BORIC ACID CONCENTRATION REDUCTION

TECHNICAL BASES

AND

OPERATIONAL ANALYSIS

PREPARED FOR

FLORIDA POWER & LIGHT COMPANY

TURKEY POINT NUCLEAR UNITS 3 AND 4

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Completed By: J.E. Philpot (Engineer) Date 11/29/90

Reviewed By: RC Cuttle (Engineer) Date 11/29/90.

Approved By: Carl J. [illegible] (Manager) Date 11/29/90.

ABB COMBUSTION ENGINEERING NUCLEAR POWER
MECHANICAL PRODUCTS AND SERVICES
Windsor, Connecticut

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1.0 INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

The purpose of this project, as proposed by Reference 10.7 and authorized by Reference 10.8, is to perform the necessary engineering work and to generate the necessary license amendment documents that would allow Florida Power & Light (FPL) to reduce the boron concentration required to be maintained in the concentrated boric acid tanks at the Turkey Point Nuclear Units 3 and 4 to a concentration of 3.0 to 3.5 weight percent boric acid. At the new boric acid concentrations the need to heat the boric acid tanks and the need to heat trace the boric acid makeup system piping and valves would no longer be required since the ambient temperatures that normally exist in the plant's auxiliary building are sufficient to prevent boric acid precipitation.

1.2 BACKGROUND

The General Design Criteria contained in the Code of Federal Regulations specifies that concentrated sources of borated water are to be available for charging into the Reactor Coolant System (RCS) of pressurized water reactor (PWR) plants as needed for reactivity control. Although these borated sources are required to be available, the concentration of the solutions contained in them is determined by the designers. The basis for determining the boric acid concentration is the ability to safely control reactivity at any time during core life. Boric acid is used to offset slow reactivity changes caused by normal changes in reactor power level, or to establish hot shutdown, cold shutdown or refueling conditions.

In the original plant design process for PWRs, two sources of borated water are typically provided, each having different boron concentrations. A refueling water storage tank is available which has a specified minimum concentration of 1950 ppm. In addition to

the refueling water storage tank three concentrated boric acid tanks are available. Each boric acid tank has a specified minimum level of 3,080 gallons with a specified concentration of 20,000 to 22,500 ppm boric acid. In order to keep the boric acid in solution at these high boron concentrations, extensive heating networks are required. These heating networks maintain the temperature of the tanks and associated pipes, pumps, and valves at greater than 145°F in order to prevent boric acid precipitation.

The requirement to maintain a highly concentrated boric acid solution in the boric acid tanks can place an undue burden on plant maintenance and operational personnel. Significant problems can be encountered in keeping the boric acid makeup system operable as required in the plant technical specifications. These problems include heat tracing failures, plugging problems due to crystalline boric acid deposits, and various corrosion problems such as seal failures, fitting leaks, and valve failures. In addition, the presence of crystalline boric acid deposits on the exterior of piping, valves, etc. can present a cleanliness problem. One solution to these problems would be to reduce the concentration requirements in the boric acid tanks by a factor of three or more below the present value. This reduction is justifiable based on the analyses presented in this report which demonstrate the ability to safely control reactivity throughout core life. At low enough concentration levels the system would no longer need to be heated since boric acid would remain in solution at temperatures below the normally anticipated ambient temperatures in the auxiliary building. Additionally, problems with corrosion and cleanliness associated with concentrated boric acid could be greatly improved.

1.3 BASIS OF BORIC ACID CONCENTRATION REDUCTION

The boric acid tank level and boron concentration minimum values specified in the current Turkey Point Technical Specifications are

based on the ability to borate the RCS to the required cold shutdown boron concentration by utilizing avialable pressurizer volume or through a feed and bleed process. The current method is to borate the RCS to the boron concentration required to provide the required shutdown margin of 1% Δk/k at 200°F prior to commencing the plant cooldown. The boration subsystem is then required to provide sufficient boric acid to first achieve this shutdown margin and, second, to provide blended makeup to compensate for the contraction of the coolant throughout the cooldown. Since boron concentration typically has to be increased by 700 to 800 ppm prior to commencing cooldown, highly concentrated boric acid solutions are required to achieve this in a reasonable period of time with limited storage volume capability.

The required boron concentration in the boric acid tanks can be reduced with a simple change in the methodology of accomplishing plant boration and cooldown. This report analyzes a number of plant cooldown scenarios where boration is accomplished concurrently with cooldown as part of the normal inventory makeup required as a result of coolant contraction during the cooldown. By identifying the exact RCS boron concentration required to maintain proper shutdown margin at each temperature during a plant cooldown and applying the makeup capacity limitations of the system, the exact volume of boric acid required from the boric acid tank can be identified. By eliminating the boric acid loss associated with the feed and bleed process and by utilizing boric acid available from the refueling water storage tank (in addition to the boric acid tank), the concentration of boric acid required for the boric acid tanks can be reduced. Effectively, the concentration required for the boric acid tanks to perform a cooldown to cold shutdown conditions can be decreased to the range of 3.0 to 3.5 weight percent where heat tracing of the boric acid system is no longer required.

Figure 1-1 is a plot showing the solubility of boric acid in water for temperatures ranging from 32°F to 160°F. (Data for Figure 1-1

were obtained from Reference 10.9 and are reprinted in Table 1-1.) Note that the solubility of boric acid at 32°F is 2.52 weight percent and at 50°F is 3.49 weight percent. At or below a concentration of 3.5 weight percent boric acid, the ambient temperature that normally exists in the auxiliary building will be sufficient to prevent precipitation within the boric acid makeup system.

This report presents the technical justification for reduction of the boric acid concentrations required to be maintained in the boric acid tanks which will then support the elimination of all boric acid system heat tracing. Section 2.0 presents the results of a detailed review of the Turkey Point boration design basis. Section 3.0 presents the analysis scenarios that were chosen to demonstrate the capability of the boration system to comply with these design basis requirements with reduced boric acid concentration. Sections 4.0, 5.0, and 6.0 present the results of the analyses completed for the scenarios identified in Section 3.0. Sections 7.0 and 8.0 identify the necessary changes to Turkey Point licensing documentation, while Section 9.0 identifies general changes that will be required for Turkey Point operating procedures.

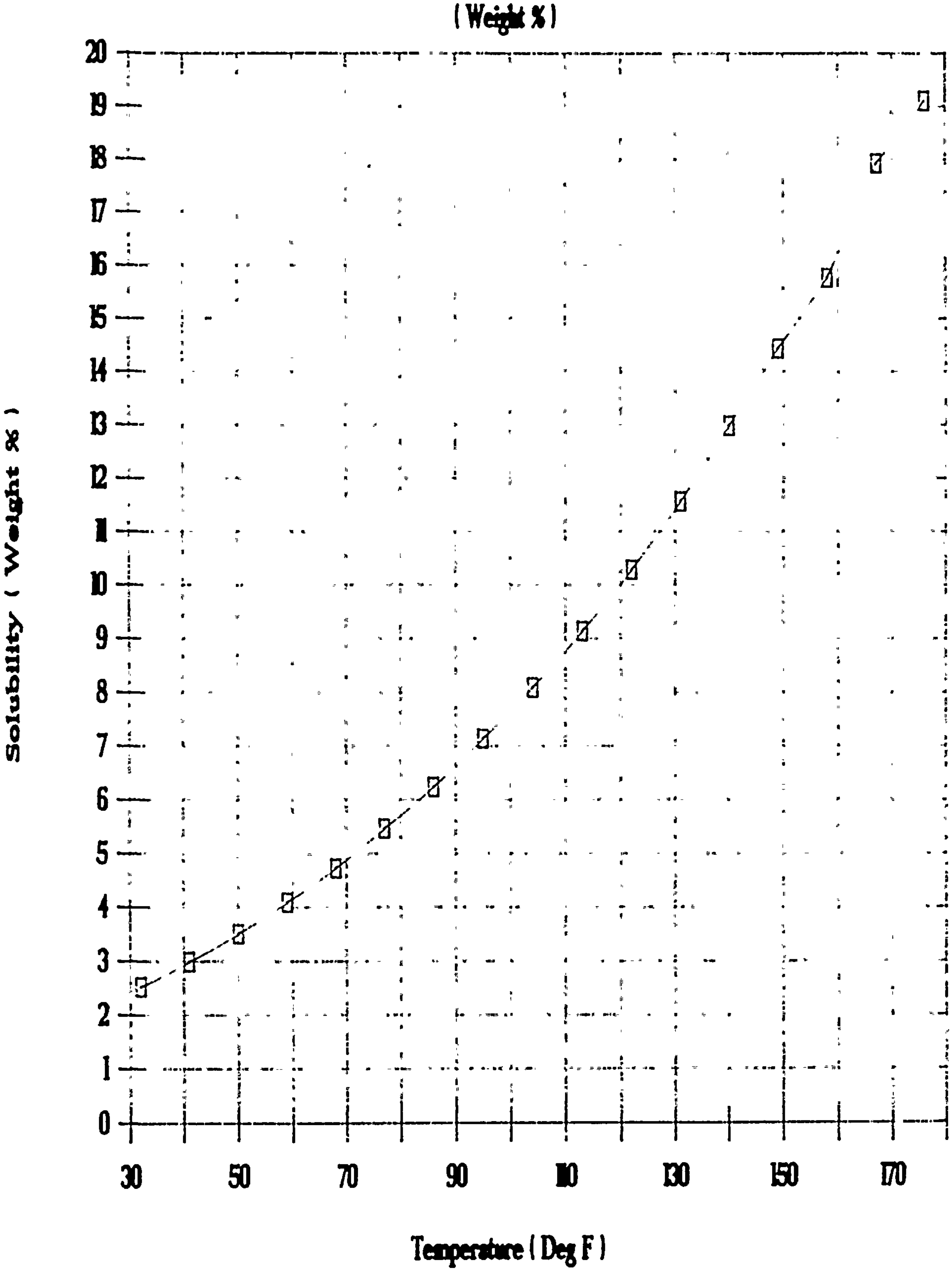
Table 1-1

Boric Acid Solubility in Water[1]

Temperature (°F)	H_3BO_3 (Wt.%)
32.0	2.52
41.0	2.98
50.0	3.49
59.0	4.08
68.0	4.72
77.0	5.46
86.0	6.23
95.0	7.12
104.0	8.08
113.0	9.12
122.0	10.27
131.0	11.55
140.0	12.97
149.0	14.42
158.0	15.75
167.0	17.91
176.0	19.10

(1) Solubility from Technical Data Sheet IC-11, US Borax & Chemical Corporation, 3-83-J.W. These data have been empirically derived and are supported by WCAP-1570 "Literature Values for Selected Chemical/Physical Properties of Aqueous Boric Acid Solutions".

Figure 1-1 Boric Acid Solubility in Water



2.0 PERFORMANCE REQUIREMENTS

To technically justify a significant reduction in the concentration of boric acid in the boration subsystem of the Chemical and Volume Control System (CVCS), a careful review of the boration design and licensing basis of the CVCS is required. It is necessary that the specific design basis and licensing performance requirements be clearly identified and understood to ensure that one or more analyses can be completed that will demonstrate these requirements continue to be met.

References 10.1 through 10.6 were reviewed to identify all performance requirements/limitations related to RCS boration and core reactivity control that should be factored into the boric acid concentration reduction analyses. This section identifies the system design basis performance requirements and the expected impact of a reduction in the concentration of stored boric acid. The need for analyses to demonstrate compliance with these system requirements is assessed and appropriate reference made to the specific analysis scenarios outlined in Section 3. The intent is not necessarily to conduct a specific analysis for each system requirement but, instead, to identify the minimum number of limiting analysis scenarios, the results of which will bound all established boration requirements.

2.1 DESIGN BASIS PERFORMANCE REQUIREMENTS: SAFETY-RELATED

This section addresses each of the safety-related design basis performance requirements presented in Section 3.1 of Reference 10.1. All requirements are addressed regardless of any impact created by a reduction in boric acid concentration. For ease of cross reference, these requirements are presented in the same order as they appear in the design basis document with the same last two digits of the section numbers used in this evaluation (i.e., Section 2.1.2 here corresponds to Section 3.1.2 of Reference 10.1).

2.1.1 The CVCS charging line and the individual Reactor Coolant Pump (RCP) seal injection lines (one for each RCP) are required to satisfy containment boundary isolation requirements.

Impact: None

Analysis: Not Applicable.

2.1.2 The CVCS shall be capable of making and holding the core subcritical from any hot operating condition including those resulting from power changes. Clarifications of Section 2.1.3 (Reference 10.1) state that the boration system is required to be capable of shutting down the reactor from a hot full power condition (with no control rod insertion) and adding sufficient boric acid subsequent to the shutdown to compensate for the eventual decay of all xenon, thereby maintaining the required shutdown margin.

Impact: References 10.1, 10.2 and 10.3 state that the required boration can be accomplished in less than 16 minutes and that, in less than 16 additional minutes, RCS boron can be increased sufficiently to fully account for the decay of xenon, thereby maintaining the required shutdown margin. (A total of 155 minutes would be required if the source of water were the refueling water storage tank instead of the boric acid tanks.) This is recognized to be a statement of system capability and does not represent a licensing requirement. A reduction in boric acid tank boron concentration will only increase the amount of time it will take and will not impact the system's ability to accomplish this task.

Analysis: Although an exponential relationship exists, the time to borate to the hot shutdown, xenon free condition is roughly inversely proportional to the boric acid concentration of the water source (at low initial concentrations and assuming one source with constant concentration and addition rate). Reduction in boron concentration by a factor of 3 to 4, therefore, is expected to

increase the completion time by a factor on the order of 3 to 4. Previous reactivity analyses have analyzed this capability with boron concentrations from 4.0 to 3.0 weight percent boric acid resulting in times to shutdown of 30 to 40 minutes, respectively. In any case, the shutdown capability of 155 minutes using the refueling water storage tank remains as the upper limit on time to achieve boration. Volume of boric acid is not considered a limitation in this instance since a stated design basis variation in the boration lineup is to use the refueling water storage tank as a sole source. The volume requirement in this instance is bounded by that required by post LOCA emergency core cooling. See Section 6.6.3.

2.1.3 The CVCS boration system is required to be capable of maintaining shutdown margin during a 100°F/hr cooldown initiated from a hot zero power subcritical condition, with the RCS borated sufficiently for a cold shutdown (= or < 200°F), xenon free condition and the most reactive control rod stuck in the fully withdrawn position.

Impact: A reduction in boron concentration of the water used to provide boration and makeup under these conditions will effectively require that a greater volume be added to the RCS for reactivity control. Additionally, greater boric acid flow rates to the blender will be required to provide blended makeup that will maintain the RCS boron concentration established prior to initiating the cooldown. The required boric acid flow rates for fast cooldowns will be available via the normal flow path with the proposed modification of flow control valve FCV-113A discussed in Section 6.1 or via the emergency boration flow path using one or both transfer pumps.

Analysis: See Section 6.6.4.

2.1.4 The CVCS charging system must be capable of satisfying the technical specification requirements to be in various stages of hot or cold

shutdown during varying time periods. Accordingly, the CVCS must: 1) meet the RCS boration requirements such that the shutdown boron concentration can be achieved prior to (and maintained during) plant cooldown; 2) satisfy RCS fluid inventory control requirements during cooldown by making up for shrinkage of the reactor coolant with blended makeup water of the correct boron concentration. The clarification of Section 3.1.4 (Reference 10.1) states that the limiting requirement in this respect is to achieve cold shutdown (1% $\Delta k/k$ shutdown, 200°F) in 30 hours from a hot zero power condition, including allowances for RCP seal leakage and identified/unidentified RCS leakage.

Impact: An exception to this design basis statement is that the methodology presented in this report involves boration in conjunction with the cooldown to minimize the boron loss that would occur during the feed and bleed process suggested (i.e., boration prior to cooldown). Such an approach is used in the licensing analysis of Section 5.0 to establish the minimum technical specification volume/concentration requirements for the boric acid tanks.

Analysis: See Sections 5.0 and 6.0.

2.1.5 The CVCS charging system must be capable of satisfying safe shutdown fire protection criteria imposed as a result of 10CFR50, Appendix R. Boration to the cold shutdown boron concentration and cooldown to 350°F must be achieved within 19 hours with suction from the refueling water storage tank. Cold shutdown is to be achieved during the ensuing period from 19 to 72 hours. Accordingly, the CVCS must: 1) meet the RCS boration requirements such that the shutdown boron concentration can be achieved prior to (and maintained during) plant cooldown; 2) satisfy RCS fluid inventory control requirements during cooldown by making up for shrinkage of reactor coolant with blended makeup water of the correct boron

concentration. The 19-hour time requirement is based on condensate storage tank capacity as the water source for auxiliary feedwater. RCP seal leakage and identified/unidentified RCS leakage are assumed.

Impact: An exception to this design basis statement is that the methodology presented in this report involves boration in conjunction with the cooldown to minimize the boron loss that would occur during the feed and bleed process suggested (i.e., boration prior to cooldown). Such an approach is used in the licensing analysis of Section 5.0 to establish the minimum technical specification volume/concentration requirements for the boric acid tanks. The 19 and 72 hour limitations are not considered limiting from the perspective of boric acid tank inventory since the refueling water storage tank is the stated source for reactivity and inventory control.

Analysis: See Sections 5.0 and 6.0.

2.1.6 The CVCS boration system is required to insert negative reactivity at a rate that is sufficient to compensate for the maximum xenon burnout rate which occurs during a return to power at a peak xenon condition following a short period at hot standby.

Impact: A reduction in the boron concentration in the boric acid tanks will require greater boric acid flow rates to add the same amount of boron in a given period of time. The preferred method of reactivity control in these circumstances is to provide a mixture of concentrated boric acid from the boric acid tank and pure makeup water from the primary water system. Water from these sources would be mixed in the blender at an established ratio to provide boric acid at the desired concentration.

If the current range of reactivity control is to be maintained using the boric acid blender as the preferred boration flow path (as opposed to the emergency boration flow path), an increase in the

flow rate of boric acid will be required. This will be necessary to be able to provide the same amount of boron to the blender in a given period of time using the reduced boric acid tank boron concentrations as compared to the existing concentrations. FPL already plans to replace the valve trim for Flow Control Valve FCV-113A to increase the achievable boric acid flow rates into the blender and, hence, satisfy this requirement.

Analysis: No additional analyses are necessary since previous analyses have shown it is possible to meet this requirement with boron concentrations in the range of 3.0 to 4.0 weight percent.

2.1.7 The CVCS boration system is required to insert negative reactivity at a rate that is sufficient to compensate for decay of xenon.

Impact: A reduction in the boron concentration of the boric acid tanks will require greater boric acid flow rates to add the same amount of boron in a given period of time. Greater boric acid flow rates to the boric acid blender will be achievable with modification of FCV-113A as discussed in Section 2.1.6 above.

Analysis: See Section 5.0.

2.1.8 The CVCS boration system is required to be available post-LOCA for use in controlling recirculation fluid pH.

Impact: None

Analysis: Not Applicable.

2.2 DESIGN BASIS PERFORMANCE REQUIREMENTS: QUALITY-RELATED

This section addresses each of the quality-related (important to safety) design basis performance requirements presented in Section 3.2 of Reference 10.1. All requirements are addressed regardless of any impact created by a reduction in boric acid concentration. For ease of cross reference, these requirements are presented in the same order as they appear in the design basis document with the same last two digits of the section numbers used in this evaluation (i.e., Section 2.2.2 here corresponds to Section 3.2.2 of Reference 10.1).

2.2.1 One charging pump is required to deliver a charging line flow of 45 gpm and a total RCP seal injection flow of 24 gpm to three RCPs for a total pump flow of 69 gpm with a normal RCS pressure of 2235 psig.

Impact: None

Analysis: Not Applicable.

2.2.2 The CVCS must provide adequate letdown and charging flow for purification, cleanup and degassing operations.

Impact: None

Analysis: Not Applicable.

2.2.3 The CVCS is required to provide seal water injection flow, nominally 8 gpm, to each RCP No. 1 seal. The temperature of the seal injection water is required to be 130°F or lower. It is required that suspended solid particles larger than 5 microns be removed from the injection stream.

Impact: None

Analysis: Not Applicable.

2.2.4 The CVCS is required to provide a means for cooling the RCP lower bearing under low RCS pressure conditions when all of the RCP No. 1 seal injection may flow directly into the RCS through the labyrinth seals instead of upward past the lower bearing.

Impact: None

Analysis: Not Applicable.

2.2.5 The CVCS is required to makeup for shrinkage during a 100°F/hr cooldown of the RCS from hot zero power (mode 3, 547°F) to 350°F. This is considered to be an original design basis function of the CVCS.

Impact: This criterion is independent of boron concentration. Since the charging system capacity is not being altered, the ability of the system to provide sufficient makeup capacity under these conditions is not impacted. Boration requirements are specified in Section 2.1.3 of this evaluation.

Analysis: See Section 6.6.4.

2.2.6 In modes 1 through 4, the CVCS is required to ensure that sufficient boric acid is available to bring each unit to cold shutdown with the required shutdown margin from a hot zero power peak xenon condition (mode 3, 547°F). It should be noted that the clarification of Section 3.2.6 (Reference 10.1) recognizes the refueling water storage tank as an alternate source of water to satisfy this design basis requirement (i.e., 70,000 gallons feed and bleed at 1950 ppm boron).

Impact: A reduction in the boron concentration of the boric acid tanks will effectively decrease the rate of RCS boration by

decreasing the amount of boron in every gallon charged to the RCS. An additional consequence will be the corresponding increase in the makeup volume required to add the total amount of boron required to compensate for xenon decay and moderator cooldown. Boration in conjunction with the cooldown, however, will significantly reduce the amount of boron lost during the traditional feed and bleed by taking advantage of the contraction of the RCS. The effective cooldown rate utilized in Section 5.0 is selected conservatively low to allow for significant xenon decay during the cooldown scenario.

The methodology presented in this report and approved by the NRC on previous plants did not assume boration starting at the post-shutdown xenon peak as stated in this design criterion. A more conservative approach was taken that assumed xenon had returned to its full power equilibrium level prior to initiation of the cooldown. In this manner, the negative reactivity inserted by the buildup of xenon after shutdown was not credited. The end of cycle was chosen since it presented the worst case xenon and moderator temperature reactivity effects to be compensated for through boration. This approach has been reviewed in detail and fully approved by the NRC. To conservatively account for this design basis requirement, however, a peak xenon transient is presented in Appendix 9.

Analysis: See Section 5.0 and Appendix 9.

2.2.7 In modes 5 and 6, the CVCS is required to ensure that sufficient boric acid is available to compensate for coolant contraction and the reactivity added due to moderator temperature effects in proceeding from mode 5 at 200°F to ambient conditions.

Impact: A reduction in the boron concentration of the boric acid tanks will effectively increase the volume of boric acid and time required to accomplish this task.

Since this final phase of the RCS cooldown goes beyond the requirement to achieve cold shutdown, the volume of boric acid required to achieve this can be batched and added to the boric acid tank(s) after cold shutdown is achieved. This volume does not need to be considered in the boric acid tank volume requirement for modes 1, 2, 3, and 4. In accordance with the Mode 5 and 6 boric acid inventory requirement bases in the technical specifications, a cooldown to 140 F is the licensing basis for the tanks.

<u>Analysis</u>: See Section 5.3.

2.3 SAFETY ANALYSIS REQUIREMENTS

A reduction in the concentration of boric acid in the boric acid tanks and elimination of the heat tracing associated with the boration subsystems will require several changes to the Turkey Point Technical Specifications as described in Section 7.0. Accordingly, Reference 10.3 was reviewed in detail to ensure the bases behind these technical specifications were understood and addressed.

A principal concern when reducing the available boric acid concentration is the possible impact on the accident analyses of Chapter 14 of the Final Safety Analysis Report (FSAR). A careful review of this chapter has shown that the Turkey Point accident analyses do not rely on any injection of <u>concentrated</u> boric acid. The only boron injection credited is the relatively low concentration from the refueling water storage tank. The boron injection tank boron concentration, as well, has been reduced to a level corresponding to the refueling water storage tank concentration. The accident analyses of Chapter 14, therefore, are not impacted by a reduction in the boron concentration of the boric acid tanks.

Several sections of the FSAR, however, describe the boration capabilities and procedures in terms of the high boron concentration

that is currently available for reactivity control. Changes to these sections are recommended through markups of the appropriate pages provided as Appendix 7. The principal areas of change are in Chapter 1 (brief descriptions of boration capability), Chapter 3 (more detailed descriptions of boration reactivity control measures/capabilities), and Chapter 9 (CVCS system description and required functions).

2.4 10CFR50 APPENDIX R REQUIREMENTS

Reference 10.5 provides a detailed assessment of the capabilities of the plant to achieve and maintain both hot and cold shutdown conditions. Safe shutdown is defined as hot subcritical conditions as a minimum (T>540°F), with the capability to proceed to cold shutdown should conditions warrant. Hot shutdown (per technical specification mode definition) is specifically defined as the initiation of Residual Heat Removal (RHR) system operation (350°F). Although the capability exists to bring the plant to cold shutdown conditions, the preferred approach appears to be to keep the plant at hot zero power (T>540°F) for as long as practically possible (while the fire and any resulting damage are dealt with). The plant would be brought to cold shutdown if, and only if, a plant configuration resulted that required such action (e.g., a technical specification limiting condition of operation not satisfied).

2.4.1 Safe Shutdown

The Turkey Point reactivity control system consists of two independent reactivity control subsystems: 1) rod cluster control assemblies (RCCAs), and 2) boric acid injection via the charging system (CVCS). It is clear from the discussions of References 10.3 and 10.5, however, that the RCCAs alone are capable of achieving and maintaining subcritical conditions during long term hot conditions. The principal reasons for the boric acid injection capability are: 1) to provide a backup to this capability, and 2) to assure adequate

reactivity control during the subsequent cooldown from the hot plant conditions. RCS makeup may or may not be required while maintaining the plant in a hot condition depending upon RCS leakage and the length of time. Adequate makeup capability exists, however, to account for normal leakage under these conditions for a reasonable period of time. Given the limited volume available in the boric acid tanks, however, provisions should be made to preserve the concentrated boric acid for the design basis cooldown scenario by providing RCS makeup during long term hot plant conditions from the refueling water storage tank.

2.4.2 Cold Shutdown

If the plant is forced to go to a cold shutdown condition, reactivity control via boric acid injection will be required. This will be necessary to compensate for the positive reactivity inserted by the reduction in core moderator temperature. In this manner, adequate shutdown margin will be maintained preventing an inadvertent return to criticality.

Boron addition and RCS makeup for contraction are possible using one of three charging pumps and one of two independent sources of a boric acid solution. The preferred source of boric acid is the three (shared) boric acid tanks containing a solution of reduced concentration boric acid via one of four shared boric acid transfer pumps. The backup source of boric acid is the charging pump direct gravity feed line from the refueling water storage tank containing a lower concentration of boric acid. Additional provisions exist to align either unit's refueling water storage tank to the suction of either unit's charging pumps.

The current methodology for conducting a plant cooldown is to initiate a feed and bleed process to bring the RCS boron

concentration to a level corresponding to the required shutdown margin for a cold xenon free core. Once this has been accomplished, the plant is cooled down with makeup for plant volume contraction provided with a combination of makeup water and boric acid blended to the new RCS concentration. This will effectively maintain a constant RCS boron concentration throughout the cooldown process.

Such a feed and bleed process requires that a bleed path be available. Turkey Point Units 3 and 4 have several design features that assure the availability of RCS letdown under a variety of conditions. The following potential letdown paths are described in the Turkey Point FSAR (Reference 10.3):

(1) letdown via the non-regenerative heat exchanger (normal path);

(2) letdown directly to the VCT or holdup tanks bypassing the non-regenerative heat exchanger (in the event of a loss of component cooling water--requires temperature to be maintained <120°F) in conjunction with balanced letdown and charging flow through the regenerative heat exchanger;

(3) letdown to the pressurizer relief tank via the letdown line safety valve (achieved by isolating the letdown line outside of containment);

(4) letdown via the RCP seal water return line to the VCT (normal) or drain tank/pressurizer relief tank (emergency).

A revised approach for conducting a plant cooldown without letdown consists of borating the plant in conjunction with the cooldown. In this manner, no feed and bleed would be necessary since all the boric acid injection would occur during the makeup provided to compensate for contraction of the reactor coolant. Such an approach allows a significant reduction in the concentration of boric acid maintained in the boric acid tanks and the elimination of boration

subsystem heat tracing. The use of letdown, however, will be evaluated in the Operations Analyses of Section 6.0.

Implementation of a boric acid concentration reduction will impact the Turkey Point Appendix R commitments since the use of the methodology presented in this report will require a change from boration prior to plant cooldown to during plant cooldown. Additionally, reduced boric acid concentrations will invalidate the times to achieve the required boron concentration presented in Reference 10.5 (which appear to be applicable to Fuel Cycle No. 8). All other aspects of the post-fire shutdown to hot standby conditions and subsequent cooldown to cold shutdown conditions will remain the same. The 19 and 72 hour limitations are not considered limiting from the perspective of boric acid tank inventory since the refuelikng water storage tank is the stated source for reactivity and inventory control.

3.0 ANALYSIS SCENARIOS

This section outlines the three basic scenarios proposed for detailed analysis of the Turkey Point Units 3 and 4 boration capabilities. These scenarios have been picked based on a careful review of the CVCS design and licensing basis for the current boration capability as outlined in Section 2.0 of this evaluation. Specifically, the first two scenarios of Section 3.1 are the ones that have been approved by the NRC and used successfully for eight C-E designed plants. The basic scenario has been updated to include the plant specific data obtained from Turkey Point design documents. The third scenario of Section 3.1 is included to address the CVCS design basis requirement to support cold shutdown from a peak xenon condition. Section 3.2 describes the non-licensing analyses performed to evaluate the impact of reduced boric acid concentration on normal plant activities.

3.1 LICENSING BASIS ANALYSES

3.1.1 Operating Modes 1, 2, 3, and 4: Equilibrium Xenon

The cooldown methodology proposed herein has been developed to allow a significant reduction in the boric acid concentration that is required to be maintained in the boric acid tanks while operating in Modes 1, 2, 3, and 4. The proposed cooldown methodology differs from the current methodology employed at Turkey Point in that boration of the reactor coolant system is performed concurrently with cooldown as opposed to borating prior to initiating plant cooldown. This approach can be justified if it can be demonstrated through conservative analyses that proper shutdown margin can be maintained when concentrated boron is added as part of normal system makeup during the cooldown process. To accomplish this, the exact boron concentration required to be present in the RCS must be known at any temperature during the cooldown process. In addition, in order to ensure applicability

for an entire cycle, a cooldown scenario must be developed which is conservative in that it places the greatest burden on an operator's ability to control reactivity (i.e., this scenario must define the boration requirements for the most limiting time in core cycle). The limiting scenario is as follows:

(1) Conservative core physics parameters are used to determine the required boron concentration and the required boric acid tank volumes to be added during plant cooldown. End of cycle (EOC) initial boron concentration is assumed to be zero. EOC moderator cooldown effects normalized to the most negative technical specification Moderator Temperature Coefficient (MTC) limit are used to maximize the reactivity insertion rate during the plant cooldown. EOC Inverse Boron Worth (IBW) data are used in combination with the EOC reactivity insertion rates, since this yields results that are more limiting than the combination of specific MTC and IBW values at any fuel cycle exposure prior to EOC. These assumptions ensure that the required boron concentration and the boric acid tank minimum volume requirements conservatively bound all plant cooldowns during core life.

(2) The most reactive rod is stuck in the full out position.

(3) Prior to time zero, the plant is operating at 100% power with 100% equilibrium xenon and with zero RCS leakage. Assuming zero RCS leakage conservatively limits the boron addition to that which is added to the RCS to make up for contraction during the cooldown. Additionally, slow cooldown rates will further reduce the boron addition by limiting the rate of reactor coolant concentration change.

(4) At time zero, the plant is shutdown and held at hot zero power (547°F) conditions for 23.5 hours. The xenon peak after shutdown will have decayed back to the 100% power

equilibrium xenon level by this time. Further xenon decay will add positive reactivity to the core during the subsequent plant cooldown. No credit is taken for the negative reactivity effects of the peak xenon concentration following the reactor shutdown.

(5) At 23.5 hours, offsite power is lost and the plant goes into natural circulation. The non-safety grade letdown is lost. During the natural circulation the RCS average temperature rises 25°F due to decay heat in the core. The initial temperature at the start of the cooldown is 572°F.

(6) Approximately 0.5 hours later, at 24 hours, the operators commence a cooldown to cold shutdown.

The scenario outlined above is used to generate the boration requirements for Modes 1, 2, 3, and 4. It produces a situation where positive reactivity will be added to the RCS simultaneously from two sources at the time that a plant cooldown from hot standby is commenced. These two reactivity sources result from a temperature effect due to an overall negative isothermal temperature coefficient of reactivity, and a poison effect as the xenon-135 level in the core starts to decay below its 100% power equilibrium value. This scenario, therefore, represents the greatest challenge to an operator's ability to borate the RCS and maintain the required technical specification shutdown margin while cooling the plant from hot standby to cold shutdown conditions.

3.1.2 Operating Modes 5 and 6

The methodology developed for Modes 5 and 6 is similar to the method proposed for Modes 1, 2, 3 and 4 in that boration of the RCS is performed concurrently with cooldown. Concentrated boric acid is added as part of normal system makeup during the cooldown

process. To accomplish this, the exact boron concentration required to be present in the RCS must be known at any temperature during the cooldown process. The following scenario was developed to identify the most limiting cooldown transient for Modes 5 and 6.

(1) EOC conditions with the initial RCS boron concentration necessary to provide shutdown margins of 1000 pcm (1% $\Delta k/k$) at 200°F and xenon free. EOC moderator cooldown effects are used to maximize the reactivity change during the plant cooldown. EOC IBW data are used in combination with EOC reactivity insertion rates normalized to the most negative technical specification MTC limit since this yields results that are more limiting than the combination of actual MTC and actual IBW values at all periods through the fuel cycle prior to EOC.

(2) The most reactive rod is stuck in the full out position.

(3) There is zero RCS leakage.

(4) RCS feed and bleed can be used to increase boron concentration (for the case where the refueling water storage tank is the source).

(5) RCS makeup is supplied either from the refueling water storage tank alone or from the boric acid tank.

(6) The most limiting scenario for boration in Mode 5 requires that a 1000 pcm (1% $\Delta k/k$) shutdown margin be maintained during the cooldown from 200°F to 135°F. The boration requirements for Mode 6 only address maintaining a previously established shutdown margin.

The scenario outlined above was used to determine the boration requirements for Modes 5 and 6. It produces a situation where positive reactivity will be added to the RCS due to the overall negative isothermal temperature coefficient of reactivity. Since the core is already assumed to be xenon free there is no contribution to core reactivity due to xenon decay.

3.1.3 Operating Modes 1,2,3, and 4: Peak Xenon

The basic elements of this analysis scenario consist of the following:

(1) the cooldown transient is initiated eight hours following a reactor trip from extended full power operation (corresponding to the peak xenon condition instead of the full power equilibrium xenon concentration) and,

(2) the subsequent cooldown boration must compensate for the decay of the entire xenon inventory from its peak value (instead of its full power equilibrium value).

This scenario presents a worst case near the end of the cycle when sufficient RCS boron concentration (>0 ppm) is available to allow RCS boron concentration to be diluted by the operator to compensate for the post-shutdown xenon buildup in anticipation of a rapid return to power. Starting a design basis cooldown to cold shutdown from the peak xenon condition under these conditions will effectively increase the amount of boron required to be charged to the RCS to compensate for the decay of the xenon peak.

Specifically, the boration required to maintain shutdown margin will be completed from the boric acid tank and refueling water storage tank in conjunction with the plant cooldown such that the volume of boric acid charged into the plant will make up for cooldown contraction. The proposed scenario for this analysis is discussed further in Appendix 9.

3.2 OPERATIONS ANALYSES

A series of analyses are presented in Section 6.0 in order to demonstrate the general impact of a reduction in boric acid tank boron concentration on a variety of plant operations. The specific areas that will be addressed will include operator response to emergency situations, typical plant feed and bleed operations, typical plant blended makeup operations, plant shutdown to refueling, and plant shutdown to cold shutdown. It is a difficult and unnecessary task to evaluate each of these five areas and consider all possible combinations of plant conditions. Instead, initial plant parameters and analyses assumptions will be selected in a conservative manner to give worst case responses. As a consequence, the results (i.e., the volumes and final concentrations that are obtained) should be bounding for any event or any set of initial plant conditions.

4.0 METHOD OF ANALYSIS AND ASSUMPTIONS

4.1 ANALYSIS METHODOLOGY

The basis for the proposed methodology for reduction in the boric acid concentrations required to be maintained in the boric acid tanks is a more efficient use of available boric acid sources. The current cooldown methodology in use at Turkey Point accomplishes RCS boration to the required cold shutdown concentrations before the cooldown begins by utilizing available volume in the pressurizer or through a feed and bleed process. Plant cooldown is initiated with makeup for contraction provided from the reactor makeup water system. This makeup water is blended with boric acid from the boric acid tank to the new RCS concentration. In this manner, RCS concentration is held constant during the cooldown process.

A proposed cooldown methodology is analyzed that will cover a worst case cooldown scenario without letdown (Section 3.1.1). This methodology makes two simple changes to the current approach:

(1) Borate the RCS in conjunction with plant cooldown by using a concentrated boric acid solution as makeup for coolant contraction.

(2) Utilize the refueling water storage tank as an additional source of boric acid makeup.

The basis for the minimum volume specified for the boric acid tank will be such that injection of the boric acid tank contents in the early phase of the cooldown will raise the RCS boron concentration to a sufficient level such that subsequent makeup from the lower concentration refueling water storage tank will maintain adequate shutdown margin throughout the completion of the cooldown. (See Section 5.0.)

Justification for this approach is accomplished in two steps. The first step is to calculate the actual RCS boron concentration requirements during each temperature increment of a plant cooldown that will ensure maintenance of adequate shutdown margin. The next step is to model a plant cooldown and to identify the expected boron delivery to the RCS as makeup for coolant contraction is provided from the boric acid tank and refueling water storage tank. As long as boron delivered to the RCS is always greater than the boron required, shutdown margin is assured. Selection of conservative physics and plant system parameters and the conservative modeling of boron injection ensure that a bounding analysis is presented that will cover those cooldown reactivity control scenarios reasonably expected to occur.

4.2 PHYSICS ANALYSIS ASSUMPTIONS

This section describes the assumptions utilized in the calculation of the required RCS boron concentration during the cooldown. The basic approach of balancing core reactivity effects with boron addition has been devised to conservatively bound the reactivity effects of the design basis cooldown scenarios described in Section 3.1.1 and 3.1.2. This is intended to ensure that these analyses conservatively bound any similar cooldown which may occur any time during the fuel cycle.

The following presents an item-by-item discussion of the specific core reactivity effects that have been accounted for in the physics analysis. Appendix 5 presents the physics data provided by FPL as input to this analysis. Table 4-1 summarizes the important physics parameters utilized in this analysis and compares them to similar values used for a typical plant that has implemented this change. Where applicable, all uncertainties and cycle to cycle variances have been applied in a conservative manner to maximize the reactivity control requirements. Appendix 8 provides a checklist of these key physics parameters to allow cycle to cycle confirmation that these prarameters remain bounding for future cycles.

1. Time in cycle

Positive reactivity is added to the core as the moderator temperature is lowered during plant cooldown. The reactivity effects associated with this cooldown vary over core life so it is important to analyze the most restrictive case. The EOC (or end of life) case was selected for the following reasons:

a. Moderator Temperature Coefficient

The MTC indicates the expected change in core reactivity with a change in moderator temperature. A negative MTC indicates that a positive reactivity effect will result from a decrease in core temperature. The MTC varies widely over core life with the most negative value occurring at EOC. A value of -3.5×10^{-4} $\Delta k/k/°F$ corresponds to the most negative technical specification limit per Specification 3.1.1.3 of Reference 10.6 and was used for this analysis.

b. Required Shutdown Margin

The shutdown margin requirements for Turkey Point are specified in Figure 3.1-1 of Reference 10.6, and, like MTC, varies with core life as a function of fuel depletion, RCS boron concentration and RCS average temperature.

A sufficient shutdown margin ensures that: 1) the reactor can be made subcritical from all operating conditions, 2) the reactivity transients associated with postulated accident conditions are controllable within acceptable limits, and 3) the reactor will be maintained sufficiently subcritical to preclude inadvertent criticality in the shutdown condition.

The most restrictive condition, again, occurs at EOC with RCS average temperature at no load operating temperature and is associated with a postulated steam line break accident and resulting uncontrolled RCS cooldown. This results in a shutdown margin of 1.77% $\Delta k/k$ for temperatures above 200°F (corresponding to an RCS boron concentration of 0 ppm) and 1.0% $\Delta k/k$ for temperatures below 200°F. The reduction in margin requirements at 200°F is due to the fact that the reactivity transients resulting from inadvertent RCS cooldown or dilution are minimal. Hence, 1% $\Delta k/k$ is adequate protection at these lower temperatures.

c. Boron Concentration

Many of the physics parameters used for this analysis vary with boron concentration. In particular, the smaller boron concentration associated with EOC gives the most negative MTC over cycle life. Consequently, an EOC boron concentration of 0 ppm is selected as the most limiting from a core physics perspective.

d. Inverse Boron Worth

IBW data were extracted from the physics data of Appendix 5. EOC IBW data were used in combination with EOC reactivity insertion rates normalized to the most negative technical specification MTC limit since it was known that this yields results that are more limiting than the combination of actual MTC and actual IBW values at all periods through the fuel cycle prior to EOC. The specific IBW values utilized for the EOC analyses are presented in Table 4-2.

2. Scram Worth

A conservative scram worth was used in the physics analysis. Specifically, the available scram worth was computed utilizing the hot zero power scram worth for all rods in, minus the worst rod stuck full out. From this value the rod bank insertion limit worths were subtracted to obtain a net available scram worth. An uncertainty of 10% was subtracted from the available scram worth for added conservatism. This scram worth is further reduced by subtracting an EOC reactivity value associated with the Full Power Defect.

3. Determination of Excess Scram Worth

Excess scram worth was determined by comparing the available scram worth at zero power (Item 2 above) to the required technical specification shutdown margin presented in Item 1b above.

It was determined that there is a 0.697% $\Delta k/k$ excess scram worth available for temperatures above 200°F and an excess scram worth of 1.468% $\Delta k/k$ for temperatures below 200°F.

4. Core Reactivity Effects

A reactivity calculation has been performed to account for the addition of positive reactivity due to both the decay of xenon and the cooldown of the moderator and fuel. Uncertainties were applied to all reactivity effects as indicated in Table 4-1. Table 4-1 summarizes the uncertainties used in this calculation and compares them to the values used for the calculation of a previous unit .

a. Xenon Reactivity Effects

As shown in the data presented in Appendix 5, the xenon worth peaks at its most negative reactivity worth around eight hours after the reactor is shutdown. Xenon decay reduces the negative reactivity of the xenon back to its full power steady state operating value at approximately 24 hours after shutdown. At times after 24 hours, the plant must be borated to compensate for the positive reactivity addition provided by further reductions in xenon concentration. As an added conservatism, the reactivity calculation does not credit the extra negative reactivity inserted by the xenon peak that occurs after shutdown. Instead, the plant is assumed to remain at hot standby for 24 hours to allow xenon to return to the 100% steady state value so that further xenon decay will add net positive reactivity simultaneously with the moderator cooldown effects. The data presented in Appendix 5 was used to determine the positive reactivity inserted into the core for times after 24 hours at discrete time intervals. Note that a slow cooldown rate will prolong the time required to reach Mode 5 where the shutdown margin drops to 1% $\Delta k/k$ and, therefore, would require a larger boron concentration to counteract xenon decay during the cooldown. A 10°F/hr cooldown rate has been utilized in this calculation. It should be noted that this method accounts for xenon decay for a full 61 hours from its full power equilibrium level. This is a much longer time frame than is expected to actually achieve cold shutdown.

The analysis of Appendix 9, however, considers the impact of borating from a peak xenon condition as discussed in Section 3.1.3.

b. Reactor Cooldown Effects

The effect of the reactor cooldown was calculated by determining the fuel temperature and moderator temperature reactivity effects for each incremental temperature decrease. Data from Appendix 5 were utilized to determine these effects. It should be noted that these reactivity effects are independent of time and solely dependent on the change in temperature of the core.

5. Effective Cooldown Rate

As discussed above, positive reactivity is added simultaneously from two sources at the time that the plant cooldown from hot standby is commenced. The component resulting from an overall negative isothermal temperature coefficient of reactivity is independent of time, but is directly dependent upon the net change in moderator temperature. In contrast, the component that results from the decay of xenon below its full power equilibrium value is independent of temperature, but directly dependent upon time. The reactivity contribution from the moderator cooldown is fixed given the fixed temperature endpoints (e.g., 572°F to 200°F). The reactivity contribution from xenon decay, however, will vary depending upon the time interval required to achieve the cooldown (i.e., the effective cooldown rate). As a result, a slower cooldown rate will require more boron to be added to the RCS than a fast cooldown rate for a given temperature decrease. This is because the cooldown will take a longer period of time allowing more positive reactivity to be added to the core from the decay of xenon.

Additionally, since the boration is being accomplished through makeup for coolant contraction, the addition rate of boron is controlled by the rate of coolant contraction. Slower cooldown

rates will result in slower makeup rates which, in turn, result in slower boron addition rates. Superimposing this effect over the temperature independent xenon decay will assure that the most limiting reactivity control scenario is analyzed.

The effective cooldown rate, therefore, is an important input parameter for these analyses. A lower limit of 10°F/hr was selected as the limiting case based on the considerations of Table 4-3.

6. Core Temperature Endpoints

a. Starting Temperature

The normal hot zero power RCS temperature corresponds to 547°F. For the purpose of the analyses presented in Section 5.0 it is assumed that the cooldown initiates from a temperature 25°F higher to conservatively model the expected thermal hydraulic response to a natural circulation condition. This temperature increase also corresponds with natural circulation tests completed at plants of similar size. The cooldown starting temperature, therefore, will be assumed to be 572°F.

b. Ending Temperature

The ending temperature for the cooldown from Hot Standby to Cold Shutdown is chosen to coincide with the 200°F transition from Mode 4 to Mode 5. At this temperature, the shutdown margin requirement is decreased to 1.0% $\Delta k/k$ and the boration source and flow path requirements are relaxed.

The additional cooldown while in Mode 5 is analyzed separately since the boration requirements while in this mode are independent of the Mode 1, 2, 3, 4 boration

requirements (source and flow path). The Bases section of Reference 10.6 indicates that the Mode 5 boration requirement in terms of volume and boron concentration is based on performing a Mode 5 cooldown to 140°F. For the purpose of these analyses with reduced boric acid concentration, the endpoint temperature is assumed to be 135°F to conservatively maximize the core reactivity effects.

Appendix 8 provides a checklist of the key physics parameters that can be used to evaluate subsequent fuel cycle data to ensure the data utilized in these analyses remain bounding.

4.3 SYSTEM ANALYSIS ASSUMPTIONS

Table 4-4 presents a list of the specific parameters utilized in the analysis of boron delivery during the design basis cooldown described in Section 3.0. A comparison is made to the St. Lucie Unit 2 data so that differences in the analyses input and output can be identified. The basic approach in conducting the cooldown analysis is identical to that used for all previous CE units. A few minor changes have been made to make the analysis more conservative. The following paragraphs describe the specific analysis assumptions in greater detail.

1. System Volumes

   a. RCS Volume

      The total coolant volume is listed in Reference 10.3 as 9343 ft^3. Subtracting the total pressurizer volume leaves 8015 ft^3 for the RCS alone. The pressurizer water volume is listed as 808 ft^3 for 100% power and 520 ft^3 for 0% power. As a conservatism, the 100% power pressurizer volume will be utilized in the analyses of Section 5.0. This will provide a higher total system mass to dilute the

boric acid added during the plant cooldown. The 0% power pressurizer volume will be used in the analyses of Section 6.0, however, since this represents the expected volume following a shutdown. Note that a basic assumption throughout the analyses of Section 5 and 6 is that the operators charge to the plant to maintain pressurizer level throughout the cooldown transient.

b. Residual Heat Removal System Volume

The RHR system is brought into service below 465 psia and below 350°F. As shown by Appendix 2, the volume of the RHR system will not impact the final boron concentration when its concentration is assumed to be equal to the RCS boron concentration.

Also, because it is connected to the RCS after the C-E methodology has shifted the RCS makeup to the refueling water storage tank, the RHR volume will not factor into the boric acid tank minimum volume requirements. However, in order to identify the specific refueling water storage tank volume requirements for each case analyzed the RHR volume must be included in the calculations for coolant contraction. To place a conservative upper bound on these volumes an RHR volume equal to the RCS volume (8015 ft^3) is assumed in the Section 5.0 analyses. The operations analyses of Section 6.0, however, assume a closer, yet still conservatively high, volume of 2000 ft^3.

2. Residual Heat Removal System Boron Concentration

For the conservative analyses of Section 5.0, the RHR system is assumed to be at the low concentration equal to the RCS concentration at the time it is lined up to the RCS. In this manner, the system model does not credit boron addition from this system.

3. Makeup Source Temperatures

Appendix 3 presents the derivation of the mass of boric acid that is added to the RCS with every gallon of water charged to the system as makeup for coolant contraction. Although there is a very slight variation in boron delivery with temperature, the effect of source temperature on the required volume is more significant. This makes the higher temperature the limiting case, because it is makeup water density that converts the RCS shrinkage mass into a makeup volume requirement. A higher temperature requires a greater volume to provide the same mass. A temperature of 120°F was selected because it is above the technical specification limit of 100°F for the refueling water storage tank and provides for the possibility of high ambient temperatures in the vicinity of the boric acid tank.

4. RCS Leakage

Zero RCS leakage is assumed throughout the analyses of Section 5.0. This is a conservative assumption because it limits the available boron addition to the RCS to that which is provided by makeup for coolant contraction alone. The effect of RCS leakage on top of the cooldown analyses presented in Section 5.0 would be a feed and bleed in conjunction with the makeup for contraction resulting in a net increase in the boric acid added to the system. Even though boric acid is being lost, the concentration of the makeup water is always higher than that which is lost assuming the boric acid tank or refueling water storage tank is the source of makeup. With RCS leakage, the contents of the boric acid tank will be added to the RCS sooner causing the transition to the refueling water storage tank sooner. The refueling water storage tank would continue to make up for leakage and coolant contraction with an effectively higher boron addition rate. The net result is that the final boron concentration in the RCS will be significantly higher than that which is indicated by the results of Section 5.0.

RCS leakage, however, will impact the total volume used from the refueling water storage tank throughout the cooldown. The refueling water storage tank volumes indicated in the tables of Section 5.0 are based on zero RCS leakage and should be adjusted accordingly. Technical specification limit leakage of 11 gpm over a 24 hour hold and a 37 hour cooldown equates to a maximum expected leakage volume of approximately 42,000 gallons. When added to the contraction makeup volumes, the refueling water storage tank volumes required to support plant cooldown are well within the volume limit of 320,000 gallons for Modes 1 through 4 (supporting emergency core cooling requirements) and need not be accounted for separately.

5. Letdown

Letdown is assumed not to be available for this analysis. The basis for this is that attempted boration is more difficult without it. The availablility of letdown would provide the opportunity to control reactivity changes (xenon and cooldown) through one or more feed and bleed operations. However, the use of letdown at 45 gpm and 60 gpm is evaluated in the Section 6.0 operations analyses to evaluate system boration capability via a feed and bleed process.

6. Boron Mixing in the RCS

Throughout the plant cooldowns analyzed in Section 5.0, a constant pressurizer level is always assumed (i.e., plant operators charge to the RCS only as necessary to makeup for coolant contraction). Under these conditions, the driving force for the mixing of fluid between the RCS and the pressurizer is relatively small. As a conservatism, however, complete and instantaneous mixing is assumed between all makeup fluid added to the RCS through the loop charging nozzles and the pressurizer. Further, a pressure reduction is performed during the plant cooldown process as indicated in Section 5.0.

This pressure reduction is necessary since the shutdown cooling system is a low pressure system and is normally aligned at or below an RCS pressure of 465 psia. Typically, such depressurizations are performed using the auxiliary pressurizer spray system under conditions where the RCPs are not running. As an added conservatism, any boron added to the pressurizer via the spray system is assumed to stay in the pressurizer and not be available for mixing with the fluid in the remainder of the RCS. In the analyses of Section 6.0, however, the boron added to the plant to account for pressurizer mass shrinkage during the depressurization from 2250 psia to 465 psia is credited since plant procedures call for regular pressurizer sprays to equalize boron concentration between the RCS and the pressurizer.

7. RHR Pressure

In accordance with Reference 10.10, RCS pressure will be controlled in the range of 375 to 400 psig. A pressure of 350 psia was chosen for the RCS pressure while on RHR cooldown to conservatively bound the allowable range. Lowering the pressurizer pressure has the effect of causing more pressurizer shrinkage mass that dilutes the RCS when no credit is taken for the boration of this shrinkage mass make up.

8. Final RCS Pressure

As one final dilution step, the RCS is assumed to be depressurized to atmosheric pressure in preparation for refueling.

9. Final Boron Concentration

Final boron concentration is arbitrarily selected as 50 ppm over the highest value for the 200°F shutdown margin requirement. This provides ample margin to support possible physics parameter changes in future cycles.

4.4 ADDITIONAL ASSUMPTIONS, MODE 5 COOLDOWN

The following additional assumptions are applicable to the cooldown analysis for Mode 5 (i.e., cooldown from 200°F to 135°F). The assumptions of Section 4.3 remain applicable, as well

1. Pressurizer Volume

   The 0% power pressurizer level is assumed for this phase of the cooldown analysis since it is a more realistic representation of the plant operations.

2. Initial RCS Boron Concentration

   The analyses of Section 5.0 indicate a final boron concentration in excess of the required boron concentration at the completion of the cooldown to 200°F. However, the initial concentration is assumed to be equal to the 200°F xenon free boron requirement. This will assess the ability of the boration system to recover and maintain a degree of margin above the absolute minimum.

   For the case where the refueling water storage tank is utilized for cooldown makeup, a feed and bleed is necessary at the start of the cooldown to ensure shutdown margin is maintained. The amount of boron added to the system during this feed and bleed was calculated to bring the final RCS boron concentration exactly to the 135°F shutdown margin requirement.

Table 4-1

Boric Acid Concentration Reduction Analysis
Comparison of Physics Parameters

Parameter	Typical C-E Unit	Turkey Point Units 3 and 4
Core Power (100%)	2560 MWt	2200 MWt
Shutdown Margin T>200°F	5.0% Δk/k	1.77% Δk/k
Shutdown Margin T<200°F	3.5% Δk/k	1.0% Δk/k
RCS Average Temperature (0% Power)	532°F	547°F
RCS Cooldown Starting Temperature	557°F (1)	572°F (1)
Moderator Temperature Coefficient	-2.7E(-4)Δk/k/°F	-3.5E(-4)Δk/k/°F
Scram Worth Data Uncertainty (Bias)	13% (-9%)	10% (0%)
Moderator Data Uncertainty (Bias)	10% (0%)	10% (0%)
Doppler Data Uncertainty (Bias)	15% (15%)	20% (0%)
IBW Data Uncertainty (Bias)	10.9% (-3.1%)	10.9% (0%)
Effective Cooldown Rate	12.5°F/hr	10°F/hr
Start of Cooldown (time after Shutdown)	26 hrs	24 hrs (2)
Excess Scram Worth (T>200°F)	0.08% Δk/k	0.697% Δk/k
Excess Scram Worth (T≤200°F)	1.58% Δk/k	1.468% Δk/k

(1) Based on 25°F heat up from hot zero power condition upon initiation of natural circulation.
(2) The analysis of Appendix 9 starts from the peak xenon condition at 8 hours after a full power shutdown.

Table 4-2

Inverse Boron Worth

Temperature (°F)	IBW
572.0	98.65
552.0	95.88
532.0	93.44
512.0	91.26
492.0	89.33
472.0	87.61
452.0	86.06
432.0	84.66
412.0	83.39
392.0	82.21
372.0	81.12
352.0	80.08
332.0	79.10
312.0	78.16
292.0	77.24
272.0	76.34
252.0	75.46
232.0	74.60
212.0	73.76
202.0	73.34
200.0	73.26

Table 4-3

Derivation of Limiting Cooldown Rate (*)
(Modes 1, 2, 3, and 4)

	Action	Time	Total
1.	Plant Shutdown to Hot Standby	0	0
2.	Initial Hold at Hot Standby(1)	4	4
3.	Plant Cooldown 572°F to approx. 350°F(2)	9	13
4.	Hold for upper Head Cooling(3)	9	22
5.	Plant Cooldown from approx. 350°F to 200°F	6	28
6.	Additional Conservatism(4)	9	37

7. Effective Cooldown Rate: (372°F)/(37 hr) = 10°F/hr

(1) Per NRC Branch Technical Position (BTP) RSB 5-1

(2) Cooldown rate limited to 25°F/hr per Reference 10.10 (normally limited to 6 hours by technical specification ACTION statements)

(3) Per Reference 10.10

(4) Allows for actual plant cooldown rates during Steps 3 and 4 as low as 15°F/hr

(*) This represents a conservative estimate of the time required to complete a cooldown to COLD SHUTDOWN to maximize xenon decay reactivity effects.

Table 4-4

Boric Acid Concentration Reduction Analysis
Comparison of System Analysis Parameters

Parameter	Typical C-E Unit	Turkey Point Units 3 and 4
RCS Volume	9398 ft^3	8015 ft^3 (1)
Pressurizer Water Volume (100% Power)	600 ft^3	808.0 ft^3 (2)
Pressurizer Water Volume (0% Power)	450 ft^3	520.0 ft^3
RCS Normal Operating Pressure	2250	2250
RCS Minimum Operating Pressure	2200	2200
RCS Cooldown Starting Pressure	2200 psia	2250 psia
RCS Cooldown Final Pressure (Mode 5)	275 psia	14.7 psia
RCS Average Temperature (100% Power)	572°F	574.2°F
RCS Average Temperature (0% Power)	532°F	547°F
Post-Shutdown RCS Temperature Increase	25°F	25°F
RCS Cooldown Starting Temperature	557°F	572°F
RCS Cooldown Final Temperature (Mode 2 to 5)	200°F	200°F
RCS Cooldown Final Temperature (Modes 5 and 6)	135°F	135°F
Effective Cooldown Rate	12.5°F/hr	10°F/hr
Shutdown Cooling System Entry Pressure	275 psia	350 psia
Shutdown Cooling System Entry Temperature	325°F	350°F
RWST Minimum Volume (Modes 1-4)	417,100 gal	320,000 gal
RWST Minimum Boron Concentration	1720 ppm	1950 ppm
RWST Temperature (Assumed)	50°F	120°F
Boric Acid Tank Temperature (Assumed)	70°F	120°F
RCS Leakage (Assumed)	0 gpm	0 gpm
Letdown Utilized	No	No
Initial RCS Boron Concentration	0 ppm	0 ppm
Pressurizer Condition	Saturated	Saturated

(1) Loop and vessel volumes only
(2) Pressurizer water volume only (the total capacity of the loops, vessel, and pressurizer is listed as 9343.

5.0 DESIGN BASIS ANALYSES

This section presents the results of the analyses completed for the scenarios outlined in Sections 3.1.1 and 3.1.2. These specific scenarios were chosen on the basis that they represent the most limiting reactivity control conditions during a design basis cooldown of the plant. Section 5.1 presents the actual RCS boron concentration requirements that conservatively maintain the required shutdown margin at discrete temperature increments. Section 5.2 discusses the conservative analysis of the cooldown from the hot standby condition to cold shutdown. Section 5.3 completes the cooldown analysis by presenting the conservative cooldown from cold shutdown conditions to refueling temperatures.

5.1 REQUIRED RCS BORON CONCENTRATION

Using the physics data of Appendix 5 and the assumptions of Section 4.2, a detailed reactivity balance calculation was completed. The output of this calculation is a specified minimum boron concentration change that must occur in the core (i.e., in the RCS) to maintain the specified shutdown margin. This reactivity balance specifically takes into account the positive reactivity addition of xenon decay below its initial full power equilibrium concentration and positive reactivity addition of moderator cooldown. With the uncertainties of Section 4.2 conservatively applied, shutdown margin will be assured if the RCS boron concentration is maintained above the levels indicated in Tables 5.1-1 through 5.1-6 for each temperature step. The data in these tables are presented in Figure 5.1-1.

As can be seen from the tables and Figure 5.1-1, the slower cooldown rates have higher boron concentration requirements. This is because in the time to get to 200°F, more xenon will have decayed, adding a greater amount of reactivity that must be compensated for.

It should also be noted that three different boron concentration requirements are specified for the 200°F temperature endpoint. The first corresponds to the endpoint of the cooldown and corresponds to a shutdown margin of 1.77% Δk/k. At 200°F, however, the shutdown margin requirement drops to 1.0% Δk/k, effectively requiring less boron to be in the system. The third entry corresponds to the boron concentration required to maintain a 1.0% Δk/k shutdown margin at 200°F with all xenon decayed away (xenon free). Xenon requires approximately 150 hours after shutdown to effectively decay away to this level. It should be noted that all of the tables indicate the same xenon free required boron concentration at 200°F.

The results of the peak xenon calculation are presented in Appendix 9. Since the Appendix 9 final concentration for 200 degrees at a 10°F/hr cooldown rate is the higher value, the acceptance criteria for the cooldown evaluations will be a final concentration 50 ppm higher than the identified limit of 840 ppm boron.

Table 5.1-1

Required Boron Concentration vs. Temperature
Equilibrium Xenon, EOC, 10°F/hr Cooldown Rate

Temperature (°F)	Required Boron (ppm)
572.0	-180.81
552.0	-63.90
532.0	48.22
512.0	147.89
492.0	233.39
472.0	307.02
452.0	370.73
432.0	426.15
412.0	474.64
392.0	517.38
372.0	555.32
352.0	589.29
332.0	619.98
312.0	647.95
292.0	673.68
272.0	697.57
252.0	719.94
232.0	741.05
212.0	761.12
202.0	770.81
200.0 (1.77% Δk/k)	772.73
200.0 (1.0% Δk/k)	710.17
200.0 (Xenon Free)	730.70

Table 5.1-2

Required Boron Concentration vs. Temperature
Equilibrium Xenon, EOC, 25°F/hr Cooldown Rate

Temperature (°F)	Required Boron (ppm)
572.0	-180.81
522.0	61.05
472.0	243.12
422.0	373.13
372.0	471.12
322.0	549.62
272.0	616.31
222.0	675.63
200.0 (1.77% $\Delta k/k$)	700.05
200.0 (1.0% $\Delta k/k$)	637.49
200.0 (Xenon Free)	730.70

Table 5.1-3

Required Boron Concentration vs. Temperature
Equilibrium Xenon, EOC, 50°F/hr Cooldown Rate

Temperature (°F)	Required Boron (ppm)
572	-180.81
522	47.11
472	218.02
422	339.06
372	429.91
322	502.89
272	565.54
222	622.11
200.0 (1.77% $\Delta k/k$)	645.68
200.0 (1.0% $\Delta k/k$)	583.12
200.0 (Xenon Free)	730.70

Table 5.1-4

Required Boron Concentration vs. Temperature
Equilibrium Xenon, EOC, 90°F/hr Cooldown Rate

Temperature (°F)	Required Boron (ppm)
572	-180.81
482	177.91
392	377.29
302	503.38
212	602.42
200.0 (1.77% $\Delta k/k$)	614.50
200.0 (1.0% $\Delta k/k$)	551.94
200.0 (Xenon Free)	730.70

Table 5.1-5

Required Boron Concentration vs. Temperature
Equilibrium Xenon, EOC, 100°F/hr Cooldown Rate

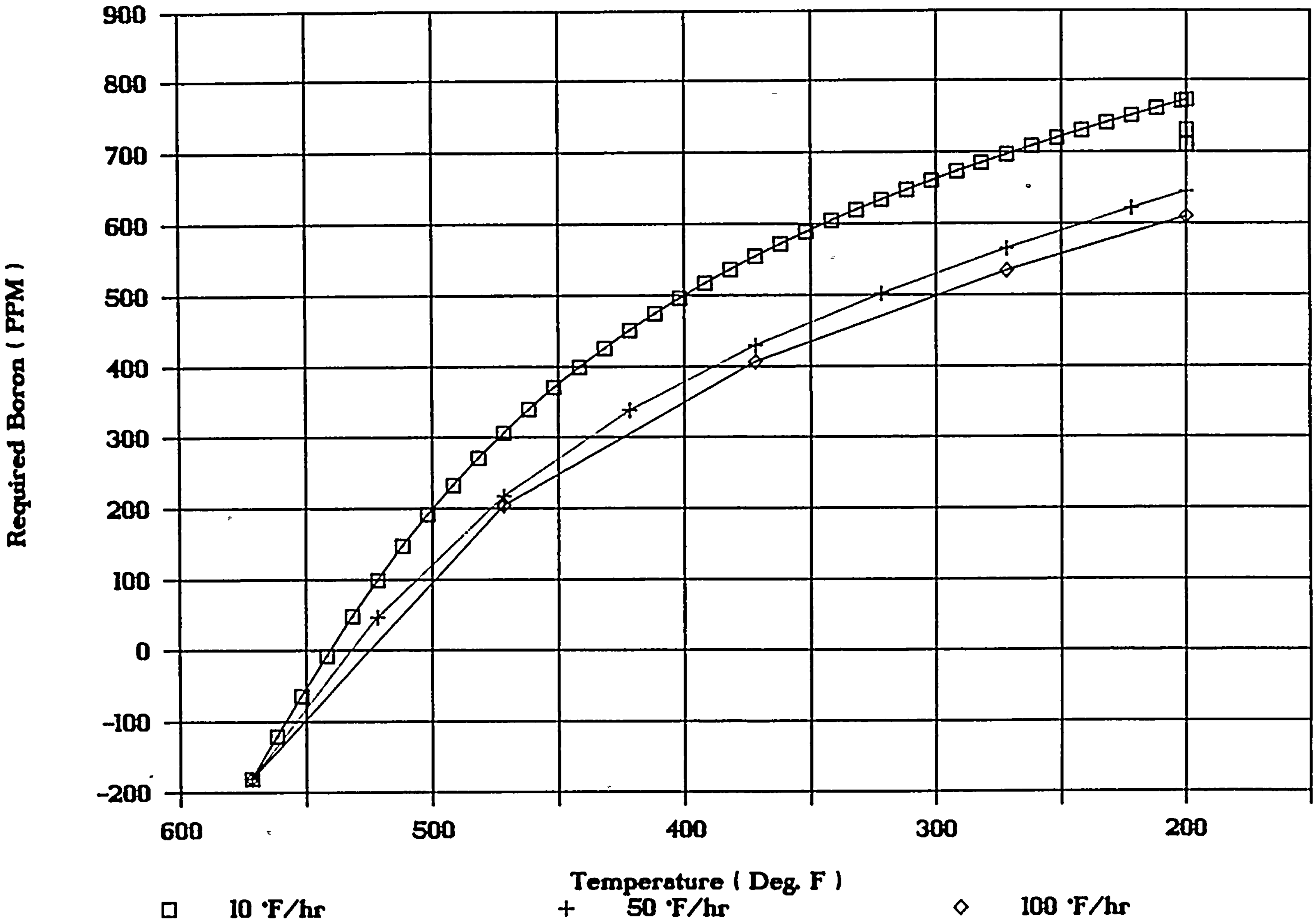
Temperature (°F)	Required Boron (ppm)
572	-180.81
472	204.79
372	406.67
272	534.57
200.0 (1.77% $\Delta k/k$)	610.44
200.0 (1.0% $\Delta k/k$)	547.88
200.0 (Xenon Free)	730.70

Table 5.1-6

Required Boron Concentration vs. Temperature
Mode 5 Cooldown to Refueling

Temperature (°F)	Required Boron (ppm)
200 (Xenon Free)	730.70
180	746.83
160	762.95
140	779.08
135	783.11

Figure 5.1-1 Required Boron Concentration



5.2 COOLDOWN FROM HOT STANDBY, EQUILIBRIUM XENON, EOC

5.2.1 Purpose

The purpose of this analysis is to model a plant cooldown from hot standby to cold shutdown to determine the actual expected boron delivery to the RCS. The criterion for this analysis is that a shutdown margin of 1.77% $\Delta k/k$ must be maintained throughout the cooldown process down to a temperature of 200°F. (At 200°F and below, the shutdown margin requirement is reduced to 1.0% $\Delta k/k$.) Maintenance of these shutdown margins will be assured as long as the actual boron delivered with the makeup provided for coolant contraction maintains RCS boron concentration above the required boron concentration of Tables 5.1-1 through 5.1-5 of Section 5 and Appendix 9.

5.2.2 Analyses

The assumptions and initial conditions for this analysis are discussed in Section 4.0 and are summarized in Table 5.2-1. Since the boron delivery to the RCS is limited to the makeup that is provided to compensate for coolant contraction, the expected coolant contraction must be determined for discrete temperature changes. A known boron content of the makeup water leads to an accounting of the accumulated boron at each temperature increment which, in turn, leads to a determination of the boron concentration. The calculations are performed in the following manner.

To begin, boron concentration in terms of weight fraction is defined as follows:

$$\text{(boron concentration)} = \frac{\text{(mass of boron in system)}}{\text{(total system mass)}}$$

where, if complete mixing is assumed between the RCS and the pressurizer, the total system mass is the sum of the boron mass in the system, the RCS water mass, and the pressurizer water

mass. Mass of boron in the system will be determined by identifying the boron added with each temperature increment.

Therefore, the initial total system mass of 393,572.1 lbm in Tables 5.2-2 through 5.2-4 was calculated as follows:

$$(\text{Total System Mass})_i = (\text{Boron Mass})_i + (\text{RCS Water Mass})_i + (\text{PZR Water Mass})_i$$

or

$$TSM = 0 + \frac{8015 \text{ ft}^3}{0.022042 \text{ ft}^3/\text{lbm}}^{(1)} + \frac{808 \text{ ft}^3}{0.02698 \text{ ft}^3/\text{lbm}}^{(2)}$$

The total system mass is then corrected for each temperature increment by accounting for both water and boron addition as makeup is provided for the contraction of the reactor coolant. The amount of coolant contraction (or shrinkage) with each temperature increment is found by comparing the specific volume at the starting temperature (v_i) of each increment to the specific volume at the final temperature (v_f) of each increment.

The following represents a summary of the calculations for each temperature increment of the plant cooldown:

Initial Temperature = T_i

Final Temperature = T_f

Initial Specific Volume = v_i (3)

Final Specific Volume = v_f (4)

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(1) Specific volume of compressed water at 572 degrees and 2250 psia.
(2) Specific volume of saturated water at 2250 psia.
(3) Obtained from Reference 10.11 for compressed liquid at given pressure and T_i
(4) Obtained from Reference 10.11 for compressed liquid at given pressure and T_f

Shrinkage Mass = (System Volume) $(1/v_f - 1/v_i)$

BAT Makeup Volume = (Shrinkage Mass) / (8.2498 lbm/gallon)[5]

RWST Makeup Volume = (Shrinkage Mass) / (8.2498 lbm/gallon)[5]

Boric Acid Added = (BAT Vol.) x (mass of boric acid/gallon)[6]

or

= (RWST Vol.) x (mass of boric acid/gallon)[6]

Total Boric Acid = (Initial Boric Acid) + (Boric Acid Added)

Total System Mass = (RCS water mass)[7] + (PZR water mass)[8] + (Total boric acid)

$$\text{Final Concentration} = \frac{(\text{Total Boric Acid})(100)(1748.34)^{(9)}}{(\text{Total System Mass})}$$

This calculation process is completed for several temperature increments (assuming constant plant pressure) until a temperature of 350°F is reached. At this temperature two things happen:

1. The RCS is depressurized to 465 psia to correspond with the maximum pressure for connecting the RHR system to the RCS. This pressure reduction actually entails a cooldown of the pressurizer and, hence, a pressurizer shrinkage mass. This is calculated by comparing the specific volumes for a saturated liquid at 2250 psia and 465 psia. The volume to accommodate this, in all cases, comes from the refueling water storage tank. As a conservatism, this volume addition is assumed not to add any boron to the RCS.

---

(5) Density of water at assumed tank temperature 120°F. (Reference 10.13)
(6) See Appendix 3 for values of dissolved boric acid in water.
(7) RCS water mass = (8015 ft^3) / (specific volume)
(8) PZR water mass = (808 ft^3) / (specific volume at indicated P_{sat}).
(9) See Appendix 4 for the conversion factor between wt.% and ppm.

2. The RCS is lined up to the RHR system which increases the total system volume and mass for the remainder of the cooldown. The RHR system is conservatively assumed to have a boron concentration equal to the RCS concentration so that no boron addition is credited. Also, the RHR system volume is assumed to be equal to the RCS volume to conservatively estimate the refueling water storage tank makeup requirements for the latter stages of the plant cooldown.

The remainder of the cooldown analysis is handled in the same manner as described above. To complete the analysis, the final boron concentration is compared to the required concentration identified in Tables 5.1-1 through 5.1-5 of Section 5.0 and Appendix 9. An arbitrary margin of 50 ppm is added to the 200°F, 1.77% $\Delta k/k$ shutdown margin required boron concentration of Appendix 9 to define the acceptance criteria for the cooldown analysis.

The purpose of this analysis is to identify the minimum acceptable volume required from the boric acid tank as input to the plant technical specifications. This is accomplished by adjusting the temperature at which the source of makeup water is switched from the boric acid tank to the refueling water storage tank. This is accomplished through an iterative process until the switch over temperature is identified that results in a final concentration just equal to or slightly higher than the established acceptance criterion. The design basis of the boric acid tank concentration and minimum volume requirement, therefore, is established. It is that volume and concentration that is necessary to raise RCS boron concentration such that subsequent makeup for coolant contraction supplied by the lower concentration refueling water storage tank alone will still maintain the required shutdown margin per Tables 5.1-1 through 5.1-5.

5.2.3 Results

A detailed parametric analysis was performed to identify the minimum acceptable boric acid tank volume for a range of concentrations. In

particular, boric acid tank concentration was varied from 3.0 weight percent boric acid to 3.5 weight percent boric acid. This concentration range strikes the optimum balance between the need to keep the concentration low (to keep the solubility temperature limit as low as possible) and the need for a higher concentration to keep the corresponding volume requirements well within the current capacity of the tanks. An optimum concentration of 3.25 ±0.25 weight percent achieves this with a control band that is well within the accuracy of the boron concentration measurement analysis.

The analyses described in Section 5.2-2 were completed utilizing the CE Utility Code BACR. A Computer Code Certificate and the Turkey Point Code input are provided as Appendix 10. Tables 5.2-2 through 5.2-4 represent the output of this code for the indicated boric acid tank and refueling water storage tank concentrations.

The boron concentration results of Tables 5.2-2 through 5.2-4 were compared to the required concentrations at each temperature increment during a plant cooldown identified in Tables 5.1-1 through 5.1-5. In each case, the actual system boron concentrations are greater than that necessary for the required shutdown margin. This is illustrated graphically by combining the curves for required boron concentration and delivered concentration for three separate cases in Figure 5.2-1 through 5.2-3.

To set the minimum technical specification boric acid tank volume corresponding to the various boric acid tank and refueling water storage tank concentrations, the tank volumes from Tables 5.2-2 through 5.2-4 were extracted and are tabulated in Table 5.2-5. The volumes contained in Table 5.2-5 are the minimum boric acid tank volumes needed (in conjunction with the refueling water storage tank) to borate the RCS to the required shutdown margin. These volumes must be contained in the region of the boric acid tank above zero percent indicated level. The refueling water storage tank volumes corresponding to each boric acid tank required volume are

provided for information only and are not intended for incorporation into the plant technical specifications. These volumes are well within the volume requirements for emergency core cooling and need not be included separately.

Table 5.2-6 summarizes the makeup flow rates that could be expected during the transient analyzed. For the limiting cooldown rate of 10°F/hr, the required boric acid flow rate ranges from 8 to 10 gpm. Such flow rates are just within the 10 gpm capacity of flow control valve FCV-113A for the manual and blended boric acid flow paths (normal boration) and well within the 60 gpm (nominal) capacity of the emergency boration flow path via motor operated valve MOV-350. Faster cooldown rates will require even greater makeup capacity to compensate for the faster contraction rate of the coolant. Table 5.2-6 shows the effective makeup capacity requirements for a cooldown rate of 25°F/hr, as well. This is the maximum cooldown rate allowed for natural circulation cooldowns in accordance with Reference 10.10. While the flow rates of 21 to 24 gpm are well within the emergency boration flow path capacity of 60 gpm (nominal), they exceed the current 10 gpm limit of FCV-113A. A modification is planned for this valve, however, to ensure the availability of the normal boration flow path for the cooldown scenarios evaluated thus far. Two transfer pumps supplying borated water via the normal or emergency boration flow path will be adequate for the faster cooldown transients.

5.2.4 Refueling Water Storage Tank Boration Requirements, Modes 1,2,3 and 4

The refueling water storage tank provides an independent source of borated water that can be used to compensate for core reactivity changes and expected transients throughout core life. It should be noted that in Modes 1, 2, 3 and 4, the minimum refueling water storage tank water volume is 320,000 gallons as required by emergency core cooling considerations. The purpose of this section

is to demonstrate that the refueling water storage tank minimum inventory requirements (in modes 1, 2, 3 and 4) required to compensate for the reactivity changes during a shutdown and cooldown (using the refueling water storage tank as the only source of borated water) are much less than the emergency core cooling requirements.

This calculation derives the minimum volume of refueling water storage tank water necessary to bring the plant from hot standby to cold shutdown while maintaining the plant at a 1.77% $\Delta k/k$ shutdown margin. The calculation approach is identical to that of the cooldown described in Section 5.2.2. The major difference is that all RCS makeup is supplied from the refueling water storage tank at a boron concentration of 1950 ppm. This cooldown is performed as described below:

1. Perform a feed and bleed with the refueling water storage tank to raise RCS boron concentration from 0 ppm to 535 ppm boron. This is a 255 minute feed and bleed using 60 gpm letdown.

2. Perform a plant cooldown from an initial RCS temperature and pressure of 572°F (547°F + 25°F as described in Section 4.2.6.a) and 2250 psia to 350°F and 350 psia. Charge from the refueling water storage tank only as required to make up for coolant contraction.

3. Align the RHR system to the RCS. Assume that its volume is 8015 ft^3. Assume that the concentration of the RHR system is equal to that of the RCS at the time of initiation.

4. Continue cooldown from 350°F and 350 psia to a final RCS condition of 200°F and 14.7 psia. Charge only as necessary to make up for coolant contraction.

Table 5.2-7 contains the results of the calculated volumes in steps 1 through 4 above. The refueling water storage tank boration requirement for Modes 1, 2, 3 and 4 is estimated to be 37,155 gallons. This value does not account for any RCS leakage during this process. Figure 5.2-4 shows the RCS boron concentration for this special case. As expected, the boration requirements impose a refueling water storage tank minimum volume which is much smaller than the minimum volume requirements placed on the tank by emergency core cooling requirements (320,000 gallons). Even with a bounding assumption of 11 gpm RCS leakage during a 24 hour hold and a 37 hour cooldown, the maximum expected refueling water storage tank makeup volume requirement is 77,415 gallons.

Table 5.2-1

Summary of Initial Conditions and Assumptions
Cooldown from 572°F to 200°F
(Mode 3 to 5)

Parameter	Value
RCS Volume	8015 ft^3 (1)
Pressurizer Volume (100% Power Level)	808 ft^3 (2)
Initial RCS Pressure	2250 psia
Final RCS Pressure	14.7 psia
Initial RCS Temperature	572°F
Final RCS Temperature	200°F
Pressurizer Condition	Saturated
Pressurizer Level	Constant
RCS Leakage	0
Initial RCS Boron Concentration	0
Initial Pressurizer Boron Concentration	0
RHR Volume	8015 ft^3 (3)
RHR Boron Concentration	[= RCS] (4)
Letdown Available	No
Refueling Water Storage Tank Temperature	120°F
Boric Acid Tank Temperature	120°F

(1) Loop and vessel volumes only
(2) Pressurizer water volume only. In combination with note (1) above, this corresponds to a total inventory 9343 cubic feet.
(3) Overestimated for conservatism
(4) Underestimated for conservatism

TABLE 5.2-2

PLANT COOLDOWN FROM 572 F TO 200 F; BAT AT 3.50 wt% BORIC ACID; RWST AT 1950 ppm BORON

AVG.SYS. TEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC. (ppm boron)
572	572	2250	1.00000	1.00000	0.0	0.0	0.0	0.0	0.0	393,572.1	0.0
572	560	2250	0.02204	0.02165	6,669.4	808.4	0.0	241.9	241.9	400,483.4	105.6
560	540	2250	0.02165	0.02106	10,376.3	1,257.8	0.0	376.3	618.2	411,236.0	262.8
540	520	2250	0.02106	0.02055	9,449.6	1,145.4	0.0	342.7	961.0	421,028.3	399.1
520	500	2250	0.02055	0.02009	8,835.5	1,071.0	0.0	320.5	1,281.4	430,184.3	520.8
500	480	2250	0.02009	0.01969	8,104.7	982.4	0.0	294.0	1,575.4	438,582.9	628.0
480	467	2250	0.01969	0.01945	5,001.7	606.3	0.0	181.4	1,756.8	443,766.0	692.1
467	440	2250	0.01945	0.01900	9,892.1	0.0	1,199.1	111.6	1,868.4	453,769.6	719.9
440	420	2250	0.01900	0.01869	6,885.8	0.0	834.7	77.7	1,946.1	460,733.1	738.5
420	390	2250	0.01869	0.01828	9,738.3	0.0	1,180.4	109.8	2,055.9	470,581.3	763.8
390	350	2250	0.01828	0.01781	11,577.2	0.0	1,403.3	130.6	2,186.5	482,289.0	792.6
350	350	350	0.02698	0.01912	12,311.3	0.0	1,492.3	0.0	2,186.5	494,600.3	772.9
350	350	350	0.01781	0.01781	0.0	0.0	0.0	0.0	4,177.7	945,042.1	772.9
350	300	350	0.01781	0.01743	19,369.8	0.0	2,347.9	218.5	4,396.2	964,630.3	796.8
300	260	350	0.01742	0.01707	18,867.7	0.0	2,287.1	212.8	4,609.0	983,710.9	819.2
260	230	350	0.01706	0.01683	12,841.0	0.0	1,556.5	144.8	4,753.8	996,696.7	833.9
230	200	350	0.01682	0.01662	11,468.5	0.0	1,390.2	129.4	4,883.2	1,008,294.6	846.7
200	200	14.7	0.01912	0.016719	6,068.8	0.0	735.6	0.0	4,883.2	1,014,363.4	841.7

TOTAL BAT VOLUME 5,871.3 GALLONS

TOTAL RWST VOLUME 13,691.4 GALLONS

TABLE 5.2-3 PLANT COOLDOWN FROM 572 F TO 200 F; BAT AT 3.25 wt% BORIC ACID; RWST AT 1950 ppm BORON

AVG.SYS. TEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC. (ppm boron)
572	572	2250	1.00000	1.00000	0.0	0.0	0.0	0.0	0.0	393,572.1	0.0
572	560	2250	0.02204	0.02165	6,669.4	808.4	0.0	224.0	224.0	400,465.5	97.8
560	540	2250	0.02165	0.02106	10,376.3	1,257.8	0.0	348.6	572.6	411,190.4	243.5
540	520	2250	0.02106	0.02055	9,449.6	1,145.4	0.0	317.4	890.0	420,957.4	369.6
520	500	2250	0.02055	0.02009	8,835.5	1,071.0	0.0	296.8	1,186.8	430,089.6	482.4
500	470	2250	0.02009	0.01951	11,965.6	1,450.4	0.0	401.9	1,588.7	442,457.1	627.8
470	452	2250	0.01951	0.01919	6,766.9	820.3	0.0	227.3	1,816.0	449,451.4	706.4
452	440	2250	0.01919	0.01900	4,265.9	0.0	517.1	48.1	1,864.2	453,765.4	718.3
440	420	2250	0.01900	0.01869	6,885.8	0.0	834.7	77.7	1,941.8	460,728.9	736.9
420	390	2250	0.01869	0.01828	9,738.3	0.0	1,180.4	109.8	2,051.7	470,577.1	762.3
390	350	2250	0.01828	0.01781	11,577.2	0.0	1,403.3	130.6	2,182.2	482,284.8	791.1
350	350	350	0.02698	0.01912	12,311.3	0.0	1,492.3	0.0	2,182.2	494,596.1	771.4
350	350	350	0.01781	0.01781	0.0	0.0	0.0	0.0	4,169.7	945,034.0	771.4
350	300	350	0.01781	0.01743	19,369.8	0.0	2,347.9	218.5	4,388.1	964,622.3	795.3
300	260	350	0.01742	0.01707	18,867.7	0.0	2,287.1	212.8	4,600.9	983,702.8	817.7
260	230	350	0.01706	0.01683	12,841.0	0.0	1,556.5	144.8	4,745.8	996,688.6	832.5
230	200	350	0.01682	0.01662	11,468.5	0.0	1,390.2	129.4	4,875.1	1,008,286.5	845.3
200	200	14.7	0.01912	0.016719	6,068.8	0.0	735.6	0.0	4,875.1	1,014,355.3	840.3

TOTAL BAT VOLUME 6,553.3 GALLONS

TOTAL RWST VOLUME 13,009.5 GALLONS

TABLE 5.2-4 PLANT COOLDOWN FROM 572 F TO 200 F; BAT AT 3.00 wt% BORIC ACID; RWST AT 1950 ppm BORON

AVG.SYS. TEMP. (F) Ti	AVG.SYS. TEMP. (F) Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	SPECIFIC VOLUME (cu.ft./lbm) Vf	SHRINKAGE MASS(lbm)	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC. (ppm boron)
572	-572	2250	1.00000	1.00000	0.0	0.0	0.0	0.0	0.0	393,572.1	0.0
572	-560	2250	0.02204	0.02165	6,669.4	808.4	0.0	206.3	206.3	400,447.8	90.1
560	-540	2250	0.02165	0.02106	10,376.3	1,257.8	0.0	320.9	527.2	411,145.0	224.2
540	-520	2250	0.02106	0.02055	9,449.6	1,145.4	0.0	292.3	819.4	420,886.8	340.4
520	-500	2250	0.02055	0.02009	8,835.5	1,071.0	0.0	273.3	1,092.7	429,995.5	444.3
500	-480	2250	0.02009	0.01969	8,104.7	982.4	0.0	250.7	1,343.4	438,350.9	535.8
480	-460	2250	0.01969	0.01933	7,688.3	931.9	0.0	237.8	1,581.2	446,277.0	619.4
460	-431	2250	0.01933	0.01886	10,327.2	1,251.8	0.0	319.4	1,900.6	456,923.6	727.2
431	-420	2250	0.01886	0.01869	3,764.0	0.0	456.3	42.5	1,943.0	460,730.1	737.3
420	-390	2250	0.01869	0.01828	9,738.3	0.0	1,180.4	109.8	2,052.8	470,578.3	762.7
390	-350	2250	0.01828	0.01781	11,577.2	0.0	1,403.3	130.6	2,183.4	482,286.0	791.5
350	350	350	0.02698	0.01912	12,311.3	0.0	1,492.3	0.0	2,183.4	494,597.3	771.8
350	350	350	0.01781	0.01781	0.0	0.0	0.0	0.0	4,171.9	945,036.3	771.8
350	300	350	0.01781	0.01743	19,369.8	0.0	2,347.9	218.5	4,390.4	964,624.5	795.7
300	260	350	0.01742	0.01707	18,867.7	0.0	2,287.1	212.8	4,603.2	983,705.1	818.1
260	230	350	0.01706	0.01683	12,841.0	0.0	1,556.5	144.8	4,748.0	996,690.9	832.9
230	200	350	0.01682	0.01662	11,468.5	0.0	1,390.2	129.4	4,877.4	1,008,288.8	845.7
200	200	14.7	0.01912	0.016719	6,068.8	0.0	735.6	0.0	4,877.4	1,014,357.6	840.7

TOTAL BAT VOLUME 7,448.8 GALLONS

TOTAL RWST VOLUME 12,114.0 GALLONS

Table 5.2-5

Minimum Required Boric Acid Tank Volumes
Modes 1, 2, 3, and 4
(RWST @ 1950 ppm)

BAT Concentration[1] wt% (ppm)	BAT Volume[2] gallons	RWST Volume[3] gallons
3.5 (6119)	5,900	14,000
3.25 (5682)	6,600	14,000
3.0 (5245)	7,500	13,000

(1) The conversion factor between wt% and ppm boron is 1.0 wt% equals 1748.34 ppm boron (Appendix 4).

(2) Includes analysis value rounded up to nearest 100 gallons. These volumes doe not include instrument error/inaccuracy since the low level alarm setpoint will be set to accommodate instrument loop errors.

(3) Rounded up to nearest 1000 gallons (this volume does not include the makeup for any RCS leakage).

Table 5.2-6

Summary of Effective Flow Rate Requirements

Source (BAT wt%) (RWST ppm)	RCSΔT[(1)] (°F)	Time To Achieve ΔT[(2)] (minutes) 10°F/hr	25°F/hr	100°F/hr	Makeup[(3)] Volume (gallons)	Effective[(4)] Flow Rate (gpm) 10°F/hr	25°F/hr	100°F/hr
BAT 3.50	90	540	216	54	5,165	9.6	23.9	95.6
RWST 1950	282	1692	676.8	169.2	14,539	8.6	21.5	85.9
BAT 3.25	102	612	244.8	61.2	5,733	9.4	23.4	93.7
RWST 1950	270	1620	648	162	13,971	8.6	21.6	86.2
BAT 3.00	119	714	285.6	71.4	6,508	9.1	22.8	91.1
RWST 1950	253	1518	607.2	151.8	13,196	8.7	21.7	86.9

(1) Extracted from Tables 5.2-2 through 5.2-4 corresponding to ΔT from cooldown start to switchover temperature (BAT) and from switchover temperature to finish (RWST)
(2) Time = (RCS ΔT) / (Cooldown Rate)
(3) Extracted from Table 5.2-2 through 5.2-4
(4) Effective Flow Rate = (Makeup Volume) / (Time)

TABLE 5.2-7 PLANT COOLDOWN FROM 572 F TO 200 F; RWST FEED AND BLEED AND MAKEUP AT 1950 ppm BORON

AVG.SYS. TEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC. (ppm boron)
572	572	2250	1.00000	1.00000	0.0	0.0	0.0	0.0	1,207.0	394,779.1	534.5
572	560	2250	0.02204	0.02165	6,669.4	0.0	808.4	75.2	1,282.2	401,523.7	558.3
560	540	2250	0.02165	0.02106	10,376.3	0.0	1,257.8	117.0	1,399.3	412,017.0	593.8
540	520	2250	0.02106	0.02055	9,449.6	0.0	1,145.4	106.6	1,505.8	421,573.2	624.5
520	500	2250	0.02055	0.02009	8,835.5	0.0	1,071.0	99.7	1,605.5	430,508.3	652.0
500	480	2250	0.02009	0.01969	8,104.7	0.0	982.4	91.4	1,696.9	438,704.4	676.3
480	453	2250	0.01969	0.01921	10,258.1	0.0	1,243.4	115.7	1,812.6	449,078.2	705.7
453	440	2250	0.01921	0.01900	4,635.6	0.0	561.9	52.3	1,864.9	453,766.2	718.5
440	420	2250	0.01900	0.01869	6,885.8	0.0	834.7	77.7	1,942.6	460,729.6	737.1
420	390	2250	0.01869	0.01828	9,738.3	0.0	1,180.4	109.8	2,052.4	470,577.8	762.5
390	350	2250	0.01828	0.01781	11,577.2	0.0	1,403.3	130.6	2,183.0	482,285.5	791.4
350	350	350	0.02698	0.01912	12,311.3	0.0	1,492.3	0.0	2,183.0	494,596.8	771.7
350	350	350	0.01781	0.01781	0.0	0.0	0.0	0.0	4,171.1	945,035.4	771.7
350	300	350	0.01781	0.01743	19,369.8	0.0	2,347.9	218.5	4,389.5	964,623.7	795.6
300	260	350	0.01742	0.01707	18,867.7	0.0	2,287.1	212.8	4,602.3	983,704.2	818.0
260	230	350	0.01706	0.01683	12,841.0	0.0	1,556.5	144.8	4,747.2	996,690.1	832.7
230	200	350	0.01682	0.01662	11,468.5	0.0	1,390.2	129.4	4,876.5	1,008,287.9	845.6
200	200	14.7	0.01912	0.016719	6,068.8	0.0	735.6	0.0	4,876.5	1,014,356.7	840.5

FEED AND BLEED RWST VOLUME (0ppm to 535ppm) = 17,592.0 GALLONS (255 minutes at 69gpm)

TOTAL RWST VOLUME = 37,154.8 GALLONS

Figure 5.2-1 RCS Boron Concentration

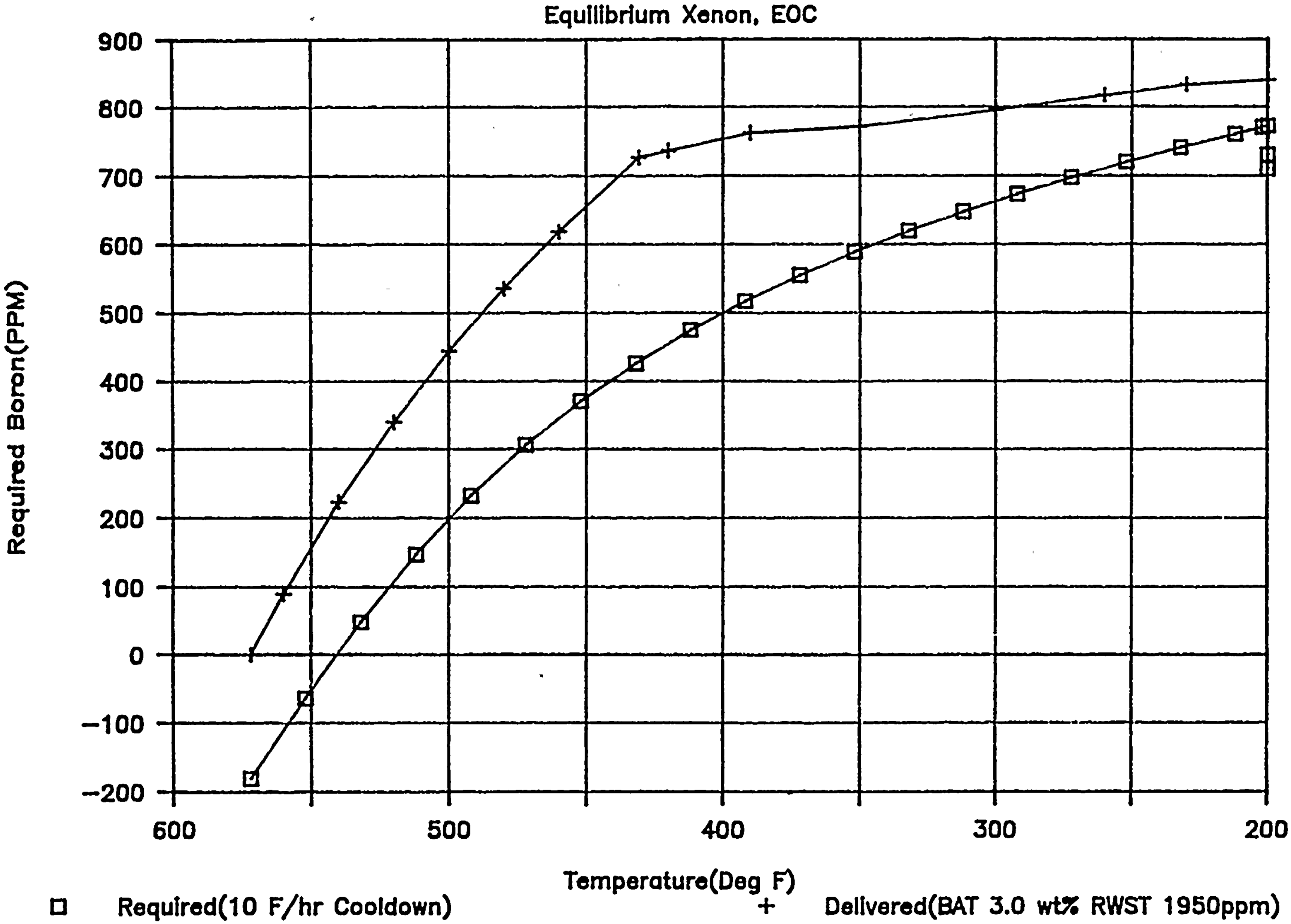


Figure 5.2-2 RCS Boron Concentration

Equilibrium Xenon, EOC

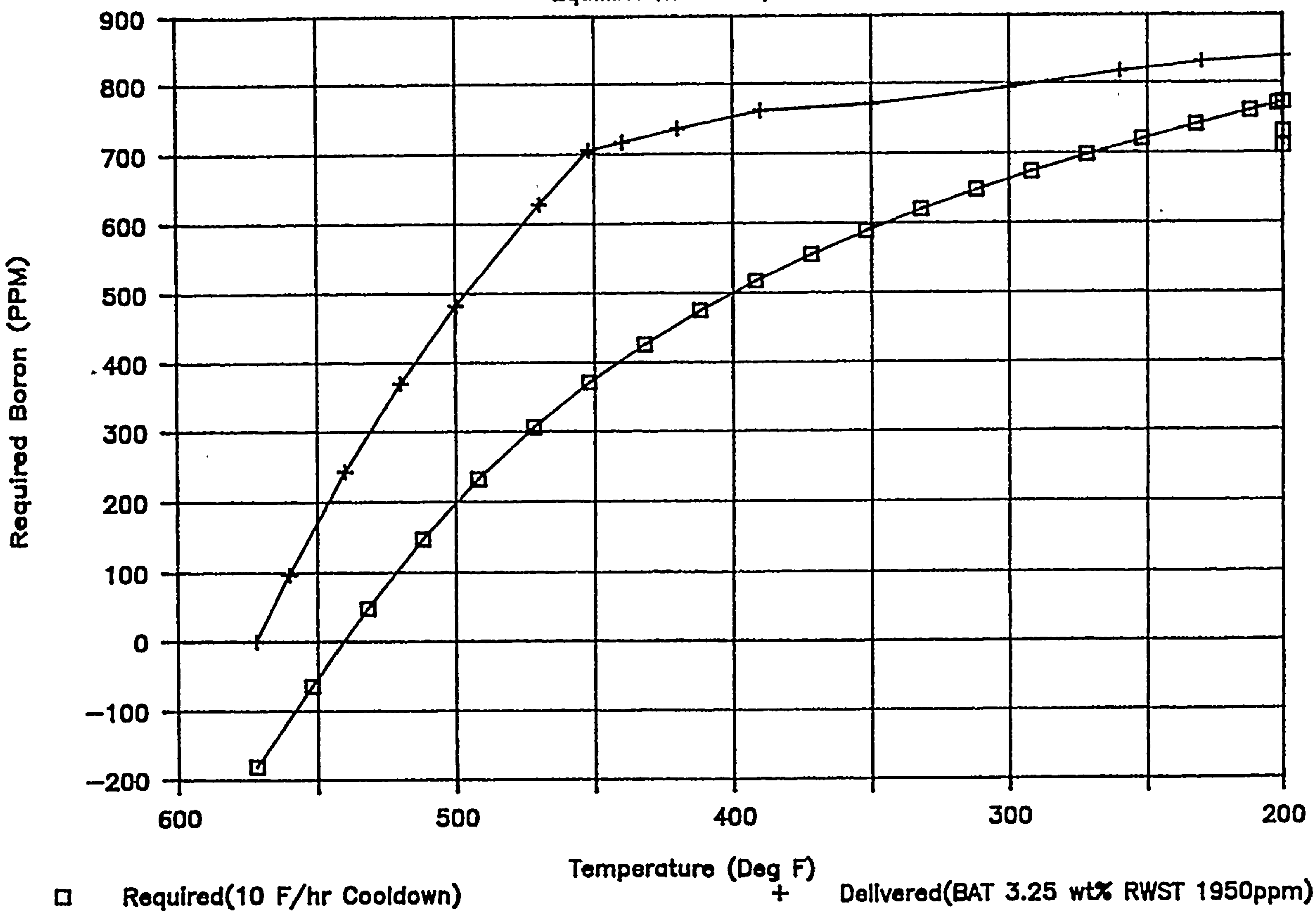


Figure 5.2–3 RCS Boron Concentration

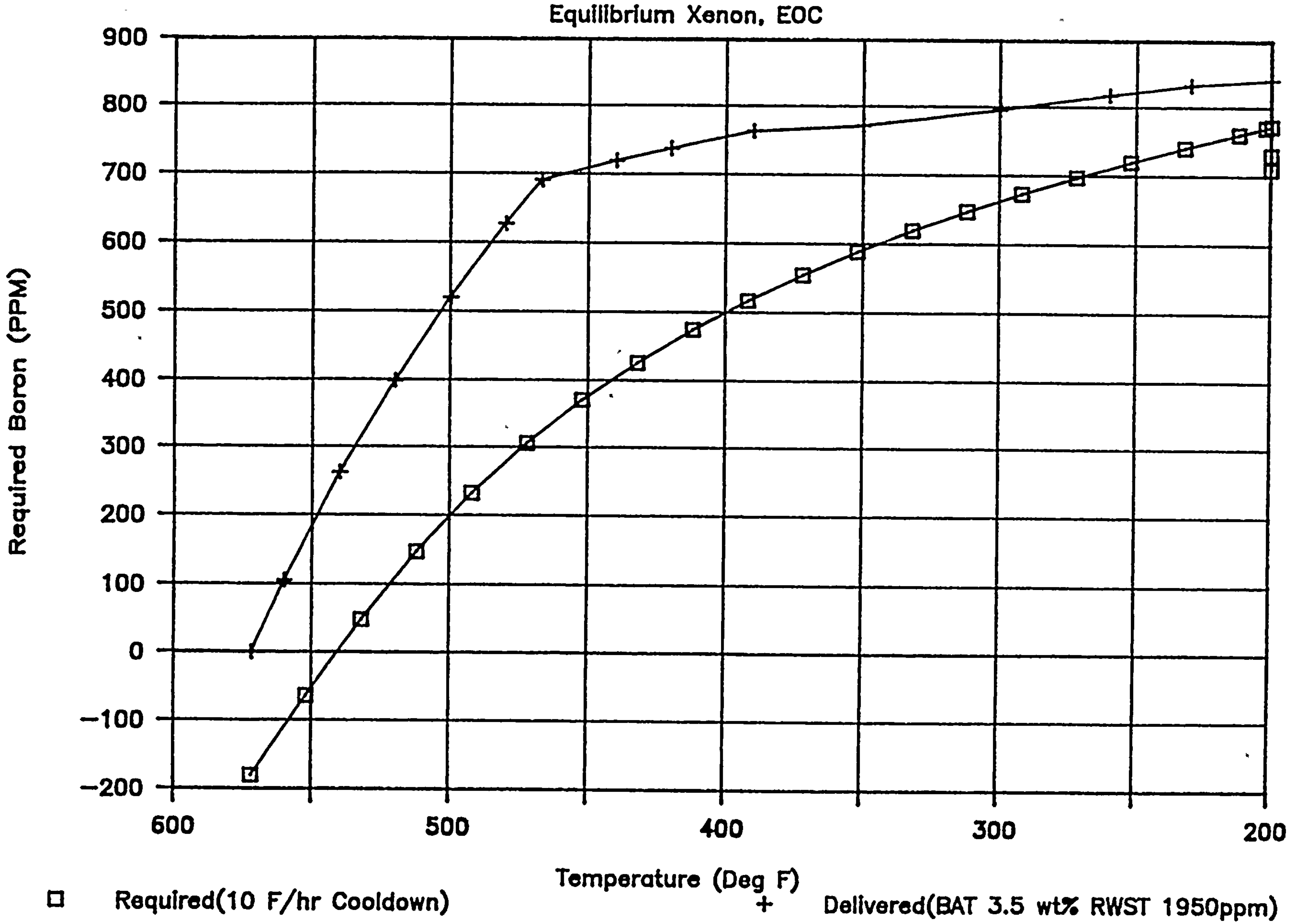
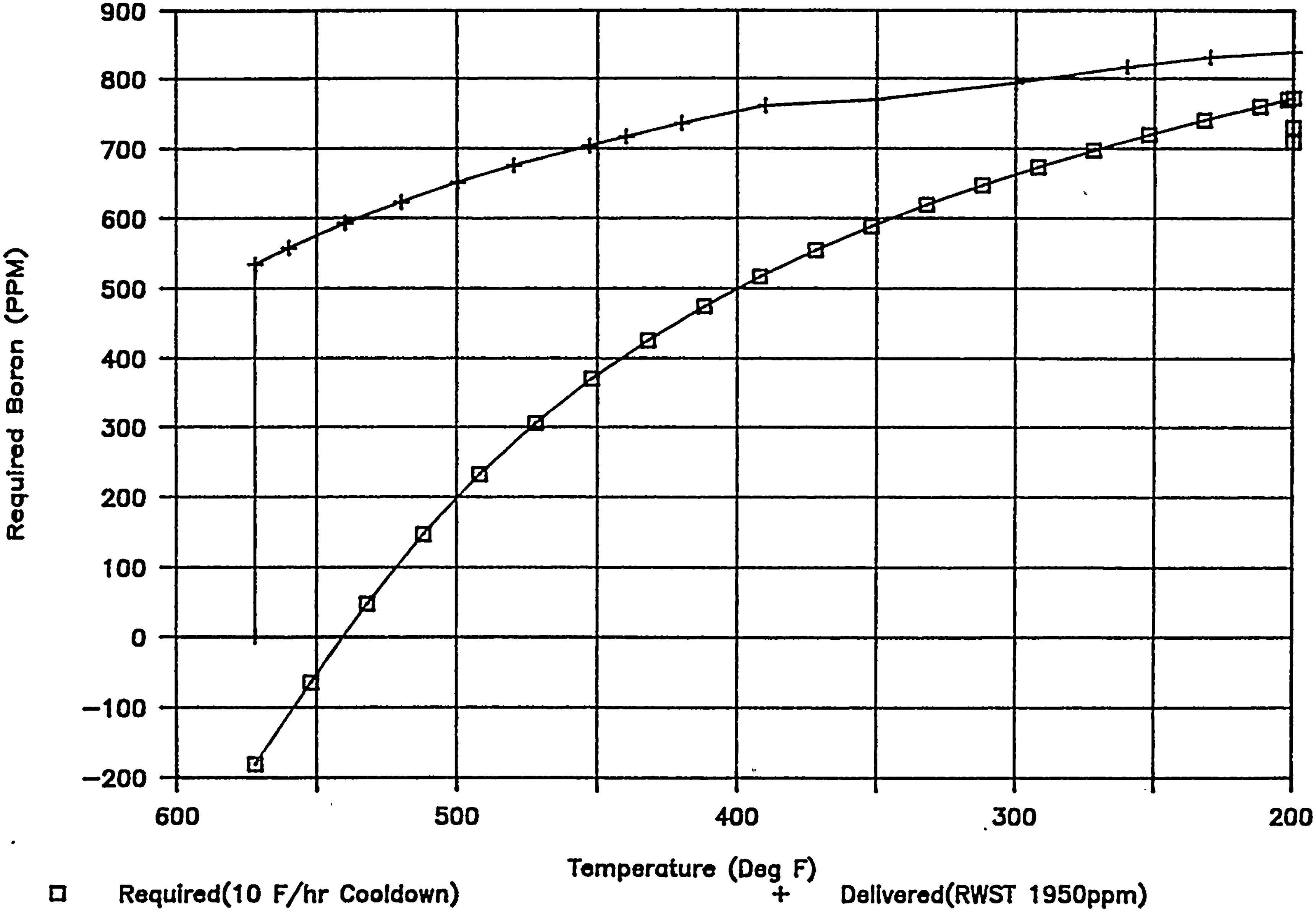


Figure 5.2-4 RCS Boron Concentration

Equilibrium Xenon, EOC



5.3 COOLDOWN FROM COLD SHUTDOWN TO REFUELING TEMPERATURE, MODE 5

5.3.1 Purpose

As stated in the plant Revised Technical Specifications (Reference 10.6), the boration capacity required below an average RCS temperature of 200°F is based upon providing a shutdown margin of 1% Δk/k following xenon decay and a plant cooldown from 200°F to 140°F. (A cooldown to 135°F will be analyzed for additional conservatism.)

The boron concentration requirements of Table 5.1-6 are the minimum required to maintain shutdown margin above the limit of 1.0% Δk/k. This analysis will demonstrate that a cooldown from 200°F to 135°F can be completed using the boric acid tank or refueling water storage tank as the source of makeup water to compensate for coolant contraction and that, accordingly, the RCS boron concentration will be maintained greater than these requirements.

5.3.2 Analyses

The assumptions and initial conditions for these analyses are discussed in Section 4.0 and are summarized in Table 5.3-1. They are essentially identical to those of Section 5.2. A few minor differences are required to account for the unique circumstances of this cooldown. The principal differences are summarized below:

1. The 0% power pressurizer level is used instead of the 100% power level.

2. The initial boron concentration coincides with the 200°F, xenon free 1.0% Δk/k shutdown margin requirement.

3. The RHR system is in service with a volume equal to that of the RCS to conservatively maximize the total system mass.

The analysis methodology is identical to that presented in Section 5.2 in that an initial total system mass is calculated and RCS shrinkage mass increments are calculated based on temperature increments during the cooldown. The shrinkage mass is then converted to a makeup water volume that, when added to maintain a constant pressurizer level, will add incremental amounts of boron. Changes in total system mass and boric acid content are then brought together to determine the resulting RCS boron concentration at each increment. This process is summarized below:

The exact system volume used in the calculation is determined as:

2 x (RCS volume) + (PZR volume at 0% power),

or

$2(8015\ ft^3) + (520\ ft^3) = 16,550\ ft^3$

Knowing the initial mass of boron in the system, the exact concentration and makeup requirements can be calculated for discrete temperature increments.

Shrinkage Mass = (RCS and RHR Volume) $(1/v_f - 1/v_i)$

Makeup Water Volume = (Shrinkage Mass) / (8.2498 lbm/gallon)[10]

Boric Acid Added = (Water Vol.) x (0.21153 lbm/gallon) [11]

Total Boric Acid = (Initial Boric Acid) + (Boric Acid Added)

Total System Mass = (Total Initial Mass) + (Shrinkage Mass) + (Boric Acid Added)

$$\text{Final Concentration} = \frac{(\text{Total Boric Acid})(100)(1748.34)^{(12)}}{(\text{Total System Mass})}.$$

(10) Water density at 120°F. (Reference 10.13)
(11) See Appendix 3 for values of dissolved boric acid in water.
(12) See Appendix 4 for the conversion factor between wt.% and ppm.

Only one of two possible boration flow paths and borated water sources need be available at any given time while in Mode 5 (i.e., either the boric acid tank <u>or</u> the refueling water storage tank). A minimum volume and concentration must be specified for each, therefore, to ensure that either one can be used for the cooldown and still maintain adequate shutdown margin per the requirements of Table 5.1-6. Two separate calculations were performed as discussed below.

5.3.2.1 Mode 5 Cooldown with Boric Acid Tank

This analysis starts with an initial boron concentration of 730.70 ppm corresponding to the minimum requirement for a xenon free core (see Table 5.1-1). In order to calculate the initial total system mass, the contribution of the boric acid must be calculated.

From Equation 2.0 of Appendix 3 and the conversion factor that is derived in Appendix 4, the initial boric acid mass in the system can be calculated as follows:

$$m_{ba} = \frac{\dfrac{788.2\ \text{ppm}}{1748.34\ \text{ppm/wt.\%}} \times \left[\dfrac{16{,}030\ \text{ft}^3}{0.01664\ \text{ft}^3/\text{lbm}^{(13)}} + \dfrac{520\ \text{ft}^3}{0.016719\ \text{ft}^3/\text{lbm}^{(14)}}\right]}{100 - (788.2\ \text{ppm})/(1748.34\ \text{ppm/wt.\%})}$$

or

m_{ba} = 4503.5 lbm boric acid

The initial total system mass is then obtained as follows:

$$TSM = (\text{Boric Acid Mass})_i + (\text{System Water Mass})_i + (\text{PZR Water Mass})_i$$

$$= 4503.5\ \text{lbm} + (16{,}030\ \text{ft}^3 / 0.01664\ \text{ft}^3/\text{lbm}) + (520\ \text{ft}^3 / 0.016791\ \text{ft}^3/\text{lbm})$$

= 998,947.2 lbm

(13) Specific volume of compressed water at 200°F and 14.7 psia
(14) Specific volume of saturated water at 14.7 psia

The incremental changes in the total system mass and the resulting changes in boron concentration are accounted for during each discrete temperature change during the cooldown as discussed previously.

5.3.2.2 Mode 5 Cooldown with Refueling Water Storage Tank

The refueling water storage tank will not provide enough boric acid to compensate for the reactivity inserted during the cooldown if charging is restricted to makeup for coolant contraction only. A system feed and bleed must be performed to raise the RCS concentration before the cooldown is commenced. The initial feed and bleed ensures that the actual RCS boron concentration is maintained above the required boron concentration for a 1.0% $\Delta k/k$ shutdown margin while the plant is cooled from 200°F to 135°F.

The endpoint RCS boron concentration for the initial feed and bleed is determined through an iterative process. This process identifies the cooldown starting concentration that results in an acceptable final concentration when boron addition is accomplished only through makeup for coolant contraction. The acceptable final concentration was chosen to coincide with the shutdown margin limit for the low end of the cooldown (135°F)

In order to identify the required time and volume to complete the initial system feed and bleed, Equation 9.0 of Appendix 1 is used with values as follows:

C_o = 788.2 ppm

C_{in} = 1950 ppm

$$T = \frac{(16{,}030\ ft^3 / 0.01664\ ft^3/lbm)^{(15)} + (520\ ft^3 / 0.016719\ ft^3/lbm)^{(16)}}{60\ \frac{gallons}{min} \times 8.2498^{(17)}\ \frac{lbm}{gallon}}$$

$$T = 2009\ min.$$

$$C(t) = C_o e^{-t/T} + C_{in}(1-e^{-t/T})$$

If one charging pump at 69 gpm and 60 gpm letdown (as assumed in calculating the value of T above) are used to conduct the system feed and bleed, 47 minutes are required. This equates to a feed and bleed volume of 3235 gallons.

From Equation 2.0 of Appendix 3 and the conversion factor derived in Appendix 4, the mass of boric acid in the system corresponding to a concentration of 805.1 ppm can be calculated as follows:

$$M_{ba} = \frac{CM_w}{100 - C}$$

$$= \frac{\left[\frac{815\ ppm}{1748.34\ ppm/wt\%}\right]\left[\frac{16030\ ft^3}{0.01664\ ft^3/lbm} + \frac{520\ ft^3}{0.016719\ ft^3/lbm}\right]}{100 - \left[\frac{815\ ppm}{1748.34\ ppm/wt\%}\right]}$$

= 4657.4 lbm boric acid

Knowing the mass of boric acid in the system following the feed and bleed, the exact concentrations and makeup requirements can be calculated for each 10 degrees of cooldown from 200°F to 135°F in the same manner as described in Section 5.3.2.

(15) Specific volume of compressed water at 200°F and 14.7 psia
(16) Specific volume of saturated water at 14.7 psia
(17) Density of water at 120°F (Reference 10.13)

5.3.3 Results

The results of these analyses are presented in Tables 5.3-2 and 5.3-3 The resulting minimum volume requirements for the boric acid tank and the refueling water storage tank for Modes 5 and 6 are summarized in Table 5.3-4

The delivered boron vs. required boron concentration is shown graphically in Figures 5.3-1 and 5.3-2. The initial feed and bleed of the refueling water storage tank case is shown by the vertical line at the origin in Figure 5.3-2.

Table 5.3-1

Summary of Initial Conditions and Assumptions
Cooldown From 200°F to 135°F
(Mode 5 to 6)

Parameter	Value
RCS Volume	8015 ft^3
Pressurizer Volume (0% Power Level)	520 ft^3
Initial RCS Pressure	14.7 psia
Final RCS Pressure	14.7 psia
Initial RCS Temperature	200°F
Final RCS Temperature	135°F
Pressurizer Condition	Saturated
Pressurizer Level	Constant
RCS Leakage	0
Initial RCS Boron Concentration	788 ppm
Initial Pressurizer Boron Concentration	788 ppm
RHR Volume	8015 ft^3 (1)
RHR Boron Concentration	[= RCS] (2)
Letdown Available	(3)
Refueling Water Storage Tank Temperature	120°F
Boric Acid Tank Temperature	120°F
Total System Volume	16550 ft^3

(1) Overestimated for conservatism
(2) Underestimated for conservatism
(3) No letdown assumed for boric acid tank analysis. Letdown is assumed for RWST analysis.

TABLE 5.3-2

PLANT COOLDOWN FROM 200 F to 135 F - BAT AT 3.0 wt. % BORIC ACID AT 120 F

AVG.SYS. TEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BAT VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC. (ppm boron)
200	200	14.7	0.01664	0.01664	0.0	0.0	0.0	4,503.7	998,945.5	788.2
200	190	14.7	0.01664	0.01657	4,069.6	493.3	125.9	4,629.6	1,003,141.0	806.9
190	180	14.7	0.01657	0.01651	3,515.7	426.2	108.7	4,738.3	1,006,765.5	822.8
180	170	14.7	0.01651	0.01645	3,541.4	429.3	109.5	4,847.8	1,010,416.4	838.8
170	160	14.7	0.01645	0.01639	3,567.3	432.4	110.3	4,958.2	1,014,094.0	854.8
160	150	14.7	0.01639	0.01634	2,992.8	362.8	92.6	5,050.7	1,017,179.3	868.1
150	140	14.7	0.01634	0.01629	3,011.1	365.0	93.1	5,143.8	1,020,283.6	881.4
140	135	14.7	0.01629	0.01627	1,209.6	146.6	37.4	5,181.3	1,021,530.7	886.8

TOTAL BAT VOLUME= 2,655.5 gallons

TABLE 5.3-3

PLANT COOLDOWN FROM 200 F TO 135 F - RWST AT 1950ppm BORON AT 120 F

AVG.SYS. TEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC. (ppm boron)
200	200	14.7	0.01664	0.01664	0.0	0.0	0.0	4,659.5	999,101.3	815.4
200	190	14.7	0.01664	0.01657	4,069.6	493.3	45.9	4,705.4	1,003,216.9	820.0
190	180	14.7	0.01657	0.01651	3,515.7	426.2	39.7	4,745.1	1,006,772.2	824.0
180	170	14.7	0.01651	0.01645	3,541.4	429.3	39.9	4,785.0	1,010,353.6	828.0
170	160	14.7	0.01645	0.01639	3,567.3	432.4	40.2	4,825.2	1,013,961.1	832.0
160	150	14.7	0.01639	0.01634	2,992.8	362.8	33.8	4,859.0	1,016,987.6	835.3
150	140	14.7	0.01634	0.01629	3,011.1	365.0	34.0	4,893.0	1,020,032.7	838.7
140	135	14.7	0.01629	0.01627	1,209.6	146.6	13.6	4,906.6	1,021,256.0	840.0

FEED & BLEED VOLUME (788ppm to 815ppm) = 3,260.0 gallons (44 minutes at 69 gpm)

RWST VOLUME FOR COOLDOWN CONTRACTION = + 2,655.5 gallons

TOTAL REQUIRED RWST VOLUME = 5,915.5 gallons

Table 5.3-4

Minimum Borated Water Source Volumes
(Mode 5)

Boric Acid Tank: ($\geq$ 3.0 wt%)	2,900 gallons[(1)]
Refueling Water Storage Tank: ($\geq$ 1950 ppm)	10,000 gallons[(2)]

(1) Includes analysis value plus 212 gallons for level instrument inaccuracy (2.5% of full range) rounded up to nearest 100 gallons.

(2) Includes analysis value plus 2% instrument error and approximately 3600 gallons unusable volume below the suction tap, all rounded up to nearest 1000 gallons

Figure 5.3–1 RCS Boron Concentration

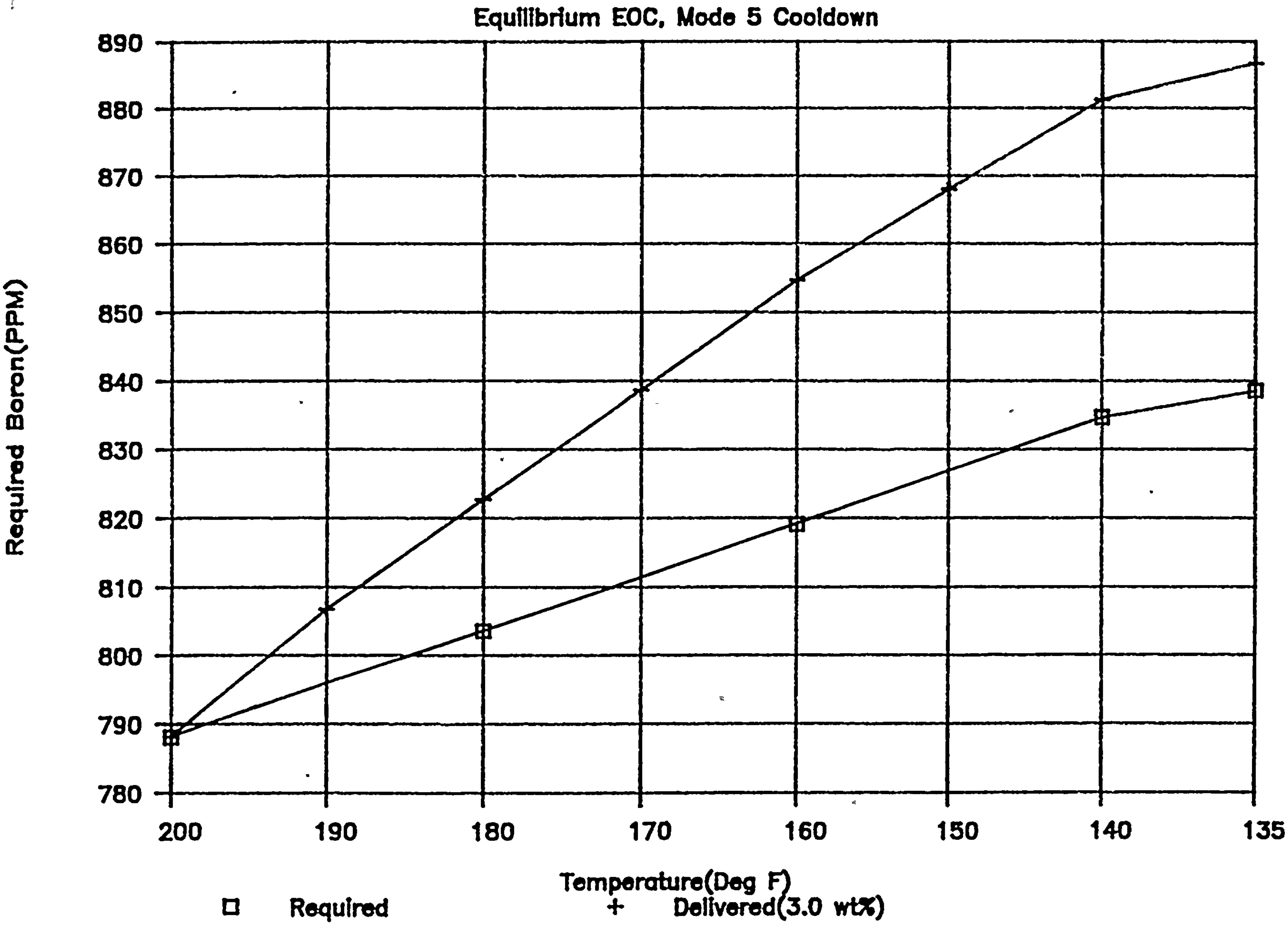
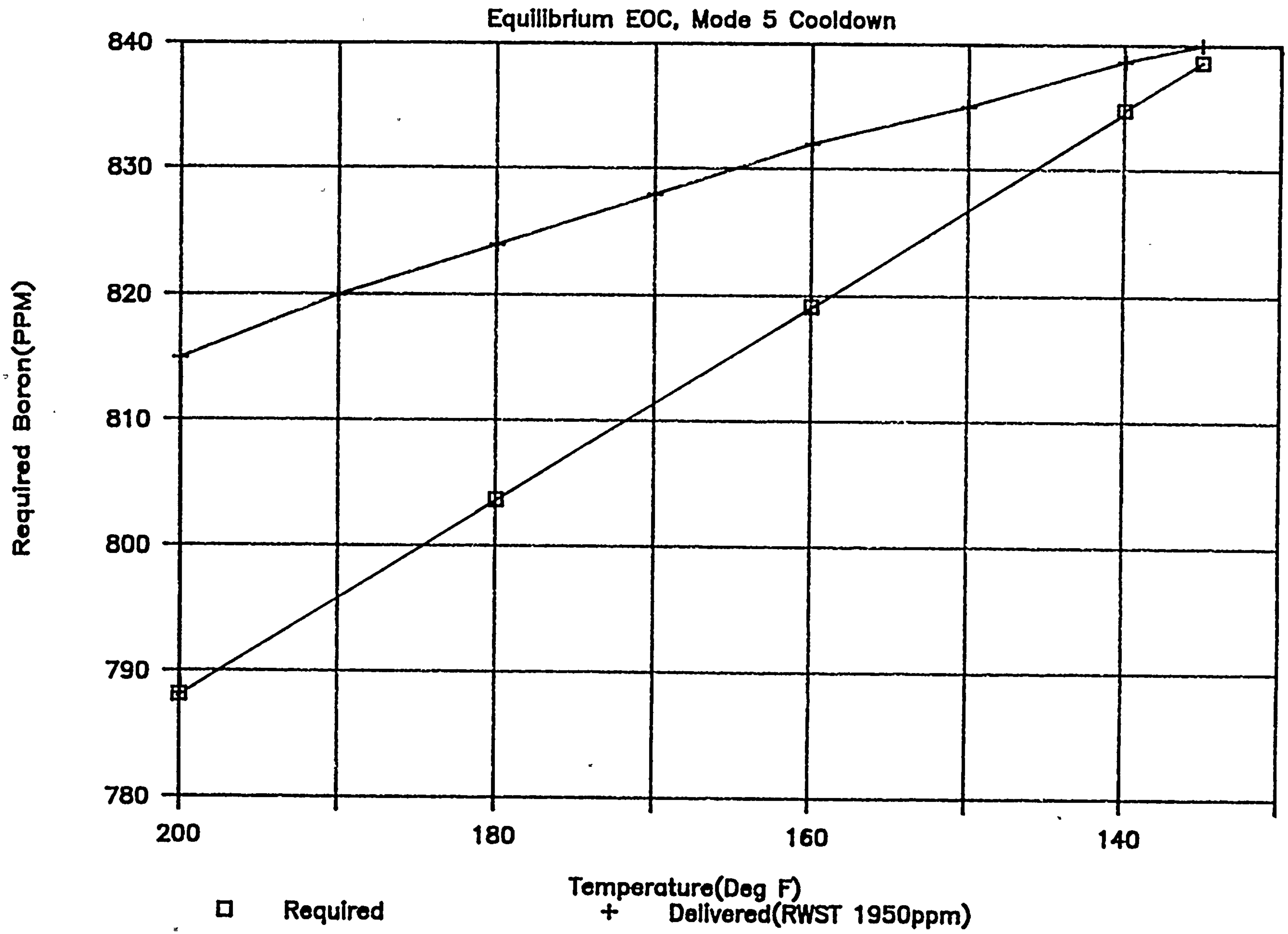


Figure 5.3–2 RCS Boron Concentration



6.0 OPERATIONS ANALYSES

Section 5.0 presented the design basis analyses for the boric acid concentration reduction program to support the licensing efforts required to fully implement it. A worst case (slow) cooldown to cold shutdown conditions was analyzed to establish the required boric acid tank concentration and volume limits to enable operator control of a challenging reactivity control scenario: boration during cooldown without the benefit of letdown. A reduction in boric acid concentration will have other effects on plant operations. This section presents the results of a detailed evaluation of plant operations with reduced concentration boric acid to identify these effects. The specific areas that will be discussed include blended makeup, feed and bleed, shutdown to cold shutdown, shutdown to refueling and operator response to emergency situations. Obviously it is an impossible task to evaluate each of these five areas and consider all possible combinations of plant conditions. Therefore, initial plant parameters and analyses assumptions were selected in a conservative manner to present a worst case analysis.

A number of options exists as to how the three boric acid tanks can be aligned to provide the required minimum volume for both plants and to provide operational flexibility in meeting day-to-day boration demands. Considering the volumes required per Table 5.2-5, most, if not all, of the operating margin will have to come from the spare tank. One possible tank configuration is to align all three tanks to the suctions of all four pumps to utilize the tanks as a common source. In this manner all three tanks will stay at the same level with the minimum required volume for both units spread across all three tanks. This arrangement offers the following advantages:

1. Maximizes volume available for day-to-day boration demands;

2. Offers lower risk of going below technical specification minimum volume;

3. Offers redundant level indication; and,

4. No manual valve manipulations required to access all available volumes.

Another option is for one tank to be dedicated to each unit with the shared tank serving as the source of makeup for both units on a day-to-day basis. The discussions in this section apply to either of these options.

Figure 6-1 presents a flow diagram of the Turkey Point CVCS extracted from Reference 10.1. Four flow paths to the charging pump suction will be considered in the evaluation:

1. Volume Control Tank (VCT)
2. Normal Boration (Blended or Manual)
3. Emergency Boration
4. Refueling Water Storage Tank

Charging pump discharge will go one of two places: into the RCS or back to the VCT via the reactor coolant pump seal leakoff line. The flow back to the VCT is important to note because it is not available for charging into the plant in those instances when the VCT is isolated (isolation valve closed or check valve seated) from the charging pump suction. In this instance, the seal leakoff would collect in the VCT until, upon high level, it is directed to the holdup tank via the VCT pressure relief valve. Under normal conditions with appropriate charging pump speed selection, however, this seal leakage (nominally 9 gpm) can be expected to recycle back to the charging pump suction so that it will not constitute a loss. In the calculation of volumes required for blended makeup and feed and bleed operations, the 9 gpm is assumed to be lost to

conservatively overestimate the volumes required to support the evolutions under consideration.

Table 6-1 presents the plant parameters used in the analysis of this section. In general, these parameters differ from those of the licensing analyses of Section 5.0 in that they are based on normal plant operations and are chosen to provide a realistic best estimate of plant boration performance while still remaining conservative. A few of the more important assumptions are discussed below.

1. Pressurizer Volume

   Pressurizer volume is assumed to remain constant at the 0% power level (i.e., operators charge to the plant to maintain pressurizer level) during the cooldown scenarios analyzed.

2. RCS Leakage

   As in Section 5.0, RCS leakage is assumed to be zero since leakage aids boron delivery to the plant. However, it does require greater makeup volumes, so that leakage assumptions should be applied to final results. This can be accomplished by multiplying an assumed leakage rate by an estimated time for completion of the cooldown evolution. This volume is then added to the contraction makeup volume to derive the total required volume. A more specific analysis of the impact of RCS leakage on the boric acid inventory requirements is presented in Section 6.7

3. RHR Volume and Concentration

   The concentration is assumed to be at the cold shutdown, 200°F, xenon free 1.77% $\Delta k/k$ shutdown margin concentration of 775 ppm (equilibrium xenon scenario per Section 5.5). RHR concentration is expected to be near, if not equal to, the cold

shutdown boron concentration since shutdown margins must be maintained during a Mode 4 heat up for a transition into Mode 3. RHR concentrations resulting from mid-cycle shutdown, for example, should be close to the appropriate shutdown margin requirement. Also, to conservatively estimate the contraction makeup contribution of this system, a volume of 2000 ft^3 is assumed for the RHR system flow paths.

4. Boric Acid Tank Concentration

Section 5.0 justified a concentration range of 3.0 to 3.5 weight percent boric acid to support a safe shutdown to cold shutdown conditions. This will result in a plant technical specification boric acid tank operability requirement stating minimum acceptable volumes for this concentration range. It is recommended that plant operations maintain the concentration in the middle of the control band. For this reason, the concentration of 3.25 weight percent will be utilized in the operations analyses of this section.

5. Cooldown Starting Temperature

The analysis of this section assumes the cooldown initiates from the hot zero power value of 547°F.

The following sections review specific plant operations with reduced boric acid concentration.

6.1 BLENDED MAKEUP OPERATIONS

During typical plant blended makeup operations, concentrated boric acid from the boric acid tanks is supplied to the blending tee via a boric acid transfer pump (0 to 60 gpm) and flow control valve FCV-113A (0 to 10 gpm) where it is mixed with pure makeup water supplied via flow control valve FCV-114A (0 to 150 gpm). The

blended boric acid is then added to the suction of the charging pumps via flow control valve FCV-113B.

A reduction in the concentration of boric acid in the boric acid tank will decrease the maximum boron concentration available at the outlet of the blending tee by a factor directly proportional to the decrease in the boric acid tank concentration. This results in a decrease in the boron delivery capability of the blending tee during normal RCS makeup and reactivity control operations.

This impact, however, can be compensated for by increasing the boric acid delivery rate to the blending tee. A corresponding decrease in the pure makeup water into the tee will raise the concentration of the boric acid mix to levels corresponding to the current boration capability of the system using 12 weight percent boric acid. This will be achievable with the modification that is currently planned for flow control valve FCV-113A. The trim of this valve will be modified to allow higher flow rates of the reduced concentration boric acid. Specifically, since a factor of four reduction in the boric acid concentration is anticipated (12 weight percent to 3 weight percent) a factor of four increase in boric acid flow to the boric acid blender will be required. In other words, the trim of FCV-113A must be modified to allow up to 40 gpm. This would assure the blended boration capability remained identical to the current system configuration with 12 weight percent boric acid with respect to the timing of boron delivery.

With this flow control valve upgrade in mind, all further analyses of the blended makeup capability (i.e., during fast cooldowns) will assume that 40 gpm will be available to the blender.

Mathematically, blended makeup operations are modeled as follows:

$$C_{out} = \frac{(F_a C_a)}{(F_a C_a) + (F_t D_w)} (100)(1748.34)$$

where:

C_{out} = concentration of boric acid exiting the blending tee

F_a = flow rate of concentrated boric acid from the boric acid tank

C_a = concentration of boric acid entering the blending tee

F_T = total flow rate exiting the blending tee

D_w = density of makeup water (assumed at 120°F)

1748.34 = conversion factor for weight percent to ppm

6.2 FEED AND BLEED OPERATIONS

During a feed and bleed operation to increase system boron content, the charging pumps are used to inject concentrated boric acid into the RCS with the excess inventory normally being diverted to the liquid waste system via letdown. The rate of increase in boron concentration is proportional to the difference between the system concentration at any given time and the concentration of the charging fluid. From this basic relationship, an equation describing feed and bleed can be derived. (Appendix 1 contains the derivation of the RCS feed and bleed equation.) In general, if the concentration within the boric acid tanks is reduced to the point where heat tracing is no longer required, the maximum rate of change of RCS boron concentration that an operator can expect to see during feed and bleed will be less than currently achievable.

The purpose of the evaluation performed in this section is to show the hot zero power feed and bleed rates that can be expected using boric acid tanks with a reduced concentration. The analysis is done

assuming hot zero power conditions with other key parameters and conditions as shown in Table 6-1. A one charging pump feed and bleed was evaluated from two initial system concentrations: zero ppm and 1100 ppm. The results are presented in Tables 6-2 to 6-5. Equation 9.0 of Appendix 1 was used to generate the results in these tables. The value of the system mass used to obtain the time constant in Equation 9.0 was calculated as follows:

$$(m_w)_{RCS} = (m_w)_{RCS} + (m_w)_{PZR}$$

or

$$(m_w) = \frac{8015 \text{ ft}^3}{0.021251 \text{ ft.}^3/\text{lbm}^{(1)}} + \frac{520 \text{ ft}^3}{0.02698 \text{ ft}^3/\text{lbm}^{(2)}}$$

From this system mass (396,432.3 lbm), the value of the feed and bleed time constant for one charging pump using the 45 gpm letdown orifice is:

$$T_{45} = \frac{396{,}432.3 \text{ lbm}}{45 \text{ gpm x } 8.2498 \text{ lbm/gallon }^{(3)}}$$

or

$$T_{45} = 1{,}067.9 \text{ min.}$$

The value of the feed and bleed time constant for one charging pump using the 60 gpm letdown orifice is:

$$T_{60} = \frac{396{,}432.3 \text{ lbm}}{60 \text{ gpm x } 8.2498 \text{ lbm/gallon }^{(3)}}$$

or

$$T_{60} = 800.9 \text{ min.}$$

---

(1) Specific volume of compressed water at 547°F and 2250 psia (assuming HZP).
(2) Specific volume of saturated water at 2250 psia (assuming HZP).
(3) Water density at 120°F.

For the case where a feed and bleed is conducted while the RHR system is in operation, a new time constant will result. Using the equation above and substituting the RHR + RCS water mass for the RCS water mass, the following result is obtained for a 60 gpm feed and bleed at 200°F:

$$\text{System Mass} = (M_w)_{RCS} + (M_w)_{RHR} + (M_w)_{PZR}$$

$$= \frac{10015 \text{ ft}^3}{.01662 \text{ ft}^3/\text{lbm}^{(4)}} + \frac{520 \text{ ft}^3}{.01912 \text{ ft}^3/\text{lbm}^{(5)}}$$

$$= 629{,}783.9 \text{ lbm}$$

$$T_{60} = \frac{629{,}783.9 \text{ lbm}}{60 \text{ gpm} \times 8.2498 \text{ lbm/gallon}} = 1272.3 \text{ min}$$

Tables 6-2 through 6-5 include the expected boric acid volume to accomplish the given boration. Two values are presented: one assuming no loss due to RCP seal leakage (45 gpm and 60 gpm) and the other assuming the 9 gpm nominal seal leakoff is collected in the VCT so that it does not immediately contribute to the desired boration (54 gpm and 69 gpm).

To identify specific changes in boron content through feed and bleed operations, the values in these tables can be used (interpolated) to provide reasonable estimates. Analytically, the time to achieve a specific change in boron content can be calculated as follows.

Appendix 1 presents boron concentration as a function of time as:

$$C_f = C_o e^{-t/T} + C_{in}(1 - e^{-t/T})$$

where:

C_f = final system boron concentration
C_o = initial system concentration
C_{in} = concentration of feed source
T = feed and bleed time constant
t = time

(4) Specific volume compressed water at 200°F and 350 psia
(5) Specific volume saturated water at 350 psia

Solving this equation for time yields:

$$t = -(T) \ln \frac{C_f - C_{in}}{C_o - C_{in}}$$

Feed and bleed operations will be incorporated into some of the operations scenarios discussed in later sections utilizing Tables 6-2 through 6-5 and the equations above.

6.3 COOLDOWN TO REFUELING - MODE 6

The plant cooldown to refueling is typically the most limiting evolution that an operator must perform with respect to system boration (i.e., this evolution normally requires the maximum amount of boron to be added to the RCS). A cooldown to refueling normally occurs at the end of core cycle when the critical boron concentration is low and requires an increase to the refueling boron concentration. In the most limiting case, boron concentration must be raised from zero ppm to the specified refueling concentration of 1950 ppm (2000 ppm).

This section presents the evaluation results of a plant shutdown to refueling. The evaluation was performed specifically to demonstrate the effect on makeup inventory requirements of a reduction in boric acid storage tank concentration. A list of key parameters and conditions assumed in the analysis is contained in Table 6-1. The evaluation was performed for EOC conditions in order to maximize the amount of boron that must be added to the RCS. As a result, the boron concentration within the RCS was required to be increased from zero ppm to the present refueling concentration of 1950 ppm. The shutdown for refueling was assumed to take place as follows:

1. The reactor is shut down via rod insertion to hot zero power conditions.

2. Following shutdown, at time zero, operators commence a system feed and bleed using one or more charging pumps and a boric acid transfer pump. (Tables 6-2 through 6-5 show the expected feed and bleed volumes and times to complete for various blended concentrations.)

3. The feed and bleed is conducted for about 180 minutes assuming 60 gpm letdown, after which time it is secured.

4. A plant cooldown and depressurization is commenced from an average coolant temperature and system pressure of 547°F and 2250 psia to an average coolant temperature and system pressure of 350°F and 465 psia. Unblended boric acid is supplied from the boric acid tanks.

5. The RHR system is placed in operation at approximately 350°F and 465 psia.

6. The plant cooldown is continued following RHR initiation from 350°F to 135°F at 465 psia.

Evaluation results showing the system concentrations as a function of time and total boric acid tank inventory requirements are contained in Table 6-6. Concentrations during the initial feed and bleed operation were calculated using the methodology discussed in Section 6.2 above. Concentrations during the subsequent plant cooldown were calculated in the same manner as the concentrations for the plant cooldowns in Section 5.2. Note that the boron content of the RCS was raised from zero ppm at the start of the evolution to greater than 1950 ppm by the time the plant had been cooled and depressurized to 135°F and 465 psia. A total volume of 27,188.8 gallons of a 3.25 weight percent boric acid solution was required. Of this volume, 10,800 gallons were used during the initial 180 minute plant feed and bleed operation and 16,388.8 gallons were charged into the system to compensate for shrinkage during the cooldown process.

As can be seen from the results in Table 6-6, the volume of a 3.25 weight percent boric acid solution required to perform the shutdown to refueling is approximately 3.6 times the current capacity of one boric acid tank (7500 gallons). A plant modification is planned, however, that will increase the capacity of the tank. Assuming approximately 8500 gallons will be available, the volume required for this evolution will be 3.2 times available capacity. Note that this result is conservative, and, therefore, represents the maximum volume that would be required to be available assuming a refueling concentration of 1950 ppm boron and a boric acid tank concentration of 3.25 weight percent boric acid. Since there is essentially only one boric acid tank dedicated to each plant and a third tank shared between the two plants, additional provisions or operator actions could be utilized to place the plant in Mode 6. These provisions could include some combination of the following:

1. Prior to conducting the evolution, all three boric acid tanks are full and available for use (minus the volume dedicated to the operating unit).

2. Concurrent with continued cooldown, replenish inventory in the tanks.

3. Borate as much of the RHR system as possible to the refueling concentration of 1950 ppm prior to initiating the RHR system cooldown at 350°F.

These provisions, or operator actions, would need to be considered only once during core cycle: just prior to conducting a shutdown for refueling. Note that they are relatively simple actions that should be well within the current plant operating capabilities. In addition, they can be planned for in advance so as to have no impact on maintenance activities or the plant refueling schedule.

6.4 COOLDOWN TO COLD SHUTDOWN - MODE 5

As discussed in the previous section, the shutdown to refueling is the most limiting evolution that an operator must perform with respect to system boration from the perspective of available boric acid inventory. This evolution is normally performed once during a fuel cycle just prior to refueling. Situations (such as unscheduled plant maintenance, etc.) can occur during a fuel cycle, however, that would require an operator to perform a plant shutdown to cold shutdown conditions. Although not limiting with respect to boration requirements, it is important for an operator to be able to perform such a shutdown quickly and efficiently.

This section presents the evaluation results of a plant shutdown and cooldown to cold shutdown conditions using only the boric acid tanks. This analysis was performed specifically to demonstrate the effect of a reduction in boric acid tank concentration on makeup inventory requirements . A list of key parameters and conditions assumed in the analysis is contained in Table 6-1. In addition to the parameters in Table 6-1, the evaluation was performed for EOC conditions assuming a cold shutdown concentration requirement of 775 ppm boron. As a result, boron concentration had to be increased from 0 ppm to 775 ppm boron. The operations scenario employed in the cooldown to cold shutdown is as follows:

1. The reactor is shut down to hot zero power conditions via rod insertion.

2. A plant cooldown and depressurization is immediately commenced from an average coolant temperature and system pressure of 547°F and 2250 psia to 350°F and 465 psia. Makeup inventory is supplied from the boric acid tanks.

3. The RHR system is placed in operation at 350°F and 465 psia.

4. The plant cooldown is continued following RHR initiation from 350°F to 135°F at 465 psia. Makeup inventory is supplied from the boric acid tanks.

Evaluation results showing the system concentrations as a function of time and total boric acid makeup tank inventory requirements are contained in Tables 6-7 and 6-8. Note that two cases were analyzed for comparison. In Case 1 the concentration within the RHR system was assumed to be equal to the concentration of the RCS at the time of RHR system initiation. In Case 2 the concentration within the RHR system was assumed to be equal to 775 ppm (the maximum 200°F, xenon free, required boron concentration) at the time of RHR initiation. Concentrations during the plant cooldown were calculated using the methodology discussed in Section 5.2. During those portions of the plant cooldown in which blended makeup was used, values were calculated using the methodology contained in Section 6.1.

A total volume of 9,246.0 gallons of a 3.25 weight percent boric acid solution was required in order to perform the shutdown to cold shutdown for Case 1. In Case 2, a total volume of 9,033.6 gallons was required.

6.5 BATCHING OPERATIONS

As the results of Sections 6.3 and 6.4 demonstrate, more than one boric acid tank will be required to complete these cooldown and boration evolutions. This section will evaluate the expected batching process and how this will impact the overall timing of the cooldown.

The Turkey Point batching system consists of an 800 gallon batching tank that is blended to the desired concentration and added to the boric acid tank via a boric acid transfer pump. The batching process consists of the following (with time estimates):

1. Fill the batching tank with pure water and increase the water temperature from 40°F to 90°F (45 minutes).

2. Add the required quantity of boric acid and mix the tank contents (20 minutes).
3. Transfer boric acid mixture to boric acid tank (20 minutes).

4. Repeat as necessary

The total time to prepare a single 800 gallon batch, therefore, is estimated to take about 1.5 hours. Given that the batching can be accomplished in only 800 gallon increments, it will take approximately 10 batches (or 15 hours) to refill a boric acid tank. The availability of a third tank that is shared between the two units suggests the possibility of using a second tank for one unit while the first tank is refilled. For the case where all three tanks are aligned to the transfer pumps and are full to maximum capacity, however, a total of about 16,000 gallons [(8500x3)-2900-6600] would be available to accommodate a unit shutdown and cooldown without operator action to realign the tanks.

Looking at the results of Section 6.3, the shutdown and cooldown to refueling required a total boric acid tank volume of 27,188.8 gallons. Assuming the tanks were at the minimum volume for 3.25 weight percent to support two operating units (13,200 gallons) leaving 6,600 gallons to support the shutdown and cooldown, a total of 20,588 gallons would have to be provided through batching. If batched, this would require about 26 batches for a total of 39 hours. However, if the tanks are full and shared, or at least filled prior to initiating the shutdown to refueling evolution, only 11,188 gallons would have to be batched. This would require 14 batches for a total of 21 hours.

The shutdown to cold shutdown conditions of Section 6.4 required a total of 9,246.0 gallons. Again, assuming 6,600 gallons in the tank at the start of the cooldown a total of 2,646 gallons must be

provided from the spare tank or batched. If batched, approximately 3.5 batches would be required which would take 5 hours at 1.5 hours per batch. If the tanks are kept full, however, this evolution would require no batching to complete.

The shutdown/cooldown evolutions analyzed thus far have assumed boration in conjunction with cooldown as analyzed in Section 5.0. This will not be a requirement for normal cooldown evolutions. In some instances FPL may have to conduct these evolutions in essentially the same manner as they are conducted now (i.e., borate the plant to the required cold shutdown concentration through feed and bleed prior to initiating the cooldown, and provide blended makeup for the coolant contraction).

This evolution is illustrated in Table 6-9 for a 50°F/hr cooldown. The feed and bleed process can be completed from either the boric acid tank or the refueling water storage tank. For the case where the boric acid tank alone is utilized, a total of 10,573.2 gallons will be required. Assuming 6,600 gallons were available, a total of 3,973.2 gallons would have to be provided through the batch process or the spare boric acid tank. At 800 gallons and 1.5 hours a batch, a total of 5 batches would be required taking approximately 7.5 hours. If the tanks are kept full, however, this evolution would not require any batching to complete.

6.6 RESPONSE TO EMERGENCY SITUATIONS

This section evaluates several of the operating evolutions that may have to be completed in response to a variety of emergency situations. Specifically, accident boration requirements, shutdown margin recovery, emergency boration, and fast cooldown scenarios will be evaluated to ensure the operator can continue to operate the plant safely with reduced boric acid tank concentrations.

6.6.1 Accident Response

In general, credit is not taken for boron addition to the RCS from the boric acid tanks for the purpose of reactivity control in the accidents analyzed in Chapter 14 of the plants' Final Safety Analysis Report. The consequences of such events as steam line break, overcooling, boron dilution, etc. will not be affected by a reduction in boric acid tank concentration. Any action to borate the plant from the boric acid tank will likely improve the reactivity control margins over those already analyzed and found acceptable in the safety analysis report.

6.6.2 Shutdown Margin Recovery

The action statements associated with Technical Specifications 3.1.1.1, 3.1.1.2, 3.9.1, and 3.10.1 require that boration be commenced at greater than 4 gpm using a solution of at least 20,000 ppm boron in the event that shutdown margin is lost. A reduction in boric acid concentration by a factor of four will require a corresponding increase in delivery capacity to ensure the same amount of boron is added in the same period of time. Such a delivery capability will be available with the proposed modification of the blended makeup flow control valve so that this reactivity control recovery capability remains unaffected. Specifically, the flow control valve FCV-113A will be modified to increase its control range from 0 - 10 gpm to 0 - 40 gpm. The availability of a 40 gpm flow of boric acid to the blender exceeds the requirement for a four times increase of 4 gpm to 16 gpm in this instance.

6.6.3 Emergency Boration

An emergency boration flow path is available from the discharge of the boric acid transfer pump directly to the suction of the charging pumps via motor operated valve MOV-350. In the event that a reactor shutdown to hot zero power is required and control rods are not available (i.e., two or more rods stuck out), an alternate shutdown

capability exists through emergency boration. According to Reference 10.3, the CVCS (with 12 weight percent boric acid) is currently capable of making the reactor subcritical in 16 minutes assuming 60 gpm through the emergency boration flow path to the charging pumps.

According to Reference 10.12, emergency boration is achieved by charging 537 gallons via the emergency boration flow path (without letdown--taking advantage of the surge volume available in the pressurizer) and raising the boron concentration by 195 ppm. This is stated as requiring 9 minutes at 60 gpm. The effect of reduced concentration boric acid on this capability is evaluated below.

Analysis of the method of achieving emergency boration by charging pressurizer level up, without letdown, requires a mass balance of boron. Assuming a conservatively high BOC boron concentration of 1100 ppm, the mass of boric acid required to increase this concentration by 195 ppm is calculated. This boric acid mass addition is equated to the boric acid mass per gallon of makeup water using the values of Appendix 3. Then this volume of makeup water is converted to a volume of water at RCS temperature to compare to the available volume in the pressurizer.

For a conservative analysis of the above, the following is assumed:

1.	Boric Acid Tank Temperature	120°F
2.	Boric Acid Tank Concentration	3.0 wt%
3.	Transfer Pump Delivery	69 gpm
4.	RCP Seal Injection	24 gpm
5.	RCP Seal Leakoff	9 gpm
6.	VCT Isolated	(-9 gpm)
7.	Initial RCS Concentration	1100 ppm
8.	Boration Required	195 ppm
9.	RCS Temperature	547°F
10.	Mixing within RCS and Pressurizer	Uniform
11.	Pressurizer Steam Bubble	Available

The results of this calculation show that approximately 2024 gallons of water at 3.0 weight percent boric acid will be required from the boric acid tank and will result in a pressurizer level change well within the available volume when level is initially within the level control band. At 69 gpm, this will achieve a 195 ppm increase in RCS boron concentration within 29.4 minutes. This volume reduces to 1760 gallons if 9 gpm seal leakoff is not a factor. This equates to approximately 300 cubic feet in the pressurizer which corresponds to the change from the 0% Power programmed level to the 100% Power programmed level.

A second option consists of conducting a system feed and bleed to accomplish the boration objective. Using the method of Section 6.2, approximately 2,670 gallons of 3.0 weight percent boric acid will be required. At 69 gpm (60 gpm letdown), this will achieve a 195 ppm increase in RCS boron concentration within 38.7 minutes.

6.6.4 Fast Cooldown Transients

Section 5.0 focused on slow cooldown evolutions since they presented the worst case boration requirement in compensating for a greater amount of xenon decay. Faster cooldowns are important from a boration perspective when the limited capacities of the normal boration flow path (currently limited to 10 gpm boric acid) and the emergency boration flow path (nominally 60 gpm) are considered, especially when the preferred boration flow path will likely be the lower capacity normal flow path (manual or blended boration). As discussed previously, however, it is anticipated that flow control valve FCV-113A will be modified to increase its capacity from 10 gpm to about 40 gpm. This will increase the flow rate of reduced concentration boric acid to the point where the boron addition rate through the normal boration flow path matches that of the current system configuration with 12 weight percent boric acid. The remaining consideration, therefore, is the limited volume available to provide the total boron requirement.

Two specific cases are presented here: 1) makeup with the boric acid tank, and 2) makeup with the refueling water storage tank. The first case considers a fast cooldown (100°F/hr) for which the normal process of borating to the cold shutdown limit prior to initiating the cooldown has been completed. This case will evaluate the capability of the boration subsystem to maintain this boron concentration during the cooldown while blending the boric acid with pure water. This particular evaluation uses the same assumptions and methodology as discussed in Section 6.4. The results are presented in Table 6-10.

As shown in Table 6-10, a total boric acid volume of 10,323.4 gallons would be required. Of this, 8,122.7 gallons would be required to accomplish the feed and bleed from 0 ppm to 775 ppm in 117.7 minutes (assuming 69 gpm charging flow and 60 gpm letdown). The remaining volume of 2,200.7 gallons would be required to make up for coolant contraction. The blend ratio of 6.5 throughout the transient ensures just enough boric acid is used to maintain the RCS concentration. Even with the addition of 9 gpm seal leakoff (assumed unavailable for makeup), the required boric acid flow rate (<15 gpm) remains less than the 40 gpm upper limit anticipated for flow control valve FCV-113A.

Under ideal conditions, such a feed and bleed and cooldown could be accomplished using the available capacity of one full dedicated tank and a portion of the shared tank. Under less ideal conditions, the minimum allowable volume of 6,600 gallons (Table 5.2-5) would be available requiring 3,723.4 gallons to be provided by the shared tank or batched. If batched, a total of 5 batches would be required for a total time of about 7.5 hours.

A variation of the above is to conduct a limited feed and bleed (0 ppm to 446 ppm, for example) and complete the fast cooldown using the refueling water storage tank as the source of makeup water. Such an approach would minimize the amount of boric acid tank volume required and, hence, the amount of batching potentially required.

The results of this evaluation are illustrated in Table 6-11. Compared to Table 6-10, only 4,485.0 gallons of boric acid at 3.25 weight percent would be required to complete the feed and bleed (well within the required minimum volume of 6,600 gallons per Table 5.2-5). The entire evolution could be completed with the refueling water storage tank alone using a total of 30,841.3 gallons of water at 1950 ppm (exclusive of RCS leakage).

6.6.5 Technical Specification Action Statements

Recovery from loss of shutdown margin per the action statements of Technical Specifications 3.1.1.1, 3.1.1.2, 3.9.1 and 3.10.1 has been discussed in Section 6.6.2. The purpose of this section is to review the capability of the boration system to meet the action requirements of the remaining technical specifications with reduced boric acid concentration.

Generally, the action statements of principal concern, with respect to boration capability, occur with Technical Specifications 3.1.2.2 (Flow Paths), 3.1.2.3 (Charging Pumps), and 3.1.2.5 (Borated Water Sources). These action statements follow the sequence outlined below.

1. Restore (flow path, pump, source) to operable status within 72 hours, or
2. Be in hot standby borated to the shutdown margin for 1.0% $\Delta k/k$ at 200°F;
3. Restore the inoperable condition within an additional 72 hours, or
4. Be in cold shutdown within the next 30 hours.

If the two 72 hour periods are removed, the most limiting action statement requirement is presented:

1. Be in hot standby, borated to 1.0% $\Delta k/k$ shutdown margin at 200°F within 6 hours and,
2. Be in cold shutdown within the following 30 hours.

The timing of the above coincides with the more restrictive action statements of Technical Specifications 3.1.3.5.b (RWST inoperable), 3.1.2.6 (boric acid tank and/or flow paths below specified temperature limit for boric acid solubility), and 3.5.4 (RWST inoperable). The above specifications do not specifically require boration to the cold (200°F) shutdown margin of 1.0% Δk/k prior to initiating the cooldown (within the first 6 hour action). However, these actions will be assumed in this evaluation so that the actions of the flow path, source, and charging pump specifications discussed previously, are bounded.

As an additional conservatism, the 1.77% Δk/k shutdown margin coinciding with the EOC 0 ppm boron condition will be evaluated to maximize the required boration. The analysis discussed in Section 6.5, therefore, is applicable and bounding for the action statements under consideration.

The limiting component of the action requirement is the boration to 775 ppm within 6 hours in that this action must be performed with either the boric acid tank or refueling water storage tank in the worst case. As shown in Table 6-9, a feed and bleed from 0 ppm to 775 ppm will require 8,122.7 gallons of 3.25 weight percent boric acid. Assuming a full boric acid tank (8,126 gallons per Reference 10.4) is available and 9 gpm is lost to RCP seal leakoff to the VCT, such a feed and bleed boration could be accomplished in approximately two hours with 60 gpm letdown and 69 gpm via the emergency boration flow path (or, more likely, 60 gpm emergency boration and 9 gpm from the VCT). If, however, only the minimum required boric acid inventory was available (6,600 gallons per Table 5.2-5), the feed and bleed would require 1522.7 gallons from the spare tank or from a batching process. If batching is required, 2 batches would be needed, bringing the total time to 5 hours if the operations were performed in series. If, instead, the batching operations (if required) are performed in parallel with the feed and bleed, this very conservative scenario will achieve boration (in excess of that required) within the allotted time of 6 hours.

The remaining cooldown to Mode 5 would require approximately 2,451 gallons for a 50°F/hr cooldown (Table 6-9). Assuming no available boric acid at this point, approximately 3 batches (4.5 hours) would be required to provide the necessary volume for boration at a 6.5 blending ratio. Continued batching at 800 gallons every 1.5 hours would provide the necessary makeup for 9 gpm RCS leakage. Periodic pump down of the VCT, as well, will provide additional leakage makeup and added boration. Altogether, the 50°F/hr cooldown would require approximately 7 hours of cooldown and 4.5 hours of initial batching for a series total of 11.5 hours. This is well within the 30 hour limit even with consideration of preparation time, RHR lineup time, etc.

For the case where only the refueling water storage tank is available, the required actions have not been affected by a reduction of the boric acid concentration in the boric acid tanks. No additional evaluation, therefore, is needed for this case.

6.7 IMPACT OF RCS LEAKAGE

Previous evaluations of the cooldown to cold shutdown conditions have not included RCS leakage as discussed in Section 4.3 Item 4. The impact of RCS leakage on total makeup inventory requirements can be significant, however. Estimates of the total inventory requirement can be made by assuming a constant leakage rate and multiplying by an estimated time to complete the cooldown evolution. A 347°F cooldown (547°F to 200°F), for example, completed at an effective cooldown rate of 50 °F/hr with a constant leakage rate of 11 gpm, would require a total of 4,580 gallons to replace the RCS leakage. This volume added to the refueling water storage tank volumes of Table 5.2-5 could possibly result in available refueling water storage tank volumes going below the 320,000 gallon limiting condition for operation for Modes 1 through 4.

Given the total capacity of the three boric acid tanks of about 25,500 gallons, as much as 16,000 gallons could be available to a unit being shut down and cooled down (after subtracting the minimum volume for one unit operation). Assuming the boric acid tanks are maintained as full as possible (i.e., filled to capacity following each significant boric acid demand), most, if not all, of the RCS contraction and leakage makeup can be provided by the boric acid tanks and/or the pure water system (for blended makeup).

Table 6-12 illustrates a specific case where the effect of RCS leakage is accounted for during a cooldown using the boric acid tanks for direct and blended makeup. A constant leakage rate is assumed. This is accounted for in the analysis by adding the leakage mass to the shrinkage mass term described in Section 5.2. The boron addition provided during the makeup for this new "shrinkage mass" term is adjusted (decreased) to account for the mass of boric acid lost with the leaking coolant. This adjustment is made by taking the RCS boron mass fraction (concentration) times the water mass that leaks out during each time (temperature) increment.

As shown by Table 6-12, RCS leakage is accommodated during the specified cooldown using a total of 7,484.7 gallons of boric acid and 14,969.3 gallons of pure water. The blending ratio varies from 0 to 2. The blending ratio of 2 in this case corresponds to a blended boric acid solution that is close to the concentration in the RWST. In this example, therefore, blended boric acid makeup has replaced the RWST makeup assumed in Section 5.2.

6.8 LONG TERM COOLING AND CONTAINMENT SUMP pH

The impact of the Boric Acid Reduction Effort on post-LOCA long term cooling and containment sump pH control was reviewed. Each analysis is discussed qualitatively below.

Performance of the Emergency Core Cooling System (ECCS) during extended periods of time following a LOCA is typically analyzed to address residual heat removal via continuous boil-off of fluid in the reactor vessel. As borated water is delivered to the core region via safety injection and virtually pure water escapes as steam, high levels of boric acid may accumulate in the reactor vessel. As an input to this analysis, boric acid tank boron concentration is typically assumed to be at the maximum of 12 weight percent. Any such calculation will conservatively bound the maximum boric acid tank boron concentration of 3.5 weight percent proposed as a result of the analyses of this report.

The containment sump pH analysis is not impacted since it has not assumed injection of boric acid from the boric acid tanks during the design basis accident.

Table 6-1

Summary of Initial Conditions and Assumptions
Operations Analysis

Parameter	Value
Reactor Coolant System Volume	8015 ft^3
RHR System Volume	2000 ft^3
Pressurizer Volume	520 ft^3
Reactor Coolant System Pressure	2250 psia
Reactor Coolant System Hot Zero Power Temperature	547°F.
Pressurizer Condition	Saturated
Reactor Coolant System Leakage	0
Boric Acid Makeup Tank Temperature	120°F
Makeup Water Temperature	120°F
Pressurizer Level	Constant
Letdown	Available
Letdown Flowrate From One Orifice	45 gpm
Letdown Flowrate From One Orifice	60 gpm
EOC Boron Concentration	0 ppm
BOC Boron Concentration	1100 ppm
BAT Boron Concentration	3.25 wt%
RWST Boron Concentration	1950 ppm
Initial RHR System Concentration	775 ppm
RCS Boron Concentration (Refueling)	1950 ppm

TABLE 6-2

RCS FEED-AND BLEED USING ONE LETDOWN ORIFICE (45 GPM) FROM AN INITIAL CONCENTRATION OF 0 PPM BORON (SOURCE @ 120 F)

TIME (minutes)	EXPONENTIAL (1-e^(-T/TAO)	RWST AT 1950 PPM	BAT AT 1.50 WT %	BAT AT 1.75 WT %	BAT AT 2.25 WT %	BAT AT 2.50 WT %	BAT AT 3.00 WT %	BAT AT 3.25 WT %	BAT AT 3.50 WT %	TOTAL VOL AT 45 GPM	TOTAL VOL AT 54 GPM
		RCS BORON CONCENTRATION RESULTING (ppm boron)									
0	0.00000	0	0	0	0	0	0	0	0	0	0
10	0.00930	18.13097	24.38392	28.44791	36.57588	40.63987	48.76784	52.83183	56.89582	450	540
20	0.01851	36.09336	48.54112	56.63131	72.81169	80.90187	97.08225	105.1724	113.2626	900	1080
30	0.02764	53.88873	72.47371	84.55267	108.7105	120.7895	144.9474	157.0263	169.1053	1350	1620
40	0.03668	71.51865	96.18378	112.2144	144.2756	160.3063	192.3675	208.3982	224.4288	1800	2160
50	0.04563	88.98464	119.6734	139.6189	179.5101	199.4556	239.3468	259.2923	279.2379	2250	2700
60	0.05451	106.2882	142.9446	166.7687	214.4169	238.2410	285.8892	309.7133	333.5374	2700	3240
70	0.06330	123.4309	165.9994	193.6660	248.9991	276.6657	331.9988	359.6654	387.3320	3150	3780
80	0.07201	140.4142	188.8399	220.3132	283.2598	314.7331	377.6798	409.1531	440.6264	3600	4320
90	0.08064	157.2396	211.4680	246.7126	317.2020	352.4466	422.9360	458.1807	493.4253	4050	4860
100	0.08918	173.9086	233.8857	272.8666	350.8285	389.8095	467.7714	506.7524	545.7333	4500	5400
110	0.09765	190.4226	256.0949	298.7774	384.1624	426.8249	512.1899	554.8724	597.5549	4950	5940
120	0.10604	206.7830	278.0977	324.4473	417.1466	463.4962	556.1955	602.5451	648.8947	5400	6480
130	0.11435	222.9913	299.8959	349.8786	449.8439	499.8265	599.7919	649.7745	699.7572	5850	7020
140	0.12259	239.0489	321.4914	375.0733	482.2372	535.8191	642.9829	696.5648	750.1467	6300	7560
150	0.13075	254.9572	342.8861	400.0338	514.3292	571.4769	685.7723	742.9200	800.0677	6750	8100
160	0.13883	270.7176	364.0819	424.7623	546.1229	606.8032	728.1639	788.8442	849.5246	7200	8640
170	0.14684	286.3315	385.0806	449.2608	577.6210	641.8011	770.1613	834.3414	898.5216	7650	9180
180	0.15477	301.8002	405.8841	473.5315	608.8262	676.4735	811.7683	879.4156	947.0630	8100	9720
190	0.16263	317.1250	426.4941	497.5765	639.7412	710.8236	852.9883	924.0707	995.1531	8550	10260
200	0.17041	332.3074	446.9126	521.3980	670.3689	744.8543	893.8252	968.3106	1042.796	9000	10800
210	0.17813	347.3486	467.1411	544.9980	700.7117	778.5686	934.2823	1012.139	1089.996	9450	11340
220	0.18577	362.2499	487.1816	568.3785	730.7724	811.9694	974.3632	1055.560	1136.757	9900	11880
230	0.19334	377.0127	507.0357	591.5417	760.5536	845.0596	1014.071	1098.577	1183.083	10350	12420
240	0.20084	391.6383	526.7053	614.4895	790.0579	877.8422	1053.410	1141.194	1228.979	10800	12960
250	0.20827	406.1278	546.1919	637.2239	819.2879	910.3199	1092.383	1183.415	1274.447	11250	13500
260	0.21563	420.4826	565.4974	659.7470	848.2461	942.4957	1130.994	1225.244	1319.494	11700	14040
270	0.22293	434.7040	584.6234	682.0606	876.9351	974.3723	1169.246	1266.684	1364.121	12150	14580
280	0.23015	448.7931	603.5715	704.1668	905.3573	1005.952	1207.143	1307.738	1408.333	12600	15120
290	0.23731	462.7512	622.3435	726.0674	933.5152	1037.239	1244.687	1348.410	1452.134	13050	15660
300	0.24440	476.5796	640.9409	747.7644	961.4113	1068.234	1281.881	1388.705	1495.528	13500	16200
310	0.25143	490.2793	659.3654	769.2596	989.0481	1098.942	1318.730	1428.625	1538.519	13950	16740
320	0.25839	503.8517	677.6186	790.5550	1016.427	1129.364	1355.237	1468.173	1581.110	14400	17280
330	0.26528	517.2979	695.7020	811.6524	1043.553	1159.503	1391.404	1507.354	1623.304	14850	17820
340	0.27211	530.6191	713.6174	832.5536	1070.426	1189.362	1427.234	1546.171	1665.107	15300	18360
350	0.27888	543.8164	731.3661	853.2605	1097.049	1218.943	1462.732	1584.626	1706.521	15750	18900
360	0.28559	556.8910	748.9498	873.7748	1123.424	1248.249	1497.899	1622.724	1747.549	16200	19440
370	0.29223	569.8440	766.3701	894.0984	1149.555	1277.283	1532.740	1660.468	1788.196	16650	19980
380	0.29881	582.6766	783.6283	914.2331	1175.442	1306.047	1567.256	1697.861	1828.466	17100	20520
390	0.30533	595.3899	800.7261	934.1805	1201.089	1334.543	1601.452	1734.906	1868.361	17550	21060
400	0.31179	607.9850	817.6650	953.9425	1226.497	1362.775	1635.330	1771.607	1907.885	18000	21600
410	0.31819	620.4629	834.4463	973.5207	1251.669	1390.743	1668.892	1807.967	1947.041	18450	22140
420	0.32453	632.8249	851.0716	992.9169	1276.607	1418.452	1702.143	1843.988	1985.833	18900	22680
430	0.33081	645.0719	867.5423	1012.132	1301.313	1445.903	1735.084	1879.675	2024.265	19350	23220
440	0.33703	657.2050	883.8599	1031.169	1325.789	1473.099	1767.719	1915.029	2062.339	19800	23760
450	0.34319	669.2253	900.0257	1050.030	1350.038	1500.042	1800.051	1950.055	2100.060	20250	24300
460	0.34930	681.1339	916.0413	1068.714	1374.061	1526.735	1832.082	1984.756	2137.429	20700	24840
470	0.35535	692.9317	931.9079	1087.225	1397.861	1553.179	1863.815	2019.133	2174.451	21150	25380
480	0.36134	704.6199	947.6270	1105.564	1421.440	1579.378	1895.254	2053.191	2211.129	21600	25920
490	0.36728	716.1993	963.2000	1123.733	1444.800	1605.333	1926.400	2086.933	2247.466	22050	26460
500	0.37316	727.6711	978.6281	1141.732	1467.942	1631.046	1957.256	2120.361	2283.465	22500	27000
510	0.37899	739.0363	993.9128	1159.565	1490.869	1656.521	1987.825	2153.477	2319.130	22950	27540
520	0.38477	750.2957	1009.055	1177.231	1513.583	1681.759	2018.110	2186.286	2354.462	23400	28080
530	0.39049	761.4505	1024.057	1194.733	1536.085	1706.762	2048.114	2218.790	2389.466	23850	28620
540	0.39615	772.5015	1038.919	1212.072	1558.379	1731.532	2077.839	2250.992	2424.145	24300	29160
550	0.40177	783.4498	1053.643	1229.250	1580.465	1756.072	2107.287	2282.894	2458.501	24750	29700

TABLE 6-3

RCS FEED-AND BLEED USING ONE LETDOWN ORIFICE (60 GPM) FROM AN INITIAL CONCENTRATION OF 0 PPM BORON (SOURCE @ 120 F)

TIME (minutes)	EXPONENTIAL (1-e^(-T/TAO)	RWST AT 1950 PPM	BAT AT 1.50 WT %	BAT AT 1.75 WT %	BAT AT 2.25 WT %	BAT AT 2.50 WT %	BAT AT 3.00 WT %	BAT AT 3.25 WT %	BAT AT 3.50 WT %	TOTAL VOL AT 60 GPM	TOTAL VOL AT 69 GPM
		RCS BORON CONCENTRATION RESULTING (ppm boron)									
0	0.00000	0	0	0	0	0	0	0	0	0	0
10	0.01238	24.13932	32.46442	37.87516	48.69663	54.10737	64.92885	70.33958	75.75032	600	690
20	0.02461	47.97983	64.52696	75.28146	96.79045	107.5449	129.0539	139.8084	150.5629	1200	1380
30	0.03668	71.52521	96.19260	112.2247	144.2889	160.3210	192.3852	208.4173	224.4494	1800	2070
40	0.04860	94.77911	127.4662	148.7106	191.1993	212.4437	254.9325	276.1768	297.4212	2400	2760
50	0.06038	117.7451	158.3527	184.7448	237.5291	263.9212	316.7055	343.0976	369.4897	3000	3450
60	0.07201	140.4269	188.8569	220.3330	283.2853	314.7615	377.7138	409.1899	440.6661	3600	4140
70	0.08350	162.8278	218.9834	255.4806	328.4751	364.9724	437.9668	474.4641	510.9613	4200	4830
80	0.09485	184.9515	248.7370	290.1932	373.1055	414.5617	497.4740	538.9302	580.3864	4800	5520
90	0.10605	206.8013	278.1223	324.4760	417.1834	463.5371	556.2446	602.5983	648.9520	5400	6210
100	0.11712	228.3806	307.1438	358.3344	460.7157	511.9063	614.2876	665.4782	716.6689	6000	6900
110	0.12805	249.6927	335.8060	391.7737	503.7091	559.6767	671.6121	727.5798	783.5475	6600	7590
120	0.13884	270.7411	364.1135	424.7990	546.1702	606.8558	728.2270	788.9126	849.5981	7200	8280
130	0.14950	291.5289	392.0705	457.4156	588.1057	653.4508	784.1410	849.4861	914.8312	7800	8970
140	0.16003	312.0593	419.6814	489.6283	629.5221	699.4690	839.3629	909.3098	979.2567	8400	9660
150	0.17043	332.3356	446.9505	521.4423	670.4258	744.9176	893.9011	968.3929	1042.884	9000	10350
160	0.18070	352.3609	473.8821	552.8624	710.8232	789.8035	947.7642	1026.744	1105.724	9600	11040
170	0.19084	372.1383	500.4803	583.8936	750.7204	834.1338	1000.960	1084.374	1167.787	10200	11730
180	0.20086	391.6709	526.7492	614.5407	790.1238	877.9153	1053.498	1141.289	1229.081	10800	12420
190	0.21075	410.9617	552.6929	644.8084	829.0394	921.1549	1105.385	1197.501	1289.616	11400	13110
200	0.22052	430.0137	578.3155	674.7014	867.4732	963.8591	1156.631	1253.016	1349.402	12000	13800
210	0.23017	448.8298	603.6208	704.2243	905.4313	1006.034	1207.241	1307.845	1408.448	12600	14490
220	0.23970	467.4130	628.6129	733.3818	942.9194	1047.688	1257.225	1361.994	1466.763	13200	15180
230	0.24911	485.7661	653.2957	762.1783	979.9435	1088.826	1306.591	1415.474	1524.356	13800	15870
240	0.25841	503.8921	677.6729	790.6184	1016.509	1129.454	1355.345	1468.291	1581.236	14400	16560
250	0.26759	521.7937	701.7483	818.7063	1052.622	1169.580	1403.496	1520.454	1637.412	15000	17250
260	0.27665	539.4736	725.5257	846.4466	1088.288	1209.209	1451.051	1571.972	1692.893	15600	17940
270	0.28561	556.9347	749.0087	873.8435	1123.513	1248.347	1498.017	1622.852	1747.687	16200	18630
280	0.29445	574.1797	772.2010	900.9012	1158.301	1287.001	1544.402	1673.102	1801.802	16800	19320
290	0.30319	591.2112	795.1063	927.6240	1192.659	1325.177	1590.212	1722.730	1855.248	17400	20010
300	0.31181	608.0318	817.7280	954.0160	1226.592	1362.880	1635.456	1771.744	1908.032	18000	20700
310	0.32033	624.6442	840.0696	980.0812	1260.104	1400.116	1680.139	1820.150	1960.162	18600	21390
320	0.32874	641.0510	862.1347	1005.823	1293.202	1436.891	1724.269	1867.958	2011.647	19200	22080
330	0.33705	657.2547	883.9266	1031.247	1325.890	1473.211	1767.853	1915.174	2062.495	19800	22770
340	0.34526	673.2577	905.4488	1056.357	1358.173	1509.081	1810.897	1961.805	2112.714	20400	23460
350	0.35337	689.0627	926.7046	1081.155	1390.056	1544.507	1853.409	2007.859	2162.310	21000	24150
360	0.36137	704.6720	947.6972	1105.646	1421.545	1579.495	1895.394	2053.343	2211.293	21600	24840
370	0.36928	720.0881	968.4299	1129.834	1452.644	1614.049	1936.859	2098.264	2259.669	22200	25530
380	0.37708	735.3134	988.9060	1153.723	1483.359	1648.176	1977.812	2142.629	2307.447	22800	26220
390	0.38479	750.3502	1009.128	1177.316	1513.693	1681.881	2018.257	2186.445	2354.633	23400	26910
400	0.39241	765.2008	1029.100	1200.617	1543.651	1715.168	2058.201	2229.718	2401.235	24000	27600
410	0.39993	779.8676	1048.825	1223.630	1573.238	1748.043	2097.651	2272.456	2447.260	24600	28290
420	0.40736	794.3528	1068.306	1246.358	1602.460	1780.511	2136.613	2314.664	2492.716	25200	28980
430	0.41470	808.6588	1087.546	1268.804	1631.319	1812.577	2175.093	2356.350	2537.608	25800	29670
440	0.42194	822.7876	1106.548	1290.972	1659.822	1844.246	2213.096	2397.520	2581.945	26400	30360
450	0.42910	836.7415	1125.314	1312.866	1687.971	1875.524	2250.628	2438.181	2625.733	27000	31050
460	0.43617	850.5227	1143.848	1334.489	1715.772	1906.413	2287.696	2478.338	2668.979	27600	31740
470	0.44315	864.1333	1162.152	1355.845	1743.229	1936.921	2324.305	2517.998	2711.690	28200	32430
480	0.45004	877.5754	1180.230	1376.936	1770.346	1967.051	2360.461	2557.167	2753.872	28800	33120
490	0.45685	890.8511	1198.085	1397.765	1797.127	1996.808	2396.170	2595.851	2795.531	29400	33810
500	0.46357	903.9624	1215.718	1418.337	1823.577	2026.197	2431.436	2634.056	2836.675	30000	34500

TABLE 6-4

RCS FEED AND BLEED: ONE LETDOWN ORIFICE (45 GPM); INITIAL CONCENTRATION OF 1100 PPM BORON (SOURCE @ 120 F)

TIME (min)	EXP. VALUE Y = 1 - X	EXP. VALUE X	RWST AT 1950 PPM	BAT AT 1.5 WT %	BAT AT 1.75 WT %	BAT AT 2.25 WT %	BAT AT 2.50 WT %	BAT AT 3.00 WT %	BAT AT 3.25 WT %	BAT AT 3.50 WT %	TOTAL VOL AT 45 GPM	TOTAL VOL AT 54 GPM
			RCS BORON CONCENTRATION RESULTING (ppm boron)									
0	1	0.00000	1100	1100	1100	1100	1100	1100	1100	1100	0	0
10	0.990702	0.00930	1107.903	1114.156	1118.220	1126.348	1130.412	1138.540	1142.604	1146.668	450	540
20	0.981490	0.01851	1115.733	1128.180	1136.270	1152.451	1160.541	1176.721	1184.812	1192.902	900	1080
30	0.972364	0.02764	1123.489	1142.074	1154.153	1178.311	1190.390	1214.548	1226.627	1238.706	1350	1620
40	0.963323	0.03668	1131.174	1155.839	1171.870	1203.931	1219.962	1252.023	1268.054	1284.084	1800	2160
50	0.954366	0.04563	1138.788	1169.476	1189.422	1229.313	1249.259	1289.150	1309.095	1329.041	2250	2700
60	0.945493	0.05451	1146.330	1182.987	1206.811	1254.459	1278.283	1325.931	1349.755	1373.579	2700	3240
70	0.936702	0.06330	1153.803	1196.371	1224.038	1279.371	1307.038	1362.371	1390.037	1417.704	3150	3780
80	0.927992	0.07201	1161.206	1209.631	1241.105	1304.051	1335.525	1398.471	1429.945	1461.418	3600	4320
90	0.919364	0.08064	1168.540	1222.768	1258.013	1328.502	1363.747	1434.236	1469.481	1504.726	4050	4860
100	0.910816	0.08918	1175.806	1235.783	1274.764	1352.726	1391.707	1469.669	1508.650	1547.631	4500	5400
110	0.902347	0.09765	1183.004	1248.677	1291.359	1376.724	1419.407	1504.772	1547.454	1590.137	4950	5940
120	0.893957	0.10604	1190.136	1261.450	1307.800	1400.499	1446.849	1539.548	1585.898	1632.247	5400	6480
130	0.885645	0.11435	1197.201	1274.105	1324.088	1424.053	1474.036	1574.001	1623.984	1673.967	5850	7020
140	0.877410	0.12259	1204.200	1286.643	1340.225	1447.389	1500.970	1608.134	1661.716	1715.298	6300	7560
150	0.869252	0.13075	1211.135	1299.064	1356.211	1470.507	1527.654	1641.950	1699.098	1756.245	6750	8100
160	0.861170	0.13883	1218.005	1311.369	1372.049	1493.410	1554.090	1675.451	1736.131	1796.812	7200	8640
170	0.853163	0.14684	1224.811	1323.560	1387.740	1516.100	1580.280	1708.641	1772.821	1837.001	7650	9180
180	0.845230	0.15477	1231.553	1335.637	1403.285	1538.579	1606.227	1741.522	1809.169	1876.816	8100	9720
190	0.837371	0.16263	1238.234	1347.603	1418.685	1560.850	1631.932	1774.097	1845.179	1916.262	8550	10260
200	0.829585	0.17041	1244.851	1359.457	1433.942	1582.913	1657.398	1806.369	1880.855	1955.340	9000	10800
210	0.821872	0.17813	1251.408	1371.200	1449.057	1604.771	1682.628	1838.342	1916.198	1994.055	9450	11340
220	0.814230	0.18577	1257.903	1382.835	1464.032	1626.426	1707.623	1870.017	1951.214	2032.411	9900	11880
230	0.806660	0.19334	1264.338	1394.361	1478.867	1647.879	1732.385	1901.397	1985.903	2070.409	10350	12420
240	0.799159	0.20084	1270.714	1405.781	1493.565	1669.133	1756.918	1932.486	2020.270	2108.054	10800	12960
250	0.791729	0.20827	1277.030	1417.094	1508.126	1690.190	1781.222	1963.286	2054.318	2145.350	11250	13500
260	0.784367	0.21563	1283.287	1428.302	1522.551	1711.050	1805.300	1993.799	2088.049	2182.298	11700	14040
270	0.777074	0.22293	1289.486	1439.405	1536.842	1731.717	1829.154	2024.029	2121.466	2218.903	12150	14580
280	0.769849	0.23015	1295.627	1450.406	1551.001	1752.191	1852.787	2053.977	2154.572	2255.168	12600	15120
290	0.762691	0.23731	1301.712	1461.304	1565.028	1772.476	1876.199	2083.647	2187.371	2291.095	13050	15660
300	0.755600	0.24440	1307.739	1472.101	1578.924	1792.571	1899.395	2113.042	2219.865	2326.689	13500	16200
310	0.748574	0.25143	1313.711	1482.797	1592.691	1812.480	1922.374	2142.162	2252.057	2361.951	13950	16740
320	0.741614	0.25839	1319.627	1493.394	1606.330	1832.203	1945.140	2171.013	2283.949	2396.886	14400	17280
330	0.734719	0.26528	1325.488	1503.892	1619.843	1851.744	1967.694	2199.595	2315.545	2431.495	14850	17820
340	0.727887	0.27211	1331.295	1514.293	1633.230	1871.102	1990.038	2227.911	2346.847	2465.783	15300	18360
350	0.721119	0.27888	1337.048	1524.597	1646.492	1890.281	2012.175	2255.964	2377.858	2499.752	15750	18900
360	0.714414	0.28559	1342.747	1534.806	1659.631	1909.281	2034.106	2283.756	2408.581	2533.406	16200	19440
370	0.707772	0.29223	1348.393	1544.919	1672.647	1928.104	2055.833	2311.289	2439.018	2566.746	16650	19980
380	0.701191	0.29881	1353.987	1554.938	1685.543	1946.753	2077.357	2338.567	2469.172	2599.776	17100	20520

TABLE 6-5

RCS FEED-AND BLEED USING ONE LETDOWN ORIFICE (60 GPM) FROM AN INITIAL CONCENTRATION OF 1100 PPM BORON (SOURCE @ 120 F)

TIME (min)	EXP. VALUE Y = 1 - X	EXP. VALUE X	RWST AT 1950 PPM	BAT AT 1.50 WT %	BAT AT 1.75 WT %	BAT AT 2.25 WT %	BAT AT 2.50 WT %	BAT AT 3.00 WT %	BAT AT 3.25 WT %	BAT AT 3.50 WT %	TOTAL VOL AT 60 GPM	TOTAL VOL AT 69 GPM
			RCS BORON CONCENTRATION RESULTING (ppm boron)									
0	1	0.00000	1100	1100	1100	1100	1100	1100	1100	1100	0	0
10	0.987620	0.01238	1110.522	1118.847	1124.258	1135.079	1140.490	1151.311	1156.722	1162.133	600	690
20	0.975394	0.02461	1120.914	1137.461	1148.215	1169.724	1180.479	1201.988	1212.742	1223.497	1200	1380
30	0.963320	0.03668	1131.177	1155.845	1171.877	1203.941	1219.973	1252.037	1268.069	1284.101	1800	2070
40	0.951395	0.04860	1141.313	1174.001	1195.245	1237.734	1258.978	1301.467	1322.711	1343.956	2400	2760
50	0.939617	0.06038	1151.324	1191.932	1218.324	1271.108	1297.500	1350.285	1376.677	1403.069	3000	3450
60	0.927986	0.07201	1161.211	1209.641	1241.117	1304.070	1335.546	1398.498	1429.974	1461.450	3600	4140
70	0.916498	0.08350	1170.976	1227.131	1263.629	1336.623	1373.120	1446.115	1482.612	1519.109	4200	4830
80	0.905153	0.09485	1180.619	1244.405	1285.861	1368.773	1410.230	1493.142	1534.598	1576.054	4800	5520
90	0.893948	0.10605	1190.144	1261.465	1307.818	1400.526	1446.880	1539.587	1585.941	1632.294	5400	6210
100	0.882881	0.11712	1199.550	1278.313	1329.504	1431.885	1483.076	1585.457	1636.648	1687.838	6000	6900
110	0.871952	0.12805	1208.840	1294.953	1350.921	1462.856	1518.824	1630.759	1686.727	1742.695	6600	7590
120	0.861158	0.13884	1218.015	1311.387	1372.073	1493.444	1554.130	1675.501	1736.186	1796.872	7200	8280
130	0.850497	0.14950	1227.076	1327.618	1392.963	1523.653	1588.998	1719.688	1785.033	1850.379	7800	8970
140	0.839969	0.16003	1236.025	1343.647	1413.594	1553.488	1623.435	1763.329	1833.276	1903.223	8400	9660
150	0.829571	0.17043	1244.864	1359.479	1433.970	1582.954	1657.446	1806.429	1880.921	1955.413	9000	10350
160	0.819302	0.18070	1253.593	1375.114	1454.094	1612.055	1691.035	1848.996	1927.976	2006.957	9600	11040
170	0.809159	0.19084	1262.214	1390.556	1473.969	1640.796	1724.209	1891.036	1974.449	2057.863	10200	11730
180	0.799143	0.20086	1270.728	1405.806	1493.598	1669.181	1756.972	1932.555	2020.347	2108.138	10800	12420
190	0.789250	0.21075	1279.137	1420.868	1512.983	1697.214	1789.330	1973.561	2065.676	2157.792	11400	13110
200	0.779480	0.22052	1287.441	1435.743	1532.129	1724.901	1821.287	2014.059	2110.445	2206.831	12000	13800
210	0.769830	0.23017	1295.643	1450.434	1551.038	1752.245	1852.848	2054.055	2154.659	2255.262	12600	14490
220	0.760301	0.23970	1303.744	1464.944	1569.712	1779.250	1884.019	2093.557	2198.325	2303.094	13200	15180
230	0.750889	0.24911	1311.744	1479.273	1588.156	1805.921	1914.804	2132.569	2241.452	2350.334	13800	15870
240	0.741593	0.25841	1319.645	1493.426	1606.371	1832.262	1945.208	2171.098	2284.044	2396.989	14400	16560
250	0.732413	0.26759	1327.448	1507.403	1624.361	1858.277	1975.235	2209.151	2326.109	2443.067	15000	17250
260	0.723346	0.27665	1335.155	1521.207	1642.128	1883.970	2004.891	2246.732	2367.653	2488.574	15600	17940
270	0.714392	0.28561	1342.766	1534.840	1659.675	1909.344	2034.179	2283.849	2408.683	2533.518	16200	18630
280	0.705548	0.29445	1350.283	1548.304	1677.005	1934.405	2063.105	2320.505	2449.206	2577.906	16800	19320
290	0.696814	0.30319	1357.707	1561.602	1694.120	1959.155	2091.673	2356.708	2489.226	2621.744	17400	20010
300	0.688188	0.31181	1365.039	1574.735	1711.023	1983.599	2119.887	2392.463	2528.751	2665.039	18000	20700
310	0.679669	0.32033	1372.280	1587.706	1727.717	2007.741	2147.752	2427.775	2567.787	2707.799	18600	21390
320	0.671255	0.32874	1379.432	1600.516	1744.205	2031.583	2175.272	2462.650	2606.340	2750.029	19200	22080
330	0.662946	0.33705	1386.495	1613.167	1760.488	2055.130	2202.452	2497.094	2644.415	2791.736	19800	22770
340	0.654739	0.34526	1393.471	1625.662	1776.570	2078.386	2229.294	2531.111	2682.019	2832.927	20400	23460
350	0.646634	0.35337	1400.360	1638.002	1792.453	2101.354	2255.805	2564.707	2719.157	2873.608	21000	24150
360	0.638629	0.36137	1407.164	1650.189	1808.139	2124.038	2281.988	2597.887	2755.836	2913.786	21600	24840
370	0.630724	0.36928	1413.884								22200	25530
380	0.622916	0.37708	1420.521								22800	26220

TABLE 6-6

PLANT COOLDOWN TO REFUELING: BAT AT 3.25 WEIGHT % BORIC ACID; RHR = 775 ppm (RHR VOLUME = 2000 FT3)

AVG.SYS.TEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BLEND RATIO	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC (ppm boron)	TOTAL RCS MAKEUP 120 F (gal)	TOTAL PURE WATER 120 F (gal)	TOTAL BAT WATER 120 F (gal)
547	547	2250	1.00000	1.00000	0.0	0	0.0	0.0	0.0	2,894.0	445,622.6	1,135.4	0.0	0.0	0.0
547	500	2250	0.02125	0.02009	21,796.0	0	2,642.0	0.0	732.2	3,626.2	468,150.7	1,354.2	2,642.0	0.0	2,642.0
500	450	2250	0.02009	0.01916	19,473.9	0	2,360.5	0.0	654.2	4,280.3	488,278.7	1,532.6	5,002.5	0.0	5,002.5
450	400	2250	0.01916	0.01842	16,814.4	0	2,038.2	0.0	564.8	4,845.1	505,658.0	1,675.2	7,040.7	0.0	7,040.7
400	370	2250	0.01842	0.01804	9,170.6	0	1,111.6	0.0	308.1	5,153.2	515,136.6	1,749.0	8,152.3	0.0	8,152.3
370	350	2250	0.01804	0.01781	5,740.8	0	695.9	0.0	192.8	5,346.0	521,070.3	1,793.7	8,848.2	0.0	8,848.2
350	350	465	0.02698	0.01961	7,243.5	0	878.0	0.0	243.3	5,589.3	528,557.2	1,848.8	9,726.2	0.0	9,726.2
350	350	465	0.01781	0.01781	0.0	0	0.0	0.0	495.8	6,085.2	636,526.6	1,671.4	9,726.2	0.0	9,726.2
350	300	465	0.01781	0.01742	12,431.4	0	1,506.9	0.0	417.6	6,502.7	649,375.6	1,750.8	11,233.1	0.0	11,233.1
300	250	465	0.01742	0.01698	14,897.7	0	1,805.8	0.0	500.4	7,003.2	664,773.7	1,841.8	13,038.9	0.0	13,038.9
250	200	465	0.01698	0.01661	13,138.5	0	1,592.6	0.0	441.3	7,444.5	678,353.5	1,918.7	14,631.5	0.0	14,631.5
200	160	465	0.01661	0.01637	8,839.8	0	1,071.5	0.0	296.9	7,741.4	687,490.3	1,968.7	15,703.0	0.0	15,703.0
160	130	465	0.01637	0.01622	5,657.7	0	685.8	0.0	190.0	7,931.5	693,338.1	2,000.0	16,388.8	0.0	16,388.8

CONTRACTION MAKEUP BAT VOLUME 16,388.8 gallons
FEED & BLEED BAT VOLUME (0ppm to 1135ppm) 10,800.0 gallons (180 min at 60 gpm) ROUNDED UP
TOTAL BAT VOLUME 27,188.8 gallons

TABLE 6-7

PLANT COOLDOWN TO COLD SHUTDOWN (CASE 1): BLENDED MAKEUP; BAT AT 3.25 WEIGHT % BORIC ACID; RHR (ppm) = RCS (ppm) (RHR VOLUME = 2000 FT3) (CASE 1)

AVG.SYS.TEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BLEND RATIO	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC. (ppm boron)	TOTAL RCS MAKEUP 120 F (gal)	TOTAL PURE WATER 120 F (gal)	TOTAL BAT WATER 120 F (gal)
547	547	2250	1.00000	1.00000	0.0	0.3	0.0	0.0	0.0	0.0	442,728.6	0.0	0.0	0.0	0
547	500	2250	0.02125	0.02009	21,796.0	0.3	2,032.3	0.0	563.2	563.2	465,087.7	211.7	2,642.0	609.7	2,032.3
500	450	2250	0.02009	0.01916	19,473.9	0.3	1,815.8	0.0	503.2	1,066.4	485,064.8	384.4	5,002.5	1,154.4	3,848.1
450	400	2250	0.01916	0.01842	16,814.4	0.3	1,567.8	0.0	434.5	1,500.9	502,313.7	522.4	7,040.7	1,624.8	5,415.9
400	370	2250	0.01842	0.01804	9,170.6	0.3	855.1	0.0	237.0	1,737.8	511,721.3	593.7	8,152.3	1,881.3	6,271.0
370	350	2250	0.01804	0.01781	5,740.8	0.3	535.3	0.0	148.3	1,886.2	517,610.4	637.1	8,848.2	2,041.9	6,806.3
350	350	465	0.02698	0.01961	7,243.5	0.3	675.4	0.0	187.2	2,073.3	525,041.2	690.4	9,726.2	2,244.5	7,481.7
350	350	465	0.01781	0.01781	0.0	0.3	0.0	0.0	426.1	2,499.4	632,940.9	690.4	9,726.2	2,244.5	7,481.7
350	320	465	0.01781	0.01763	5,583.3	0.3	520.6	0.0	144.3	2,643.7	638,668.5	723.7	10,403.0	2,400.7	8,002.3
320	290	465	0.01763	0.01733	9,833.8	2.4	350.6	0.0	97.2	2,740.8	648,599.4	738.8	11,595.0	3,242.1	8,352.9
290	260	465	0.01733	0.01706	9,146.1	2.4	326.1	0.0	90.4	2,831.2	657,835.9	752.5	12,703.6	4,024.7	8,679.0
260	230	465	0.01706	0.01682	8,376.4	2.4	298.6	0.0	82.8	2,914.0	666,295.1	764.6	13,719.0	4,741.4	8,977.6
230	200	465	0.01682	0.01661	7,527.9	2.4	268.4	0.0	74.4	2,988.3	673,897.4	775.3	14,631.5	5,385.5	9,246.0

TOTAL BAT VOLUME 9,246.0 gallons

TOTAL RWST VOLUME 0.0

TABLE 6-8

PLANT COOLDOWN TO COLD SHUTDOWN (CASE 2): BLENDED MAKEUP; BAT AT 3.25 WEIGHT % BORIC ACID; RHR (ppm) = 775 ppm (RHR VOLUME = 2000 FT3) (CASE 2)

AVG.SYS.TEMP. (F) Ti	AVG.SYS.TEMP. (F) Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	SPECIFIC VOLUME (cu.ft./lbm) Vf	SHRINKAGE MASS(lbm)	BLEND RATIO	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC (ppm boron)	TOTAL RCS MAKEUP 120 F (gal)	TOTAL PURE WATER 120 F (gal)	TOTAL BAT WATER 120 F (gal)
547	547	2250	1.00000	1.00000	0.0	0.3	0.0	0.0	0.0	0.0	442,728.6	0.0	0	0.0	0.0
547	500	2250	0.02125	0.02009	21,796.0	0.3	2,032.3	0.0	563.2	563.2	465,087.7	211.7	2,642.0	609.7	2,032.3
500	450	2250	0.02009	0.01916	19,473.9	0.3	1,815.8	0.0	503.2	1,066.4	485,064.8	384.4	5,002.5	1,154.4	3,848.1
450	400	2250	0.01916	0.01842	16,814.4	0.3	1,567.8	0.0	434.5	1,500.9	502,313.7	522.4	7,040.7	1,624.8	5,415.9
400	370	2250	0.01842	0.01804	9,170.6	0.3	855.1	0.0	237.0	1,737.8	511,721.3	593.7	8,152.3	1,881.3	6,271.0
370	350	2250	0.01804	0.01781	5,740.8	0.3	535.3	0.0	148.3	1,886.2	517,610.4	637.1	8,848.2	2,041.9	6,806.3
350	350	465	0.02698	0.01961	7,243.5	0.3	675.4	0.0	187.2	2,073.3	525,041.2	690.4	9,726.2	2,244.5	7,481.7
350	350	465	0.01781	0.01781	0.0	0.3	0.0	0.0	495.8	2,569.2	633,010.6	709.6	9,726.2	2,244.5	7,481.7
350	320	465	0.01781	0.01763	5,583.3	0.3	520.6	0.0	144.3	2,713.4	638,738.2	742.7	10,403.0	2,400.7	8,002.3
320	290	465	0.01763	0.01733	9,833.8	3.1	290.7	0.0	80.6	2,794.0	648,652.6	753.1	11,595.0	3,302.0	8,293.0
290	260	465	0.01733	0.01706	9,146.1	3.1	270.4	0.0	74.9	2,868.9	657,873.6	762.4	12,703.6	4,140.2	8,563.4
260	230	465	0.01706	0.01682	8,376.4	3.1	247.6	0.0	68.6	2,937.6	666,318.7	770.8	13,719.0	4,907.9	8,811.1
230	200	465	0.01682	0.01661	7,527.9	3.1	222.6	0.0	61.7	2,999.2	673,908.3	778.1	14,631.5	5,597.8	9,033.6

TOTAL BAT VOLUME = 9,033.6 gallons

TOTAL RWST VOLUME = 0.0

TABLE 6-9

PLANT COOLDOWN TO COLD SHUTDOWN: FEED AND BLEED AND BLENDED MAKEUP FOR 50 F/HR COOLDOWN; BAT AT 3.25 WT %; RHR (ppm) = 775 m ---------(9 gpm SEAL LEAKAGE)--------

AVG.SYSTEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BLEND RATIO	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/ (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC (ppm boron)	TOTAL RCS MAKEUP 120 F (gal)	TOTAL PURE WATER 120 F (gal)	TOTAL BAT WATER 120 F (gal)
547	547	2250	1.00000	1.00000	0.0	6.5	0.0	0.0	0.0	1,962.5	442,728.6	775.0	0	0.0	0.0
547	540	2250	0.02125	0.02106	3,511.0	6.5	56.7	0.0	15.7	1,978.2	446,255.2	775.0	501.2	434.4	66.8
540	530	2250	0.02106	0.02079	4,852.2	6.5	78.4	0.0	21.7	2,000.0	451,129.2	775.1	1,197.3	1,037.7	159.6
530	520	2250	0.02079	0.02055	4,597.4	6.5	74.3	0.0	20.6	2,020.5	455,747.1	775.1	1,862.6	1,614.3	248.3
520	510	2250	0.02055	0.02031	4,513.9	6.5	73.0	0.0	20.2	2,040.8	460,281.3	775.2	2,517.8	2,182.1	335.7
510	500	2250	0.02031	0.02009	4,321.5	6.5	69.8	0.0	19.4	2,060.1	464,622.2	775.2	3,149.6	2,729.7	419.9
500	490	2250	0.02009	0.01989	4,011.6	6.5	64.8	0.0	18.0	2,078.1	468,651.7	775.2	3,743.9	3,244.7	499.2
490	480	2250	0.01989	0.01969	4,093.1	6.5	66.2	0.0	18.3	2,096.4	472,763.2	775.3	4,348.0	3,768.3	579.7
480	470	2250	0.01969	0.01951	3,860.9	6.5	62.4	0.0	17.3	2,113.7	476,641.3	775.3	4,924.0	4,267.5	656.5
470	460	2250	0.01951	0.01933	3,827.5	6.5	61.9	0.0	17.1	2,130.9	480,485.9	775.4	5,496.0	4,763.2	732.8
460	450	2250	0.01933	0.01916	3,680.9	6.5	59.5	0.0	16.5	2,147.3	484,183.3	775.4	6,050.1	5,243.4	806.7
450	440	2250	0.01916	0.01900	3,524.5	6.5	57.0	0.0	15.8	2,163.1	487,723.6	775.4	6,585.4	5,707.3	878.0
440	430	2250	0.01900	0.01884	3,471.5	6.5	56.1	0.0	15.5	2,178.7	491,210.6	775.4	7,114.2	6,165.6	948.6
430	420	2250	0.01884	0.01869	3,414.3	6.5	55.2	0.0	15.3	2,194.0	494,640.2	775.5	7,636.0	6,617.9	1,018.1
420	410	2250	0.01869	0.01855	3,353.0	6.5	54.2	0.0	15.0	2,209.0	498,008.3	775.5	8,150.5	7,063.7	1,086.7
410	400	2250	0.01855	0.01842	3,051.0	6.5	49.3	0.0	13.7	2,222.6	501,073.0	775.5	8,628.3	7,477.9	1,150.4
400	390	2250	0.01842	0.01828	3,334.3	6.5	53.9	0.0	14.9	2,237.6	504,422.2	775.6	9,140.5	7,921.7	1,218.7
390	380	2250	0.01828	0.01816	2,898.9	6.5	46.9	0.0	13.0	2,250.6	507,334.1	775.6	9,599.8	8,319.9	1,280.0
380	370	2250	0.01816	0.01804	2,937.5	6.5	47.5	0.0	13.2	2,263.7	510,284.7	775.6	10,063.9	8,722.1	1,341.9
370	360	2250	0.01804	0.01792	2,976.8	6.5	48.1	0.0	13.3	2,277.1	513,274.8	775.6	10,532.7	9,128.4	1,404.4
360	350	2250	0.01792	0.01781	2,764.0	6.5	44.7	0.0	12.4	2,289.4	516,051.2	775.6	10,975.8	9,512.3	1,463.4
350	350	465	0.02698	0.01961	7,243.5	6.5	117.1	0.0	32.4	2,321.9	523,327.2	775.7	11,853.8	10,273.3	1,580.5
350	350	465	0.01781	0.01781	0.0	6.5	0.0	0.0	495.8	2,817.7	633,259.1	777.9	11,853.8	10,273.3	1,580.5
350	330	465	0.01781	0.01773	2,379.4	6.5	38.5	0.0	10.7	2,828.4	635,649.2	777.9	12,358.2	10,710.5	1,647.8
330	310	465	0.01773	0.01763	3,204.0	6.5	51.8	0.0	14.4	2,842.7	638,867.5	777.9	12,962.6	11,234.2	1,728.3
310	290	465	0.01763	0.01742	6,848.1	6.5	110.7	0.0	30.7	2,873.4	645,746.3	778.0	14,008.7	12,140.9	1,867.8
290	270	465	0.01742	0.01724	6,002.6	6.5	97.0	0.0	26.9	2,900.3	651,775.7	778.0	14,952.3	12,958.7	1,993.6
270	250	465	0.01724	0.01706	6,129.2	6.5	99.1	0.0	27.5	2,927.7	657,932.4	778.0	15,911.2	13,789.7	2,121.5
250	230	465	0.01706	0.01690	5,557.8	6.5	89.8	0.0	24.9	2,952.6	663,515.2	778.0	16,800.9	14,560.8	2,240.1
230	210	465	0.01690	0.01675	5,306.9	6.5	85.8	0.0	23.8	2,976.4	668,845.8	778.0	17,660.2	15,305.5	2,354.7
210	200	465	0.01675	0.01661	5,039.6	6.5	81.4	0.0	22.6	2,998.9	673,908.0	778.0	18,379.1	15,928.5	2,450.5

FEED AND BLEED BAT VOLUME (0ppm to 775ppm) = 8,122.7 gallons (117.7 minutes at 69 gpm, 3.25 wt %)

FEED AND BLEED RWST VOLUME (0ppm to 775ppm) = 28,060.0 gallons (406.7 minutes at 69 gpm, 1950 ppm)

TOTAL BAT VOLUME: FEED AND BLEED PLUS MAKEUP = 10,573.2 gallons

TABLE 6-10

PLANT COOLDOWN TO COLD SHUTDOWN: BLENDED MAKEUP FOR 100 F/HR COOLDOWN; BAT AT 3.25 WEIGHT % BORIC ACID; RHR (ppm) = 775 ppm ---------(9 gpm SEAL LEAKAGE)---------

AVG.SYSTEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BLEND RATIO	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/ (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC (ppm boron)	TOTAL RCS MAKEUP 120 F (gal)	TOTAL PURE WATER 120 F (gal)	TOTAL BAT WATER 120 F (gal)
547	547	2250	1.00000	1.00000	0.0	6.5	0.0	0.0	0.0	1,962.5	442,728.6	775.0	0.0	0.0	0.0
547	540	2250	0.02125	0.02106	3,511.0	6.5	56.7	0.0	15.7	1,978.2	446,255.2	775.0	463.4	401.6	61.8
540	530	2250	0.02106	0.02079	4,852.2	6.5	78.4	0.0	21.7	2,000.0	451,129.2	775.1	1,105.5	958.1	147.4
530	520	2250	0.02079	0.02055	4,597.4	6.5	74.3	0.0	20.6	2,020.5	455,747.1	775.1	1,716.8	1,487.9	228.9
520	510	2250	0.02055	0.02031	4,513.9	6.5	73.0	0.0	20.2	2,040.8	460,281.3	775.2	2,318.0	2,008.9	309.1
510	500	2250	0.02031	0.02009	4,321.5	6.5	69.8	0.0	19.4	2,060.1	464,622.2	775.2	2,895.8	2,509.7	386.1
500	490	2250	0.02009	0.01989	4,011.6	6.5	64.8	0.0	18.0	2,078.1	468,651.7	775.2	3,436.1	2,977.9	458.1
490	480	2250	0.01989	0.01969	4,093.1	6.5	66.2	0.0	18.3	2,096.4	472,763.2	775.3	3,986.2	3,454.7	531.5
480	470	2250	0.01969	0.01951	3,860.9	6.5	62.4	0.0	17.3	2,113.7	476,641.3	775.3	4,508.2	3,907.1	601.1
470	460	2250	0.01951	0.01933	3,827.5	6.5	61.9	0.0	17.1	2,130.9	480,485.9	775.4	5,026.2	4,356.0	670.2
460	450	2250	0.01933	0.01916	3,680.9	6.5	59.5	0.0	16.5	2,147.3	484,183.3	775.4	5,526.3	4,789.5	736.8
450	440	2250	0.01916	0.01900	3,524.5	6.5	57.0	0.0	15.8	2,163.1	487,723.6	775.4	6,007.6	5,206.6	801.0
440	430	2250	0.01900	0.01884	3,471.5	6.5	56.1	0.0	15.5	2,178.7	491,210.6	775.4	6,482.4	5,618.0	864.3
430	420	2250	0.01884	0.01869	3,414.3	6.5	55.2	0.0	15.3	2,194.0	494,640.2	775.5	6,950.2	6,023.5	926.7
420	410	2250	0.01869	0.01855	3,353.0	6.5	54.2	0.0	15.0	2,209.0	498,008.3	775.5	7,410.7	6,422.6	988.1
410	400	2250	0.01855	0.01842	3,051.0	6.5	49.3	0.0	13.7	2,222.6	501,073.0	775.5	7,834.5	6,789.9	1,044.6
400	390	2250	0.01842	0.01828	3,334.3	6.5	53.9	0.0	14.9	2,237.6	504,422.2	775.6	8,292.7	7,187.0	1,105.7
390	380	2250	0.01828	0.01816	2,898.9	6.5	46.9	0.0	13.0	2,250.6	507,334.1	775.6	8,698.0	7,538.3	1,159.7
380	370	2250	0.01816	0.01804	2,937.5	6.5	47.5	0.0	13.2	2,263.7	510,284.7	775.6	9,108.1	7,893.7	1,214.4
370	360	2250	0.01804	0.01792	2,976.8	6.5	48.1	0.0	13.3	2,277.1	513,274.8	775.6	9,522.9	8,253.2	1,269.7
360	350	2250	0.01792	0.01781	2,764.0	6.5	44.7	0.0	12.4	2,289.4	516,051.2	775.6	9,912.0	8,590.4	1,321.6
350	350	465	0.02698	0.01961	7,243.5	6.5	117.1	0.0	32.4	2,321.9	523,327.2	775.7	10,790.0	9,351.3	1,438.7
350	350	465	0.01781	0.01781	0.0	6.5	0.0	0.0	495.8	2,817.7	633,259.1	777.9	10,790.0	9,351.3	1,438.7
350	330	465	0.01781	0.01773	2,379.4	6.5	38.5	0.0	10.7	2,828.4	635,649.2	777.9	11,186.4	9,694.9	1,491.5
330	320	465	0.01773	0.01763	3,204.0	6.5	51.8	0.0	14.4	2,842.7	638,867.5	777.9	11,628.8	10,078.3	1,550.5
320	300	465	0.01763	0.01742	6,848.1	6.5	110.7	0.0	30.7	2,873.4	645,746.3	778.0	12,566.9	10,891.3	1,675.6
300	280	465	0.01742	0.01724	6,002.6	6.5	97.0	0.0	26.9	2,900.3	651,775.7	778.0	13,402.5	11,615.5	1,787.0
280	260	465	0.01724	0.01706	6,129.2	6.5	99.1	0.0	27.5	2,927.7	657,932.4	778.0	14,253.4	12,353.0	1,900.5
260	240	465	0.01706	0.01690	5,557.8	6.5	89.8	0.0	24.9	2,952.6	663,515.2	778.0	15,035.1	13,030.5	2,004.7
240	220	465	0.01690	0.01675	5,306.9	6.5	85.8	0.0	23.8	2,976.4	668,845.8	778.0	15,786.4	13,681.6	2,104.9
220	200	465	0.01675	0.01661	5,039.6	6.5	81.4	0.0	22.6	2,998.9	673,908.0	778.0	16,505.3	14,304.6	2,200.7

FEED AND BLEED BAT VOLUME (0ppm to 775ppm) = 8,122.7 gallons (117.7 minutes at 69 gpm, 3.25 wt %)

FEED AND BLEED RWST VOLUME (0ppm to 775ppm) = 28,060.0 gallons (406.7 minutes at 69 gpm, 1950 ppm)

TOTAL BAT VOLUME: FEED AND BLEED PLUS MAKEUP = 10,323.4 gallons

TABLE 6-11

PLANT COOLDOWN TO COLD SHUTDOWN: FEED AND BLEED AND RWST MAKEUP FOR 100 F/HR COOLDOWN; RWST AT 1950 ppm BORON; RHR (ppm) = 775 ppm -----(9 gpm SEAL LEAKAGE)------

AVG.SYSTEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BLEND RATIO	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/ (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC (ppm boron)	TOTAL RCS MAKEUP 120 F (gal)	TOTAL PURE WATER 120 F (gal)	TOTAL BAT WATER 120 F (gal)
547	547	2250	1.00000	1.00000	0.0	0	0.0	0.0	0.0	1,130.0	442,728.6	446.2	0.0	0.0	0.0
547	540	2250	0.02125	0.02106	3,511.0	0	0.0	425.6	39.6	1,169.6	446,279.1	458.2	463.4	0.0	0.0
540	530	2250	0.02106	0.02079	4,852.2	0	0.0	588.2	54.7	1,224.3	451,186.0	474.4	1,105.5	0.0	0.0
530	520	2250	0.02079	0.02055	4,597.4	0	0.0	557.3	51.9	1,276.2	455,835.3	489.5	1,716.8	0.0	0.0
520	510	2250	0.02055	0.02031	4,513.9	0	0.0	547.2	50.9	1,327.1	460,400.1	504.0	2,318.0	0.0	0.0
510	500	2250	0.02031	0.02009	4,321.5	0	0.0	523.8	48.7	1,375.8	464,770.4	517.6	2,895.8	0.0	0.0
500	490	2250	0.02009	0.01989	4,011.6	0	0.0	486.3	45.2	1,421.1	468,827.2	529.9	3,436.1	0.0	0.0
490	480	2250	0.01989	0.01969	4,093.1	0	0.0	496.1	46.2	1,467.3	472,966.5	542.4	3,986.2	0.0	0.0
480	470	2250	0.01969	0.01951	3,860.9	0	0.0	468.0	43.5	1,510.8	476,870.9	553.9	4,508.2	0.0	0.0
470	460	2250	0.01951	0.01933	3,827.5	0	0.0	463.9	43.2	1,554.0	480,741.5	565.1	5,026.2	0.0	0.0
460	450	2250	0.01933	0.01916	3,680.9	0	0.0	446.2	41.5	1,595.5	484,463.9	575.8	5,526.3	0.0	0.0
450	440	2250	0.01916	0.01900	3,524.5	0	0.0	427.2	39.8	1,635.2	488,028.2	585.8	6,007.6	0.0	0.0
440	430	2250	0.01900	0.01884	3,471.5	0	0.0	420.8	39.2	1,674.4	491,538.9	595.6	6,482.4	0.0	0.0
430	420	2250	0.01884	0.01869	3,414.3	0	0.0	413.9	38.5	1,712.9	494,991.7	605.0	6,950.2	0.0	0.0
420	410	2250	0.01869	0.01855	3,353.0	0	0.0	406.4	37.8	1,750.7	498,382.5	614.2	7,410.7	0.0	0.0
410	400	2250	0.01855	0.01842	3,051.0	0	0.0	369.8	34.4	1,785.1	501,468.0	622.4	7,834.5	0.0	0.0
400	390	2250	0.01842	0.01828	3,334.3	0	0.0	404.2	37.6	1,822.7	504,839.9	631.2	8,292.7	0.0	0.0
390	380	2250	0.01828	0.01816	2,898.9	0	0.0	351.4	32.7	1,855.4	507,771.5	638.9	8,698.0	0.0	0.0
380	370	2250	0.01816	0.01804	2,937.5	0	0.0	356.1	33.1	1,888.6	510,742.0	646.5	9,108.1	0.0	0.0
370	360	2250	0.01804	0.01792	2,976.8	0	0.0	360.8	33.6	1,922.1	513,752.4	654.1	9,522.9	0.0	0.0
360	350	2250	0.01792	0.01781	2,764.0	0	0.0	335.0	31.2	1,953.3	516,547.6	661.1	9,912.0	0.0	0.0
350	350	465	0.02698	0.01961	7,243.5	0	0.0	878.0	81.7	2,035.0	523,872.9	679.2	10,790.0	0.0	0.0
350	350	465	0.01781	0.01781	0.0	0	0.0	0.0	495.8	2,530.8	632,972.3	699.0	10,790.0	0.0	0.0
350	330	465	0.01781	0.01773	2,379.4	0	0.0	288.4	26.8	2,557.7	635,378.5	703.8	11,186.4	0.0	0.0
330	320	465	0.01773	0.01763	3,204.0	0	0.0	388.4	36.1	2,593.8	638,618.6	710.1	11,628.8	0.0	0.0
320	300	465	0.01763	0.01742	6,848.1	0	0.0	830.1	77.2	2,671.1	645,543.9	723.4	12,566.9	0.0	0.0
300	280	465	0.01742	0.01724	6,002.6	0	0.0	727.6	67.7	2,738.8	651,614.2	734.8	13,402.5	0.0	0.0
280	260	465	0.01724	0.01706	6,129.2	0	0.0	743.0	69.1	2,807.9	657,812.6	746.3	14,253.4	0.0	0.0
260	240	465	0.01706	0.01690	5,557.8	0	0.0	673.7	62.7	2,870.6	663,433.1	756.5	15,035.1	0.0	0.0
240	220	465	0.01690	0.01675	5,306.9	0	0.0	643.3	59.9	2,930.4	668,799.9	766.1	15,786.4	0.0	0.0
220	200	465	0.01675	0.01661	5,039.6	0	0.0	610.9	56.8	2,987.3	673,896.3	775.0	16,505.3	0.0	0.0

FEED AND BLEED BAT (3.25WT%) VOLUME (0ppm to 446ppm) = 4,485.0 gallons (65 minutes at 69 gpm)
FEED AND BLEED RWST (1950ppm) VOLUME (0ppm to 446ppm) = 14,336.0 gallons (207 minutes at 69 gpm)
TOTAL RWST VOLUME: FEED AND BLEED PLUS MAKE UP = 30,841.3

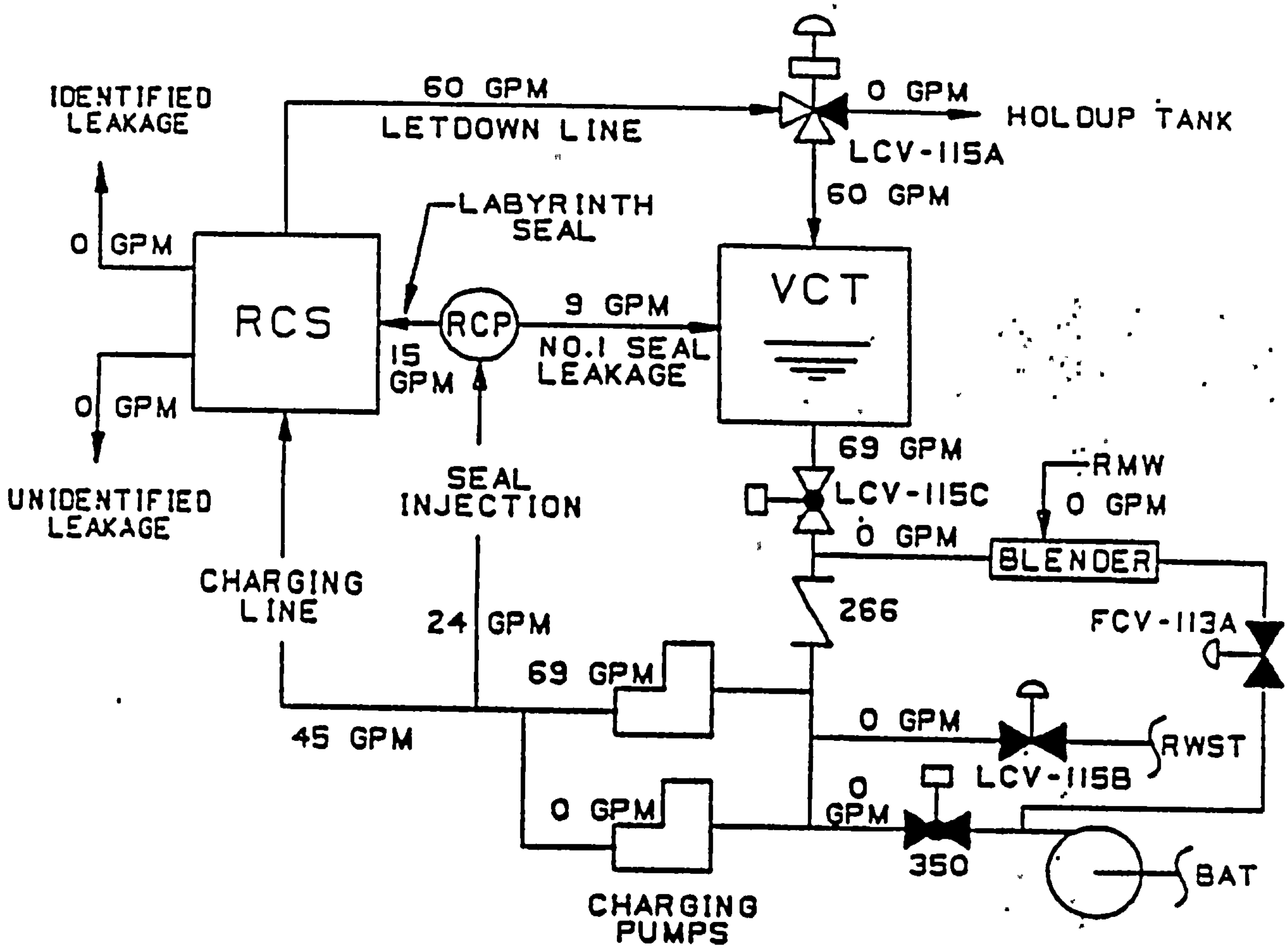
TABLE 6-12

PLANT COOLDOWN TO COLD SHUTDOWN: 11 gpm RCS LEAKAGE; BLENDED MAKEUP FOR 50 F/HR COOLDOWN; BAT AT 3.25 WT %; RHR = 775ppm; R ---------(9 gpm SEAL LEAKAGE)-------

TIME (min)	AVG.SYSTEMP. (F) Ti	Tf	PZR PRESS (psia)	SPECIFIC VOLUME (cu.ft./lbm) Vi	Vf	SHRINKAGE MASS(lbm)	BLEND RATIO	BAT VOL @ 120 F (gal)	RWST VOL @ 120 F (gal)	B/A ADDED (lbm)	TOTAL B/A (lbm)	TOTAL SYS. MASS (lbm)	FINAL CONC (ppm boron)	TOTAL RCS MAKEUP 120 F (gal)	TOTAL PURE WATER 120 F (gal)	TOTAL BAT WATER 120 F (gal)
0	547	547	2250	1.00000	1.00000	0.0	0	0.0	0.0	0.0	0.0	442,728.6	0.0	0.0	0.0	0.0
8.4	547	540	2250	0.02125	0.02106	4,097.4	0	496.7	0.0	137.6	137.6	446,963.6	53.8	572.3	0.0	572.3
12	540	530	2250	0.02106	0.02079	5,700.7	0	691.0	0.0	191.2	328.9	452,855.5	127.0	1,371.3	0.0	1,371.3
12	530	520	2250	0.02079	0.02055	5,456.0	0	661.3	0.0	182.6	511.5	458,494.2	195.1	2,140.6	0.0	2,140.6
12	520	510	2250	0.02055	0.02031	5,382.5	0	652.4	0.0	179.8	691.4	464,056.5	260.5	2,901.1	0.0	2,901.1
12	510	500	2250	0.02031	0.02009	5,199.6	0	630.3	0.0	173.4	864.7	469,429.4	322.0	3,639.3	0.0	3,639.3
12	500	490	2250	0.02009	0.01989	4,898.5	0	593.8	0.0	162.9	1,027.6	474,490.8	378.6	4,341.1	0.0	4,341.1
12	490	480	2250	0.01989	0.01969	4,989.0	0	604.7	0.0	165.6	1,193.3	479,645.4	435.0	5,053.8	0.0	5,053.8
12	480	470	2250	0.01969	0.01951	4,765.2	0	577.6	0.0	157.8	1,351.1	484,568.5	487.5	5,739.5	0.0	5,739.5
12	470	460	2250	0.01951	0.01933	4,740.3	0	574.6	0.0	156.7	1,507.8	489,465.4	538.6	6,422.0	0.0	6,422.0
12	460	450	2250	0.01933	0.01916	4,601.8	1	278.9	0.0	74.5	1,582.2	494,141.7	559.8	7,087.9	3,543.9	3,543.9
12	450	440	2250	0.01916	0.01900	4,453.2	2	179.9	0.0	46.9	1,629.1	498,641.8	571.2	7,735.6	5,157.1	2,578.5
12	440	430	2250	0.01900	0.01884	4,407.8	2	178.1	0.0	46.3	1,675.4	503,095.8	582.2	8,377.9	5,585.3	2,792.6
12	430	420	2250	0.01884	0.01869	4,358.1	2	176.1	0.0	45.7	1,721.1	507,499.6	592.9	9,014.2	6,009.5	3,004.7
12	420	410	2250	0.01869	0.01855	4,304.2	2	173.9	0.0	45.0	1,766.0	511,848.8	603.2	9,643.9	6,429.3	3,214.6
12	410	400	2250	0.01855	0.01842	4,009.0	2	162.0	0.0	41.6	1,807.6	515,899.4	612.6	10,237.9	6,825.3	3,412.6
12	400	390	2250	0.01842	0.01828	4,299.5	2	173.7	0.0	44.8	1,852.4	520,243.7	622.5	10,867.1	7,244.7	3,622.4
12	390	380	2250	0.01828	0.01816	3,870.5	2	156.4	0.0	39.9	1,892.2	524,154.1	631.2	11,444.2	7,629.5	3,814.7
12	380	370	2250	0.01816	0.01804	3,915.6	2	158.2	0.0	40.3	1,932.6	528,109.9	639.8	12,026.9	8,017.9	4,009.0
12	370	360	2250	0.01804	0.01792	3,961.5	2	160.1	0.0	40.8	1,973.3	532,112.1	648.4	12,615.0	8,410.0	4,205.0
12	360	350	2250	0.01792	0.01781	3,754.7	2	151.7	0.0	38.4	2,011.7	535,905.2	656.3	13,178.2	8,785.4	4,392.7
0	350	350	465	0.02698	0.01961	7,243.5	2	292.7	0.0	81.1	2,092.8	543,229.9	673.5	14,056.2	9,370.8	4,685.4
0	350	350	465	0.01781	0.01781	0.0	2	0.0	0.0	495.8	2,588.6	633,030.1	714.9	14,056.2	9,370.8	4,685.4
24	350	330	465	0.01781	0.01773	4,369.2	2	176.5	0.0	40.8	2,629.4	637,440.1	721.2	14,801.8	9,867.9	4,933.9
12	330	320	465	0.01773	0.01763	4,204.5	2	169.9	0.0	43.0	2,672.3	641,687.6	728.1	15,419.5	10,279.6	5,139.8
24	320	300	465	0.01763	0.01742	8,873.4	2	358.5	0.0	90.9	2,763.3	650,651.8	742.5	16,711.1	11,140.7	5,570.4
24	300	280	465	0.01742	0.01724	8,049.0	2	325.2	0.0	81.4	2,844.7	658,782.2	755.0	17,902.7	11,935.1	5,967.6
24	280	260	465	0.01724	0.01706	8,197.2	2	331.2	0.0	82.9	2,927.6	667,062.3	767.3	19,112.3	12,741.6	6,370.8
24	260	240	465	0.01706	0.01690	7,645.4	2	308.9	0.0	76.4	3,004.0	674,784.2	778.3	20,255.1	13,503.4	6,751.7
24	240	220	465	0.01690	0.01675	7,413.2	2	299.5	0.0	73.6	3,077.6	682,271.0	788.7	21,369.7	14,246.4	7,123.2
24	220	200	465	0.01675	0.01661	7,163.6	2	289.4	0.0	70.6	3,148.3	689,505.2	798.3	22,454.0	14,969.3	7,484.7

Figure 6-1 CVCS Flow Diagram

(Normal Operation - 60gpm Letdown)



7.0 TECHNICAL SPECIFICATIONS

7.1 RECOMMENDED CHANGES

1. TECHNICAL SPECIFICATION 3/4.1 - REACTIVITY CONTROL SYSTEM

Specification 3.1.1.1 - Action Statement

Substitute "16 gpm" for "4 gpm" and "3.0 wt.% (5245 ppm) boron" for "20,000 ppm boron."

Evaluation: The required flow rate is increased by a factor of four to conservatively accommodate the decrease in the boric acid tank minimum concentration by a factor of approximately four (20,000 ppm, or 11.4 weight percent (wt.%), down to 3.0 weight percent). This adjustment ensures equal boration capability for shutdown margin recovery. The 16 gpm will be available via the emergency boration path or the manual boration path following the modification of FCV-113A. The required boron concentration is adjusted to reflect the minimum concentration of 3.0 weight percent to be available from the boric acid tank.

Specification 3.1.1.2 - Action Statement

Substitute "16 gpm" for "4 gpm" and "3.0 wt.% (5245 ppm)" for "20,000 ppm."

Evaluation: Same as Specification 3.1.1.1.

Specification 4.1.2.1 - Surveillance Requirement

Change Surveillance Requirement 4.1.2.1.a :

"... by verifying that the temperature of the heat traced portion of the flow path is greater than or equal to 145°F when a flow path from the boric acid tank is used"

to read,

"... by verifying that the temperature of the rooms containing flow path components is greater than or equal to 55°F when a flow path from the boric acid tanks is used"

Evaluation: The boration system flow path surveillance requirement is modified to reflect the reduced boric acid solubility temperature. The maximum boric acid concentration to be specified is 3.5 weight percent with a solubility temperature limit of 50°F. A margin of 5°F is added to this to make 55°F the critical temperature for boric acid solubility. The 7 day surveillance interval is justified because the temperature of the rooms containing boration system flow paths and components will be provided with an alarm in the control room. The actions required in the event that temperature decreases below the critical temperature are identical to the current specification (i.e., if temperature is less than 55°F, the flow path in question becomes inoperable and the appropriate actions carried out).

Specification 3.1.2.2 - Limiting Condition for Operation

Add the following words to the footnote:

"from the boric acid transfer pump discharge to the charging pump suction."

Evaluation: The footnote regarding flow path separation is modified to reflect the recommended boric acid tank lineup where all three tanks are interconnected via the transfer pump suction lines. This lineup maximizes the available volume from the boric acid tanks with no valve manipulations required to access the entire inventory. Boric acid tank inventory control in accordance with Technical Specification 3.1.2.5

will ensure that the tanks shared between the two units will have the total minimum required volume necessary to support both units. Maintaining the separation criteria for the remaining flow path from the boric acid transfer pumps to the charging pumps assures the appropriate level of active component redundancy for each unit.

Specification 4.1.2.2 - Surveillance Requirement

Change Surveillance Requirements 4.1.2.2.a :

"... by verifying that the temperature of the heat traced portion of the flow path from the boric acid tanks is greater than or equal to 145°F when it is a required water source;"

to read,

"... by verifying that the temperature of the rooms containing flow path components are greater than or equal to 55°F when a flow path from the boric acid tank is used;"

Substitute "16 gpm" for "4 gpm" in Surveillance Requirement 4.1.2.2.c

Evaluation: Same as Specification 4.1.2.1. This change also makes Surveillance Requirement 4.1.2.2.c consistent with Limiting Conditions for Operation 3.1.1.1 and 3.1.1.2.

Specification 3.1.2.4 - Limiting Condition for Operation

For the Boric Acid Storage System (3.1.2.4.a) change:

1. "A minimum indicated borated water volume of 500 gallons,"

to read,

1. "A minimum indicated borated water volume of 2,900 gallons per unit,"

change:

2. "A boron concentration between 20,000 ppm and 22,500 ppm, and"

to read,

2. "A boron concentration between 3.0 wt.% (5245 ppm) and 3.5 wt.% (6119 ppm), and"

change:

3. "A minimum solution temperature of 145°F."

to read,

3. "A minimum boric acid tanks room temperature of 55°F."

Evaluation: The boric acid tank operability requirements are revised to reflect the analysis of Reference 1. A minimum volume of 2,900 gallons per unit is specified, and includes an instrument accuracy of 2.5% of full range for the tank level instrument. Unusable volume is not accounted for here since the tank level instrumentation will have its indicated range calibrated to account for unusable volumes at the bottom of the tank. The concentration is limited to the recommended band of 3.0 weight percent to 3.5 weight percent. The temperature limit corresponds to the solubility limit for 3.5 weight percent boric acid (50°F) with 5°F added margin.

The minimum refueling water storage tank volume is not changed since this is known to be conservative from the analysis of Reference 1.

Specification 4.1.2.4 - Surveillance Requirement

Change Surveillance Requirement 4.1.2.4.a.3) :

"Verifying the boric acid storage tank solution temperature when it is the source of borated water."

to read,

"Verifying that the temperature of the boric acid tanks room is greater than or equal to 55°F, when it is the source of borated water."

Evaluation: The borated water source surveillance requirement is modified to reflect the reduced boric acid solubility temperature. The maximum boric acid concentration to be specified is 3.5 weight percent with a solubility temperature limit of 50°F. A margin of 5°F is added to this to make 55°F the critical temperature for boric acid solubility. The 7 day surveillance interval is justified because the temperature of the room containing the boric acid tanks will be provided with an alarm in the control room. Action statement requirements for temperatures below 55°F remain identical to the current required actions for temperatures below the current limit of 145°F. In this respect, the required actions remain as limiting as the current Technical Specifications.

Specification 3.1.2.5 - Limiting Condition for Operation

For the Boric Acid Storage System (3.1.2.5.a) change:

1. "A minimum indicated borated water volume of 3080 gallons,"

to read,

1. "A minimum indicated borated water volume in accordance with Figure 3.1.2.5,"

change:

2. "A boron concentration between 20,000 ppm and 22,500 ppm, and"

to read,

2. "A boron concentration in accordance with Figure 3.1.2.5, and"

change:

3. "A minimum solution temperature of 145°F."

to read,

3. "A minimum boric acid tanks room temperature of 55°F."

Action Statement

Add an asterisk (*) to ACTION 'a' to reference a note at the bottom of the page.

Add note at the bottom of the page:

"* If this action applies to both units simultaneously, be in at least HOT STANDBY within the next 12 hours."

Add the following:

c. With the boric acid tank inventory concentration greater than 3.5 wt.%, verify that the boric acid solution temperature for boration sources and flow paths is greater than the solubility limit for the concentration.

Add Figure 3.1.2.5 as provided

Evaluation: The boric acid tank operability requirements regarding volume and concentration will consist of a concentration vs. volume curve. Note that the volumes represent the combined volumes in all three tanks with allowance for the minimum required volume for two operating units (Modes 1-4) and for one operating and one shutdown unit (Mode 5 or 6). The minimum temperature for boric acid tank operability coincides with the solubility limit for 3.5 weight percent boric acid (50°F) plus 5°F margin. ACTION times allow for an orderly sequential shutdown of both units when the inoperability of a component(s) affects both units with equal severity. When a single unit is affected, the time to be in HOT STANDBY is 6 hours. When an ACTION statement requires a dual unit shutdown, the time to be in HOT STANDBY is 12 hours.

<u>Specification 4.1.2.5 - Surveillance Requirements</u>

Change Surveillance Requirement 4.1.2.5.a.3) :

"Verifying the Boric Acid Storage System solution temperature when it is the source of borated water."

to read,

"Verifying that the temperature of the boric acid tanks room is greater than or equal to 55°F, when it is the source of borated water."

Evaluation: The borated water source surveillance requirement is modified to reflect the reduced boric acid solubility temperature. The maximum boric acid concentration to be specified is 3.5 weight percent with a solubility temperature limit of 50°F. A margin of 5°F is added to this to make 55°F the critical temperature for boric acid solubility. The 7 day surveillance interval is justified because the temperature of the room containing the boric acid tanks will be provided with an alarm in the control room. Action statement requirements for temperatures below 55°F remain identical to the current required actions for temperatures below the current limit of 145°F. In this respect, the required actions remain as limiting as the current technical specifications.

Specification 3.1.2.6 - Limiting Condition for Operation

Add note at the bottom :

"This is no longer applicable once boric acid tanks inventory and boric acid source and flow path inventories have been diluted to less than or equal to 3.5 weight percent (wt.%)."

Evaluation: This specification is retained to allow the concentration transition (from 12 weight percent boric acid to 3.5 weight percent boric acid) of the boric acid tank inventory and boric acid source and flow path inventories. The boric acid tank operability requirements regarding volume and concentration will remain in accordance with specification 3.1.2.5. Action statement requirements regarding temperature and heat tracing remain identical to the current Technical Specifications. As identified in reference 1, a reduction in the boric acid concentration corresponds to a reduction in the solubility limit. FPL remains conservative by maintaining the boric acid storage tank and flow path temperatures greater than the appropriate solubility limit.

2. TECHNICAL SPECIFICATION 3/4.9 - REFUELING OPERATIONS

Specification 3.9.1 - Action Statement

Substitute "16 gpm" for "4 gpm" and "3.0 wt.% (5245 ppm)" for "20,000 ppm"

Evaluation: Same evaluation as provided for in Specification 3.1.1.1.

3. TECHNICAL SPECIFICATION 3/4.10 - SPECIAL TEST EXCEPTIONS

Specification 3.10.1 - Action Statement

Substitute "16 gpm" for "4 gpm" and "3.0 wt.% (5245 ppm)" for "20,000 ppm"

Evaluation: Same evaluation as provided for in Specification 3.1.1.1.

4. TECHNICAL SPECIFICATIONS BASES 3/4.1 - REACTIVITY CONTROL SYSTEMS

Specification Bases 3/4.1.1 - Boration Control

Substitute "16 gpm" for "4 gpm" and "3.0 wt.% (5245 ppm)" for "20,000 ppm"

Evaluation: The increase in the required flow rate by a factor of four (4 gpm to 16 gpm) conservatively accommodates the decrease in the minimum boric acid tank concentration by a factor of approximately four (20,000 ppm, or 11.4 weight percent, down to 3.0 weight percent). This adjustment assures equal minimum boration capability for shutdown margin recovery as compared to the current capability at 11.4 weight percent.

The capability to restore the shutdown margin with one OPERABLE charging pump is consistent with the current Technical Specifications.

Specification Bases 3/4.1.2 - Boration Systems

o Delete the wording:

"(5) associated Heat Tracing Systems, and (6) an emergency power supply from OPERABLE diesel generators."

Evaluation: Wording revised to reflect the basis of this program and the Emergency Power System (EPS) Enhancement Project submittal.

o Insert the wording:

"ACTION times allow for an orderly sequential shutdown of both units when the inoperability of a component(s) affects both units with equal severity. When a single unit is affected, the time to be in HOT STANDBY is 6 hours. When an ACTION statement requires a dual unit shutdown, the time to be in HOT STANDBY is 12 hours."

Evaluation: Wording inserted to reflect the basis of the previous EPS Enhancement Project submittal.

o Delete the wording:

"with independent power supplies", and

"However, the ACTION Statement restrictions allow 7 days to restore an inoperable pump provided that two charging

pumps are available. This restriction is acceptable based on the low probability of losing the power source common to both charging pumps."

- o Substitute the words "Each bus" for "The bus" and the words "a startup transformer." for "the startup transformer."

  Evaluation: Wording revised to reflect the basis of the previous EPS Enhancement Project submittal.

- o Delete the wording:

  "... BOL from full power equilibrium xenon conditions and require 3080 gallons of 20,000 PPM borated water from the boric acid storage tanks or 320,000 gallons of 1950 PPM borated water from the refueling water storage tank (RWST)."

  and replace with the wording:

  "... EOL peak xenon conditions without letdown such that boration occurs only during the makeup provided for coolant contraction. This requirement can be met for a range of boric acid concentrations in the boric acid tank and the refueling water storage tank. The range of boric acid tank requirement is defined by Technical Specification 3.1.2.5."

- o Substitute "2,900 gallons of at least 3.0 wt.% (5245 ppm) borated water per unit" for "500 gallons of 20,000 ppm borated water"

- Substitute the wording "... requirement of 55°F and corresponding surveillance intervals..." for the wording "... of the redundant heat tracing channels..."

- Insert the wording - "The temperature limit of 55°F includes a 5°F margin over the 50°F solubility limit of 3.5 wt.% boric acid. Portable instrumentation may be used to measure the temperature of the rooms containing boric acid sources and flow paths."

- Add the footnote - "This is no longer applicable once boric acid tanks inventory and boric acid source and flow path inventories have been diluted to less than or equal to 3.5 weight percent."

Evaluation: The basis for the boric acid tank minimum volume required for modes 1 through 4 is modified to reflect the analyses of Reference 1. Specifically, the worst case expected plant boration requirement occurs at EOL peak xenon conditions without letdown such that boration occurs only during the makeup provided for coolant contraction. This requirement can be met for a range of boric acid concentrations in the boric acid tank and the refueling water storage tank. This range is bounded by Figure 3.1.2.5.

Below 200°F, the boric acid tank minimum volume requirement is based on the minimum volume of 3.0 weight percent boric acid required to maintain a 1.0% $\Delta k/k$ shutdown margin during a cooldown from 200°F to 140°F. (The analysis of Reference 1 conservatively assumed 135°F as the cooldown endpoint.) The refueling water storage tank minimum volume with RCS temperature less than 200°F remains unchanged since it is conservative with respect to the cooldown analysis. Reference to

heat tracing in this section is deleted since it is anticipated that all heat tracing will be removed. The basis of the 55°F temperature limit is established as the 50°F solubility limit for 3.5 weight percent boric acid plus 5°F margin. Continuous surveillance of the temperature of the rooms containing boration system flow paths and components is provided and verified by an alarm in the control room. A footnote is added to the heat tracing discussion. This identifies the heat tracing as not being applicable once boric acid tanks inventory and source and flow path inventories have been diluted to less than 3.5 weight percent.

5. TECHNICAL SPECIFICATION BASES 3/4.9 - REFUELING OPERATIONS

Specification 3/4.9.1 - Boron Concentration Bases

Substitute the wording "16 gpm of 3.0 wt.% (5245 ppm)" for "4 gpm of 20,000 ppm".

Evaluation: Same as Specification Bases 3/4.1.1

7.2 NO SIGNIFICANT HAZARDS EVALUATION

The proposed changes have been deemed not to involve a significant hazards consideration focusing on the three standards set forth in 10 CFR 50.92(c) as quoted below:

The Commission may make a final determination, pursuant to the procedures in 50.91, that a proposed amendment to an operating license for a facility licensed under 50.21(b) or 50.22 or for a testing facility involves no significant hazards considerations, 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 a new or different kind of accident from any accident previously evaluated; or

3. Involve a significant reduction in a margin of safety.

It has been determined that the activities associated with this amendment request do not meet any of the significant hazards consideration standards of 10 CFR 50.92(c) and, accordingly, a no significant hazards consideration finding is justified. A discussion of each of the above three significant hazards consideration standards is provided below.

<u>Introduction</u>

The current Turkey Point CVCS design employs three boric acid tanks, containing 12 weight percent (wt.%) boric acid, for the two units. One tank is dedicated to each unit and the third is available as a backup for either dedicated tank. Each dedicated tank has adequate volume to store the cold shutdown boric acid volume required for one unit. The boric acid tanks provide a source of concentrated boric acid to the reactor to offset slow reactivity changes caused by normal changes in power level, or to establish hot shutdown, cold shutdown or refueling shutdown conditions. The safety function of the boric acid tanks is to maintain adequate boric acid volume and concentration to borate the RCS to a cold shutdown concentration at any time during the core cycle, with a shutdown margin consistent with the Technical Specifications.

A reduction in the boric acid concentration to 3.0 to 3.5 weight percent provides the opportunity to delete the system heat tracing presently required for 12 weight percent boric acid. The basis for deletion is the corresponding reduction in the solubility

temperature from 135°F for 12 weight percent boric acid to 50°F for 3.5 weight percent boric acid. At this lower solubility temperature, the normally occurring ambient room temperatures are adequate to maintain fluid temperatures above the solubility limit rather than relying on tank heaters or heat tracing.

This proposed amendment improves the availability of the boration system and, therefore, improves plant safety. It also reduces routine maintenance requirements by eliminating the need for boric acid tank internal heaters and boration flow path heat tracing channels. Furthermore, potential problems associated with boric acid crystalization, flow path blockage, and component corrosion are significantly reduced.

Evaluation

The following evaluation demonstrates that the proposed amendment involves no significant hazards considerations.

1. Involve a significant increase in the probability or consequences of an accident previously evaluated.

   The operation of the facility in accordance with the proposed changes does not involve a significant increase in the probability or consequences of any accident previously evaluated. Deleting the requirement for a heat tracing circuit by reducing the boron concentration in the boric acid tank is accounted for by increasing the volume of boric acid solution that must be contained in the tanks and also by crediting borated water from the refueling water storage tank. Since the components (or their function) necessary to perform a safe shutdown have not been changed or modified, this change does not significantly increase the probability or consequences of any accident previously evaluated. In

addition, technical specification controls on the boric acid tank temperature and boron concentration ensure that the lack of heat tracing does not result in precipitation of the boron.

Credit is not taken for boron addition to the RCS from the boric acid tanks for the purpose of reactivity control in the accidents analyzed in Chapter 14 of the Final Safety Analysis Report. Response to such events as steam line break, overcooling, boron dilution, etc. will not be affected by a reduction in the boric acid tank concentration.

The action statements associated with Technical Specification 3.1.1.1 currently require that boration be commenced at greater than 4 gallons per minute using a solution of at least 20,000 ppm boron in the event that shutdown margin is lost. This Specification has been changed to 16 gpm at 3.0 weight percent (5245 ppm) to accomplish the same minimum boration rate. A plant modification to flow control valve FCV-113A will increase blended makeup capacity and assure this system's capability to deliver this flow rate. Boration via the emergency boration flow path already exits at a rate of 60 gpm (nominal).

2. <u>Create the possibility of a new or different kind of accident from any accident previously evaluated.</u>

The operation of the facility in accordance with the proposed changes does not create the possibility of a new or different kind of accident from any accident previously evaluated. This is because such operation will not increase the likelihood of boric acid source or flow path failure nor will such failures initiate any new or different kind of accident from any previously evaluated. The boron dilution analysis performed for Turkey Point Units 3 and 4 is not impacted by a reduction from a nominal 12 weight percent boric acid to 3.0 to 3.5

weight percent. The boron concentration in the boric acid tanks is greater than any anticipated RCS boron concentration, thus, an inadvertent RCS boron dilution due to the addition of boric acid from the boric acid tanks is precluded.

The reason for requiring a heat tracing circuit was to ensure that the dissolved boric acid remained in solution and, hence, available for injection into the RCS to adjust core reactivity throughout core life. By lowering the boron concentration to a maximum of 3.5 weight percent, chemical analyses have shown there is no possibility of the boron precipitating out of solution as long as the temperature of the boric acid solution remains above 50°F. Normal ambient temperatures in the vicinity of these components remain above this temperature. Therefore, there is no longer a need for heat tracing. Since the boron will be in solution when the boric acid tank flow paths are credited for reactivity control during a cooldown to cold shutdown scenario, heat tracing is no longer required to maintain the boric acid storage system operable. In conclusion, this change does not create the possibility of a new or different kind of accident from those previously evaluated.

3. <u>Involve a significant reduction in a margin of safety.</u>

The operation of the facility in accordance with the proposed Technical Specification changes does not involve a significant reduction in the margin of safety. The intent of these Technical Specifications is to ensure that there are two independent flow paths from the two independent borated water sources (boric acid tanks and refueling water storage tank) to the RCS to allow control of core reactivity throughout core life. This requires that sufficient quantities of boron be stored in the tanks, and that this borated water can be

delivered to the RCS when required. Reducing the maximum boric acid concentration to less than or equal to 3.5 weight percent has been compensated for by increasing the required volumes of borated water. Elimination of the separation criteria for the flow paths for the two units between the three shared boric acid tanks and the boric acid transfer pumps has been compensated for by technical specification volume control that accounts for the needs of both units.

In addition to the boric acid transfer pumps delivering the boric acid tank contents to the charging pumps, the charging pumps also can take suction from the refueling water storage tank. Since these independent boration capabilities control the RCS boron inventory, the original licensing basis of the plant does not require the boric acid tanks to meet single failure criteria.

Additionally, reducing the maximum boron concentration allows a deletion of the requirement to heat trace the boric acid storage system since chemical analyses have shown that a 3.5 weight percent solution of boric acid will remain in solution at temperatures above 50°F. An operability requirement of 55°F minimum temperature for the rooms containing boration sources and flow paths includes a 5°F margin above the solubility limit of 50°F. Technical Specification controls on the boric acid tank and boration flow path room temperatures and boron concentration ensure that a lack of heat tracing does not result in precipitation of the boron.

In conclusion, the reduction of boric acid concentration and the deletion of heat tracing in the Boric Acid Makeup System does not cause a significant reduction in the margin of safety for this plant.

Summary

In summation, it has been shown that the proposed modifications and proposed Technical Specifications do not:

1. Involve a significant increase in the probability or consequences of an accident previously evaluated; or

2. Create the possibility of a new or different kind of accident from any accident previously evaluated; or

3. Involve a significant reduction in a margin of safety.

Therefore, it is determined that the proposed amendment involves no significant hazards considerations.

8.0 SAFETY EVALUATION

Operation with reduced boric acid concentration in a manner similar to that analyzed in Sections 5 and 6 will involve a change in the manner in which the facility is operated as compared to the current descriptions in the updated Final Safety Analysis Report (FSAR). Reference 10.3 was reviewed in detail to identify the necessary changes to reflect full implementation of reduced boric acid concentration. Although, changes are required in several locations, the changes consist of the following basic elements:

1. Revision of boric acid tank concentration range (3.0 to 3.5 weight percent);

2. Revision of boric acid tank minimum volume design basis to include:

    a. Boration completed in conjunction with the makeup for coolant contraction during cooldown,

    b. Credit given to refueling water storage tank volume;

3. Revision of alternate shutdown capability (boration rate);

4. Deletion of heat tracing and boric acid tank heaters; and,

5. Revision of boric acid evaporator bottoms concentration.

Specific descriptions of each of these changes is provided in Section 8.1. This will be followed by a No Unreviewed Safety Question evaluation in Section 8.2.

8.1 RECOMMENDED FSAR CHANGES

Recommended markups of the specific pages to be changed are provided in Appendix 7. The following is a page by page discussion of the recommended changes.

Page 1.3-13

The design basis of the minimum volume maintained in the boric acid tank is revised to reflect the analyses of Section 5.0. Specifically, the minimum volume maintained in this tank is that volume necessary to increase the RCS boron concentration during the course of a cooldown, through makeup for coolant contraction alone, such that subsequent use of the refueling water storage tank for contraction makeup will maintain adequate shutdown margin throughout the remaining cooldown.

Additionally, the alternate shutdown capability is revised to reflect the analysis of Section 6.6.3. Less than forty minutes of feed and bleed would be required to raise the RCS boron concentration from 1100 ppm to 1295 ppm. Since both sixteen minute periods listed in the FSAR are feed and bleeds per Reference 10.1, forty minutes should be required to accomplish the second boration requirement to compensate for xenon decay.

Outside power is corrected to Offsite power and reference to hot shutdown is corrected to hot standby.

Page 3.1.2-6

Same as page 1.3-13.

Page 8.2-18

Reference to the boric acid tank heaters is deleted since these heaters will be electrically deenergized.

Page 9.2-3

Same as page 1.3-13.

Page 9.2-6

The boric acid tank concentration is revised to 3.0 to 3.5 weight percent and all reference to heat tracing is deleted. It is anticipated that all heat tracing circuits will be disconnected since the ambient temperatures within the auxiliary building will maintain boric acid tank and boration flow path temperatures above the solubility limit of 50°F.

Page 9.2-6a

Same as page 9.2-6.

Page 9.2-7

Same as page 9.2-6.

Page 9.2-8

Operation of the boric acid evaporator must be revised such that the boric acid that remains within the evaporator as the bottoms of the distillation process does not concentrate above the boric acid tank control band of 3.0 to 3.5 weight percent.

Page 9.2-11

The discussion of boration without letdown is modified to incorporate the analyses of Section 5.0 and Section 6.6.3. Specifically, since the boric acid tank concentration is reduced by a factor of four, the volume required to be charged using the available volume in the pressurizer has increased by a factor of four. Achieving boration to the cold shutdown concentration through this method, therefore, is not possible with reduced concentrations. Per the analysis of Section 6.6.3, however, boration to hot zero power is achievable using the available volume in the pressurizer.

Boration to cold shutdown is still achievable without letdown using the methodology outlined in Section 5.0. Specifically, if boric acid is injected to maintain constant pressurizer level during a cooldown to cold shutdown (using a boric acid tank and the refueling water storage tank to make up for coolant contraction) sufficient boric acid will be added to the RCS to maintain the required shutdown margins.

Page 9.2-23

The design basis of the boric acid tank minimum volume is modified per the discussion for page 1.3-13 changes. Batching tank capabilities are revised to reflect the impact of reduced concentrations.

Page 9.2-24

The batching tank steam jacket design basis is modified to maintain the boric acid batching solutions above the solubility limit without specific reference to temperature limits. The addition of the per unit qualifier to the boric acid transfer pump description reflects the actual redundancy of the pumps.

Page 9.2-27

Same as page 9.2-8.

Page 9.2-29

Reference to boration system heat tracing is deleted since it is anticipated that all heat racing will be removed. This is achievable since the normally expected ambient temperatures within the auxiliary building will maintain system temperatures above the solubility limit of 50°F.

Page 9.2-30

Same as page 9.2-29.

Page 9.2-31

Same as page 9.2-29.

Table 9.2-2

The maximum rate of boration is revised based on the analysis of Section 6.2. A feed and bleed of 60 gpm will establish a boration rate of 5.4 ppm per minute starting from the 1800 ppm initial concentration listed in the table. Should the available volume in the pressurizer be utilized in accordance with the analysis of Section 6.6.3, a boration of 195 ppm in 29.4 minutes (6.6 ppm per minute) is achievable starting from the assumed maximum BOC concentration of 1100 ppm. The equivalent cooldown rate was divided by the same factor of reduction shown for the maximum boration rate.

The boric acid tank minimum volume is revised per the analyses of Section 5.0 as discussed for changes to page 9.2-3. A curve similar to the recommended technical specification is suggested for inclusion in the FSAR.

Table 9.2-3

The boric acid tank is being modified to maximize the usable volume. This table should be updated once the maximum available volume is identified.

Additionally, the refueling water storage tank is added to the list of tanks available to the CVCS. This reflects the possible use of this tank for contraction makeup during the design basis cooldown analyzed in Section 5.0.

8.2 NO UNREVIEWED SAFETY QUESTIONS DETERMINATION

Introduction

The current Turkey Point CVCS design employs three boric acid tanks containing 12 weight percent boric acid shared between the two units. One tank is currently dedicated to each unit and the third is currently available as a backup for either dedicated tank. Each dedicated tank has adequate volume to store the cold shutdown boric acid volume required for one unit.

The boric acid tanks provide a source of concentrated boric acid to the reactor to offset slow reactivity changes caused by normal changes in power level, or to establish hot shutdown, cold shutdown or refueling shutdown conditions. The safety function of the boric acid tanks is to maintain adequate boric acid volume and concentration to borate the RCS to a cold shutdown concentration at any time during the core cycle, with a shutdown margin consistent with the technical specifications.

The high boron solubility temperature required by 12 weight percent boric acid (135°F minimum) is maintained by internal tank heaters and flow path heat tracing. The need to perform maintenance on the heaters and heat tracing affects the availability of the boric acid tanks. Therefore, the capability to perform maintenance on the boric acid tank without taking the units off-line was considered necessary for the present CVCS design. This capability is currently accomplished by the backup tank. The third boric acid tank, as a backup tank, permits either dedicated tank to be taken out-of-service for maintenance while both units remain on-line.

A reduction in the boric acid concentration to 3.0 to 3.5 weight percent provides the opportunity to delete system heat tracing, presently required for 12 weight percent boric acid. The basis for deletion is the corresponding reduction in the solubility

temperature from 135°F for 12 weight percent boric acid to 50°F for 3.5 weight percent boric acid. At this lower concentration, the normally occurring ambient room temperatures are adequate to maintain fluid temperatures above the solubility limit without using tank heaters or heat tracing.

The proposed modification would improve plant availability and reduces maintenance requirements by eliminating the demand of the boric acid tank internal heaters and boration flow path heat tracing channels.

Evaluation

An evaluation of the Turkey Point CVCS boration capabilities was completed in Sections 5.0 and 6.0 of this report. Specifically, the analysis of Section 5.0 justified a reduction in the concentration of boric acid maintained in the boric acid tanks from 12 weight percent down to a range of 3.0 to 3.5 weight percent. This was accomplished by demonstrating that the required shutdown margin could be maintained during a cooldown if boration was accomplished in conjunction with the makeup for coolant contraction. This analysis was completed with the following significant changes from the current manner in which a cooldown to cold shutdown is accomplished:

1. Basis: Cooldown transient initiated from peak xenon concentration (8 hours) without the use of letdown;

2. Means: Boration accomplished only through the makeup provided for coolant contraction; and,

3. Sources: Credit given to the availability of refueling water storage tank volume to supplement the boron addition of the boric acid tanks.

4. Configuration: Tank lineup consisting of all three tanks lined up to the common suction header for the boric acid transfer pumps.

The acceptability of these considerations from the perspective of plant safety is reviewed in the following safety evaluation. The considerations discussed above, in conjunction with the reduced boric acid tank inventory concentrations, have been found not to raise an unreviewed safety question as documented in the following.

As defined in 10CFR50.59, an unreviewed safety question exists: (i) if the probability of occurrence or the consequences of an accident or malfunction of equipment important to safety previously evaluated in the Updated Final Safety Analysis Report (FSAR) may be increased; or (ii) if a possibility of an accident or malfunction of a different type than any previously evaluated in the FSAR may be created; or (iii) if the margin of safety as defined in the basis of any Technical Specification is reduced.

In accordance with 10CFR50.59, the following evaluation serves to determine whether this modification constitutes an unreviewed safety question:

1. <u>Does the proposed change increase the probability of occurrence of an accident previously evaluated in the FSAR?</u>

   The probability of occurrence of an accident previously evaluated in the FSAR will not increase because this modification does not affect any equipment whose malfunction is postulated in the FSAR to initiate an accident. Specifically, maintenance of shutdown margin in accordance with technical specification limits during plant cooldowns assures the acceptability of reactivity excursions analyzed in the FSAR. Borating the plant through the makeup for coolant contraction during a plant cooldown has been shown to maintain RCS boron

concentration well above that required to maintain adequate shutdown margin.

The boron dilution analysis performed for Turkey Point Units 3 and 4 is not impacted by a reduction in boric acid concentration from a nominal 12 weight percent down to 3.0 to 3.5 weight percent. The boron concentration in the boric acid tanks is greater than any anticipated RCS boron concentration and thus, an inadvertent RCS boron dilution due to the addition of boric acid from the boric acid tanks is precluded.

Therefore, the probability of an accident previously evaluated in the FSAR would not be increased.

2. <u>Does the proposed change increase the consequences of an accident previously evaluated in the FSAR?</u>

The consequences of an accident previously evaluated in the FSAR will not increase because the equipment affected by these modifications is not credited for operation during any accidents analyzed in the FSAR. System operation or malfunction will not impact the consequences of any of these analyses nor will it affect any other equipment whose malfunction could adversely affect any safety related structures, systems, or components. With the proposed modification to FCV-113A, an equivalent boration capability has been retained such that response to any event requiring emergency boration is not adversely impacted.

Therefore, the consequences of an accident previously evaluated in the FSAR would not be increased.

3. <u>Does the proposed change increase the probability of an occurrence of a malfunction of equipment important to safety previously evaluated in the FSAR?</u>

The proposed reduction in boric acid concentration for Turkey Point Units 3 and 4, will not adversely impact the structural integrity or performance capability of the boric acid tanks, heaters, pumps, and associated piping, valves and instrumentation. A reduction in the boric acid concentration to 3.0 to 3.5 weight percent provides the opportunity to delete system heat tracing, and subsequently, provides the potential to reduce maintenance requirements. In addition, since the corrosive property of boric acid is accelerated at higher concentrations and temperatures, nominal 3.25 weight percent boric acid actually decreases the potential for corrosion of equipment, valves and piping surfaces.

Thus, the probability of a malfunction of equipment important to safety previously evaluated in the FSAR would not be increased.

4. <u>Does the proposed change increase the consequences of a malfunction of equipment important to safety previously evaluated in the FSAR?</u>

The consequences of a malfunction of equipment important to safety are not increased by this modification from that previously evaluated in the FSAR. This is because the operation of the equipment affected by this modification is not credited in any of the equipment malfunctions analyzed in the safety analysis report. The consequences of these events, therefore, remain unchanged.

Therefore, the boric acid tanks continue to provide a source of concentrated boric acid to the reactor for offsetting slow

reactivity changes caused by normal changes in power level, or to establish hot shutdown, cold shutdown or refueling shutdown conditions, and the consequences of a malfunction of equipment important to safety previously evaluated in the FSAR would not be increased.

5. <u>Does the proposed change create the possibility of an accident of a different type than any previously evaluated in the FSAR?</u>

   While this approach modifies the system configuration (interconnection and sharing of all three tanks) and the design basis of the boration sources, it does not introduce failure modes of a different type than any previously analyzed in the FSAR. Specifically, the likelihood of a boric acid tank, transfer pump, flow path or charging pump failure is not increased. In addition, none of these failures initiates a new and different kind of accident from any previously evaluated.

   Therefore, there is no possibility that an accident may be created that is different from any already evaluated in the FSAR.

6. <u>Does the proposed change create the possibility of a malfunction of equipment important to safety of a different type than any previously evaluated in the FSAR?</u>

   While this approach modifies the system configuration (interconnection and sharing of three tanks) and the design basis of the boration sources, it does not introduce failure modes of a different type than any previously analyzed in the FSAR.

   A reduction from nominal 12 weight percent boric acid to 3.0 to 3.5 weight percent boric acid concentration will not adversely impact the structural integrity or performance capability of

the boric acid tanks, heaters, pumps, associated piping, valves, instrumentation, or related equipment. A reduced boric acid concentration provides the opportunity to delete system heat tracing. Elimination of the technical specification requirement for heat tracing will eliminate the time spent in action statements due to inoperability of the heat tracing channels.

In addition, a reduction in boric acid concentration reduces the potential for precipitation of boric acid crystals. Elimination or reduction of precipitation will reduce maintenance requirements on equipment susceptible to boron precipitation.

Therefore, the possibility of a malfunction of equipment important to safety different than any already evaluated in the FSAR will not be created.

7. <u>Does the proposed change reduce the margin of safety as defined in the basis for any Technical Specifications?</u>

The design basis of the boration subsystem of the CVCS is to provide a sufficient volume of boric acid at a concentration that will maintain shutdown margin during a design basis cooldown. While the design basis cooldown has been modified with regard to boration methodology, the design basis, function or operating logic of any safety related equipment has not been changed. Additionally, this change does not adversely affect any other safety related structures, systems and components. Therefore, this modification does not reduce the margin of safety as defined in the bases for the Technical Specifications. The technical specifications of particular interest include: 3.4.1.1, Boration Control; 3/4.1.2, Boration systems; 3/4.9.1, Boron Concentration (Refueling); and 3/4.10.1 Shutdown margin (Special Test Exceptions). Changes to these

Specifications have been recommended in Section 7.0 and are required to implement the analysis results of Section 5.0.

Complete implementation of the boric acid concentration reduction will entail some plant modification. Specifically, the proposed flow control valve modification increases its flow capacity so that the boration rate achievable through this valve for the normal blended or manual boration flowpath at least matches the current boration rate achievable with higher boric acid concentrations.

Removal of heat tracing does not lower any margins of safety for boration source and flow path requirements because the concentration of boric acid has been decreased sufficiently to allow Auxiliary Building ambient temperatures to maintain boron solubility. The 5°F margin on top of the 50°F solubility limit temperature for the maximum allowable boric acid concentration assures that ambient temperatures will maintain source and flow path operability with the same margin of safety as the installed heat tracing used for 12 weight percent boric acid.

In addition to the boric acid transfer pumps delivering the boric acid tank contents to the charging pumps, the charging pumps also can take suction from the refueling water storage tank. Due to these redundant sources of boration capability provided by the Turkey Point CVCS to control the RCS boron inventory, the original licensing basis of the plant does not require the boric acid tanks to meet single failure criteria. Sharing the three boric acid tanks, therefore, is acceptable with appropriate technical specification controls over the minimum available volume to account for the needs of both units.

Plant Restrictions

None.

Conclusions

This modification has been reviewed against the requirements of 10CFR50.59 and has been found not to constitute an unreviewed safety question.

9.0 OPERATING PROCEDURE GUIDELINES

Section 5.0 provides technical justification for reduction of boric acid tank concentrations and minimization of required volumes. These analyses were based on a worst case cooldown scenario where letdown was not available. Hence, boration to cold shutdown limits had to occur in conjunction with the cooldown evolution (i.e., through makeup for coolant contraction).

Normal cooldowns, however, do not have to be conducted in this manner. FPL may opt to minimize the impact on operating procedures and continue the current practice of borating to the cold shutdown limit through a feed and bleed process (prior to initiating cooldown). Then a blended makeup will be provided during the cooldown process to maintain the boron concentration. This process will require greater volumes from the boric acid tank(s) and, hence, more frequent boric acid batching as discussed in Section 6.5.

If this is the option FPL selects, procedure changes will be limited to such items as the following:

1. Delete heat tracing related procedures to the extent that all heat tracing is disconnected and removed.

2. Revise all procedures that reference the boric acid tank available (usable) volume, minimum required volumes, and boric acid concentration ranges.

3. Revise the emergency boration procedure (Reference 10.12) to reflect the analysis of Section 6.6.3.

4. Revise procedures for operation of the boric acid evaporator to maintain the boric acid concentration of the bottoms of the distillation process within the new boric acid tank control band of 3.0 to 3.5 weight percent.

5. Revise procedures for boric acid blender operation (or ones that reference blender capacity) to reflect the proposed modification to FCV-113A (PC/M as-building).

6. Revise procedures for boric acid batching to reflect the new boric acid concentration range of 3.0 to 3.5 weight percent.

7. Develop a procedure to conduct a cooldown in response to the scenario analyzed in Section 5.0. Such a procedure would be required for cases where a cooldown would be necessary on one boric acid tank (and the refueling water storage tank) or for cases where letdown is not available. Such a procedure should make provisions for more frequent boron sampling during the cooldown process.

8. The analysis presented in Sections 5 and 6 assumed an RHR boron concentration in the range of 500 to 800 ppm boron. This is a realistic assumption given that cold shutdown boron concentrations are maintained in the RCS/RHR until after the RCS is disconnected from the RHR. Efforts should be made to ensure the RHR concentration is maintained as high as reasonably possible so that the boron addition from this system will help minimize batching requirements. This would entail recirculating portions of the system that have this capability and refilling it with borated water whenever the system is drained for maintenance.

If all subsequent cooldowns are to be completed in the manner described in Section 5 (i.e., boration in conjunction with cooldown) all shutdown, cooldown, and boration related procedures will require modification in addition to the changes discussed above. Provisions should be made, however, to accommodate the use of letdown, batching to replenish boric acid, and desired plant lineups to accommodate this mode of operation.

Optimum use can be made of the available boric acid by consideration of the following:

1. Maintain boric acid tanks as full as possible. Align the suctions of all transfer pumps to all three tanks, thereby interconnecting the three tanks. Allow the technical specification minimum allowable volume for both units to be spread among the three tanks. This will maximize the volume available in the tanks for day to day boration needs.

2. When using one or more boric acid tanks as the source of boration (emergency, manual, or blended) with RCP seal injection in service, borated water will be lost to the VCT via RCP seal leakoff (nominally 9 gpm) if the VCT is isolated (isolation valve shut or check valve seated). The batching evaluation of Section 6.5 assumed this to be the case to maximize the volumes required for feed and bleeds and blended makeup operations. By adjusting charging pump speed accordingly to provide seal injection flow from the VCT, the concentrated boric acid diverted to the VCT will be utilized. In this manner, VCT level should remain roughly constant, and eventual loss of RCP seal leakoff to the holdup tank (via VCT pressure relief) will not occur.

10.0 REFERENCES

10.1 Turkey Point Units 3 and 4 Design Basis Document, Chemical and Volume Control System, 5610-046-DB-001, Revision 1.

10.2 Turkey Point Units 3 and 4 Design Basis Document, Chemical and Volume Control System, 5610-046-DB-002, Revision 1.

10.3 Turkey Point Units 3 and 4 Updated Final Safety Analysis Report (UFSAR), Revision 8.

10.4 Deleted

10.5 Turkey Point Units 3 and 4 10CFR50 Appendix R Fire Protection Review.

10.6 Turkey Point Units 3 and 4 Docket Nos. 50-250 and 50-251, Revised Technical Specifications, Amendments 137 and 132.

10.7 C-E Letter F-CE-10852, J. M. Westhoven (CE) to S. T. Hale (FPL) dated February 23, 1990; Proposal 90-241-55A.

10.8 FPL Purchase Order No. B90671-10032, DWA No. 626610.

10.9 Technical Data Sheet IC-11, US Borax and Chemical Corporation, 3-83-J. W.

10.10 Turkey Point Emergency Operating Procedure 3/4-EOP-ES-0.2, Natural Circulation Cooldown.

10.11 ASME Steam Tables, Third Edition.

10.12 Turkey Point Operating Procedure 3/4-ONOP-046.1, Emergency Boration.

10.13 Crane, Flow of Fluids Through Valves, Fittings and Pipe Technical Paper No. 410, 1981.

BORIC ACID CONCENTRATION REDUCTION

TECHNICAL BASES
AND
OPERATIONAL ANALYSES

APPENDICES

Appendix 1

Derivation of the Reactor Coolant System Feed-and-Bleed Equation

Purpose of Definitions

This appendix presents the detailed derivation of an equation which can be used to compute the reactor coolant system (RCS) boron concentration change during a feed and bleed operation. For this derivation, the following definitions were used:

$\dot{m}_{in}$ = mass flowrate into the RCS
$\dot{m}_{out}$ = mass flowrate out of the RCS
$\dot{m}_{b}$ = boron mass flowrate
$\dot{m}_{w}$ = water mass flowrate
m_{b} = boron mass
m_{w} = water mass
C_{in} = boron concentration going into RCS
C_{out} = boron concentration going out of RCS
C_{o} = initial boron concentration
$C(t)$ = boron concentration as a function of time
C_{RCS} = RCS boron concentration

Simplifying Assumptions

During a feed and bleed operation, the RCS can be pictured as a closed container having a certain volume, a certain mass, and an initial boron concentration. Coolant is added at one end via the charging pumps. The rate of addition is dependent on the number of charging pumps that are running with the concentration being determined by the operator. Coolant is removed at the other end via letdown at a rate that is approximately equal to the charging rate and at a concentration determined by fluid mixing within the RCS. The mass flowrate into the RCS is given by the following equation:

$$\dot{m}_{in} = (\dot{m}_b + \dot{m}_w)_{in}$$

For typical boron concentrations within the chemical and volume control system, m_w is very much greater than m_b. (For example, a 3.5 weight percent boric acid solution contains only 0.04 lbm of boric acid per lbm of water). Therefore, the above equation can be simplified to the following:

$$\dot{m}_{in} = (\dot{m}_w)_{in} \quad (1.0)$$

In a similar manner, the mass flowrate coming out of the RCS, given by

$$\dot{m}_{out} = (\dot{m}_b + \dot{m}_w)_{out}$$

can be simplified by again realizing that m_w is very much greater than m_b or

$$\dot{m}_{out} = (\dot{m}_w)_{out} \quad (2.0)$$

For a feed and bleed operation with a constant pressurizer level and a constant system temperature, the mass flowrate into the RCS will be equal to the mass flowrate out of the RCS, or

$$\dot{m}_{in} = \dot{m}_{out} = (\dot{m}_w)_{in} = (\dot{m}_w)_{out} \quad (3.0)$$

Finally, if it assumed that the boron which is added to the RCS mixes completely and instantly with the entire RCS mass, the concentration of the fluid coming out of the system will be equal to the system concentration, or

$$C_{out} = C_{RCS} \quad (4.0)$$

Derivation

THe rate of change of boron mass within the RCS is equal to the mass of boron being charged into the system minus the mass of boron leaving via letdown. In equation form, this becomes

$$\frac{d(m_b)_{RCS}}{dt} = \dot{m}_{in}C_{in} - \dot{m}_{out}C_{out}$$

From Equation 3.0,

$$\frac{d(m_b)_{RCS}}{dt} = \dot{m}_{in}(C_{in} - C_{out}) = (\dot{m}_w)_{in}(C_{in} - C_{out}) \qquad (5.0)$$

The concentration of boron in the RCS, (i.e., the weight fraction of boron), is defined as follows:

$$C_{RCS} = \frac{m_b}{m_b + m_w}_{RCS}$$

Since $m_w >> m_b$,

$$C_{RCS} = \frac{m_b}{m_w}_{RCS}$$

Where $(m_w)_{RCS}$ is a constant for a constant system temperature. The rate of change of the RCS concentration is, therefore:

$$\frac{dC_{RCS}}{d} = \frac{\frac{d(m_b)_{RCS}}{dt}}{(m_w)_{RCS}} \qquad (6.0)$$

Substituting Equation 5.0 into Equation 6.0 yields the following:

$$\frac{dC_{RCS}}{dt} = \frac{(\dot{m}_w)_{in}(C_{in} - C_{out})}{(m_w)_{RCS}}$$

and from Equation 4.0,

$$\frac{dC_{RCS}}{dt} = \frac{(\dot{m}_w)_{in}(C_{in} - C_{RCS})}{(m_w)_{RCS}} \qquad (7.0)$$

Solving Equation 7.0 for concentration yields:

$$\frac{dC_{RCS}}{C_{in} - C_{RCS}} = \frac{(\dot{m}_W)_{in}}{(m_W)_{RCS}} dt$$

or

$$\int_{C_o}^{C(t)} \frac{dC_{RCS}}{C_{in} - C_{RCS}} = \frac{(\dot{m}_W)_{in}}{(m_W)_{RCS}} \int_0^t dt$$

Integrating from some initial concentration C_o to some final concentration C(t) and multiplying through by negative one gives the following:

$$\ln (C_{RCS} - C_{IN}) \Big|_{C_o}^{C(t)} = - \frac{(\dot{m}_W)_{in}}{(m_W)_{RCS}} t$$

or

$$\ln \frac{C(t) - C_{in}}{C_o - C_{in}} = - \frac{(m_W)_{in}}{(m_W)_{RCS}} t$$

Continuing to solve for C(t), this equation becomes:

$$\frac{C(t) - Cin}{C_o - C_{in}} = e^{-(\dot{m}_W)_{in} t / (m_W)_{RCS}}$$

or

$$C(t) = C_{in} + (C_o - C_{in}) e^{-(\dot{m}_W)_{in} t / (m_W)_{RCS}} \qquad (8.0)$$

If we define the time constant T to be as follows:

$$T = \frac{(m_W)_{RCS}}{(\dot{m}_W)_{in}}$$

then Equation 8.0 becomes

$$C(t) = C_o e^{-t/T} + C_{in} (1 - e^{-t/T}) \qquad (9.0)$$

Appendix 2

A Proof that Final System Concentration is Independent of System Volume

Purpose of Definitions

This appendix presents a detailed proof that during a plant cooldown where an operator is charging only as necessary to makeup for coolant contraction, the final system concentration that results using a given boration source concentration will be independent of the total system volume. For this proof, the following definitions were used:

c_i = initial boron concentration Plant 1
m_{bi} = initial boron mass Plant 1
m_{wi} = initial water mass Plant 1
c_f = final boron concentration Plant 1
c_a = boron concentration of makeup solution Plant 1
m_{ba} = mass of boron added Plant 1
m_{wa} = mass of water added Plant 1
m_{bf} = final boron mass Plant 1
C_i = initial boron concentration Plant 2
M_{bi} = initial boron mass Plant 2
M_{wi} = initial water mass Plant 2
C_f = final boron concentration Plant 2
C_a = boron concentration of makeup solution Plant 2
M_{ba} = mass of boron added Plant 2
M_{wa} = mass of water added Plant 2

Proof

For this proof, consider two plants at the same initial temperature, the same initial pressure, and the same initial boron concentration. One plant, Plant 2, has exactly twice the system volume as the other plant, Plant 1. Initially, boron concentration Plant 1 = boron concentration Plant 2,

or

$$c = C = \frac{m_{bi}}{m_{bi} + m_{wi}} = \frac{M_{bi}}{M_{bi} + M_{wi}} \quad (1.0)$$

Since the volume of Plant 2 is twice that of Plant 1, $M_{wi} = 2m_{wi}$. Substituting this relationship into Equation 1.0 and solving yields the following:

$$\frac{m_{bi}}{m_{bi} + m_{wi}} = \frac{M_{bi}}{M_{bi} + 2m_{wi}}$$

$$m_{bi}M_{bi} + 2m_{bi}m_{wi} = m_{bi}M_{bi} + m_{wi}M_{bi}$$

and

$$M_{bi} = 2m_{bi} \quad (2.0)$$

Therefore, the initial boron mass in Plant 2 is exactly twice the initial boron mass in Plant 1.

During the cooldown process for Plant 1, the final boron mass in the system will equal the initial boron mass plus the added boron mass, or

$$m_{bf} = m_{bi} + m_{ba} \quad (3.0)$$

If, during this cooldown process, operators charge only as necessary to makeup for coolant contraction, water and boron will be added only as space is made available in the system due to coolant shrinkage. The final boron concentration from Equation 3.0 can therefore be expressed as follows:

$$m_{bf} = m_{bi} + m_{ba} + m_{wi} + m_{wa} \quad \frac{m_{bf}}{m_{bi} + m_{ba} + m_{wi} + m_{wa}}$$

If concentration is expressed in terms of weight percent, this last equation becomes

$$m_{bf} = m_{bi} + m_{ba} + m_{wi} + m_{wa} \quad c_f \quad (4.0)$$

Similarly, the remaining two components of Equation 3.0 become

$$m_{bi} = m_{bi} + m_{wi} \quad c_i \qquad (5.0)$$

and

$$m_{ba} = m_{ba} + m_{wa} \quad c_a \qquad (6.0)$$

Substituting Equations 4.0, 5.0, and 6.0 into Equation 3.0 and solving for the final concentration yields the following:

$$c_f = \frac{m_{bi} + m_{wi} \quad c_i + \quad m_{ba} + m_{wa} \quad c_a}{m_{bi} + m_{ba} + m_{wi} + m_{wa}} \qquad (7.0)$$

For Plant 2, Equation 7.0 becomes

$$C_f = \frac{M_{bi} + M_{wi} \quad C_i + \quad M_{ba} + \quad M_{wa} \, C_a}{M_{bi} + M_{ba} + M_{wi} + M_{wa}} \qquad (8.0)$$

During a cooldown, the shrinkage mass, (i.e., the mass of fluid that must be added to the system in order to keep pressurizer level constant), is calculated by dividing the system volume by the change in specific volume, or

$$m_{wa} = \frac{\text{System Volume Plant 1}}{\Delta \text{ Specific volume}} \qquad (9.0)$$

and

$$M_{wa} = \frac{\text{System Volume Plant 2}}{\Delta \text{ Specific volume}} \qquad (10.0)$$

where System Volume Plant 1 = (1/2) System Volume Plant 2.

For a given cooldown, dividing Equation 9.0 by Equation 10.0 gives the following:

$$M_{wa} = 2m_{wa} \qquad (11.0)$$

In addition, if the charging source for both plants is at the same concentration and temperature,

$$C_a = c_a \tag{12.0}$$

and

$$M_{ba} = 2m_{ba} \tag{13.0}$$

Substituting Equations 2.0, 11.0, 12,0, and 13.0 into Equation 8.0 yields the following:

$$C_f = \frac{2m_{bi} + M_{wi} \quad C_i + \quad 2m_{ba} \quad + 2m_{wa} \quad c_a}{2m_{bi} \quad + 2m_{ba} + M_{wi} + 2m_{wa}}$$

Since the initial concentrations are the same, $C_i = c_i$, and since Plant 2 is twice as large as Plant 1, $M_{wi} = 2m_{wi}$,

$$C_f = \frac{2m_{bi} + 2m_{wi} \quad c_i + \quad 2m_{ba} \quad + 2m_{wa} \quad c_a}{2m_{bi} \quad + 2m_{ba} + 2m_{wi} + 2m_{wa}} = c_f$$

or

$$C_f = c_f \tag{14.0}$$

Therefore, for a cooldown where pressurizer level is maintained constant, the final boron concentration for Plant 2 is equal to the final boron concentration for Plant 1 (i.e., the change in boron concentration is independent of the exact system volume).

Appendix 3

Methodology for Calculating Dissolved Boric Acid per Gallon of Water

Purpose

The purpose of this appendix is to show the methodology used to calculate the mass of boric acid dissolved in each gallon of water for solutions of various boric acid concentrations. Two solution temperatures are presented corresponding to the maximum expected refueling water tank and boric acid tank temperature of 120°F and a nominal temperature of 70°F.

Methodology and Results

Boric acid concentration expressed in terms of weight percent is defined as follows:

$$C = \frac{\text{mass of boric acid}}{\text{total solution mass}} \times 100$$

or

$$C = \frac{\text{mass of boric acid}}{(\text{mass of boric acid}) + (\text{mass of water})} \times 100 \qquad (1.0)$$

If we define m_{ba} to be the mass of boric acid and m_w to be the mass of water, and if we substitute these defined terms into Equation 1.0 and solve for the mass of boric acid we have the following:

$$C = \frac{m_{ba}}{m_{ba} + m_w} \times 100$$

or

$$m_{ba} = \frac{C \times m_w}{100 - C} \qquad (2.0)$$

From Appendix A of the Crane Company Manual (Flow of Fluids Through Valves, Fittings, and Pipe, Crane Co., 1981, Technical Paper No. 410), the density of water at 70°F is 8.3290 lbm/gallon and at 120°F is 8.2498 lbm/gallon. Using these water masses and Equation 2.0 above, the mass of boric acid per gallon of solution is as follows:

	Concentration		Mass of acid per gallon of solution at	
source	wt.% boric acid	ppm boron	70°F	120°F
RWST	1.11534	1950	0.09394	0.09305
RWST	1.22974	2150	0.10370	0.10271
RWST	1.34413	2350	0.11348	0.11240
boric acid tank	1.50	2622	0.12684	0.12563
boric acid tank	2.50	4371	0.21356	0.21153
boric acid tank	2.75	4808	0.23552	0.23328
boric acid tank	3.00	5245	0.25760	0.25515
boric acid tank	3.25	5682	0.27979	0.27712
boric acid tank	3.50	6119	0.30209	0.29922
boric acid tank	3.75	6556	0.32451	0.32142
boric acid tank	4.00	6993	0.34704	0.34374

Appendix 4

Methodology for Calculating the Conversion Factor Between Weight Percent Boric Acid and ppm Boron

Purpose

The purpose of this appendix is to show the methodology used to derive the conversion factor between concentration in terms of weight percent boric acid and concentration in terms of parts per million (ppm) of naturally occurring boron.

Results

For any species (solute) dissolved in some solvent, a solution having a concentration of exactly 1 ppm can be obtained by dissolving 1 lbm of solute in 999,999 lbm of solvent. An aqueous solution having a concentration of 1 ppm boric acid, therefore, can be obtained by dissolving 1 lbm of boric acid in 999,999 lbm of water, or

$$1 \text{ ppm} = \frac{1 \text{ lbm boric acid}}{1 \text{ lbm boric acid} + 999{,}999 \text{ lbm water}} = \frac{1 \text{ lbm boric acid}}{10^6 \text{ lbm solution}}$$

For any species (solute) dissolved in some solvent, a solution having a concentration of 1 weight percent (wt.%) can be obtained by dissolving 1 lbm of solute in 99 lbm of solvent. An aqueous solution having a concentration of 1 wt.% boric acid, therefore, can be obtained by dissolving 1 lbm of boric acid in 99 lbm of water, or

$$\frac{1 \text{ wt.\%}}{100} = \frac{1 \text{ lbm boric acid}}{1 \text{ lbm boric acid} + 99 \text{ lbm water}} = \frac{1 \text{ lbm boric acid}}{100 \text{ lbm solution}}$$

Dividing these last two equations yields a ratio of 10^4, or

$$1 \text{ wt.\% boric acid} = 10{,}000 \text{ ppm boric acid} \qquad (1.0)$$

To convert from ppm boric acid (weight fraction) to ppm boron (weight fraction), multiply Equation 1.0 by the ratio of the molecular weight of boric acid (naturally occurring H_3BO_3) to the atomic weight of naturally occurring boron. From the Handbook of Chemistry and Physics, CRC Press,

$$1 \text{ wt.\% boric acid} = (10{,}000)\ \frac{10.81}{61.83} \text{ ppm boron}$$

or

$$1 \text{ wt.\% boric acid} = 1748.34 \text{ ppm boron.}$$

Appendix 5

Bounding Physics Data Inputs

P.O. Box 14000, Juno Beach, FL 33408-0420

MAY 4 1990

JPN-PTP-90-1248

APR 27 1990

Combustion Engineering, Inc.
1000 Prospect Hill Road
Windsor, Connecticut 06095

Attention: Mr. J. M. Westhoven

TURKEY POINT UNITS 3 & 4
BORIC ACID CONCENTRATION REDUCTION
REA TPN-88-733 IS MOD 1311
CCO NO. 30383 PC/M: N/A
FILE: TPN-88-733-2

Reference: C-E letter F-CE-10852 dated February 23, 1990

Gentlemen:

Table II in the letter referenced above described the type of data you require from FPL to develop the technical documents to support a technical specification change to reduce boron concentration. Table II was subsequently updated by you after conversations between your Mr. Carl Gimbrone and Mr. Abe Ortega. We are enclosing the data requested in the updated version of Table II.

The data was generated by our Fuel Technology Department and has been reviewed and approved for release to you. If you have any questions strictly regarding the nature of the data, please contact Mr. Modesto Jimenez at (305)552-3427.

If you have any other questions, please contact Mr. Abe Ortega at (407)694-5094.

Very truly yours,

R. L. Wade for
S. T. Hale
Engineering Project Manager

SAO/lh

Copies:
H. S. Bowles
J. Krumins
C. L. Larsen (w/)
J. Porter
R. S. Sanders (w/)
A. T. Zielonka

FPL

Inter-Office Correspondence

NF-90-140

To: [redacted] Date: April 3, 1990

From: M. Jimenez Department: Nuclear Fuel

Subject: **Turkey Point Units 3 & 4 Boric Acid Concentration Reduction Project - Physics Data**

Attached is the physics data requested in RAA 3065 to support the boric acid concentration reduction project at Turkey Point. The information provided consists of best estimate calculated average values covering several fuel cycles. Uncertainties noted in the attachment represents the range of variation among the cycles and do not include calculational uncertainty. Additional conservatisms should be applied to these results to envelope all future cycles. The data provided in the attachment have been reviewed in accordance to Nuclear Fuel's Quality Instructions.

If you have any questions or comments, please contact me at 552-3427.

M. Jimenez
Reactor Support

Approved By: J.L. Perryman
Reactor Support Supervisor

Copies To: T.J. Cahill
G.L. Marsh
J.L. Perryman
D.C. Poteralski
L.E. Rudicel LER
W. Skelley
D.G. Weeks

Form 1003 (Stocked) Rev. 2/83

TURKEY POINT UNITS 3 & 4
BORIC ACID CONCENTRATION REDUCTION PROJECT

REQUIRED PHYSICS DATA

1. Required shutdown margins:

Condition	Shutdown Margin (pcm)
a. T-avg > 200°F.	**See Figure 1**
b. T-avg < 200°F.	**1000**

2. Moderator cooldown curve from Hot Full Power (HFP) equilibrium conditions to 68 °F for the rodded condition when all rods are inserted minus the most worthy rod (ARI/wrso). The moderator cooldown curve should be normalized such that the corresponding All Rods Out (ARO) HFP Moderator Temperature Coefficient (MTC) is equal to the most negative Technical Specification limit.

   Figure 2

3. Doppler curve down to 68°F.

   Table 1

4. Xenon worth versus time (100 hours) after shutdown from 100% power.

   Tables 2 & 3 presents xenon worth versus time after shutdown from 100% at EOC 11 for Turkey Point Units 3 and 4, respectively. These xenon worth tables are representative of all recent cycles at Turkey Point. As shown in these tables, the xenon worth is negligible after 100 hours.

5. HZP scram worths for the ARI/wrso condition. (Moderator and Doppler distribution and xenon concentration held constant between the rodded and unrodded calculation).

   6500 +/- 5% pcm. The 5% uncertainty in this value represents the range of variation for the 8 most recent cycles at Turkey Point and does not include calculational uncertainty of 10%.

6. Differential Boron Worth (DBW) versus Temperature from HZP to CZP.

Figure 3. The following data points were used to generate this figure:

Moderator Temperature (°F)	DBW (pcm/ppm)
68	-14.5 +/-1.0
350	-12.5 +/-0.5
547	-10.5 +/-0.4

7. PPM measurement uncertainty for the boronometer (or measurement method used during normal and off-normal shutdowns).

1% or 5 ppm, whichever is greater.

8. Power Defect (Moderator and Doppler) for ARO, 0% to 100% power, constant HFP equilibrium xenon concentration at EOC EFPH.

Figure 4. The following data points were used to generate this figure:

Percent of Full Power	Total Power Defect (pcm)
0	0
30	- 800 +/- 50
50	-1270 +/- 50
70	-1700 +/-100
100	-2300 +/-100

9. Beta-Eff. if reactivity data is given in terms of dollars ($).

All reactivities given in pcm.

10. HFP PDIL.

The HFP PDIL or Insertion Limit is control Bank D at 171 steps withdrawn (75%). The calculated worth to this insertion limit is 240 +/- 50 pcm. The rod insertion allowance in the calculation of shutdown margin is conservatively estimated at 500 pcm by the fuel vendor.

TABLE 1

TURKEY POINT UNITS 3 & 4
DOPPLER ONLY FUEL TEMPERATURE COEFFICIENT
Vs. FUEL TEMPERATURE

Fuel Temperature (oF)	Doppler Coefficient (pcm/oF)
68	-2.90
100	-2.75
200	-2.37
300	-2.07
400	-1.84
500	-1.67
600	-1.54
700	-1.45
800	-1.38
900	-1.33
1000	-1.30
1100	-1.26
1200	-1.24
1300	-1.21
1400	-1.17
1500	-1.14
1600	-1.10
1700	-1.07
1800	-1.04
1900	-1.02
2000	-1.02

TABLE 2

TURKEY POINT UNIT 3 CYCLE 11

XENON WORTH AFTER TRIP AT EOL (12000)
ENTER PRE-TRIP POWER LEVEL (%) OR ENTER -E- TO END
> 100
SUMMARY OF RESULTS

HR AFT SD	XE WRTH(PCM)	HR AFT SD	XE WRTH(PCM)	HR AFT SD	XE WRTH(PCM)
0.0	2775.1	28.0	2150.4	56.0	354.3
2.0	3709.5	30.0	1918.1	58.0	308.2
4.0	4261.5	32.0	1705.3	60.0	267.9
6.0	4532.4	34.0	1511.6	62.0	232.7
8.0	4600.3	36.0	1336.4	64.0	202.0
10.0	4525.1	38.0	1178.8	66.0	175.2
12.0	4352.2	40.0	1037.6	68.0	151.9
14.0	4115.8	42.0	911.7	70.0	131.6
16.0	3841.5	44.0	799.7	75.0	91.8
18.0	3548.1	46.0	700.3	80.0	63.8
20.0	3249.3	48.0	612.5	85.0	44.3
22.0	2954.6	50.0	535.0	90.0	30.7
24.0	2670.6	52.0	466.8	95.0	21.2
26.0	2401.7	54.0	406.8	100.0	14.7

ENTER C TO CONTINUE CALCULATIONS, G TO GRAPH OR -E- TO END >

TABLE 3

TURKEY POINT UNIT 4 CYCLE 11

XENON WORTH AFTER TRIP AT EOL (12000)
ENTER PRE-TRIP POWER LEVEL (%) OR ENTER -E- TO END
> 100
SUMMARY OF RESULTS

HR.AFT.SD.	XE.WRTH(PCM)	HR.AFT.SD.	XE.WRTH(PCM)	HR.AFT.SD.	XE.WRTH(PCM)
0.0	2874.6	28.0	2216.8	56.0	365.1
2.0	3834.7	30.0	1977.3	58.0	317.6
4.0	4401.3	32.0	1757.8	60.0	276.1
6.0	4678.6	34.0	1558.1	62.0	239.8
8.0	4747.1	36.0	1377.5	64.0	208.2
10.0	4668.3	38.0	1215.0	66.0	180.6
12.0	4489.1	40.0	1069.5	68.0	156.5
14.0	4244.7	42.0	939.7	70.0	135.6
16.0	3961.4	44.0	824.2	75.0	94.6
18.0	3658.6	46.0	721.8	80.0	65.8
20.0	3350.2	48.0	631.3	85.0	45.6
22.0	3046.2	50.0	551.4	90.0	31.6
24.0	2753.3	52.0	481.1	95.0	21.9
26.0	2475.9	54.0	419.3	100.0	15.1

ENTER C TO CONTINUE CALCULATIONS, G TO GRAPH OR -E- TO END >

FIGURE 1

Turkey Point Units 3 & 4

Required Shutdown Margin Vs. Boron Concentration
For T-Avg > 200 oF

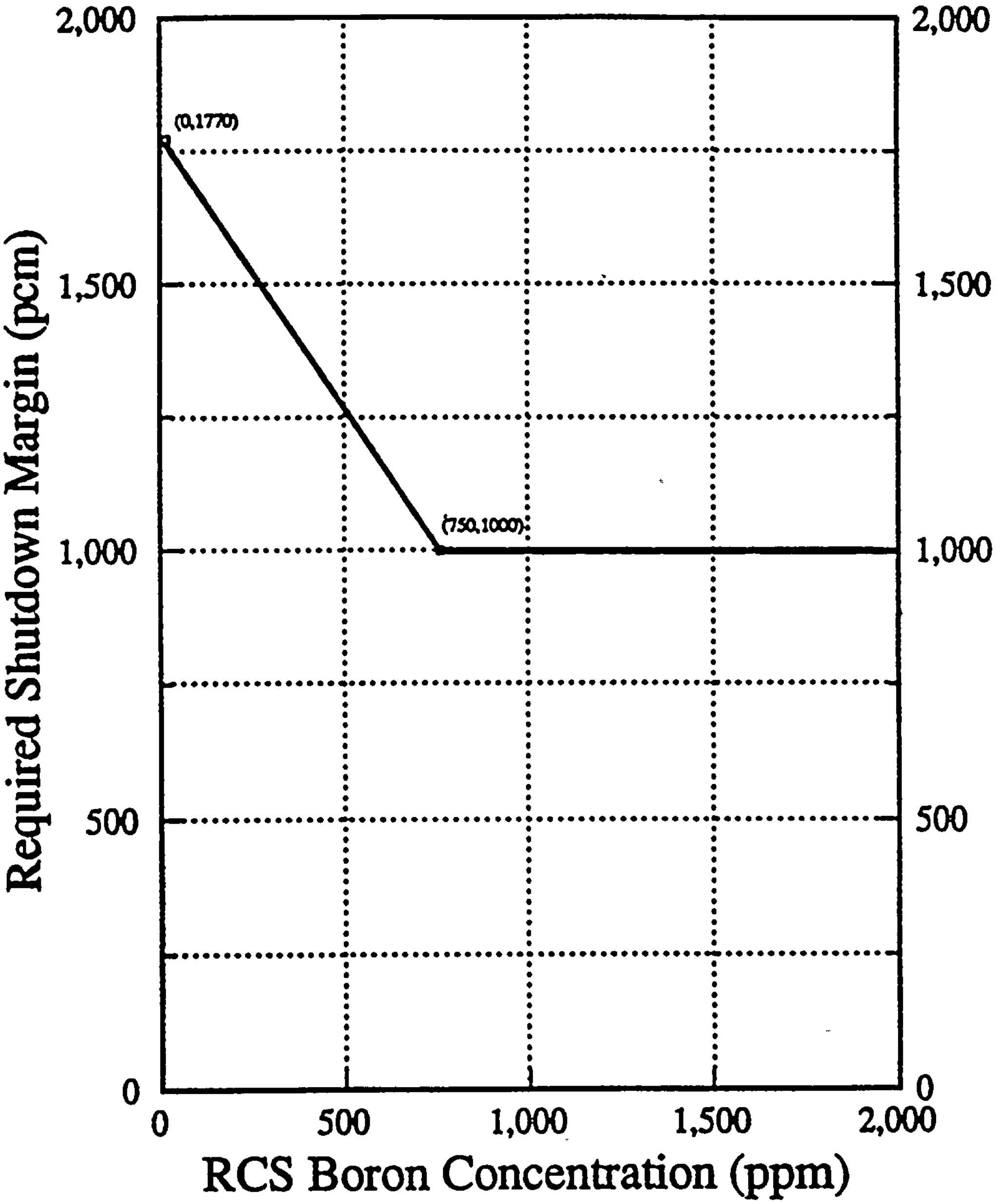
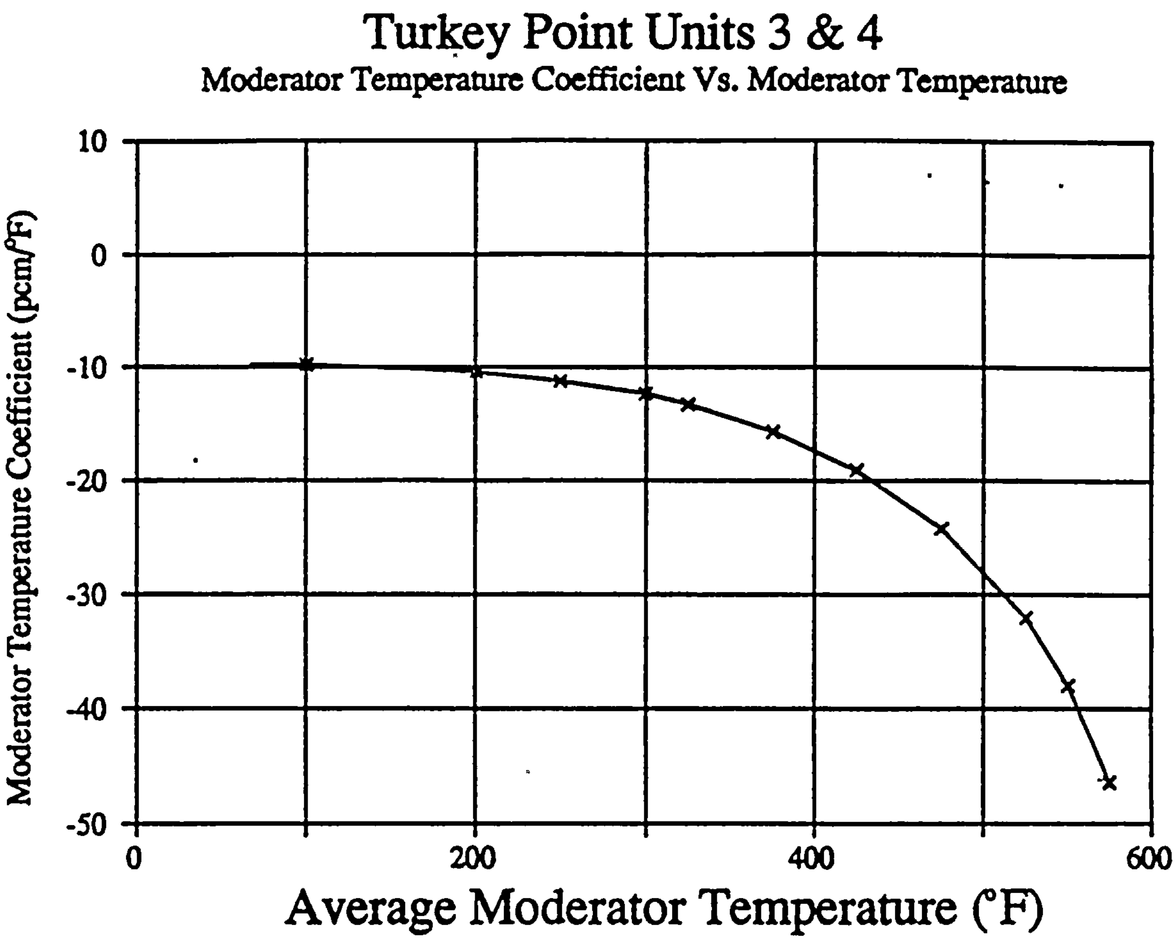
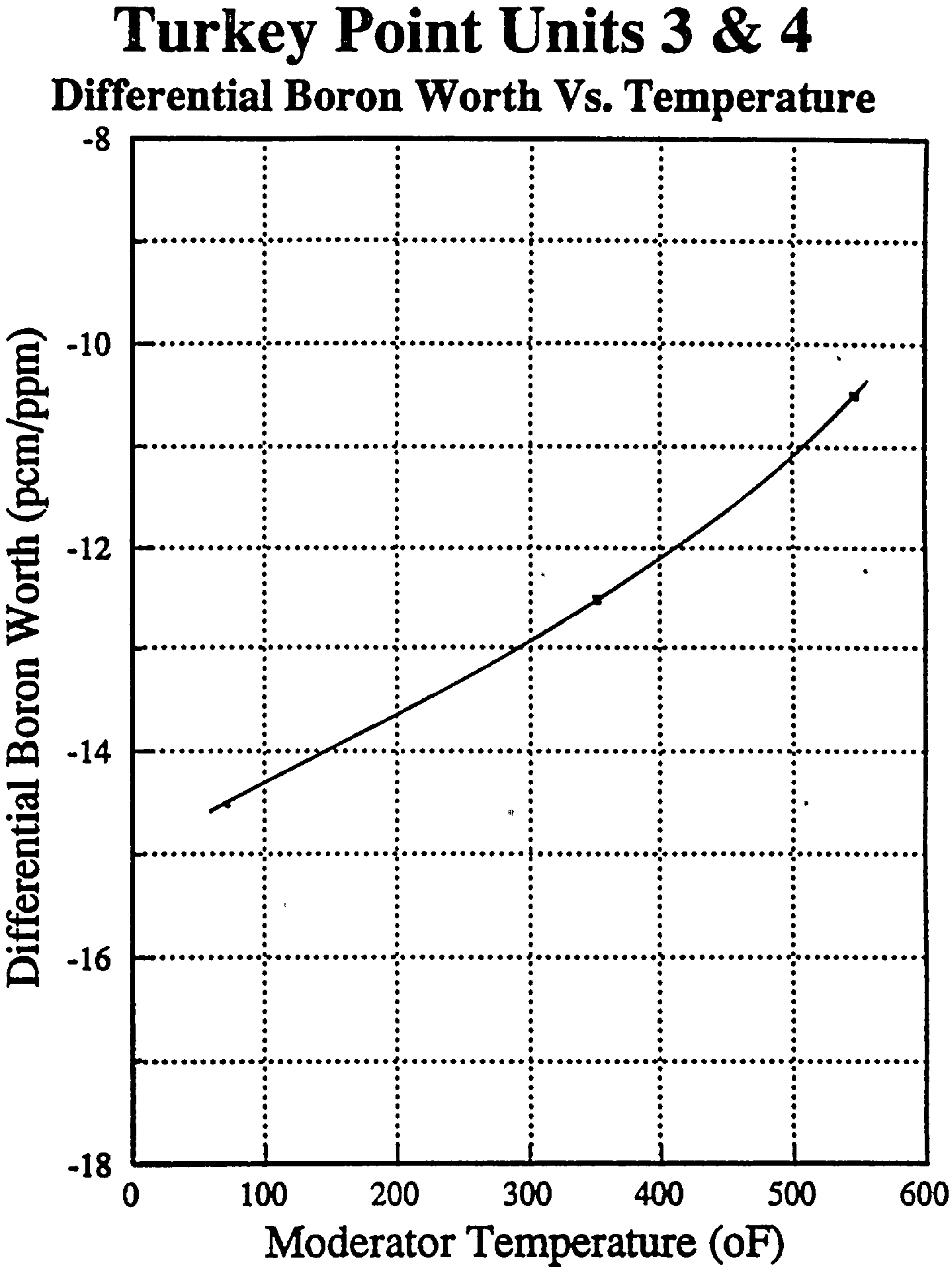


FIGURE 2



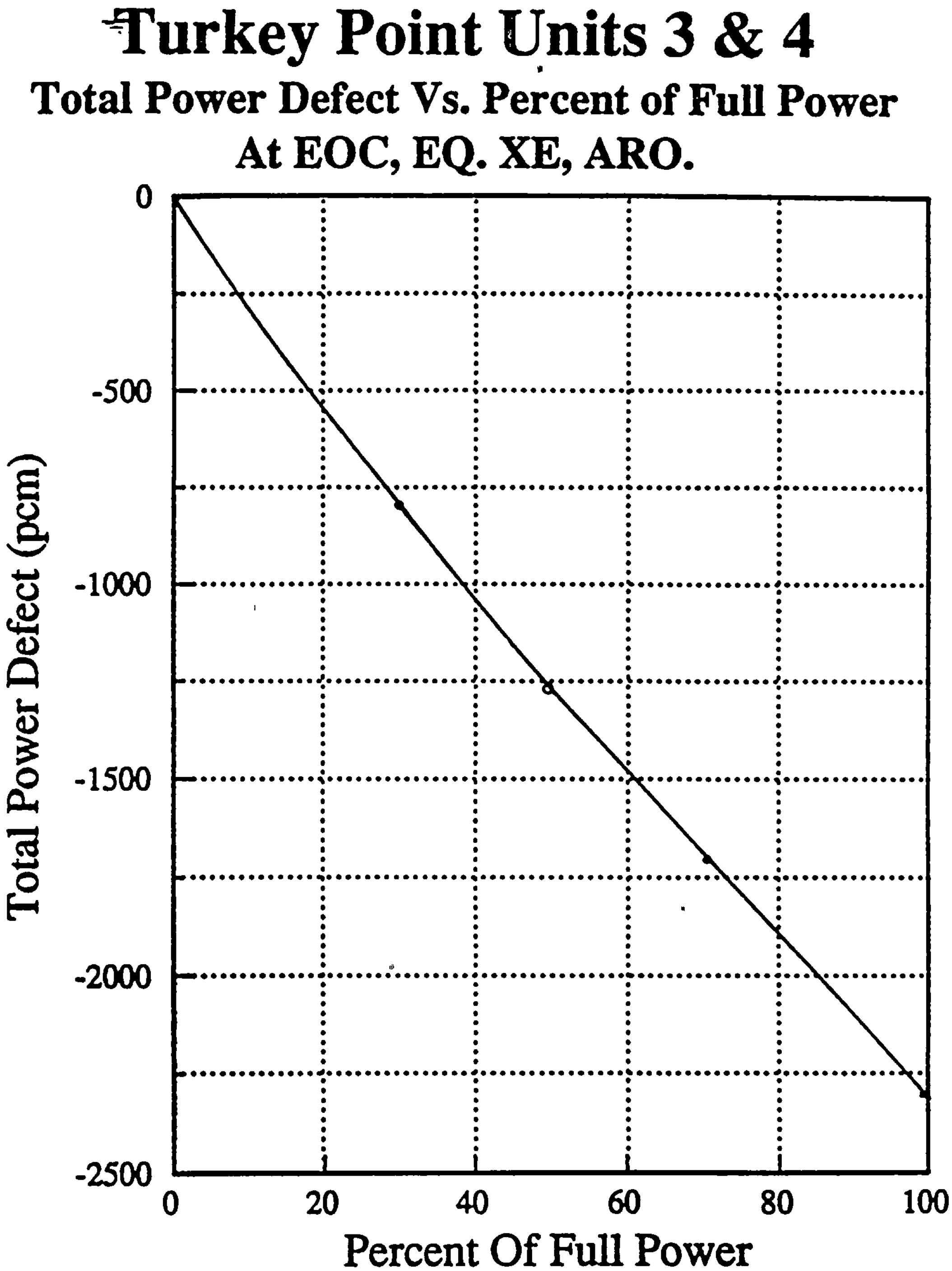
Turkey Point Units 3 & 4
Moderator Temperature Coefficient Vs. Moderator Temperature
Moderator Temperature Coefficient (pcm/°F)
10
0
-10
-20
-30
-40
-50
0
200
400
600
Average Moderator Temperature (°F)

FIGURE 3



Turkey Point Units 3 & 4
Differential Boron Worth Vs. Temperature
-8
-10
-12
-14
-16
-18
Differential Boron Worth (pcm/ppm)
0
100
200
300
400
500
600
Moderator Temperature (oF)

FIGURE 4



Turkey Point Units 3 & 4
Total Power Defect Vs. Percent of Full Power
At EOC, EQ. XE, ARO.
0
-500
-1000
-1500
-2000
-2500
Total Power Defect (pcm)
0
20
40
60
80
100
Percent Of Full Power

Appendix 6

Marked-Up Revised Technical Specifications

Note: These draft technical specification revisions reflect the proposed boric acid tank configuration where all three tanks are tied together via the transfer pump suction lines. In this manner, the combined volume of these tanks is shared between the two units. Required minimum volumes, therefore, have been doubled to ensure adequate volume is available to either unit.

Technical Specification Inserts

Insert A:

...EOL peak xenon conditions without letdown such that boration occurs only during the makeup provided for coolant contraction. This requirement can be met for a range of boric acid concentrations in the boric acid tank and the refueling water storage tank. The range of boric acid tank requirements is defined by Technical Specification 3.1.2.5.

Insert B:

...requirement of 55°F and corresponding surveillance intervals...

Insert C:

The temperature limit of 55°F includes a 5°F margin over the 50°F solubility limit of 3.5 wt.% boric acid. Portable instrumentation may be used to measure the temperature of the rooms containing boric acid sources and flow paths.

Insert D:

ACTION times allow for an orderly sequential shutdown of both units when the inoperability of a component(s) affects both units with equal severity. When a single unit is affected, the time to be in HOT STANDBY is 6 hours. When an ACTION statement requires a dual unit shutdown, the time to be in HOT STANDBY is 12 hours.

Insert E:

...by verifying that the temperature of the rooms containing flow path components is greater than or equal to 55°F when a flow path from the boric acid tanks is used;

Insert F:

Verifying that the temperature of the boric acid tanks room is greater than or equal to 55°F when it is the source of borated water.

3/4.1 REACTIVITY CONTROL SYSTEMS

3/4.1.1 BORATION CONTROL

SHUTDOWN MARGIN - T_{avg} GREATER THAN 200°F

LIMITING CONDITION FOR OPERATION

3.1.1.1 The SHUTDOWN MARGIN shall be greater than or equal to the applicable value shown in Figure 3.1-1.

APPLICABILITY: MODES 1, 2*, 3, and 4.

ACTION:

With the SHUTDOWN MARGIN less than the applicable value shown in Figure 3.1-1, immediately initiate and continue boration at greater than or equal to 4 gpm of a solution containing greater than or equal to 20,000 ppm boron or equivalent until the required SHUTDOWN MARGIN is restored.

SURVEILLANCE REQUIREMENTS

4.1.1.1.1 The SHUTDOWN MARGIN shall be determined to be greater than or equal to the applicable value shown in Figure 3.1-1:

a. Within 1 hour after detection of an inoperable control rod(s) and at least once per 12 hours thereafter while the rod(s) is inoperable. If the inoperable control rod is immovable or untrippable, the above required SHUTDOWN MARGIN shall be verified acceptable with an increased allowance for the withdrawn worth of the immovable or untrippable control rod(s);

b. When in MODE 1 or MODE 2 with K_{eff} greater than or equal to 1 at least once per 12 hours by verifying that control bank withdrawal is within the limits of Specification 3.1.3.6;

c. When in MODE 2 with K_{eff} less than 1, within 4 hours prior to achieving reactor criticality by verifying that the predicted critical control rod position is within the limits of Specification 3.1.3.6;

d. Prior to initial operation above 5% RATED THERMAL POWER after each fuel loading, by consideration of the factors of Specification 4.1.1.1.1e. below, with the control banks at the maximum insertion limit of Specification 3.1.3.6; and

*See Special Test Exceptions Specification 3.10.1.

SHUTDOWN MARGIN - T_{avg} LESS THAN OR EQUAL TO 200°F

LIMITING CONDITION FOR OPERATION

3.1.1.2 The SHUTDOWN MARGIN shall be greater than or equal to 1% Δk/k.

APPLICABILITY: MODE 5.

ACTION:

With the SHUTDOWN MARGIN less than 1% Δk/k, immediately initiate and continue boration at greater than or equal to ~~4~~ 16 gpm of a solution containing greater than or equal to ~~20,000 ppm~~ 3.0 wt % (5245 ppm) boron or equivalent until the required SHUTDOWN MARGIN is restored.

SURVEILLANCE REQUIREMENTS

4.1.1.2 The SHUTDOWN MARGIN shall be determined to be greater than or equal to 1% Δk/k:

a. Within 1 hour after detection of an inoperable control rod(s) and at least once per 12 hours thereafter while the rod(s) is inoperable. If the inoperable control rod is immovable or untrippable, the SHUTDOWN MARGIN shall be verified acceptable with an increased allowance for the withdrawn worth of the immovable or untrippable control rod(s); and

b. At least once per 24 hours by consideration of the following factors:

1) Reactor Coolant System boron concentration,

2) Control rod position,

3) Reactor Coolant System average temperature,

4) Fuel burnup based on gross thermal energy generation,

5) Xenon concentration, and

6) Samarium concentration.

3/4.1.2 BORATION SYSTEMS

FLOW PATH - SHUTDOWN

LIMITING CONDITION FOR OPERATION

3.1.2.1 As a minimum, one of the following boron injection flow paths shall be OPERABLE and capable of being powered from an OPERABLE emergency power source:

a. A flow path from the boric acid storage tanks via a boric acid transfer pump and a charging pump to the Reactor Coolant System if the boric acid storage tank in Specification 3.1.2.4a. is OPERABLE, or

b. The flow path from the refueling water storage tank via a charging pump to the Reactor Coolant System if the refueling water storage tank in Specification 3.1.2.4b. is OPERABLE.

APPLICABILITY: MODES 5 and 6.

ACTION:

With none of the above flow paths OPERABLE or capable of being powered from an OPERABLE emergency power source, suspend all operations involving CORE ALTERATIONS or positive reactivity changes.

SURVEILLANCE REQUIREMENTS

4.1.2.1 At least one of the above required flow paths shall be demonstrated OPERABLE:

a. At least once per 7 days ~~by verifying that the temperature of the heat traced portion of the flow path is greater than or equal to 145°F when a flow path from the boric acid tanks is used,~~ and

b. At least once per 31 days by verifying that each valve (manual, power-operated, or automatic) in the flow path that is not locked, sealed, or otherwise secured in position, is in its correct position.

INSERT E

FLOW PATHS - OPERATING

LIMITING CONDITION FOR OPERATION

3.1.2.2 The following boron injection flow paths shall be OPERABLE:

a. The source path from a boric acid storage tank via a boric acid transfer pump to the charging pump suction*, and

b. At least one of the two source paths from the refueling water storage tank to the charging pump suction; and,

c. The flow path from the charging pump discharge to the Reactor Coolant System via the regenerative heat exchanger.

APPLICABILITY: MODES 1, 2, 3, and 4.

ACTION:

a. With no boration source path from a boric acid storage tank OPERABLE,

   1. Demonstrate the OPERABILITY of the second source path from the refueling water storage tank to the charging pump suction by verifying the flow path valve alignment; and

   2. Restore the boration source path from a boric acid storage tank to OPERABLE status within 72 hours or be in at least HOT STANDBY and borated to a SHUTDOWN MARGIN equivalent to at least 1% Δk/k at 200°F within the next 6 hours; restore the boration source path from a boric acid storage tank to OPERABLE status within the next 72 hours or be in COLD SHUTDOWN within the next 30 hours.

b. With only one boration source path OPERABLE or the regenerative heat exchanger flow path to the RCS inoperable, restore the required flow paths to OPERABLE status within 72 hours or be in at least HOT STANDBY and borated to a SHUTDOWN MARGIN equivalent to at least 1% Δk/k at 200°F within the next 6 hours; restore at least two boration source paths to OPERABLE status within the next 72 hours or be in COLD SHUTDOWN within the next 30 hours.

c. With the boration source path from a boric acid storage tank and the charging pump discharge path via the regenerative heat exchanger inoperable, within one hour initiate boration to a SHUTDOWN MARGIN equivalent to 1% Δk/k at 200°F and go to COLD SHUTDOWN as soon as possible within the limitations of the boration and pressurizer level control functions of the CVCS.

---

*The flow required in Specification 3.1.2.2.a above shall be isolated from the other unit from the boric acid transfer pump discharge to the charging pump suction.

SURVEILLANCE REQUIREMENTS

4.1.2.2 The above required flow paths shall be demonstrated OPERABLE:

a. At least once per 7 days ~~by verifying that the temperature of the heat traced portion of the flow path from the boric acid tanks is greater than or equal to 145°F when it is a required water source~~;

b. At least once per 31 days by verifying that each valve (manual, power-operated, or automatic) in the flow path that is not locked, sealed, or otherwise secured in position, is in its correct position;

c. At least once per 18 months by verifying that the flow path required by Specification 3.1.2.2a. and c. delivers at least ~~4~~ 16 gpm to the RCS.

INSERT E

BORATED WATER SOURCE - SHUTDOWN

LIMITING CONDITION FOR OPERATION

3.1.2.4 As a minimum, one of the following borated water sources shall be OPERABLE:

a. A Boric Acid Storage System with:

1) A minimum indicated borated water volume of ~~500 gallons,~~ 2,900 gallons per unit,

2) A boron concentration between ~~20,000 ppm and 22,500 ppm,~~ 3.0 wt % (5245 ppm) and 3.5 wt % (6119 ppm), and

3) ~~A minimum solution temperature of 145°F.~~ A minimum boric acid tanks room temperature of 55°F.

b. The refueling water storage tank (RWST) with:

1) A minimum indicated borated water volume of 20,000 gallons,

2) A minimum boron concentration of 1950 ppm, and

3) A minimum solution temperature of 39°F.

APPLICABILITY: MODES 5 and 6.

ACTION:

With no borated water source OPERABLE, suspend all operations involving CORE ALTERATIONS or positive reactivity changes.

SURVEILLANCE REQUIREMENTS

4.1.2.4 The above required borated water source shall be demonstrated OPERABLE:

a. At least once per 7 days by:

1) Verifying the boron concentration of the water,

2) Verifying the indicated borated water volume, and

3) ~~Verifying the boric acid storage tank solution temperature when it is the source of borated water.~~ INSERT F

BORATED WATER SOURCES - OPERATING

LIMITING CONDITION FOR OPERATION

3.1.2.5 The following borated water sources shall be OPERABLE:

a. A Boric Acid Storage System with:

1) A minimum indicated borated water volume ~~of 3080 gallons,~~ [in accordance with Figure 3.1.2.5,]

2) A boron concentration ~~between 20,000 ppm and 22,500 ppm,~~ [in accordance with Figure 3.1.2.5,] and

3) ~~A minimum solution temperature of 145°F.~~ [A minimum boric acid tanks room temperature of 55°F.]

b. The refueling water storage tank (RWST) with:

1) A minimum indicated borated water volume of 320,000 gallons,

2) A minimum boron concentration of 1950 ppm,

3) A minimum solution temperature of 39°F, and

4) A maximum solution temperature of 100°F.

APPLICABILITY: MODES 1, 2, 3, and 4.

ACTION:

a. With the required Boric Acid Storage System inoperable verify that the RWST is OPERABLE; restore the system to OPERABLE status within 72 hours or be in at least HOT STANDBY within the next 6 hours* and borated to a SHUTDOWN MARGIN equivalent to at least 1% Δk/k at 200°F; restore the Boric Acid Storage System to OPERABLE status within the next 72 hours or be in COLD SHUTDOWN within the next 30 hours.

b. With the RWST inoperable, restore the tank to OPERABLE status within 1 hour or be in at least HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.

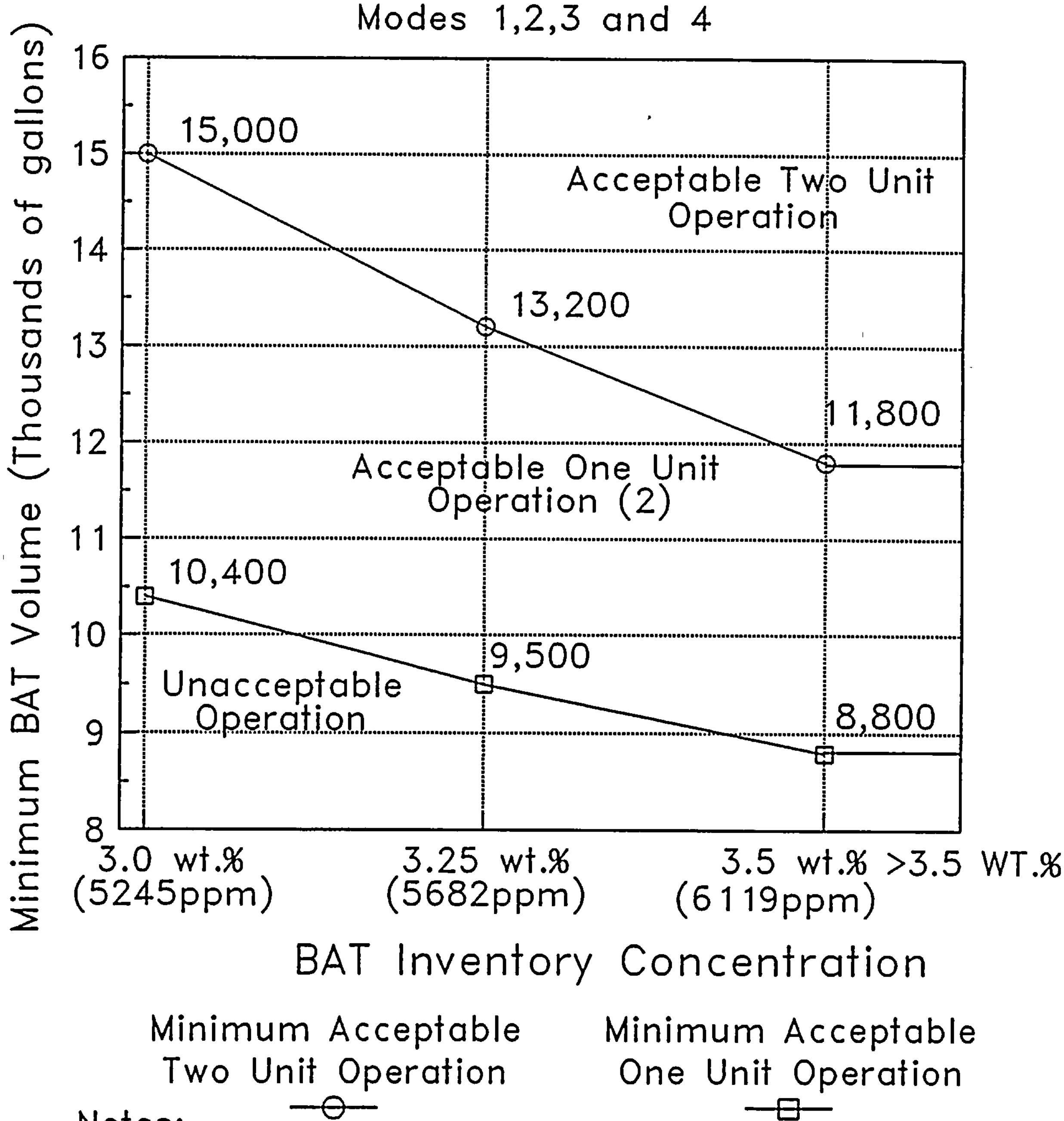
c. [With the boric acid tank inventory concentration greater than 3.5 wt %, verify that the boric acid solution temperature for boration sources and flow paths is greater than the solubility limit for the concentration.]

[* If this action applies to both units simultaneously, be in at least HOT STANDBY within the next twelve hours.]

Figure 3.1.2.5

BORIC ACID TANK MINIMUM VOLUME (1)

Modes 1,2,3 and 4



Notes:

(1) Combined volume of all available boric acid tanks assuming RWST boron concentration greater than or equal to 1950 ppm.

(2) Includes 2900 gallons for shutdown unit.

4.1.2.5 Each borated water source shall be demonstrated OPERABLE:

a. At least once per 7 days by:

1) Verifying the boron concentration in the water,

INSERT F

2) Verifying the indicated borated water volume of the water source, and

3) ~~Verifying the Boric Acid Storage System solution temperature when it is the source of borated water.~~

b. By verifying the RWST temperature is within limits whenever the outside air temperature is less than 39°F or greater than 100°F at the following frequencies:

1) Within one hour upon the outside temperature exceeding its limit for 23 consecutive hours, and

2) At least once per 24 hours while the outside temperature exceeds its limits.

REACTIVITY CONTROL SYSTEMS

HEAT TRACING

LIMITING CONDITION FOR OPERATION

(*) 3.1.2.6 At least two independent channels of heat tracing shall be OPERABLE for the boric acid storage tank and for the heat traced portions of the associated flow paths required by Specification 3.1.2.2.

APPLICABILITY: MODES 1, 2, 3 and 4
MODES 5 and 6 (when the boric acid storage tank is the borated water source per Specification 3.1.2.4)

ACTION:

MODES 1, 2, 3 and 4

With only one channel of heat tracing on either the boric acid storage tank or on the heat traced portion of an associated flow path OPERABLE, operation may continue for up to 30 days provided the tank and flow path temperatures are verified to be greater than or equal to 145°F at least once per 8 hours; otherwise, be in at least HOT STANDBY within 6 hours and in COLD SHUTDOWN within the following 30 hours.

MODES 5 and 6

With only one channel of heat tracing on either the boric acid storage tank or on the heat traced portion of an associated flow path OPERABLE, operations involving CORE ALTERATIONS or positive reactivity additions may continue for up to 30 days provided the tank and flow path temperatures are verified to be greater than or equal to 145°F at least once per 8 hours; otherwise, suspend all activities involving CORE ALTERATIONS or positive reactivity changes.

SURVEILLANCE REQUIREMENTS

4.1.2.6 Each heat tracing channel for the boric acid storage tank and associated flow path required by Specification 3.1.2.2 shall be demonstrated OPERABLE:

a. At least once per 31 days by energizing each heat tracing channel, and

b. At least once per 7 days by verifying the tank and flow path temperatures to be greater than or equal to 145°F. The tank temperature shall be determined by measurement. The flow path temperature shall be determined by either measurement or recirculation flow until establishment of equilibrium temperatures within the tank.

(*) This is no longer applicable once boric acid tanks inventory and boric acid source and flow paths inventories have been diluted to less than or equal to 3.5 weight percent (wt %).

3/4.9 REFUELING OPERATIONS

3/4.9.1 BORON CONCENTRATION

LIMITING CONDITION FOR OPERATION

3.9.1 The boron concentration of all filled portions of the Reactor Coolant System and the refueling canal shall be maintained uniform and sufficient to ensure that the more restrictive of the following reactivity conditions is met; either:

a. A K_{eff} of 0.95 or less, or

b. A boron concentration of greater than or equal to 1950 ppm.

APPLICABILITY: MODE 6.*

ACTION:

With the requirements of the above specification not satisfied, immediately suspend all operations involving CORE ALTERATIONS or positive reactivity changes and initiate and continue boration at greater than or equal to ~~4~~ 16 gpm of a solution containing greater than or equal to ~~20,000 ppm~~ 3.0 wt% (5245 ppm) boron or its equivalent until K_{eff} is reduced to less than or equal to 0.95 or the boron concentration is restored to greater than or equal to 1950 ppm, whichever is the more restrictive.

SURVEILLANCE REQUIREMENTS

4.9.1.1 The more restrictive of the above two reactivity conditions shall be determined prior to:

a. Removing or unbolting the reactor vessel head, and

b. Withdrawal of any full-length control rod in excess of 3 feet from its fully inserted position within the reactor vessel.

4.9.1.2 The boron concentration of the Reactor Coolant System and the refueling canal shall be determined by chemical analysis at least once per 72 hours.

4.9.1.3 Valves isolating unborated water sources** shall be verified closed and secured in position by mechanical stops or by removal of air or electrical power at least once per 31 days.

4.9.1.4 The spent fuel pit boron concentration shall be determined at least once per 31 days.

*The reactor shall be maintained in MODE 6 whenever fuel is in the reactor vessel with the vessel head closure bolts less than fully tensioned or with the head removed.

**The primary water supply to the boric acid blender may be opened under administrative controls for makeup.

3/4.10 SPECIAL TEST EXCEPTIONS

3/4.10.1 SHUTDOWN MARGIN

LIMITING CONDITION FOR OPERATION

3.10.1 The SHUTDOWN MARGIN requirement of Specification 3.1.1.1 may be suspended for measurement of control rod worth and SHUTDOWN MARGIN provided reactivity equivalent to at least the highest estimated control rod worth is available for trip insertion from OPERABLE control rod(s).

APPLICABILITY: MODE 2.

ACTION:

a. With any full-length control rod not fully inserted and with less than the above reactivity equivalent available for trip insertion, immediately initiate and continue boration at greater than or equal to ~~4~~ 16 gpm of a solution containing greater than or equal to ~~20,000 ppm~~ 3.0 wt% (5245 ppm) boron or its equivalent until the SHUTDOWN MARGIN required by Specification 3.1.1.1 is restored.

b. With all full-length control rods fully inserted and the reactor subcritical by less than the above reactivity equivalent, immediately initiate and continue boration at greater than or equal to ~~4~~ 16 gpm of a solution containing greater than or equal to ~~20,000 ppm~~ 3.0 wt% (5245 ppm) boron or its equivalent until the SHUTDOWN MARGIN required by Specification 3.1.1.1 is restored.

SURVEILLANCE REQUIREMENTS

4.10.1.1 The position of each full-length control rod either partially or fully withdrawn shall be determined at least once per 2 hours.

4.10.1.2 Each full-length control rod not fully inserted shall be demonstrated capable of full insertion when tripped from at least the 50% withdrawn position within 24 hours prior to reducing the SHUTDOWN MARGIN to less than the limits of Specification 3.1.1.1.

3/4.1.1 BORATION CONTROL

3/4.1.1.1 and 3/4.1.1.2 SHUTDOWN MARGIN

A sufficient SHUTDOWN MARGIN ensures that: (1) the reactor can be made subcritical from all operating conditions, (2) the reactivity transients associated with postulated accident conditions are controllable within acceptable limits, and (3) the reactor will be maintained sufficiently subcritical to preclude inadvertent criticality in the shutdown condition.

SHUTDOWN MARGIN requirements vary throughout core life as a function of fuel depletion, RCS boron concentration, and RCS T_{avg}. The most restrictive condition occurs at EOL, with T_{avg} at no load operating temperature, and is associated with a postulated steam line break accident and resulting uncontrolled RCS cooldown. Figure 3.1-1 shows the SHUTDOWN MARGIN equivalent to 1.77% Δk/k at the end-of-core-life with respect to an uncontrolled cooldown. Accordingly, the SHUTDOWN MARGIN requirement is based upon this limiting condition and is consistent with FSAR safety analysis assumptions. With T_{avg} less than 200°F, the reactivity transients resulting from an inadvertent cooldown of the RCS or an inadvertent dilution of RCS boron are minimal and a 1% Δk/k SHUTDOWN MARGIN provides adequate protection.

The boron rate requirement of 4 [16] gpm of ~~20,000 ppm~~ [3.0 wt% (5246 ppm)] boron or equivalent ensures the capability to restore the shutdown margin with one OPERABLE charging pump.

3/4.1.1.3 MODERATOR TEMPERATURE COEFFICIENT

The limitations on moderator temperature coefficient (MTC) are provided to ensure that the value of this coefficient remains within the limiting condition assumed in the FSAR accident and transient analyses.

The MTC values of this specification are applicable to a specific set of plant conditions; accordingly, verification of MTC values at conditions other than those explicitly stated will require extrapolation to those conditions in order to permit an accurate comparison.

The most negative MTC, value equivalent to the most positive moderator density coefficient (MDC), was obtained by incrementally correcting the MDC used in the FSAR analyses to nominal operating conditions. These corrections

MODERATOR TEMPERATURE COEFFICIENT (Continued)

involved subtracting the incremental change in the MDC associated with a core condition of all rods inserted (most positive MDC) to an all rods withdrawn condition and, a conversion for the rate of change of moderator density with temperature at RATED THERMAL POWER conditions. This value of the MDC was then transformed into the limiting MTC value -3.5×10^{-4} Δk/k/°F. The MTC value of -3.0×10^{-4} Δk/k/°F represents a conservative value (with corrections for burnup and soluble boron) at a core condition of 300 ppm equilibrium boron concentration and is obtained by making these corrections to the limiting MTC value of -3.5×10^{-4} Δk/k/°F.

The Surveillance Requirements for measurement of the MTC at the beginning and near the end of the fuel cycle are adequate to confirm that the MTC remains within its limits since this coefficient changes slowly due principally to the reduction in RCS boron concentration associated with fuel burnup.

3/4.1.1.4 MINIMUM TEMPERATURE FOR CRITICALITY

This specification ensures that the reactor will not be made critical with the Reactor Coolant System average temperature less than 541°F. This limitation is required to ensure: (1) the moderator temperature coefficient is within it analyzed temperature range, (2) the trip instrumentation is within its normal operating range, (3) the pressurizer is capable of being in an OPERABLE status with a steam bubble, and (4) the reactor vessel is above its minimum RT_{NDT} temperature.

3/4.1.2 BORATION SYSTEMS

The Boron Injection System ensures that negative reactivity control is available during each mode of facility operation. The components required to perform this function include: (1) borated water sources, (2) charging pumps, (3) separate flow paths, and (4) boric acid transfer pumps. ~~(5) associated Heat Tracing Systems, and (6) an emergency power supply from OPERABLE diesel generators.~~

With the RCS average temperature above 200°F, a minimum of two boron injection flow paths are required to ensure single functional capability in the event an assumed failure renders one of the flow paths inoperable. One flow path from the charging pump discharge is acceptable since the flow path components subject to an active failure are upstream of the charging pumps.

BASES

BORATION SYSTEMS (Continued)

The boration flow path specification allows the RWST and the boric acid storage tank to be the boron sources. Due to the lower boron concentration in the RWST, borating the RCS from this source is less effective than borating from the boric acid tank and additional time may be required to achieve the desired SHUTDOWN MARGIN required by ACTION statement restrictions. INSERT D

The ACTION statement restrictions for the boration flow paths allow continued operation in mode 1 for a limited time period with either boration source flow path or the normal flow path to the RCS (via the regenerative heat exchanger) inoperable. In this case, the plant capability to borate and charge into the RCS is limited and the potential operational impact of this limitation on mode 1 operation must be addressed. With both the flow path from the boric acid tanks and the regenerative heat exchanger flow path inoperable, immediate initiation of action to go to COLD SHUTDOWN is required but no time is specified for the mode reduction due to the reduced plant capability with these flow paths inoperable.

Two charging pumps ~~with independent power supplies~~ are required to be OPERABLE to ensure single functional capability in the event an assumed failure renders one of the pumps or power supplies inoperable. ~~However, the ACTION statement restrictions allow 7 days to restore an inoperable pump provided that two charging pumps are available. This restriction is acceptable based on the low probability of losing the power source common to both charging pumps.~~ ~~The~~ Each bus supplying the pumps can be fed from either the Emergency Diesel Generator or the offsite grid through ~~the~~ a startup transformer.

The boration capability of either flow path is sufficient to provide the required SHUTDOWN MARGIN in accordance with Figure 3.1-1 from expected operating conditions after xenon decay and cooldown to 200°F. The maximum expected boration capability requirement occurs at ~~BOL from full power equilibrium xenon conditions and requires 3880 gallons of 20,000 PPM borated water from the boric acid storage tanks or 320,000 gallons of 1950 PPM borated water from the refueling water storage tank (RWST).~~ INSERT A

With the RCS temperature below 200°F, one boron injection source flow path is acceptable without single failure consideration on the basis of the stable reactivity condition of the reactor and the additional restrictions prohibiting CORE ALTERATIONS and positive reactivity changes in the event the single boron injection system source flow path becomes inoperable.

The boron capability required below 200°F is sufficient to provide a SHUTDOWN MARGIN of 1% $\Delta k/k$ after xenon decay and cooldown from 200°F to 140°F. This condition requires either ~~500~~ 2,900 gallons of ~~20,000 ppm borated water~~ at least 3.0 wt% (5245 ppm) borated water per unit from the boric acid storage tanks or 20,000 gallons of 1950 ppm borated water from the RWST.

BORATION SYSTEMS (Continued)

The charging pumps are demonstrated to be OPERABLE by testing as required by Section XI of the ASME code or by specific surveillance requirements in the specification. These requirements are adequate to determine OPERABILITY because no safety analysis assumption relating to the charging pump performance is more restrictive than these acceptance criteria for the pumps.

The boron concentration of the RWST in conjunction with manual addition of borax ensures that the solution recirculated within containment after a LOCA will be basic. The basic solution minimizes the evolution of iodine and minimizes the effect of chloride and caustic stress corrosion on mechanical systems and components. The temperature requirements for the RWST are based on the containment integrity and large break LOCA analysis assumptions.

The OPERABILITY of one Boron Injection System during REFUELING ensures that this system is available for reactivity control while in MODE 6.

The OPERABILITY ~~of the redundant heat tracing channels~~ [INSERT B] associated with the boric acid tank system ensures that the solubility of the boron solution will be maintained. [INSERT C]

(*) One channel of heat tracing is sufficient to maintain the specified temperature limit. Since one channel of heat tracing is sufficient to maintain the specified temperature, operation with one channel out-of-service is permitted for a period of 30 days provided additional temperature surveillance is performed.

3/4.1.3 MOVABLE CONTROL ASSEMBLIES

The specifications of this section ensure that: (1) acceptable power distribution limits are maintained, (2) the minimum SHUTDOWN MARGIN is maintained, and (3) the potential effects of rod misalignment on associated accident analyses are limited. OPERABILITY of the control rod position indicators is required to determine control rod positions and thereby ensure compliance with the control rod alignment and insertion limits continue. OPERABLE condition for the analog rod position indicators is defined as being capable of indicating rod position to within ±12 steps of the demand counter position. For the Shutdown Banks and Control Banks A and B, the Position Indication requirement is defined as the group demand counter indicated position between 0 and 30 steps withdrawn inclusive, and between 200 and 228 steps withdrawn inclusive. This permits the operator to verify that the control rods in these banks are either fully withdrawn or fully inserted, the normal operating modes for these banks. Knowledge of these bank positions in these two areas satisfies all accident analysis assumptions concerning their position. For Control Banks C and D, the Position Indication requirement is defined as the group demand counter indicated position between 0 and 228 steps withdrawn inclusive.

(*) This is no longer applicable once boric acid tanks inventory and boric acid source and flow path inventories have been diluted to less than or equal to 3.5 weight percent (wt %).

BASES

3/4.9.1 BORON CONCENTRATION

The limitations on reactivity conditions during REFUELING ensure that: (1) the reactor will remain subcritical during CORE ALTERATIONS, and (2) a uniform boron concentration is maintained for reactivity control in the water volume having direct access to the reactor vessel. These limitations are consistent with the initial conditions assumed for the boron dilution incident in the safety analyses. With the required valves closed during refueling operations the possibility of uncontrolled boron dilution of the filled portion of the RCS is precluded. This action prevents flow to the RCS of unborated water by closing flow paths from sources of unborated water. The boration rate requirement of ~~44~~ 16 gpm of ~~20,000 ppm~~ 3.0 wt% (5245 ppm) boron or equivalent ensures the capability to restore the SHUTDOWN MARGIN with one OPERABLE charging pump.

3/4.9.2 INSTRUMENTATION

The OPERABILITY of the Source Range Neutron Flux Monitors ensures that redundant monitoring capability is available to detect changes in the reactivity condition of the core. There are four source range neutron flux channels, two primary and two backup. All four channels have visual and alarm indication in the control room and interface with the containment evacuation alarm system. The primary source range neutron flux channels can also generate reactor trip signals and provide audible indication of the count rate in the control room and containment. At least one primary source range neutron flux channel to provide the required audible indication, in addition to its other functions, and one of the three remaining source range channels shall be OPERABLE to satisfy the LCO.

3/4.9.3 DECAY TIME

The minimum requirement for reactor subcriticality prior to movement of irradiated fuel assemblies in the reactor vessel ensures that sufficient time has elapsed to allow the radioactive decay of the short-lived fission products. This decay time is consistent with the assumptions used in the safety analyses.

3/4.9.4 CONTAINMENT BUILDING PENETRATIONS

The requirements on containment building penetration closure and OPERABILITY ensure that a release of radioactive material within containment will be restricted from leakage to the environment. The OPERABILITY and closure restrictions are sufficient to restrict radioactive material release from a fuel element rupture based upon the lack of containment pressurization potential while in the REFUELING MODE.

3/4.9.5 COMMUNICATIONS

The requirement for communications capability ensures that refueling station personnel can be promptly informed of significant changes in the facility status or core reactivity conditions during CORE ALTERATIONS.

Appendix 7

Marked-up Safety Analysis Report Pages

Safety Analysis Report Inserts

Insert A

...to support a cooldown to cold shutdown conditions without letdown. Under these conditions, adequate boration can be achieved simply by providing makeup for coolant contraction from a boric acid tank and the refueling water storage tank. The minimum volume maintained in the boric acid tanks, therefore, is that volume necessary to increase the RCS boron concentration during the early phase of the cooldown of each unit such that subsequent use of the refueling water storage tank for contraction makeup will maintain the required shutdown margin throughout the remaining cooldown. In addition, the boric acid tanks have sufficient boric acid solution to achieve cold shutdown for each unit if the most reactive RCCA is not inserted.

Insert B

...forty minutes when a feed and bleed process is utilized (less than 30 minutes when the available pressurizer volume is utilized). In forty...

Insert C

The solubility limit for 3.5 weight percent boric acid is reached at a temperature of 50°F. This temperature is sufficiently low that the normally expected ambient temperatures within the auxiliary building will maintain boric acid solubility.

Insert D

Boration to the cold shutdown concentration is also achievable without letdown when boration is performed in conjunction with the plant cooldown through the required makeup for coolant contraction. Specifically, if boric acid is

injected first from the boric acid tanks and then from the refueling water storage tank to maintain constant pressurizer level during the cooldown, sufficient boric acid will be added to the RCS to maintain the required shutdown margins.

The reactivity control systems provided are capable of making and holding the core subcritical from any hot standby or hot operating condition, including those resulting from power changes.

The Rod Cluster Control (RCC) assemblies are divided into two categories comprising control and shutdown rod groups. One control group of RCC assemblies is used to compensate for short term reactivity changes at power such as those produced due to variations in reactor power requirements or in coolant temperature. The chemical shim control is used to compensate for the more slowly occurring changes in reactivity throughout core life such as those due to fuel depletion and fission product buildup and decay.

The shutdown groups are provided to supplement the control groups of RCC assemblies to make the reactor at least one per cent subcritical (k_{eff} = 0.99) following trip from any credible operating condition to the hot, zero power condition assuming the most reactive RCC assembly remains in the fully withdrawn position.

Any time that the reactor is at power, the quantity of boric acid retained in the boric acid tanks and ready for injection will always exceed that quantity required ~~for normal cold shutdown.~~ [Insert A]

Boric acid is pumped from the boric acid tanks by one of two boric acid transfer pumps to the suction of one of three charging pumps which inject boric acid into the reactor coolant. Any charging pump and either boric acid transfer pump can be operated from diesel generator power on loss of ~~outside~~ [offsite] power. Boric acid can be injected by one pump at a rate which takes the reactor to hot ~~shutdown~~ [standby] with no rods inserted in less than ~~sixteen minutes. In sixteen~~ [Insert B] additional minutes, enough boric acid can be injected to compensate for xenon decay although xenon decay below the equilibrium operating level does not begin until approximately 15 hours after shutdown. If two boric acid pumps are available, these time periods are reduced. Additional boric acid injection is employed if it is desired to bring the reactor to cold shutdown conditions.

Any time that the reactor [Insert A] is at power, the quantity of boric acid retained in the boric acid tanks and ready for injection always exceeds that required ~~for the normal cold shutdown.~~ This quantity also exceeds that required to bring the reactor to hot ~~shutdown~~ standby and to compensate for subsequent xenon decay.

Boric acid is pumped from the boric acid tanks by one of two boric acid transfer pumps to the suction of one of three charging pumps which inject boric acid into the reactor coolant. Any charging pump and either boric acid transfer pump can be operated from diesel generator power on loss of ~~outside~~ offsite power. Boric acid can be injected by one pump at a rate which takes the reactor to hot ~~shutdown~~ standby with no rods inserted in less than ~~sixteen minutes. In sixteen~~ [Insert B] additional minutes, enough boric acid can be injected to compensate for xenon decay although xenon decay below the equilibrium operating level does not begin until approximately 15 hours after shutdown. If two boric acid pumps are available, these time periods are reduced. Additional boric acid injection is employed if it is desired to bring the reactor to cold shutdown conditions.

On the basis of the above, the injection of boric acid is shown to afford backup reactivity shutdown capability, independent of control rod clusters which normally serve this function in the short term situation. Shutdown for long term and reduced temperature conditions can be accomplished with boric acid injection using redundant components, thus achieving the measure of reliability implied by the criterion.

Alternately, boric acid solution at lower concentration can be supplied from the refueling water tank. This solution can be transferred directly by the charging pumps. The reduced boric concentration lengthens the time required to achieve equivalent shutdown.

If pressure is reduced in the primary, a second alternative method comprises the injection of boric acid solution by operation of the safety injection pumps taking suction from the refueling water storage tank.

Event specific analyses were performed to evaluate the acceptability of securing various loads at given times for the one EDG available case. It is acceptable for the operator to secure the RHR pump at about 30 minutes after accident initiation for both small break and large break loss of coolant accidents (LOCA). The operator may also secure one containment spray pump at approximately 30 minutes following initiation of a LOCA. These actions serve to reduce EDG loading.

The normal containment coolers (NCCs) which are required for normal operation are tripped on loss of offsite power and are blocked from automatically restarting upon restoration of bus voltage. Manual control capabilities are provided in the control room. Operator actions required to manually load the NCCs for a unit in a non-accident condition are specified in the EOPs which includes assessing the available capacity of the EDGs. Containment heat removal for a unit in an accident condition is accomplished via the Emergency Containment Coolers and Containment Spray Systems.

The Boric Acid (BA) transfer pumps ~~and the BA tank heaters~~ upon Loss of Offsite Power (LOOP) remain deenergized for the short term (up to 8 hours). Manual control is available ~~locally for the heaters and~~ in the control room for the BA transfer pumps. The EOPs specify operator actions required to manually load the BA transfer pumps ~~and BA tank heaters~~ which include assessing the available capacity of the EDG.

The Instrument Air Compressors (IACs) are blocked (by administrative control of breakers) from automatic starting whenever offsite power is not available. The unavailability of the IACs following a LOOP is adequately compensated for through the use of air receivers, nitrogen accumulators, and non-safety related, self-contained air compressors that do not require the EDG for power.

The turbine auxiliaries such as the turbine turning gear oil pump, turbine bearing lift pump, and turbine turning gear drive provide a protective function to the main turbine generator. Accordingly, these turbine auxiliaries are blocked from automatic starting whenever offsite power is not available. While these loads are not required to be powered following a LOOP, the operator may manually initiate these as specified in the EOPs which include assessing the available capacity of the EDG.

The CRDM cooler fans are required for normal operation only and are shed during diesel loading. If required, CRDM cooler fans can be manually loaded onto the EDGs. Strict administrative controls must be used in the addition of manual loads in this condition of plant operation to ensure that the EDGs are not overloaded.

Reactivity Hold-Down Capability

Criterion: The reactivity control systems provided shall be capable of making the core subcritical under credible accident conditions with appropriate margins for contingencies and limiting any subsequent return to power such that there will be no undue risk to the health and safety of the public. (GDC 30)

Normal reactivity shutdown capability is provided by RCC assemblies, with boric acid injection used to compensate for the long term xenon decay transient and for cooldown. Any time that the unit is at power, the quantity of boric acid retained in the boric acid tanks and ready for injection will always exceed that quantity required ~~for the normal cold shutdown.~~ This quantity will always exceed the quantity of boric acid required to bring the reactor to hot ~~shutdown~~ and to compensate for subsequent xenon decay.

standby Insert A

The boric acid solution is transferred from the boric acid tanks by boric acid pumps to the suction of the charging pumps which inject boric acid into the reactor coolant. Any charging pump and any boric acid transfer pump can be operated from diesel generator power on loss of power. Boric acid can be injected by one charging pump and one boric acid transfer pump at a rate which shuts the reactor down with no rods inserted in less than ~~sixteen minutes. In sixteen~~ additional minutes, enough boric acid can be injected to compensate for xenon decay although xenon decay below the equilibrium operating level will not begin until approximately 12-15 hours after shutdown. If two boric acid pumps and two charging pumps are available, these time periods are reduced. Additional boric acid is employed if it is desired to bring the reactor to cold shutdown conditions.

Insert B

On the basis of the above, the injection of boric acid is shown to afford backup reactivity shutdown capability, independent of control rod clusters which normally serve this function in the short term situation. Shutdown for long term and reduced temperature conditions can be accomplished with boric acid injection using redundant components.

Hydrogen is automatically supplied, as determined by pressure control, to the vapor space in the volume control tank, which is predominantly hydrogen and water vapor. The hydrogen supply line has an excess flow valve (Fig 11.1-2) upstream and outside of the Charging Pump Room which will automatically close if the hydrogen flow increases beyond its specific flow setting due to a downstream pipe rupture. The hydrogen within this tank is supplied to the reactor coolant for maintaining a low oxygen concentration. Fission gases are periodically removed from the system by venting the volume control tank to the Waste Disposal System.

The charging pumps take suction from the volume control tank and return the coolant to the Reactor Coolant System through the tube side of the regenerative heat exchanger.

The cation bed demineralizer, located downstream of the mixed bed demineralizers, is used intermittently to control cesium activity in the coolant and also to remove excess lithium which is formed from B^{10} (n, α) Li^{7} reaction.

Boric acid is dissolved in hot water in the batching tank to a concentration of approximately ~~12~~ 3.0 to 3.5 percent by weight. The lower portion of the batching tank is jacketed to permit heating of the batching tank solution with low pressure steam. A transfer pump is used to transfer the batch to the boric acid tanks. Small quantities of boric acid solution are metered from the discharge of an operating transfer pump for blending with primary water as makeup for normal leakage or for increasing the reactor coolant boron concentration during normal operation. ~~Electric immersion heaters maintain the temperature of the boric acid tanks solution high enough to prevent precipitation.~~ Insert C

~~Electrical heat tracing is provided in conjunction with insulation on all piping, line mounted instrumentation and components normally containing concentrated boric acid solution. All such piping requiring this heat tracing is located in the auxiliary building. The heat tracing is designed to maintain the temperature of the piping and contents at 160°F to 180°F with an ambient air temperature of 40°F. In the event the building temperature should fall an additional 20°F the contents of the piping would be maintained at least at 140°F. This is well above 130°F, the temperature that 12 percent boric acid solution begins to precipitate.~~

~~Based on one heat tracing train in operation for each component, to assure continuous solution temperatures above 130°F, temperature indications over 145°F were specified because of the complex geometry generated by the tracing installation and by the limited number of measurement monitors.~~

~~Separate, duplicate heat tracing circuits are installed on all heat traced lines and valves to provide standby capacity if the operating section malfunctions. The power supply for each section of the heat tracing is connected to one of the diesel powered busses to ensure continuous operating during a condition of prolonged outage of normal power. Transfer from normal to standby heat tracing circuits is effected manually.~~

~~Separate thermostatic controls are provided for each section of the heat tracing to maintain the temperature within the specified control band. High and low temperature alarms are provided in the control room to warn of failure to maintain the temperature within the control band.~~

Excess liquid effluents containing boric acid flow from the Reactor Coolant System through the letdown line and are collected in the holdup tanks. As liquid enters the holdup tanks, the nitrogen cover gas is displaced to the gas decay tanks in the Waste Disposal System through the waste vent header. The concentration of boric acid in the holdup tanks varies throughout core life from the refueling concentration to essentially zero at the end of the core cycle. A recirculation pump is provided to transfer liquid from one holdup tank to another and to recirculate the contents of individual holdup tanks.

Liquid effluent in the holdup tanks is processed as a batch operation. This liquid is pumped through the evaporator base and cation exchangers which primarily remove lithium and fission-products such as long-lived cesium. It then flows through the ion exchanger filter and into the gas stripper where dissolved gases are removed from the liquid. The gases are vented to the Waste Disposal System. The liquid effluent from the gas stripper enters the boric acid evaporator.

The vapor produced in the boric acid evaporator leaves the evaporator condenser and is pumped through a condensate cooler where the distillate is cooled to the operating temperature of the evaporator condensate demineralizers. After non-volatile evaporator carry over is removed by one of the two evaporator condensate demineralizers the condensate flows through the condensate filter and accumulates in one of two monitor tanks. The dilute boric acid solution originally in the boric acid evaporator remains as the bottoms of the distillation process and is concentrated to approximately ~~twelve~~ 3.0 to 3.5 weight per cent boric acid.

Subsequent handling of the condensate is dependent on the results of sample analysis. Discharge from the monitor tanks may be pumped to the primary water storage tank, recycled through the evaporator condensate demineralizers, returned to the holdup tanks for reprocessing in the evaporator train or discharged to the environment with the condenser circulating water when within the allowable activity concentration as discussed in Section 11. If the sample analysis of the monitor tank contents indicates that it may be discharged safely to the environment, two valves must be opened to provide a discharge path. As the effluent leaves, it is continuously monitored by the waste disposal system liquid effluent monitor. If an unexpected increase in radioactivity is sensed, one of the valves in the discharge line to the condenser circulating water closes automatically and an alarm sounds in the control room.

Boric acid evaporator bottoms are discharged through a concentrates filter to the concentrates holding tank. Solution collected in the concentrates holding tank is sampled and then transferred to the boric acid tanks if

Reactor Makeup Control

The reactor makeup control consists of a group of instruments arranged to provide a manually pre-selected makeup composition to the charging pump suction header or the volume control tank. The makeup control functions are to maintain desired operating fluid inventory in the volume control tank and to adjust reactor coolant boron concentration for reactivity and shim control.

Makeup for normal leakage is regulated by the reactor makeup control which is set by the operator to blend water from the primary water storage tank with concentrated boric acid to match the reactor coolant boron concentration.

The makeup system also provides concentrated boric acid or primary water to either increase or decrease the boric acid concentration in the Reactor Coolant System. To maintain the reactor coolant volume constant, an equal amount of reactor coolant is let down to the holdup tanks. Should the letdown line be out of service during operation, sufficient volume exists in the pressurizer to accept the amount of boric acid necessary for ~~cold shutdown.~~ hot standby. Insert D

Makeup water to the Reactor Coolant System is provided by the Chemical and Volume Control System from the following sources:

a) The primary water storage tank, which provides water for dilution when the reactor coolant boron concentration is to be reduced

b) The boric acid tanks, which supply concentrated boric acid solution when reactor coolant boron concentration is to be increased

c) The refueling water storage tank, which supplies borated water for normal or emergency makeup

d) The chemical mixing tank, which is used to inject small quantities of solution when additions of hydrazine or pH control chemical are necessary.

Boric Acid Tanks

[Insert A]

The boric acid tank capacities are sized to store sufficient boric acid solution ~~for refueling plus enough boric acid solution for a cold shutdown shortly after initial full power operation is achieved. In addition, each tank has sufficient boric acid solution to achieve cold shutdown if the most reactive RCCA is not inserted. One tank is normally used with each unit and a third tank serves as a shared standby.~~

The concentration of boric acid solution in storage is maintained between [3.0 and 3.5 percent] ~~11.5 and 12.5%~~ by weight. Periodic manual sampling is performed and corrective action is taken, if necessary, to ensure that these limits are maintained. Therefore, measured amounts of boric acid solution can be delivered to the reactor coolant to control the concentration. The combination overflow and breather vent connection has a water loop seal to minimize vapor discharge during storage of the solution. The tanks are constructed of austenitic stainless steel.

~~Boric Acid Tank Heaters~~

~~Two 100% capacity electric immersion heaters located near the bottom of each boric acid tank are designed to maintain the temperature of the boric acid solution at 165 F with an ambient air temperature of 40 F thus ensuring a temperature in excess of the solubility limit (for 20,000 ppm boron this is 130 F). The temperature is monitored and low temperature is alarmed in the control room. The heaters are sheathed in austenitic stainless steel.~~

Batching Tank

The batching tank is sized to hold [several days] ~~one week's~~ makeup supply of boric acid solution for the boric acid tank. The basis for makeup is reactor coolant leakage of 1/2 gpm at beginning of core life. The tank may also be used for solution storage. A local sampling point is provided for verifying the solution concentration prior to transferring it to the boric acid tank or for draining the tank.

The tank manway is provided with a removable screen to prevent entry of foreign particles. In addition, the tank is provided with an agitator to improve mixing during batching operations. The tank is constructed of austenitic stainless steel, and is not used to handle radioactive substances. The tank is provided with a steam jacket for heating the boric acid solution to ~~165F.~~ above the solubility limit.

Boric Acid Transfer Pumps

Two 100% capacity centrifugal pumps per unit are used to circulate or transfer chemical solutions. The pumps circulate boric acid solution through the boric acid tanks and inject boric acid into the charging pump suction header.

Although one pump is normally used for boric acid batching and transfer and the other for boric acid injection, either pump may function as standby for the other. The design capacity of each pump is equal to the normal letdown flow rate. The design head is sufficient, considering line and valve losses, to deliver rated flow to the charging pump suction header when volume control tank pressure is at the maximum operating value (relief valve setting). All parts in contact with the solutions are austenitic stainless steel and other adequately corrosion-resistant material.

The transfer pumps are operated either automatically or manually from the control room or from a local control panel. The reactor makeup control operates one of the pumps automatically when boric acid solution is required for makeup or boration.

Boric Acid Blender

The boric acid blender promotes thorough mixing of boric acid solution and reactor makeup water from the reactor coolant makeup circuit. The blender consists of a conventional pipe fitted with a perforated tube insert. All material is austenitic stainless steel. The blender decreases the pipe length required to homogenize the mixture for taking a representative local sample.

The gas strippers consist of a hot well with heating coil to store stripped water, a stripping section packed with pall rings, a spray type liquid inlet header and an overhead integral reflux condenser. Liquid flowing to the gas strippers is controlled to constant rate by a flow controller. The gas strippers are designed for the same flow rate as the evaporator and are designed to reduce the influent gas concentration by a factor of 10^5.

Two gas stripper bottom pumps per gas stripper, operated from level control, transfer effluent from the gas stripper hot wells to the boric acid evaporator via the gas stripper preheaters. Each centrifugal pump is rated at the evaporator processing rate. The pumps are austenitic stainless steel and one is an installed standby for the operating pump.

Boric Acid Evaporator Equipment

Two boric acid evaporators concentrate boric acid for reuse in the Reactor Coolant System. Borated water enters the evaporator and the liquid is concentrated to approximately ~~12~~ 3.0 to 3.5 weight per cent boric acid. Vapors leave the evaporator and are condensed. The solids decontamination factor between the condensate and the bottoms is approximately 10^6. All evaporator equipmen is constructed of austenitic stainless steel and is supplied as a unit. Each boric acid evaporator package consists of the boric acid evaporator feed tank, two boric acid evaporator concentrates pumps, boric acid evaporat boric acid evaporator condenser, two boric acid evaporator condensate pumps, boric acid evaporator condensate cooler, two vacuum pumps and associated piping and instrumentation.

The boric acid evaporator feed tank has sufficient capacity to hold one ~~day's~~ approximately 6-7 hours production of ~~12~~ 3.0 to 3.5 weight per cent boric acid solution produced from refueling concentration feed. The evaporator and condenser heat transfer area is sufficient to maintain the required feed rate. The evaporator is steam heated. Component cooling water flows through the tube of the condenser.

Concentrates Filters

Two disposable synthetic cartridge type filters remove particulates from the evaporator concentrates. Design flow capacity of each filter is equal to the boric acid evaporator concentrates transfer pump capacity. The vessels are made of austenitic stainless steel.

Concentrates Holding Tank

The concentrates holding tank is sized to hold the production of concentrates from one batch of evaporator operation. The tank is supplied with an electrical heater which prevents boric acid precipitation and is constructed of austenitic stainless steel.

Concentrates Holding Tank Transfer Pumps

Two holding tank transfer pumps discharge boric acid solution from the concentrates holding tank to the boric acid tanks or the hold up tanks. Each canned centrifugal pump is sized to empty the concentrates holding tank in approximately 10 minutes. The wetted surfaces are constructed of authen::ic stainless steel and other adequately corrosion-resistant material.

~~Electrical Heat Tracing~~

~~Electrical heat tracing is installed under the insulation on piping, valves, line mounted instrumentation, and components normally containing concentrated boric acid solution. The heat tracing is designed to prevent boric acid precipitation due to cooling, by compensating for heat loss.~~

~~Exceptions are:~~

~~a) Lines which may transport concentrated boric acid but are subsequently flushed with reactor coolant or other liquid of low boric acid concentration during normal operation.~~

~~b) The boric acid tanks, which are provided with immersion heaters.~~

~~c) The batching tank, which is provided with a steam jacket.~~

~~d) The concentrates holding tank, which is provided with an immersion heater.~~

~~Duplicate tracing on sections of the Chemical and Volume Control System normally containing concentrated boric acid solution provides standby capacity if the operating tracing malfunctions.~~

~~Lines which are provided with heat tracing are shown on Figure 9.2-1b.~~

Valves

Valves that perform a modulating function are equipped with two sets of packing and an intermediate leakoff connection that discharges to the Waste Disposal System. All other valves have stem leakage control. Globe valves are installed with flow over the seats when such an arrangement reduces the possibility of leakage. Basic material of construction is stainless steel for all valves except the batching tank steam jacket valves which are carbon steel.

Isolation valves are provided at all connections to the Reactor Coolant System. Lines entering the reactor containment also have check valves inside the containment to prevent reverse flow from the containment.

Relief valves are provided for lines and components that might be pressurized above design pressure by improper operation or component malfunction. Pressure relief for the tube side of the regenerative heat exchanger is provided by the auxiliary spray line isolation valve which is designed to open when pressure under the seat exceeds reactor coolant pressure by 250 psi. Relief valves settings and capacities are given in Table 9.2-3.

Turkey Point Unit 3 has installed manual operating features to selected air-operated valves (Table 9.6A-11) in the Chemical and Volume Control System. The installation of these features provides an alternate means of operating these valves if the valve misoperates due to receipt of a spurious electrical signal resulting from a postulated fire. These changes implement recommendations made as part of the Appendix R Safe Shutdown Analysis in order to met the licensing commitments of 10CFR50 Appendix R (see Subsection 9.6A-5.6).

Piping

All Chemical and Volume Control System piping handling radioactive liquid is austenitic stainless steel. All piping joints and connections are welded, except where flanged connections are required to facilitate equipment removal for maintenance and hydrostatic testing.

9.2.3 SYSTEM DESIGN EVALUATION

Availability and Reliability

A high degree of functional reliability is assured in this system by providing standby components where performance is vital to safety and by assuring fail-safe response to the most probable mode of failure. ~~Special provisions include duplicate heat tracing with alarm protection of lines, valves, and components normally containing concentrated boric acid.~~

The system has three charging pumps, each capable of supplying the normal reactor coolant pump seal and makeup flow.

TABLE 9.2-2

NOMINAL CHEMICAL AND VOLUME CONTROL SYSTEM PERFORMANCE*

Unit design life, years	40
Seal water supply flow rate, gpm**	24
Seal water return flow rate, gpm	9
Normal letdown flow rate, gpm	60
Maximum letdown flow rate, gpm	120
Normal charging pump flow (one pump), gpm	69
Normal charging line flow, gpm	45
Maximum rate of boration with one transfer and one charging pump, ppm/min, (from initital RCS concentration of 1800 ppm)	~~23.8~~ 5.4
Equivalent cooldown rate to above rate of boration, F/min	~~6.8~~ 1.5
Maximum rate of boron dilution (two charging pumps) ppm/hour (from initial RCS concentration of 2500 ppm)	350
Two-pump rate of boration, using refueling water, ppm/min (from initial RCS concentration of 10 ppm)	6.2
Equivalent cooldown rate to above rate of boration, F/min	1.7
Temperature of reactor coolant entering system at full power, F (design)	555.0
Temperature of coolant return to Reactor Coolant System at full power, F (design)	493.0
Normal coolant discharge temperature to holdup tanks, F	127.0
Amount of ~~20,000 ppm~~ 3.0 weight percent boron solution required to meet cold shutdown requirements ~~shortly after full power operation (Table 3.2.1-1, Line 37),~~ End of life, peak xenon gallons (including consideration for one stuck rod)	~~3080~~ 7500

* Reactor coolant water quality is given in Table 4.2-2.

**Volumetric flow rates in gpm are based on 130°F and 2350 psig.

TABLE 9.2-3

PRINCIPLE COMPONENT DATA SUMMARY

	Quantity[1]	Heat Transfer Btu/hr	Letdown Flow lb/hr	Letdown ΔT F	Design Pressure psig,shell/tube	Design Temperature F,shell/tube
Heat Exchangers						
Regenerative	1	8.65×10^6	29,826	265	2485/2735	650/650
Non regenerative	1	14.8×10^6	29,826	163	150/600	250/400
Seal water	1	2.17×10^6	126,756	17	150/150	250/250
Excess letdown	1	4.75×10^6	12,400	360	150/2485	250/650

	Quantity[1]	Type	Capacity Each gpm	Head	Design Pressure psig	Design Temperature F
Pumps						
Charging	3	Pos. displ.	77	2385 psi	3000	250
Boric acid transfer	4*	Centrifugal	60	235 ft.	150	250
Holdup tank recirculation	1*	Centrifugal	500	100 ft.	150	200
Monitor tank	2*	Centrifugal	100	150 ft.	150	200
Concentrates holding tank transfer	2*	Canned	20	150 ft.	75	250
Gas stripper feed	3*	Canned	25	185 ft.	150	200
Gas stripper bottom	2	Centrifugal	12.5	93 ft.	75	300

	Quantity[1]	Type	Volume, Each	Design Pressure psig	Design Temperature F
Tanks					
Volume	1	Vert.	300 ft^3	75 Int/15Ext	250
Boric acid	3*	Vert.	~~7500~~ gal (Later)	Atmos.	250
Chemical mixing	1	Vert.	6.0 gal	150	250
Batching	1*	Jacket Btm.	800 gal	Atmos.	250
Holdup	3*	Vert.	13,000 ft^3	15	200
RWST	1	Vert.	338,000 gal	Atmos.	200

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Appendix 8

Future Fuel Cycle Review for Comparison of Bounding Physics Parameters(1)

Parameter	Turkey Point Units 3 and 4
Core Power (100%)	≤2200 MWt
Shutdown Margin T>200°F	≤1.77% Dk/k
Shutdown Margin T\200°F	≤1.0% Dk/k
RCS Average Temperature (0% Power)	≤547°F
Moderator Temperature Coefficient	≤-3.5E(-4)Dk/k/°F (less negative)
Hot Zero Power Net Rod Worth	≥6.175
Hot Zero Power Rod Insertion Limit (%Dq)	≤2.0
Hot Full Power Rod Insertion Limit (%Dq)	≤0.5
Power Defect (%Dq)	≤2.4
Xenon Worth	≤Table 3 (2)
Doppler Coefficient	Table 1 (2) (less negative)
Moderator Cooldown Curve	Figure 2 (2) (less negative)
Differential Boron Worth	Figure 3 (2) (more negative)
Scram Worth Data Uncertainty	≤10%
Moderator Data Uncertainty	≤10%
Doppler Data Uncertainty	≤20%
IBW Data Uncertainty	≤10.9%
Excess Scram Worth (T>200°F)	≥0.697% Dk/k
Excess Scram Worth (T\200°F)	≥1.468% Dk/k

Notes:

(1) This table allows cycle to cycle comparison of core reload physics parameters to those utilized in the boric acid concentration analyses.

(2) Extracted from bounding physics data provided by FPL and included as Appendix 5 of the base report. Uncertainties and cycle to cycle variations included in this data where applied in the conservative direction.

Appendix 9

Analysis of Peak Xenon Scenario

1.0 INTRODUCTION

This appendix presents the results of an analysis that is identical to that presented in Section 5.0 of the base report with the exception of how the xenon transient is accounted for. Similar analyses have been reviewed by other boric acid concentration reduction evaluations and are included here for consideration of the reactivity design basis of the plant (see Section 2.2.6 of the base report). The final RCS boron concentration required to maintain adequate shutdown margin is actually higher in this analysis, the peak xenon case establishes the boric acid tank inventory requirement. This is discussed in greater detail in the sections that follow. Table and figure numbers in this appendix are assigned in a manner that matches those in Section 5 of the base report. This allows direct comparison of the results of the two analyses.

2.0 BASIS

The basic differences between this analysis and the analysis of the base report is the following:

(1) the cooldown transient is initiated at eight hours of 24 hours (corresponding to the peak xenon condition instead of the full power equilibrium xenon concentration) and,

(2) the subsequent cooldown boration must compensate for the decay of the entire xenon inventory from its peak value (instead of its full power equilibrium value).

This scenario presents a worst case near the end of the cycle when sufficient RCS boron concentration (>0 ppm) is available to allow RCS boron concentration to be diluted by the operator to compensate for the post-shutdown xenon buildup in anticipation of a rapid return to power.

Starting a design basis cooldown to cold shutdown from the peak xenon condition under these conditions will effectively increase the amount of boron required to be charged to the RCS to compensate for the decay of the xenon peak back to its full power equilibrium value where the analysis of Section 5.0 of the base report started. This is a conservative assumption but is still achievable with reduced boric acid concentration and the appropriate balance of boration from the boric acid tank and the refueling water storage tank during cooldown (contraction makeup).

3.0 ANALYSIS SCENARIO

This scenario is suggested for analysis in response to the worst case shutdown, cooldown, and boration scenario presented in References 10.1 and 10.3 of the base report. Although it is a conservative assumption/ scenario it has been analyzed in a similar manner as the scenarios of Section 3.1 of the base report to assess the boration system capability with reduced boric acid concentration. Specifically, the boration required to maintain shutdown margin will be completed from the boric acid tank and refueling water storage tank in conjunction with the plant cooldown such that the volume of boric acid charged into the plant will make up for cooldown contraction. The proposed scenario for this analysis is discussed below:

SHUTDOWN AND COOLDOWN AT PEAK XENON

(1) The conservative physics parameters of the base report will be used to maximize the xenon and moderator cooldown reactivity effects.

(2) Reactor initially at hot full power (574.2°F), all rods out, equilibrium xenon at an equilibrium cycle exposure corresponding to a critical boron concentration of approximately 100-200 ppm. The boron concentration is arbitrarily chosen to allow for dilution to 0 ppm presenting the worst case (EOC) physics parameters.

(3) Reactor brought to hot zero power (547°F) with rods initiating xenon transient (increase).

(4) While at hot zero power (547°F), operator maintains criticality by diluting RCS boron to compensate for xenon buildup (anticipating a quick return to full power).

(5) At hot zero power (547°F), peak xenon condition, core is critical with approximately 0 ppm boron..

(6) Plant forced to go to cold shutdown (200°F): cooldown rates of 100°F/hr, 90°F/hr, 50°F/hr, 25°F/hr, and 10°F/hr will be analyzed.

(7) Zero RCS leakage (conservatively limits boron addition to contraction makeup).

(8) Boric acid tank and refueling water storage tank used to make up for RCS contraction during cooldown and to maintain shutdown margin.

4.0 ANALYSIS ASSUMPTIONS

Other than the variation in the treatment of xenon and the starting point of the cooldown transient, the assumptions for this analysis are identical to those presented in Section 4.0 of the base report.

5.0 ANALYSIS RESULTS

The analysis methodology is identical to that presented in Section 5.0 of the base report. The results of the peak xenon reactivity analysis are presented in Tables 5.1-1 through 5.1-6. Because the endpoint boron concentration requirement is higher in this scenario the value presented here is used as the basis for determining the minimum boric acid tank inventory. The boron delivery analysis of Section 5.2 is based on providing a 50 ppm margin over the minimum required cold shutdown boron concentration of 788 ppm.

Table 5.1-1

Required Boron Concentration vs. Temperature
Peak Xenon, Near EOC, 10°F/hr Cooldown Rate

Temperature (°F)	Required Boron (ppm)
572.0	-321.94
552.0	-222.14
532.0	-114.12
512.0	-10.00
492.0	85.31
472.0	171.90
452.0	250.19
432.0	320.79
412.0	384.39
392.0	441.72
372.0	493.48
352.0	540.34
332.0	582.90
312.0	621.71
292.0	657.25
272.0	689.94
252.0	720.14
232.0	748.16
212.0	774.26
202.0	786.67
200.0	789.10
200.0	726.54
200.0	788.15

Table 5.1-2

Required Boron Concentration vs. Temperature
Peak Xenon, Near EOC, 25°F/hr Cooldown Rate

Temperature (°F)	Required Boron (ppm)
572.0	-321.94
522.0	-91.31
472.0	90.91
422.0	227.79
372.0	336.66
322.0	428.35
272.0	509.38
222.0	583.32
200.0	614.08
200.0	551.52
200.0	788.15

Table 5.1-3

Required Boron Concentration vs. Temperature
Peak Xenon, Near EOC, 50°F/hr Cooldown Rate

Temperature (°F)	Required Boron (ppm)
572.0	-321.94
472.0	73.43
372.0	288.98
272.0	433.46
222.0	495.98
200.0	522.37
200.0	459.81
200.0	788.15

Table 5.1-4

Required Boron Concentration vs. Temperature
Peak Xenon, Near EOC, 90°F/hr Cooldown Rate

Temperature (°F)	Required Boron (ppm)
572.0	-321.94
482.0	39.94
392.0	241.61
302.0	370.69
212.0	474.27
200.0	487.07
200.0	424.51
200.0	788.15

Table 5.1-5

Required Boron Concentration vs. Temperature
Peak Xenon, Near EOC, 100°F/hr Cooldown Rate

Temperature (°F)	Required Boron (ppm)
572.0	-321.94
472.0	68.13
372.0	272.80
272.0	404.19
200.0	483.58
200.0	421.02
200.0	788.15

Table 5.1-6

Required Boron Concentration vs. Temperature
Mode 5 Cooldown to Refueling
(Near EOC Peak Xenon Scenario)

Temperature (°F)	Required Boron (ppm)
200 (Xenon Free)	788.15
180	803.68
160	819.21
140	834.74
135	838.62

Appendix 10

Computer Code Certificate and Input

COMBUSTION ENGINEERING

COMPUTER CODE CERTIFICATE

The following code, as noted by its name, version number, and permanent file identification, is hereby approved for design application.

Code Name BACR

Version Number REV. 00

Permanent File Identification BACR (00)

Computer IBM PC (OR IBM PC COMPATIBLE)

CODE CLASSIFICATION

- ☐ C-E Proprietary Code
- ☒ C-E Utility Code
- ☐ C-E NRC Approved Code
- ☐ Non C-E (State of the Art) Code

DESIGNATED PROGRAM ENGINEER

G.F. CARUTHERS 9421/Mechanical P & S — Manger & Dept/Section Name

9421-423 — CEP Code

Code Testing Completed By D. M. Hayes *D. M. Hayes* Date *10-10-86*

Independent Reviewer W. E. HIGGINS *W E Higgins* Date *10-13-86*

7/2/90 - FP&L - (120 F BAT AND RWST)
TURKEY POINT BORIC ACID CONCENTRATION REDUCTION EFFORT
EQUILIBRIUM XENON SCENARIO RWST AT 1950 PPM

TABLE I THROUGH TABLE X PARAMETERS

A	B	C	ROW #
RCS water volume	8,015.00000	cu.ft	9
MODES 1-4			10
Specific volume of			11
compressed water at			12
572 F & 2250 psia	0.02204	cu.ft./lbm	13
			14
PZR water vol.(100% POWER)	808.00000	cu.ft	15
			16
Specific volume of			17
saturated water at			18
2250 psia	0.02698	cu.ft./lbm	19
			20
Specific volume of			21
compressed water at			22
200F & 350 psia	0.01662	cu.ft./lbm	23
			24
RCS pressure	400.00000	psia	25
			26
PZR 0% POWER (MODES5-6)	520.00000	cu.ft.	27
			28
Specific vol. of water			29
200F & 14.7 psia	0.01664	cu.ft./lbm	30
			31
Specific vol. of			32
saturated water			33
@ 14.7 psia	0.01672	cu.ft./lbm	34
			35
RCS water volume	8,015.00000	cu.ft	36
MODES 5-6			37
			38
RCS MASS MODES 5-6	963,341.34615	LBM	39
			40
RWST temperature	120.00000	deg. F	41
			42
BAT temperature	120.00000	deg. F	43
			44
Density of water			45
at 120 F	8.24980	lbm/gal	46
			47
Mass of boric acid			48
per gal of solution			49
@ 120 deg F, 1950 PPM	0.09305	lbm	50
			51
			52
Density of water			53
@ 120 deg F	8.24980	lbm/gal	54
			55
Mass of boric acid			56
per gal of solution			57
@ 120 deg F, 3.5 wt.%	0.29922	lbm	58
			59
Mass of boric acid			60

A B C

A	B	C
per gal of solution à 120 deg F, 3.25 wt.%	0.27712	lbm
Mass of boric acid per gal of solution à 120 degF, 3.0 wt.%	0.25515	lbm
Mass of boric acid per gal of solution à 120 F, 2350 ppm	0.11240	lbm
Density of water at 120 deg.F	8.24980	lbm/gal
Mass of boric acid per gal of solution à 120 F, 2150 ppm	0.10271	lbm
Mass of boric acid per gal of solution à 120 F, 3.75 wt%	0.32142	lbm
Mass of boric acid per gal of solution à 120 F, 4.00 wt%	0.34374	lbm
INITIAL SYSTEM MASS	393,572.10027	lbm
CONVERSION FACTOR BETWEEN wt.% b/a & ppm boron	1,748.34000	ppm
RCS WATER MASS =MODES1-4	363,623.99056	lbm
PZR WATER MASS =MODES1-4 (à2250 psia)	29,948.10971	lbm
PZR WATER MASS =modes1-4 (à350 psia)	48,325.35885	lbm
PZR WATER MASS =modes5-6 (à14.7 psia)	31,100.47847	lbm
INITIAL TOTAL SYS MASS MODES 5-6	994,441.82462	LBM
Mass of boric acid per gal of solution à 120 F, 2.75 wt%	0.23328	lbm
Mass of boric acid per gal of solution à 120 F, 2.50 wt%	0.21153	lbm
INITIAL TOTAL SYS MASS		

A B C

MODES 5-6 after f&b	994,441.82462	LBM
TOTAL RCS/SDCS WATER MASS AT SDCS START	892538.9755	
TOTAL WATER MASS AT SDCS START	940864.33435	
A	B	C

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** TOTAL PAGE.005 **