
500	68.0	137.4	106.0	88.8	207.6	186.1	249.5

TABLE B-1. Hatch Unit 1 P-T Curve Values for 40 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES B-1 THROUGH B-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	40 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	40 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	40 EFPY RPV CURVE C (°F)
510	68.0	141.7	106.0	91.1	209.6	187.1	249.6
520	68.0	145.7	106.0	93.3	211.7	188.1	251.7
530	68.0	149.5	106.0	95.5	213.6	189.1	253.6
540	68.0	153.1	106.0	97.6	215.6	190.1	255.6
550	68.0	156.5	106.0	99.6	217.4	191.1	257.4
560	68.0	159.8	106.0	101.5	219.2	192.0	259.2
570	69.5	162.9	106.0	103.5	221.0	192.9	261.0
580	71.8	165.8	106.0	105.3	222.7	193.8	262.7
590	74.0	168.7	106.0	107.1	224.4	194.7	264.4
600	76.1	171.4	106.0	108.9	226.0	195.6	266.0
610	78.2	174.1	106.0	110.6	227.6	196.5	267.6
620	80.2	176.6	106.0	112.3	229.2	197.3	269.2
630	82.1	179.0	106.0	113.9	230.7	198.2	270.7
640	84.0	181.4	106.0	115.5	232.2	199.0	272.2
650	85.9	183.7	106.7	117.1	233.7	199.8	273.7
660	87.7	185.9	108.6	118.6	235.1	200.6	275.1
670	89.4	188.0	110.4	120.1	236.5	201.4	276.5
680	91.1	190.1	112.2	121.6	237.9	201.9	277.9
690	92.8	192.1	114.0	123.0	239.3	202.3	279.3
700	94.4	194.1	115.7	124.4	240.6	202.8	280.6
710	96.0	196.0	117.4	125.8	241.9	203.2	281.9
720	97.6	197.9	119.0	127.1	243.2	203.6	283.2
730	99.1	199.7	120.6	128.4	244.4	204.0	284.4
740	100.6	201.4	122.2	129.7	245.7	204.4	285.7
750	102.0	203.1	123.7	131.0	246.9	204.8	286.9
760	103.5	204.8	125.2	132.3	248.0	205.2	288.0
770	104.8	206.4	126.7	133.5	249.2	205.6	289.2

TABLE B-1. Hatch Unit 1 P-T Curve Values for 40 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES B-1 THROUGH B-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	40 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	40 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	40 EFPY RPV CURVE C (°F)
780	106.2	208.0	128.1	134.7	250.4	206.0	290.4
790	107.6	209.6	129.5	135.9	251.5	206.4	291.5
800	108.9	211.1	130.9	137.0	252.6	206.7	292.6
810	110.2	212.6	132.2	138.2	253.7	207.1	293.7
820	111.4	214.1	133.5	139.3	254.8	207.5	294.8
830	112.7	215.5	134.8	140.4	255.8	207.9	295.8
840	113.9	216.9	136.1	141.5	256.9	208.3	296.9
850	115.1	218.3	137.3	142.6	257.9	208.7	297.9
860	116.3	219.6	138.6	143.6	258.9	209.0	298.9
870	117.5	221.0	139.8	144.7	259.9	209.4	299.9
880	118.6	222.2	140.9	145.7	260.9	209.8	300.9
890	119.7	223.5	142.1	146.7	261.9	210.1	301.9
900	120.8	224.8	143.3	147.7	262.8	210.5	302.8
910	121.9	226.0	144.4	148.7	263.8	210.9	303.8
920	123.0	227.2	145.5	149.7	264.7	211.2	304.7
930	124.0	228.4	146.6	150.6	265.6	211.6	305.6
940	125.1	229.6	147.7	151.6	266.5	212.0	306.5
950	126.1	230.7	148.7	152.5	267.4	212.3	307.4
960	127.1	231.8	149.8	153.4	268.3	212.7	308.3
970	128.1	232.9	150.8	154.3	269.2	213.0	309.2
980	129.1	234.0	151.8	155.2	270.0	213.4	310.0
990	130.0	235.1	152.8	156.1	270.9	213.7	310.9
1000	131.0	236.2	153.8	157.0	271.7	214.1	311.7
1010	131.9	237.2	154.7	157.8	272.6	214.4	312.6
1020	132.9	238.2	155.7	158.7	273.4	214.8	313.4
1030	133.8	239.2	156.6	159.5	274.2	215.1	314.2
1040	134.7	240.2	157.6	160.4	275.0	215.4	315.0

TABLE B-1. Hatch Unit 1 P-T Curve Values for 40 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES B-1 THROUGH B-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	40 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	40 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	40 EFPY RPV CURVE C (°F)
1050	135.6	241.2	158.5	161.2	275.8	215.8	315.8
1060	136.5	242.2	159.4	162.0	276.6	216.1	316.6
1070	137.3	243.1	160.3	162.8	277.4	216.5	317.4
1080	138.2	244.1	161.2	163.6	278.1	216.8	318.1
1090	139.0	245.0	162.0	164.4	278.9	217.1	318.9
1100	139.9	245.9	162.9	165.1	279.6	217.5	319.6
1110	140.7	246.8	163.7	165.9	280.4	217.8	320.4
1120	141.5	247.7	164.6	166.7	281.1	218.1	321.1
1130	142.3	248.6	165.4	167.4	281.8	218.4	321.8
1140	143.1	249.5	166.2	168.1	282.5	218.8	322.5
1150	143.9	250.3	167.0	168.9	283.3	219.1	323.3
1160	144.7	251.2	167.8	169.6	284.0	219.4	324.0
1170	145.5	252.0	168.6	170.3	284.7	219.7	324.7
1180	146.2	252.9	169.4	171.0	285.3	220.0	325.3
1190	147.0	253.7	170.2	171.7	286.0	220.4	326.0
1200	147.7	254.5	170.9	172.4	286.7	220.7	326.7
1210	148.5	255.3	171.7	173.1	287.4	221.0	327.4
1220	149.2	256.1	172.4	173.8	288.0	221.3	328.0
1230	149.9	256.9	173.2	174.5	288.7	221.6	328.7
1240	150.6	257.6	173.9	175.1	289.3	221.9	329.3
1250	151.3	258.4	174.6	175.8	290.0	222.2	330.0
1260	152.0	259.1	175.4	176.5	290.6	222.5	330.6
1270	152.7	259.9	176.1	177.1	291.3	222.8	331.3
1280	153.4	260.6	176.8	177.8	291.9	223.1	331.9
1290	154.1	261.4	177.5	178.4	292.5	223.4	332.5
1300	154.8	262.1	178.1	179.0	293.1	223.7	333.1
1310	155.4	262.8	178.8	179.6	293.7	224.0	333.7

TABLE B-1. Hatch Unit 1 P-T Curve Values for 40 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES B-1 THROUGH B-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	40 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	40 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	40 EFPY RPV CURVE C (°F)
1320	156.1	263.5	179.5	180.3	294.3	224.3	334.3
1330	156.8	264.2	180.2	180.9	294.9	224.6	334.9
1340	157.4	264.9	180.8	181.5	295.5	224.9	335.5
1350	158.1	265.6	181.5	182.1	296.1	225.2	336.1
1360	158.7	266.3	182.1	182.7	296.7	225.5	336.7
1370	159.3	267.0	182.8	183.3	297.3	225.8	337.3
1380	159.9	267.6	183.4	183.9	297.9	226.1	337.9
1390	160.6	268.3	184.0	184.5	298.4	226.4	338.4
1400	161.2	268.9	184.7	185.0	299.0	226.7	339.0

APPENDIX C
HATCH UNIT 1 P-T CURVE
VALID TO 44 EFPY

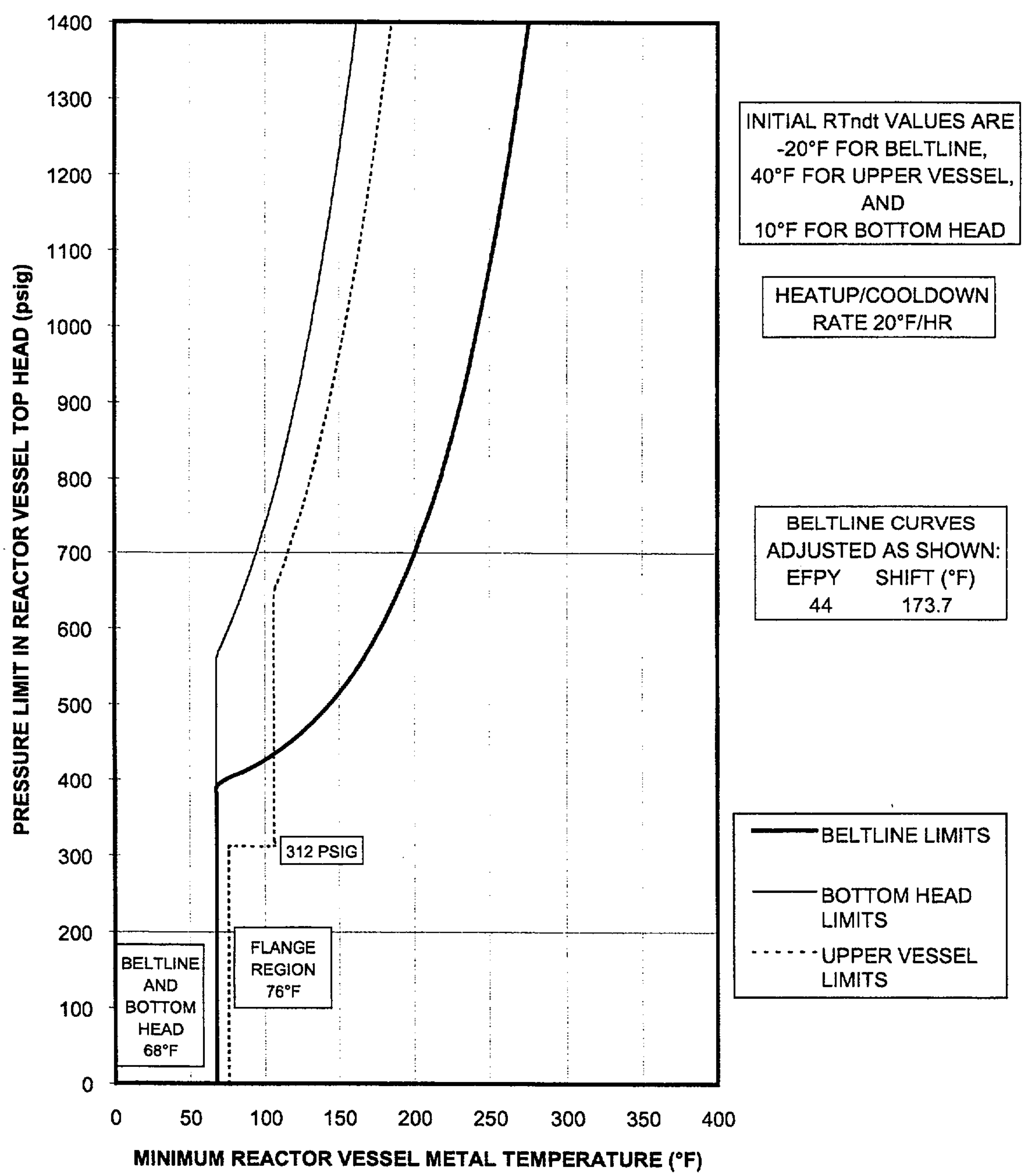

Figure C-1: P-T Curve for Unit 1 (Curve A)

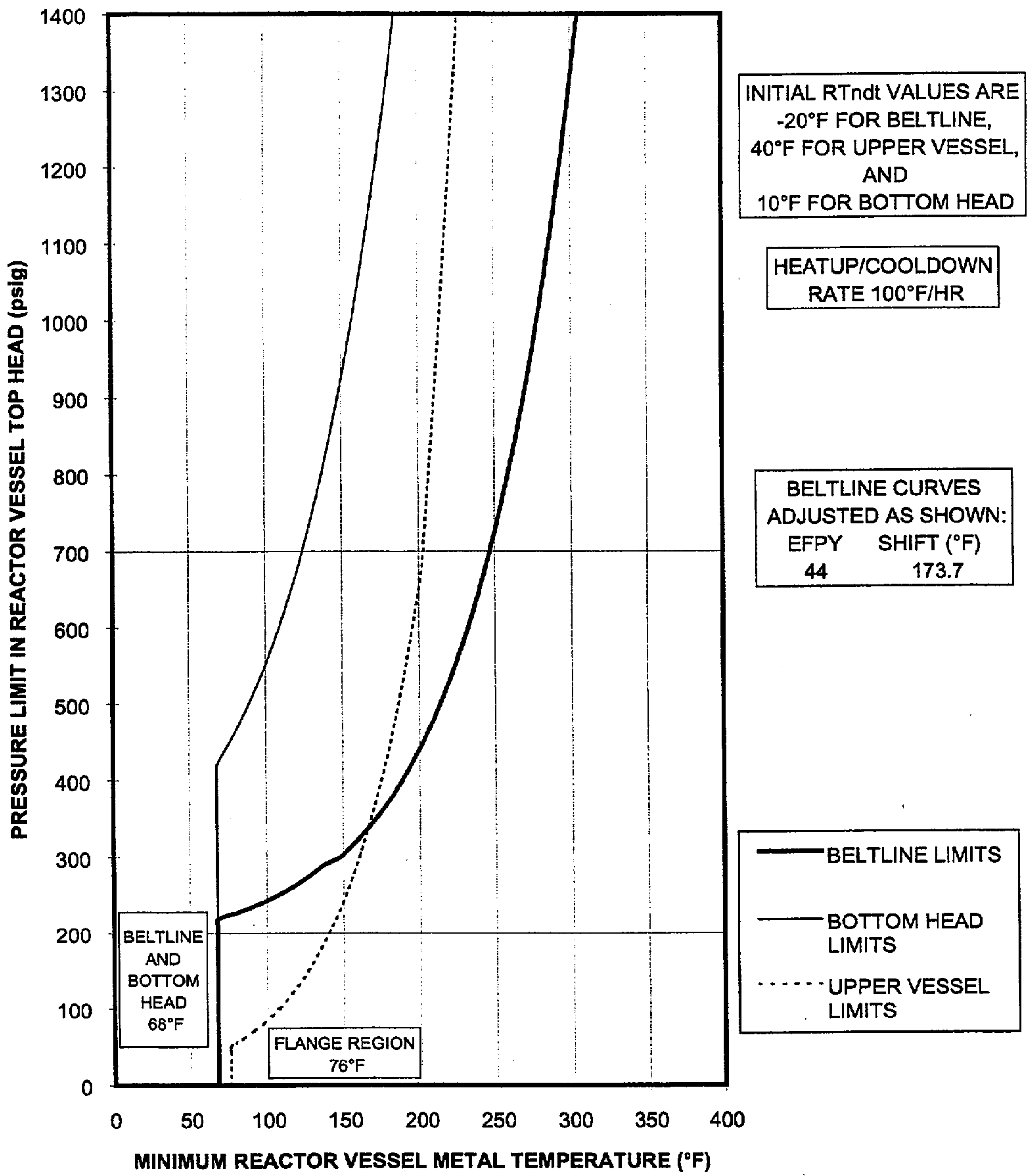

Figure C-2: P-T Curve for Unit 1 (Curve B)

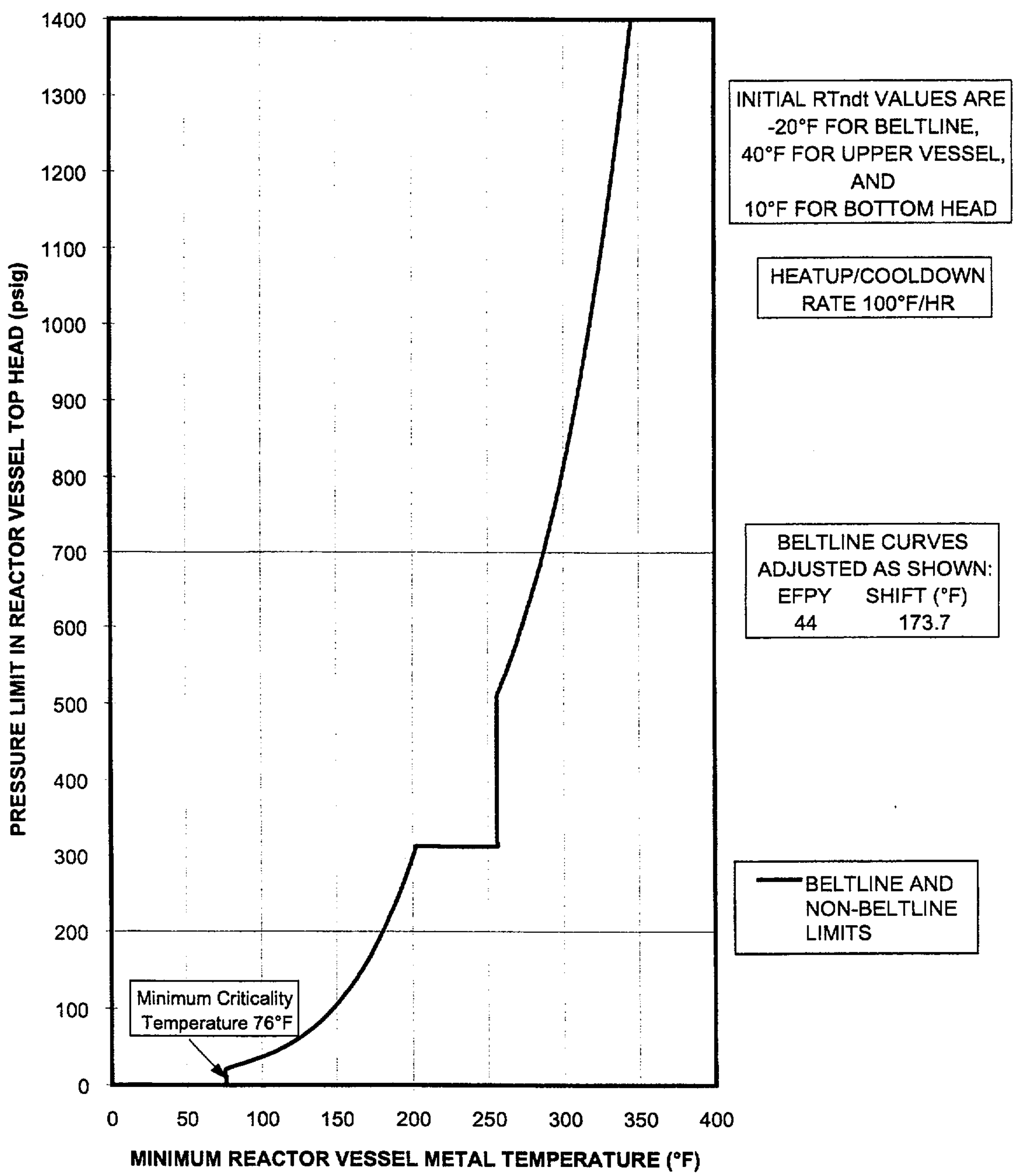

Figure C-3: P-T Curve for Unit 1 (Curve C)

TABLE C-1. Hatch Unit 1 P-T Curve Values for 44 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES C-1 THROUGH C-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	44 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	44 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	44 EFPY RPV CURVE C (°F)
0	68.0	68.0	76.0	68.0	68.0	76.0	76.0
10	68.0	68.0	76.0	68.0	68.0	76.0	76.0
20	68.0	68.0	76.0	68.0	68.0	76.0	76.0
30	68.0	68.0	76.0	68.0	68.0	76.0	90.6
40	68.0	68.0	76.0	68.0	68.0	76.0	104.5
50	68.0	68.0	76.0	68.0	68.0	76.0	115.2
60	68.0	68.0	76.0	68.0	68.0	83.9	123.9
70	68.0	68.0	76.0	68.0	68.0	91.1	131.1
80	68.0	68.0	76.0	68.0	68.0	97.4	137.4
90	68.0	68.0	76.0	68.0	68.0	102.7	142.7
100	68.0	68.0	76.0	68.0	68.0	107.5	147.5
110	68.0	68.0	76.0	68.0	68.0	111.9	151.9
120	68.0	68.0	76.0	68.0	68.0	116.1	156.1
130	68.0	68.0	76.0	68.0	68.0	120.1	160.1
140	68.0	68.0	76.0	68.0	68.0	123.6	163.6
150	68.0	68.0	76.0	68.0	68.0	126.8	166.8
160	68.0	68.0	76.0	68.0	68.0	129.8	169.8
170	68.0	68.0	76.0	68.0	68.0	132.8	172.8
180	68.0	68.0	76.0	68.0	68.0	135.6	175.6
190	68.0	68.0	76.0	68.0	68.0	138.2	178.2
200	68.0	68.0	76.0	68.0	68.0	140.6	180.6
210	68.0	68.0	76.0	68.0	68.0	142.9	182.9
220	68.0	68.0	76.0	68.0	68.7	145.2	185.2
230	68.0	68.0	76.0	68.0	83.9	147.4	187.4
240	68.0	68.0	76.0	68.0	96.3	149.4	189.4
250	68.0	68.0	76.0	68.0	106.8	151.4	191.4

TABLE C-1. Hatch Unit 1 P-T Curve Values for 44 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES C-1 THROUGH C-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	44 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	44 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	44 EFPY RPV CURVE C (°F)
260	68.0	68.0	76.0	68.0	115.9	153.3	193.3
270	68.0	68.0	76.0	68.0	124.0	155.1	195.1
280	68.0	68.0	76.0	68.0	131.2	157.0	197.0
290	68.0	68.0	76.0	68.0	137.7	158.7	198.7
300	68.0	68.0	76.0	68.0	148.0	160.3	200.3
310	68.0	68.0	76.0	68.0	153.3	162.0	202.0
312.5	68.0	68.0	76.0	68.0	154.6	162.3	202.3
312.5	68.0	68.0	106.0	68.0	154.6	162.3	255.7
320	68.0	68.0	106.0	68.0	158.2	163.5	255.7
330	68.0	68.0	106.0	68.0	162.8	165.1	255.7
340	68.0	68.0	106.0	68.0	167.1	166.6	255.7
350	68.0	68.0	106.0	68.0	171.2	168.0	255.7
360	68.0	68.0	106.0	68.0	175.0	169.4	255.7
370	68.0	68.0	106.0	68.0	178.6	170.8	255.7
380	68.0	68.0	106.0	68.0	182.0	172.1	255.7
390	68.0	68.0	106.0	68.0	185.3	173.4	255.7
400	68.0	73.8	106.0	68.0	188.5	174.7	255.7
410	68.0	84.9	106.0	68.0	191.4	176.0	255.7
420	68.0	94.5	106.0	68.0	194.3	177.2	255.7
430	68.0	103.0	106.0	70.3	197.1	178.4	255.7
440	68.0	110.5	106.0	73.2	199.7	179.6	255.7
450	68.0	117.2	106.0	76.1	202.3	180.7	255.7
460	68.0	123.4	106.0	78.8	204.7	181.8	255.7
470	68.0	129.0	106.0	81.5	207.1	182.9	255.7
480	68.0	134.3	106.0	84.0	209.4	184.0	255.7
490	68.0	139.1	106.0	86.5	211.6	185.1	255.7
500	68.0	143.6	106.0	88.8	213.8	186.1	255.7

TABLE C-1. Hatch Unit 1 P-T Curve Values for 44 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES C-1 THROUGH C-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	44 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	44 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	44 EFPY RPV CURVE C (°F)
510	68.0	147.9	106.0	91.1	215.8	187.1	255.8
520	68.0	151.9	106.0	93.3	217.9	188.1	257.9
530	68.0	155.7	106.0	95.5	219.8	189.1	259.8
540	68.0	159.3	106.0	97.6	221.8	190.1	261.8
550	68.0	162.7	106.0	99.6	223.6	191.1	263.6
560	68.0	166.0	106.0	101.5	225.4	192.0	265.4
570	69.5	169.1	106.0	103.5	227.2	192.9	267.2
580	71.8	172.0	106.0	105.3	228.9	193.8	268.9
590	74.0	174.9	106.0	107.1	230.6	194.7	270.6
600	76.1	177.6	106.0	108.9	232.2	195.6	272.2
610	78.2	180.3	106.0	110.6	233.8	196.5	273.8
620	80.2	182.8	106.0	112.3	235.4	197.3	275.4
630	82.1	185.2	106.0	113.9	236.9	198.2	276.9
640	84.0	187.6	106.0	115.5	238.4	199.0	278.4
650	85.9	189.9	106.7	117.1	239.9	199.8	279.9
660	87.7	192.1	108.6	118.6	241.3	200.6	281.3
670	89.4	194.2	110.4	120.1	242.7	201.4	282.7
680	91.1	196.3	112.2	121.6	244.1	201.9	284.1
690	92.8	198.3	114.0	123.0	245.5	202.3	285.5
700	94.4	200.3	115.7	124.4	246.8	202.8	286.8
710	96.0	202.2	117.4	125.8	248.1	203.2	288.1
720	97.6	204.1	119.0	127.1	249.4	203.6	289.4
730	99.1	205.9	120.6	128.4	250.6	204.0	290.6
740	100.6	207.6	122.2	129.7	251.9	204.4	291.9
750	102.0	209.3	123.7	131.0	253.1	204.8	293.1
760	103.5	211.0	125.2	132.3	254.2	205.2	294.2
770	104.8	212.6	126.7	133.5	255.4	205.6	295.4

TABLE C-1. Hatch Unit 1 P-T Curve Values for 44 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES C-1 THROUGH C-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	44 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	44 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	44 EFPY RPV CURVE C (°F)
780	106.2	214.2	128.1	134.7	256.6	206.0	296.6
790	107.6	215.8	129.5	135.9	257.7	206.4	297.7
800	108.9	217.3	130.9	137.0	258.8	206.7	298.8
810	110.2	218.8	132.2	138.2	259.9	207.1	299.9
820	111.4	220.3	133.5	139.3	261.0	207.5	301.0
830	112.7	221.7	134.8	140.4	262.0	207.9	302.0
840	113.9	223.1	136.1	141.5	263.1	208.3	303.1
850	115.1	224.5	137.3	142.6	264.1	208.7	304.1
860	116.3	225.8	138.6	143.6	265.1	209.0	305.1
870	117.5	227.2	139.8	144.7	266.1	209.4	306.1
880	118.6	228.4	140.9	145.7	267.1	209.8	307.1
890	119.7	229.7	142.1	146.7	268.1	210.1	308.1
900	120.8	231.0	143.3	147.7	269.0	210.5	309.0
910	121.9	232.2	144.4	148.7	270.0	210.9	310.0
920	123.0	233.4	145.5	149.7	270.9	211.2	310.9
930	124.0	234.6	146.6	150.6	271.8	211.6	311.8
940	125.1	235.8	147.7	151.6	272.7	212.0	312.7
950	126.1	236.9	148.7	152.5	273.6	212.3	313.6
960	127.1	238.0	149.8	153.4	274.5	212.7	314.5
970	128.1	239.1	150.8	154.3	275.4	213.0	315.4
980	129.1	240.2	151.8	155.2	276.2	213.4	316.2
990	130.0	241.3	152.8	156.1	277.1	213.7	317.1
1000	131.0	242.4	153.8	157.0	277.9	214.1	317.9
1010	131.9	243.4	154.7	157.8	278.8	214.4	318.8
1020	132.9	244.4	155.7	158.7	279.6	214.8	319.6
1030	133.8	245.4	156.6	159.5	280.4	215.1	320.4
1040	134.7	246.4	157.6	160.4	281.2	215.4	321.2

TABLE C-1. Hatch Unit 1 P-T Curve Values for 44 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES C-1 THROUGH C-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	44 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	44 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	44 EFPY RPV CURVE C (°F)
1050	135.6	247.4	158.5	161.2	282.0	215.8	322.0
1060	136.5	248.4	159.4	162.0	282.8	216.1	322.8
1070	137.3	249.3	160.3	162.8	283.6	216.5	323.6
1080	138.2	250.3	161.2	163.6	284.3	216.8	324.3
1090	139.0	251.2	162.0	164.4	285.1	217.1	325.1
1100	139.9	252.1	162.9	165.1	285.8	217.5	325.8
1110	140.7	253.0	163.7	165.9	286.6	217.8	326.6
1120	141.5	253.9	164.6	166.7	287.3	218.1	327.3
1130	142.3	254.8	165.4	167.4	288.0	218.4	328.0
1140	143.1	255.7	166.2	168.1	288.7	218.8	328.7
1150	143.9	256.5	167.0	168.9	289.5	219.1	329.5
1160	144.7	257.4	167.8	169.6	290.2	219.4	330.2
1170	145.5	258.2	168.6	170.3	290.9	219.7	330.9
1180	146.2	259.1	169.4	171.0	291.5	220.0	331.5
1190	147.0	259.9	170.2	171.7	292.2	220.4	332.2
1200	147.7	260.7	170.9	172.4	292.9	220.7	332.9
1210	148.5	261.5	171.7	173.1	293.6	221.0	333.6
1220	149.2	262.3	172.4	173.8	294.2	221.3	334.2
1230	149.9	263.1	173.2	174.5	294.9	221.6	334.9
1240	150.6	263.8	173.9	175.1	295.5	221.9	335.5
1250	151.3	264.6	174.6	175.8	296.2	222.2	336.2
1260	152.0	265.3	175.4	176.5	296.8	222.5	336.8
1270	152.7	266.1	176.1	177.1	297.5	222.8	337.5
1280	153.4	266.8	176.8	177.8	298.1	223.1	338.1
1290	154.1	267.6	177.5	178.4	298.7	223.4	338.7
1300	154.8	268.3	178.1	179.0	299.3	223.7	339.3
1310	155.4	269.0	178.8	179.6	299.9	224.0	339.9

TABLE C-1. Hatch Unit 1 P-T Curve Values for 44 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES C-1 THROUGH C-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	44 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	44 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	44 EFPY RPV CURVE C (°F)
1320	156.1	269.7	179.5	180.3	300.5	224.3	340.5
1330	156.8	270.4	180.2	180.9	301.1	224.6	341.1
1340	157.4	271.1	180.8	181.5	301.7	224.9	341.7
1350	158.1	271.8	181.5	182.1	302.3	225.2	342.3
1360	158.7	272.5	182.1	182.7	302.9	225.5	342.9
1370	159.3	273.2	182.8	183.3	303.5	225.8	343.5
1380	159.9	273.8	183.4	183.9	304.1	226.1	344.1
1390	160.6	274.5	184.0	184.5	304.6	226.4	344.6
1400	161.2	275.1	184.7	185.0	305.2	226.7	345.2

APPENDIX D
HATCH UNIT 1 P-T CURVES
VALID TO 48 EFPY

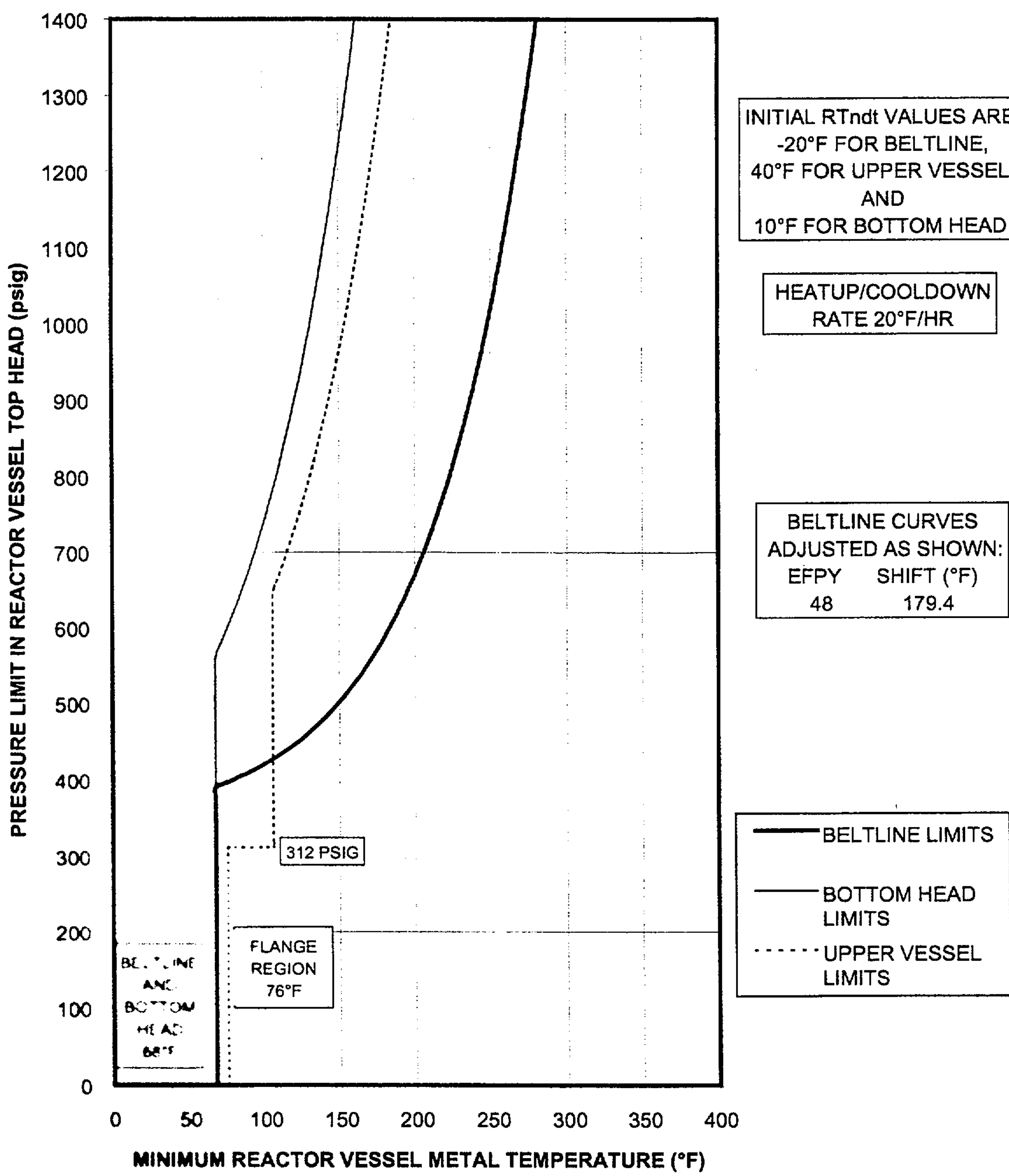

Figure D-1: P-T Curve for Unit 1 (Curve A)

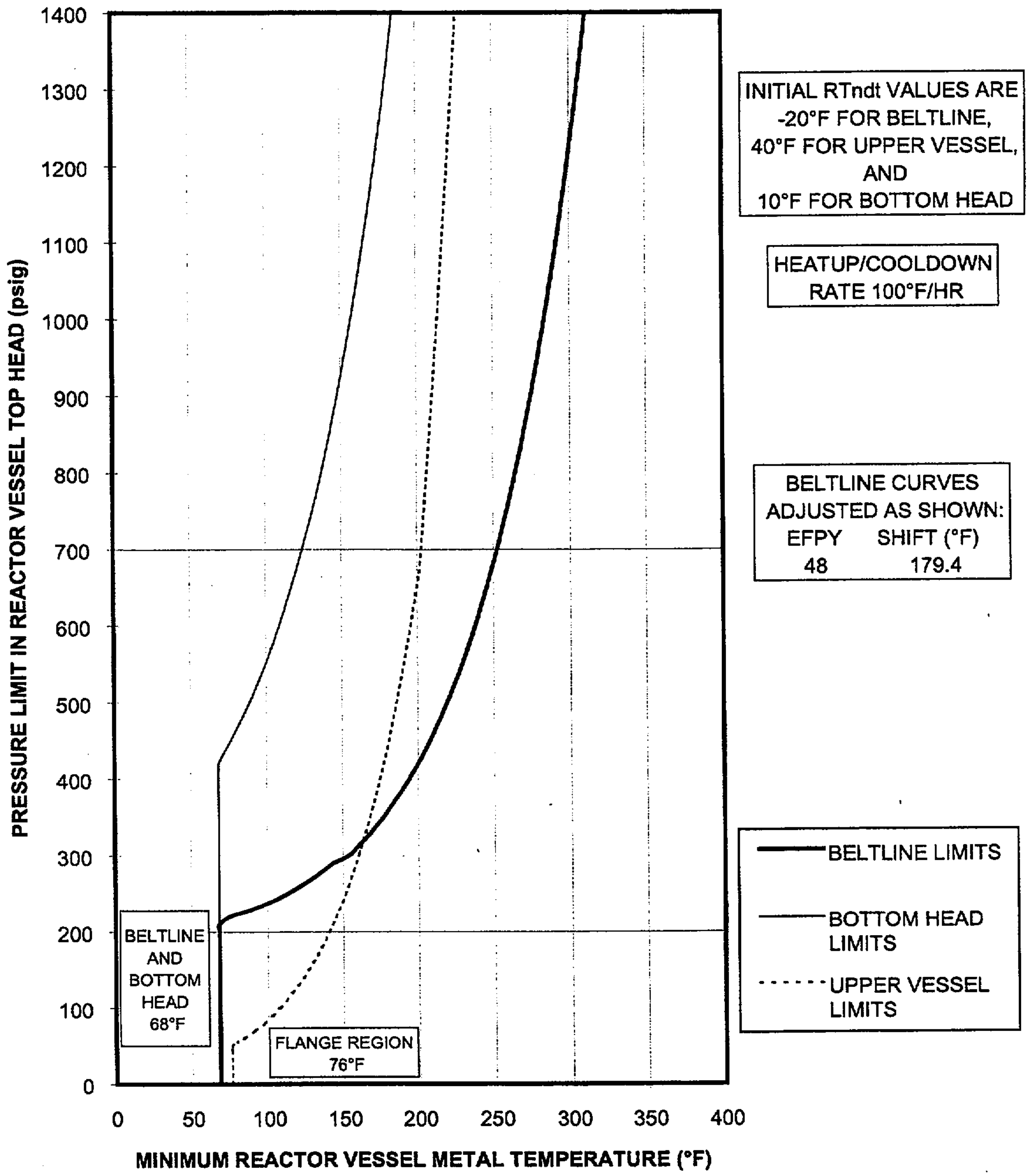

Figure D-2: P-T Curve for Unit 1 (Curve B)

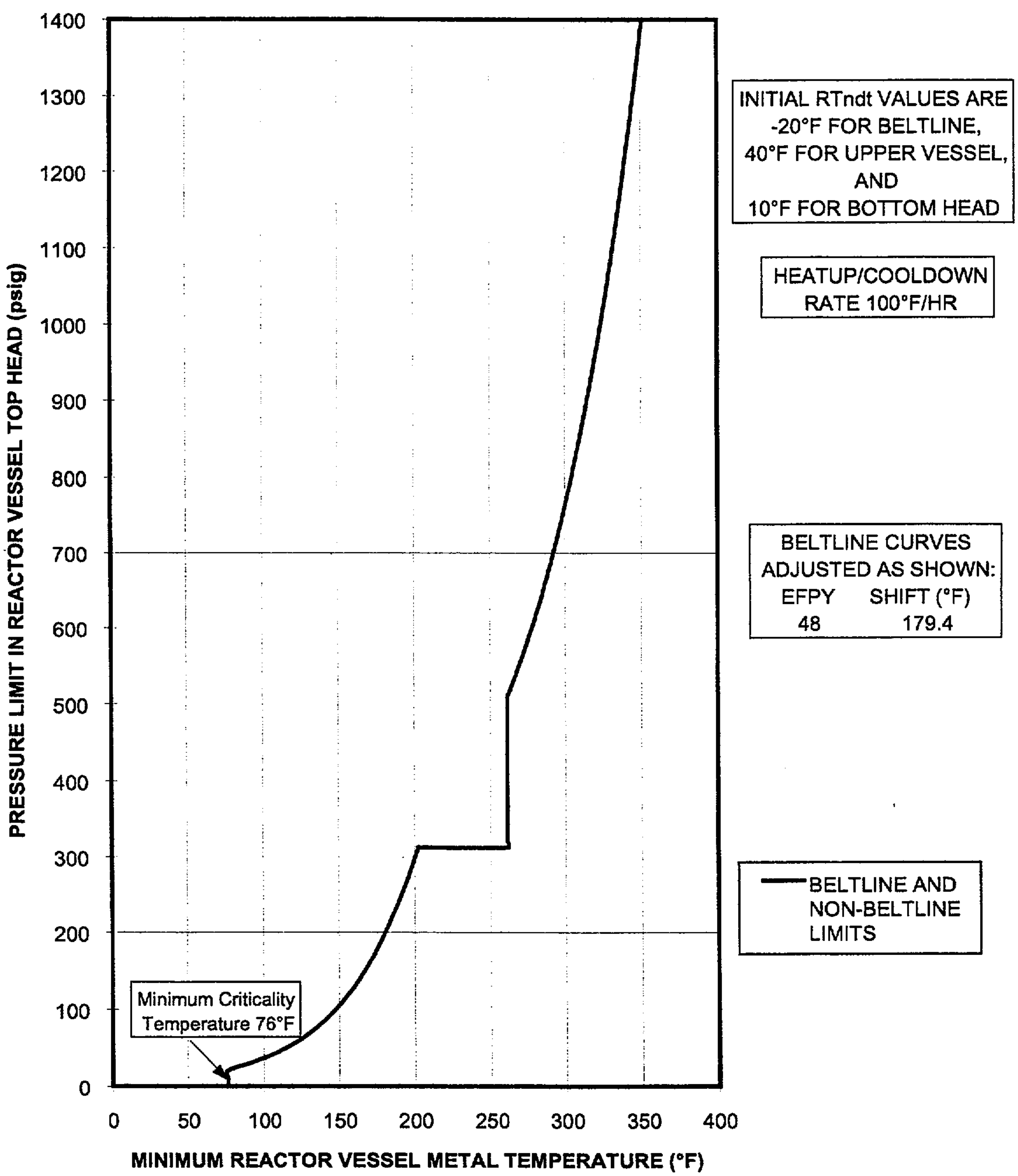

Figure D-3: P-T Curve for Unit 1 (Curve C)

TABLE D-1. Hatch Unit 1 P-T Curve Values for 48 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES D-1 THROUGH D-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	48 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	48 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	48 EFPY RPV CURVE C (°F)
0	68.0	68.0	76.0	68.0	68.0	76.0	76.0
10	68.0	68.0	76.0	68.0	68.0	76.0	76.0
20	68.0	68.0	76.0	68.0	68.0	76.0	76.0
30	68.0	68.0	76.0	68.0	68.0	76.0	90.6
40	68.0	68.0	76.0	68.0	68.0	76.0	104.5
50	68.0	68.0	76.0	68.0	68.0	76.0	115.2
60	68.0	68.0	76.0	68.0	68.0	83.9	123.9
70	68.0	68.0	76.0	68.0	68.0	91.1	131.1
80	68.0	68.0	76.0	68.0	68.0	97.4	137.4
90	68.0	68.0	76.0	68.0	68.0	102.7	142.7
100	68.0	68.0	76.0	68.0	68.0	107.5	147.5
110	68.0	68.0	76.0	68.0	68.0	111.9	151.9
120	68.0	68.0	76.0	68.0	68.0	116.1	156.1
130	68.0	68.0	76.0	68.0	68.0	120.1	160.1
140	68.0	68.0	76.0	68.0	68.0	123.6	163.6
150	68.0	68.0	76.0	68.0	68.0	126.8	166.8
160	68.0	68.0	76.0	68.0	68.0	129.8	169.8
170	68.0	68.0	76.0	68.0	68.0	132.8	172.8
180	68.0	68.0	76.0	68.0	68.0	135.6	175.6
190	68.0	68.0	76.0	68.0	68.0	138.2	178.2
200	68.0	68.0	76.0	68.0	68.0	140.6	180.6
210	68.0	68.0	76.0	68.0	68.0	142.9	182.9
220	68.0	68.0	76.0	68.0	74.4	145.2	185.2
230	68.0	68.0	76.0	68.0	89.6	147.4	187.4
240	68.0	68.0	76.0	68.0	102.0	149.4	189.4
250	68.0	68.0	76.0	68.0	112.5	151.4	191.4

TABLE D-1. Hatch Unit 1 P-T Curve Values for 48 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES D-1 THROUGH D-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	48 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	48 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	48 EFPY RPV CURVE C (°F)
260	68.0	68.0	76.0	68.0	121.6	153.3	193.3
270	68.0	68.0	76.0	68.0	129.7	155.1	195.1
280	68.0	68.0	76.0	68.0	136.9	157.0	197.0
290	68.0	68.0	76.0	68.0	143.4	158.7	198.7
300	68.0	68.0	76.0	68.0	153.7	160.3	200.3
310	68.0	68.0	76.0	68.0	159.0	162.0	202.0
312.5	68.0	68.0	76.0	68.0	160.3	162.3	202.3
312.5	68.0	68.0	106.0	68.0	160.3	162.3	261.4
320	68.0	68.0	106.0	68.0	163.9	163.5	261.4
330	68.0	68.0	106.0	68.0	168.5	165.1	261.4
340	68.0	68.0	106.0	68.0	172.8	166.6	261.4
350	68.0	68.0	106.0	68.0	176.9	168.0	261.4
360	68.0	68.0	106.0	68.0	180.7	169.4	261.4
370	68.0	68.0	106.0	68.0	184.3	170.8	261.4
380	68.0	68.0	106.0	68.0	187.7	172.1	261.4
390	68.0	68.0	106.0	68.0	191.0	173.4	261.4
400	68.0	79.5	106.0	68.0	194.2	174.7	261.4
410	68.0	90.6	106.0	68.0	197.1	176.0	261.4
420	68.0	100.2	106.0	68.0	200.0	177.2	261.4
430	68.0	108.7	106.0	70.3	202.8	178.4	261.4
440	68.0	116.2	106.0	73.2	205.4	179.6	261.4
450	68.0	122.9	106.0	76.1	208.0	180.7	261.4
460	68.0	129.1	106.0	78.8	210.4	181.8	261.4
470	68.0	134.7	106.0	81.5	212.8	182.9	261.4
480	68.0	140.0	106.0	84.0	215.1	184.0	261.4
490	68.0	144.8	106.0	86.5	217.3	185.1	261.4
500	68.0	149.3	106.0	88.8	219.5	186.1	261.4

TABLE D-1. Hatch Unit 1 P-T Curve Values for 48 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES D-1 THROUGH D-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	48 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	48 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	48 EFPY RPV CURVE C (°F)
510	68.0	153.6	106.0	91.1	221.5	187.1	261.5
520	68.0	157.6	106.0	93.3	223.6	188.1	263.6
530	68.0	161.4	106.0	95.5	225.5	189.1	265.5
540	68.0	165.0	106.0	97.6	227.5	190.1	267.5
550	68.0	168.4	106.0	99.6	229.3	191.1	269.3
560	68.0	171.7	106.0	101.5	231.1	192.0	271.1
570	69.5	174.8	106.0	103.5	232.9	192.9	272.9
580	71.8	177.7	106.0	105.3	234.6	193.8	274.6
590	74.0	180.6	106.0	107.1	236.3	194.7	276.3
600	76.1	183.3	106.0	108.9	237.9	195.6	277.9
610	78.2	186.0	106.0	110.6	239.5	196.5	279.5
620	80.2	188.5	106.0	112.3	241.1	197.3	281.1
630	82.1	190.9	106.0	113.9	242.6	198.2	282.6
640	84.0	193.3	106.0	115.5	244.1	199.0	284.1
650	85.9	195.6	106.7	117.1	245.6	199.8	285.6
660	87.7	197.8	108.6	118.6	247.0	200.6	287.0
670	89.4	199.9	110.4	120.1	248.4	201.4	288.4
680	91.1	202.0	112.2	121.6	249.8	201.9	289.8
690	92.8	204.0	114.0	123.0	251.2	202.3	291.2
700	94.4	206.0	115.7	124.4	252.5	202.8	292.5
710	96.0	207.9	117.4	125.8	253.8	203.2	293.8
720	97.6	209.8	119.0	127.1	255.1	203.6	295.1
730	99.1	211.6	120.6	128.4	256.3	204.0	296.3
740	100.6	213.3	122.2	129.7	257.6	204.4	297.6
750	102.0	215.0	123.7	131.0	258.8	204.8	298.8
760	103.5	216.7	125.2	132.3	259.9	205.2	299.9
770	104.8	218.3	126.7	133.5	261.1	205.6	301.1

TABLE D-1. Hatch Unit 1 P-T Curve Values for 48 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES D-1 THROUGH D-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	48 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	48 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	48 EFPY RPV CURVE C (°F)
780	106.2	219.9	128.1	134.7	262.3	206.0	302.3
790	107.6	221.5	129.5	135.9	263.4	206.4	303.4
800	108.9	223.0	130.9	137.0	264.5	206.7	304.5
810	110.2	224.5	132.2	138.2	265.6	207.1	305.6
820	111.4	226.0	133.5	139.3	266.7	207.5	306.7
830	112.7	227.4	134.8	140.4	267.7	207.9	307.7
840	113.9	228.8	136.1	141.5	268.8	208.3	308.8
850	115.1	230.2	137.3	142.6	269.8	208.7	309.8
860	116.3	231.5	138.6	143.6	270.8	209.0	310.8
870	117.5	232.9	139.8	144.7	271.8	209.4	311.8
880	118.6	234.1	140.9	145.7	272.8	209.8	312.8
890	119.7	235.4	142.1	146.7	273.8	210.1	313.8
900	120.8	236.7	143.3	147.7	274.7	210.5	314.7
910	121.9	237.9	144.4	148.7	275.7	210.9	315.7
920	123.0	239.1	145.5	149.7	276.6	211.2	316.6
930	124.0	240.3	146.6	150.6	277.5	211.6	317.5
940	125.1	241.5	147.7	151.6	278.4	212.0	318.4
950	126.1	242.6	148.7	152.5	279.3	212.3	319.3
960	127.1	243.7	149.8	153.4	280.2	212.7	320.2
970	128.1	244.8	150.8	154.3	281.1	213.0	321.1
980	129.1	245.9	151.8	155.2	281.9	213.4	321.9
990	130.0	247.0	152.8	156.1	282.8	213.7	322.8
1000	131.0	248.1	153.8	157.0	283.6	214.1	323.6
1010	131.9	249.1	154.7	157.8	284.5	214.4	324.5
1020	132.9	250.1	155.7	158.7	285.3	214.8	325.3
1030	133.8	251.1	156.6	159.5	286.1	215.1	326.1
1040	134.7	252.1	157.6	160.4	286.9	215.4	326.9

TABLE D-1. Hatch Unit 1 P-T Curve Values for 48 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES D-1 THROUGH D-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	48 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	48 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	48 EFPY RPV CURVE C (°F)
1050	135.6	253.1	158.5	161.2	287.7	215.8	327.7
1060	136.5	254.1	159.4	162.0	288.5	216.1	328.5
1070	137.3	255.0	160.3	162.8	289.3	216.5	329.3
1080	138.2	256.0	161.2	163.6	290.0	216.8	330.0
1090	139.0	256.9	162.0	164.4	290.8	217.1	330.8
1100	139.9	257.8	162.9	165.1	291.5	217.5	331.5
1110	140.7	258.7	163.7	165.9	292.3	217.8	332.3
1120	141.5	259.6	164.6	166.7	293.0	218.1	333.0
1130	142.3	260.5	165.4	167.4	293.7	218.4	333.7
1140	143.1	261.4	166.2	168.1	294.4	218.8	334.4
1150	143.9	262.2	167.0	168.9	295.2	219.1	335.2
1160	144.7	263.1	167.8	169.6	295.9	219.4	335.9
1170	145.5	263.9	168.6	170.3	296.6	219.7	336.6
1180	146.2	264.8	169.4	171.0	297.2	220.0	337.2
1190	147.0	265.6	170.2	171.7	297.9	220.4	337.9
1200	147.7	266.4	170.9	172.4	298.6	220.7	338.6
1210	148.5	267.2	171.7	173.1	299.3	221.0	339.3
1220	149.2	268.0	172.4	173.8	299.9	221.3	339.9
1230	149.9	268.8	173.2	174.5	300.6	221.6	340.6
1240	150.6	269.5	173.9	175.1	301.2	221.9	341.2
1250	151.3	270.3	174.6	175.8	301.9	222.2	341.9
1260	152.0	271.0	175.4	176.5	302.5	222.5	342.5
1270	152.7	271.8	176.1	177.1	303.2	222.8	343.2
1280	153.4	272.5	176.8	177.8	303.8	223.1	343.8
1290	154.1	273.3	177.5	178.4	304.4	223.4	344.4
1300	154.8	274.0	178.1	179.0	305.0	223.7	345.0
1310	155.4	274.7	178.8	179.6	305.6	224.0	345.6

TABLE D-1. Hatch Unit 1 P-T Curve Values for 48 EFPY

Required Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

(FOR FIGURES D-1 THROUGH D-3)

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	48 EFPY BELTLINE CURVE A (°F)	UPPER VESSEL CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	48 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	48 EFPY RPV CURVE C (°F)
1320	156.1	275.4	179.5	180.3	306.2	224.3	346.2
1330	156.8	276.1	180.2	180.9	306.8	224.6	346.8
1340	157.4	276.8	180.8	181.5	307.4	224.9	347.4
1350	158.1	277.5	181.5	182.1	308.0	225.2	348.0
1360	158.7	278.2	182.1	182.7	308.6	225.5	348.6
1370	159.3	278.9	182.8	183.3	309.2	225.8	349.2
1380	159.9	279.5	183.4	183.9	309.8	226.1	349.8
1390	160.6	280.2	184.0	184.5	310.3	226.4	350.3
1400	161.2	280.8	184.7	185.0	310.9	226.7	350.9