DONALD C. COOK NUCLEAR PLANT

BORIC ACID CONCENTRATION REDUCTION

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AMERICAN ELECTRIC POWER SERVICE CORPORATION

COLUMBUS, OHIO

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1. INTRODUCTION AND DEFINITION OF TERMS

1.1 Introduction

The Donald C. Cook Nuclear Plant, constructed and operated by the American Electric Power Corporation, is located along the eastern shore of Lake Michigan in Bridgman, Berrien County, Michigan. The reactor is a closed-cycle, pressurized, light water moderated and cooled system, which uses slightly enriched uranium oxide fuel. The Unit 1 reactor is designed to produce 3250 $MW_{thermal}$ and Unit 2 is designed to produce 3411 $MW_{thermal}$. This report describes results of the analyses performed to modify the boration system technical specifications.

1.2 Definition of Terms

The following list of symbols, terms and abbreviations will be used consistently throughout this report:

BOL	:	Beginning of Life
MOL	:	Middle of Life
EOL	:	End of Life
MWD/MTU	:	Megawatt days per metric tonne of uranium metal (represents burnup of fuel)
RCCA	:	Rod Cluster Control Assemblies (type of control rods used)
T/S	:	Technical Specification
RTP	:	Rated Thermal Power

$\Delta\rho$	:	Change in reactivity ($\Delta\rho = \ln(k_1/k_2)$ where k_1 and k_2 are eigenvalues obtained from two calculations)
pcm	:	Percent mille (a reactivity change of 1 pcm equals a reactivity change of $10^{-5}\Delta\rho$)
step	:	A unit of control rod travel equal to 0.625 inch
ppm	:	Parts per million by weight (specifies chemical shim boron concentration)
HFP	:	Hot Full Power
HZP	:	Hot Zero Power
RCS	:	Reactor Coolant System
CVCS	:	Chemical and Volume Control System
RHR	:	Residual Heat Removal System
BAST	:	Boric Acid Storage Tank (High Boron Concentration Storage Tank)
RWST	:	Refueling Water Storage Tank (Low Boron Concentration Storage Tank)
LBLOCA	:	Large Break Loss of Coolant Accident
SBLOCA	:	Small Break Loss of Coolant Accident
SLBA	:	Steam Line Break Accident
PC-NDR	:	Personal Computer based Nuclear Design Report. Provides the user with reactivity coefficients, power distributions and contains procedures to determine shutdown boron / estimated critical positions.

2. BORATION SYSTEM TECHNICAL SPECIFICATION

2.1 Problem Description

The current Technical Specifications (T/S) require a boric acid storage tank (BAST) containing borated water at concentration between 20,000 ppm and 22,500 ppm of boron. This concentration and the current minimum BAST borated water volume of 5641 gal for Unit 1 and 4905 gal for Unit 2 are based on the ability to borate the reactor coolant system (RCS) to the required cold shutdown concentration through the feed and bleed process. Prior to commencing the cooldown, the RCS is borated to a concentration required to provide a shutdown margin of 1000 pcm at 68°F. In addition, the BAST water volume must provide blended makeup to compensate for coolant contraction that occurs during cooldown. RCS boron concentration is maintained constant during the cooldown process.

Since the concentration of borated water in the BAST is very high, the solution has to be kept at a high temperature of 145°F. This is accomplished through heat tracing of all associated tanks and pipes. This high concentration presently creates two major operational problems in the chemical and volume control system (CVCS). First, the high boric acid concentration causes accelerated Boric Acid Transfer Pump seal wear which requires additional maintenance and can result in pump inoperability. The heat tracing associated with the high

boric acid concentration also contributes to higher maintenance requirements through temperature degradation of the diaphragm valves associated with the boric acid system piping. In addition, the heat trace itself requires significant maintenance to keep it fully operational and much of this activity results in radiation exposure to the maintenance personnel. If a heat trace failure is undetected, the possibility of pipe blockage due to boric acid precipitation may render one of the flow paths inoperable, thus impacting safety system availability.

2.2 Problem Solution

Information regarding solubility of boric acid in water versus temperature of the solution for temperatures between 32°F and 160°F was obtained from reference 1. The solubility temperature of the solution with 4 weight percent (6990 ppm) boric acid is 58°F. Assuming a measurement uncertainty/conservatism of 5°F, solution temperature of 63°F is required to prevent precipitation. At or below a concentration of 4.0 weight percent, the normal ambient temperature in the auxiliary building will be sufficient to preclude precipitation within the boric acid makeup system. By reducing the concentration in the BAST to between 6550 ppm and 6990 ppm (between 3.5 and 4.0 weight percent), heat tracing problems can be avoided.

The reduction in BAST boron concentration is achieved by relying on both the BAST and the RWST for cooldown. Specifically, the BAST borated water is used for increasing the RCS boron concentration at hot conditions and the RWST borated water is used for overcoming coolant contraction. After reactor shutdown, boration through feed and bleed operation using BAST borated water is completed to satisfy the hot zero power shutdown margin requirement. This negative reactivity is introduced to compensate for the decrease in power and xenon decay. Water from the refueling water storage tank (RWST) is then used for coolant contraction.

Calculations were performed to determine the maximum volume of borated water required in the BAST to accomplish core boration to compensate for the above mentioned effects. To compensate for the reduced concentration, calculations were also performed to determine the minimum delivery volume flow rate from the BAST. For further cooldown, the RCS shrinkage mass is obtained from a second BAST, batching tank, or a combination of the two. In lieu of the boric acid storage tank system, the refueling Water Storage Tank (RWST) borated water can also be used for RCS boration for plant shutdown and cooldown. Calculations were performed to determine the amount of RWST borated water to compensate for the above mentioned reactivity effects.

3. SAFETY ANALYSIS CONCERNS

3.1 Large Break LOCA

The current Large Break Loss-of-Coolant Accident (LBLOCA) analysis of record for Cook Nuclear Plant was performed using the NRC approved Westinghouse ECCS Evaluation Model. The proposed reduction in the boron concentration in the BAST will not adversely affect the LBLOCA because the evaluation model codes used in analyzing the large break do not take credit for boron concentration in the BAST.

3.2 Small Break LOCA

The current Small Break Loss-of-Coolant Accident (SBLOCA) analysis of record for Cook Nuclear Plant was performed using NRC-approved SBLOCA ECCS evaluation model with NOTRUMP. The proposed reduction in the boron concentration in the BAST will not adversely affect the SBLOCA because the evaluation model codes used in analyzing the small break do not take credit for boron concentration in the BAST.

3.3 Steam Line Break

The steam line break accident (SLBA) was the only original design basis event that could have been significantly affected by the proposed reduction of the high concentration in the BAST, since the highly concentrated borated water initially found in the boron injection tank (BIT) was recirculated with

the borated water in the BAST. Reanalysis of the SLBA, however, was performed in 1991 using an NRC approved methodology to eliminate the BIT for high concentration boric acid injection. That is, pure water is currently assumed to be in the BIT. This reanalysis was submitted to the NRC on March 26, 1991 via letter AEP:NRC:1140. The NRC safety evaluation was obtained on November 20,1991 (amendment 158 for unit 1 and 142 for unit 2). As a result, the current SLBA is not affected by the proposed reduction in the BAST boron concentration.

3.4 Long Term Core Cooling

Since the solution stored in the BAST is not pumped into the RCS by the Emergency Core Cooling System during a Design Basis Accident, the change in BAST concentration will have no effect on this issue.

3.5 Reactivity Consideration

The Reactivity Holddown Capability Criterion in the UFSAR states: "The reactivity control systems provided shall be capable of making the core subcritical under credible accident conditions with appropriate margins for contingencies, and shall be capable of limiting any subsequent return to power such that there will be no undue risk to the health and safety of the public."

Normal reactivity shutdown capability is provided by control rods with boric acid injection used to compensate for long term xenon decay. Technical Specifications on BAST volume and boron concentration ensure that two flow paths and associated sources of borated water are available to maintain subcriticality. Therefore, calculations were performed to determine how much BAST and RWST water is required to counteract the reactivity increase due to reactor shutdown and subsequent xenon decay. Calculations were also performed to determine the required flow rate of the boric acid solution at the reduced boron concentration. The results of these calculations are presented in Section 4.0 of this report.

4.0 REACTIVITY CALCULATIONS

Several cooldown scenarios were investigated for both units and for several operating cycles (Reference 3 and 4). The purpose of the investigation was to determine the amount of boric acid in the BAST required to counteract positive reactivity addition due to reactor shutdown and xenon decay. For this, shutdown from a full power equilibrium xenon condition and shutdown from a 100% RTP, peak xenon condition were investigated to determine if the reduced concentration boric acid in the BAST was sufficient to keep the reactor subcritical at hot conditions even after xenon decay. Next, the rate of boron addition required to counteract xenon decay after reactor shutdown and to counteract xenon burnout during power operation after a startup at peak xenon were investigated. Finally, the boration requirements for cooldown below 200°F was investigated.

4.1 Design Requirements

- The amount of boric acid in the BAST must be sufficient to maintain the reactor subcritical by 1600 pcm at hot conditions following a reactor trip from all credible operating conditions. [Note that the control rods provide at least a shutdown margin of 1600 pcm ($k_{eff} \approx$ 0.984) immediately following a reactor trip from full power conditions assuming that the most reactive RCCA is fully withdrawn]. Or, in other words, sufficient borated water in the BAST must be available to compensate for

xenon decay.

- The flow rate of boric acid from the BAST must be sufficient to follow the highest burnout rate of xenon following reactor startup from peak xenon conditions.

4.2 Cooldown Shutdown Margin Requirement

To protect against the consequences of postulated increased steam loads with safeguards blocked below P-11 and P-12 (RCS temperature of approximately 541°F), it is a requirement at Cook Nuclear Plant that the RCS be borated to cold (68°F) shutdown boron conditions prior to cooldown below 541°F. Therefore, feed and bleed operation will be started at hot conditions before commencing cooldown. Once the required boron concentration is achieved in the RCS, then RWST water at 2400 ppm will be added for contraction makeup of the RCS mass due to cooldown. Calculations were performed to show that the addition of RWST water maintains the necessary shutdown boron concentration in the RCS.

Also, an inadvertent boron dilution event while shutdown and operating on the RHR system is of concern. Therefore, RCS boron concentration is increased (boron dilution penalty) to provide the operator sufficient time to identify and terminate the event. This boron dilution penalty is included in the shutdown boron values provided in the PC-NDR computer program (Reference 2).

[Note that these requirements are not T/S requirements but are administrative controls.]

4.3 Analysis Method

The amount of BAST boric acid required to increase the RCS boron concentration from critical boron concentration to hot shutdown boron concentration (i.e., boron concentration at 547°F with no xenon) by feed and bleed operation was calculated using the equation

$$C_{fb} = C_o \times e^{-\tau} + C_{BAST}(1-e^{-\tau}) \qquad (1)$$

where C_o - initial boron concentration

C_{fb} - final boron concentration after feed and bleed operation

C_{BAST} - boron concentration in BAST

$$\tau = \frac{(M_w)_{BAST}}{(M_w)_{RCS}}$$

M_w - mass of water

The amount of source water used for feed and bleed operation was calculated using the equation

$$V_{BAST} = V_{RCS} \times \frac{v_{BAST}}{v_{RCS}} \times \ln\left[\frac{C_{BAST}-C_o}{C_{BAST}-C_{fb}}\right] \qquad (2)$$

where V_{BAST} - volume of BAST water used for feed

and bleed operation.

V_{RCS} = volume of RCS

v_{RCS} = specific volume of RCS water

v_{BAST} = specific volume of BAST water

After feed and bleed operation to obtain the cold shutdown boron concentration, RWST water is added to the RCS to compensate for contraction due to cooldown. Final RCS concentration is calculated using the equation

$$C_{fs} = C_{fb} \times \frac{v_f}{v_i} + C_{RWST}(1-\frac{v_f}{v_i}) \qquad (3)$$

where C_{fs} = final RCS boron concentration

C_{RWST} = boron concentration in RWST

v_i = specific volume of RCS water before cooldown

v_f = specific volume of RCS water after cooldown

The mass of make-up water required was then calculated for cooldown to 350°F, 200°F and 68°F using the following equation

$$M_s = V_{RCS}\left(\frac{1}{v_f} - \frac{1}{v_i} \right) \qquad (4)$$

where M_s = Shrinkage mass

V_{RCS} - volume of RCS

The volume of make-up water was then calculated as follows.

$$V_s = M_s \times v_{RWST} \times (7.4805 gal/ft^3) \qquad (5)$$

where V_s - shrinkage volume in gallons

4.4 Reactor Trip from Full Power Equilibrium Xenon Conditions

In this calculation, it is assumed that the reactor is shutdown from full power, equilibrium conditions. All control and shutdown rods except the most reactive rod are assumed to be in the core. Shutdown boron values for no xenon conditions are obtained from the PC-NDR computer program. Shutdown boron calculated by the PC-NDR program include 100 ppm for conservatism and a Boron -10 depletion allowance. It should be noted that, in this calculation, T/S shutdown margin requirements are met; but other requirements noted in section 4.2 are not taken into account since additional administrative requirements are not needed to keep the reactor subcritical. The amount of boric acid solution from the BAST (6550 ppm) required to increase the RCS critical boron concentration to HZP shutdown boron concentration was then calculated. To show that there is enough RWST water available for further cooldown, calculations were performed using RWST water at a

lower boron concentration (2400 ppm) to compensate for shrinkage. The resulting RCS boron concentration due to the addition of RWST water was then calculated.

Results for Unit 1, Cycle 14 (BOL, MOL and EOL) are shown in tables 4.4.-1 through 4.4-3. Results for Unit 2, Cycle 10 (BOL, MOL and EOL) are shown in tables 4.4.-4 through 4.4-6. Values for Unit 2, cycle 10 are shown to be limiting compared to other cycles analyzed [Note that three cycles per unit were analyzed and the limiting cases are presented here]. Review of the data shows that, for any credible incident requiring reactor shutdown, the amount of boric acid solution available in the BAST should be 2939 gallons. There is also sufficient RWST water available in the event that cooldown is required.

4.5 Reactor Trip from Full Power Peak Xenon Conditions

In this case, it was assumed that the reactor is tripped from a peak xenon condition. That is, the reactor was assumed to be at full power approximately 8 hrs after a previous trip. In this condition, the RCS boron concentration will be at a minimum due to the xenon buildup from the earlier trip. Once the RCS is at this low boron concentration, the reactor is again assumed to trip, requiring RCS boron concentration to be increased to the no xenon, HZP shutdown boron concentration. Shutdown boron values for no xenon conditions are obtained from the PC-NDR computer program. Shutdown boron calculated

by PC-NDR program include 100 ppm for conservatism and a Boron -10 depletion allowance. It should be noted that in this calculation T/S shutdown margin requirements are met; but no other requirements, such as that noted in section 4.2, are taken into account since additional administrative requirements are not needed to keep the reactor subcritical. The amount of BAST boric acid solution at 6550 ppm required to increase the boron concentration to hot shutdown boron concentration by feed and bleed operations was then calculated. Finally, the amount of RWST water at 2400 ppm required for shrinkage due to cooldown to 68°F was calculated.

Results for Unit 1, cycle 14 (BOL, MOL and EOL) are shown in tables 4.5-1 through 4.5-3. Results for Unit 2, cycle 10 (BOL, MOL and EOL) are shown in tables 4.5-4 through 4.5-6. Review of the data shows that, even for a reactor trip from peak xenon conditions, the maximum amount of boric acid in the BAST required to keep the reactor at hot conditions with no xenon in the core is 6017 gallons. There is also sufficient RWST water available in the event that cooldown is required.

4.6 Normal Shutdown

The purpose of this section is to show that, for all expected normal shutdown scenarios, there is enough BAST borated water volume available to increase the RCS boron concentration by feed and bleed operation to cold shutdown boron concentration.

During a normal shutdown, the RCS boron is first increased to the shutdown boron concentration (i.e., shutdown boron corresponding to 547°F) by feed and bleed operation. Next, if a cooldown is to be conducted, the RCS boron concentration is increased to the cold shutdown boron concentration (i.e., shutdown boron corresponding to 68°F) via feed and bleed operation before blocking safeguards below P-11 and P-12 (i.e., before cooling below 541°F).

For normal shutdown, the pre-trip boron concentration will be that corresponding to the equilibrium xenon critical boron concentration for 100% RTP. This value is higher than that assumed for the peak xenon conditions. As a result, the RCS needs to be borated to a lesser extent than that described in section 4.5. Therefore, using available BAST borated water, RCS boron can be increased to that required for cold shutdown while staying at hot conditions. The required boron concentration at the cold condition is higher compared to that given in previous sections due to the boron dilution penalty which was discussed in section 4.2. [In the cases described in sections 4.4 and 4.5, cooldown to HZP T_{ave} was considered for shutdown margin requirements. Further cooldown calculations in sections 4.4 and 4.5 were performed to show that the volume of the RWST water is sufficient for coolant contraction and to keep the reactor subcritical.]

For cooldown below 541°F, the contraction volume is filled with water from the RWST and the resulting RCS boron concentration was checked to see that the RCS boron concentration is always above the required boron concentration.

Results for Unit 1, cycle 14 (BOL, MOL and EOL) are shown in Tables 4.6-1 through 4.6-3. Results for Unit 2, cycle 10 (BOL, MOL and EOL) are shown in Tables 4.6-4 through 4.6-6. From these tables, it can be seen that 7498 gallons of boric acid in the BAST is enough for borating the core to meet shutdown margin requirements. This calculation provides a rough idea of how much BAST boric acid solution will be used during normal operation.

4.7 Flow Rate Verification

Xenon Decay

Due to the reduction of the boric acid concentration in the BAST, calculations were performed to determine the BAST flow rate needed to counteract the xenon decay following shutdown. For this calculation, the reactor is assumed to be tripped from an equilibrium xenon condition. Table 4.7-1 shows the xenon decay rate for BOL, MOL and EOL for unit 2, cycle 10 [Note that calculations were performed for units 1 and 2 and only the worst case results are presented in this section]. From this table, it can be seen that the maximum decay rate is

183 pcm/hr. To counteract this xenon decay, it was found that the core has to be borated at approximately 24 ppm/hr. The flow rate necessary to increase RCS boron at this rate is approximately 6 gpm of BAST boric acid at 6550 ppm.

Xenon Burnout

Due to the reduced boric acid concentration in the BAST, calculations were also performed to determine the rate of BAST boric acid solution addition required to counteract xenon burnout. In this scenario, reactor startup is assumed 8 hrs after a previous trip.

For conservatism, a step jump to full power was assumed and the xenon that was built up due to the initial trip begins to burnout. The burnout rate for Unit 2 for cycle 10 is shown in Table 4.7-2 [Note that calculations were performed for units 1 and 2 and only the worst case results are presented in this section].

The maximum boration rate is approximately 137 ppm/hr. This translates to approximately 33 gpm of boric acid addition from BAST. Therefore, a conservative value of 34 gpm flow requirement is chosen.

4.8 Shutdown Boration Requirements (Modes 5 & 6)

Current technical specifications require us to maintain a

shutdown margin of 1600 pcm down to a temperature of 200°F and a shutdown margin of 1000 pcm below RCS temperature of 200°F. During a normal shutdown, the RCS boron concentration is first increased to the hot shutdown boron concentration (i.e., shutdown boron corresponding to 547°F) by feed and bleed operation. Next, if a cooldown is to be conducted, the RCS boron concentration is increased to the cold shutdown boron concentration (i.e., shutdown boron corresponding to 68°F) via feed and bleed operation before blocking safeguards below P-11 and P-12 (i.e., before cooling below 541°F). Because of this fact, there is no need for additional core boration for cooldown from 200°F to 68°F. The maximum amount of BAST water necessary for blending to compensate for the resulting shrinkage from 200°F to 68°F is 900 gallons. The maximum amount of RWST water necessary to compensate for the resulting shrinkage from 200°F to 68°F is 3264 gallons.

In Mode 6, with the reactor vessel head detensioned or removed, a boron concentration sufficient to ensure the more restrictive of the following reactivity conditions must be maintained: a k_{eff} of 0.95 or less, or 2400 ppm. With the high boric acid concentration in the RCS, the reactivity addition due to any postulated dilution accident is slow enough to allow the operator to determine the cause of the dilution and take corrective action before shutdown margin is lost.

4.9 Applicability for Future Cycles

Calculations were performed for Unit 1 cycles 12, 13 and 14 and for Unit 2 cycles 8, 9 and 10. These are representative of the cycles for Units 1 and 2. It should be noted that the required shutdown margin (as specified in the current T/S - reference 5 and 6) for these 6 cycles was 1600 pcm. New safety analysis for both units shows that only 1300 pcm is required and the T/S are being amended to reflect this change. Therefore, the calculations presented have a 300 pcm (~ 30 ppm) margin built into the analysis. This margin will take care of uprating or cycle length increase planned for the future. Also, for added conservatism the minimum amount of boric acid solution required has been increased from 6017 gallons to 8500 gallons for hot shutdown requirements. [It is also noted that 8500 gallons is sufficient to borate the RCS to cold shutdown (68°F) boron conditions with the BAST, should the operator choose to do this for normal shutdown situations.] Requirement for Modes 5 and 6 is increased from 900 gallons to 5000 gallons. These conservatisms are enough to conclude that future cycles of both units are enveloped with this analysis.

5.0 Operational Analysis

The impact on plant operations from a reduction in the boron concentration in the BAST is presented in this section.

5.1 Response to Emergency Situation

Return to criticality during the cooldown following a Steam Line Break Accident (SLBA) or a Steam Generator Tube Rupture (SGTR) event. Following a SLBA or SGTR, the plant procedures and instructions direct the operators to borate the RCS to maintain shutdown margin. The boration is to be performed from either the RWST or the BAST. Therefore, emergency procedures directing blender control settings will be modified to reflect the reduction in the BAST boron concentration.

5.2 Normal Boration

During a feed-and-bleed operation performed to increase the system boron concentration, the charging pumps are used to inject concentrated boric acid into the RCS. The rate of increase in boron concentration at any given point in time is proportional to the difference between the system concentration and the concentration of the charging fluid. Therefore, the normal operating procedures will be changed to reflect the reduction in the BAST boron concentration.

5.3 Technical Specification Changes

The technical specification (3.1.2.8) on borated water sources is changed to require 8500 gal of boric acid at a boron concentration between 6550 ppm and 6990 ppm. The calculations discussed in section 3.5 justify the changes in volume and concentration of borated water. The technical specifications for modes 1, 2, 3 and 4 were also changed to include a note for the BAST volume requirement stating that the volume of borated water is not required once the reactor is tripped and the borated water is injected into the RCS for boron concentration increase. The amount (8500 gal) of BAST water is required only in modes 1 & 2 in anticipation of a reactor shutdown and subsequent increase in reactivity due to xenon decay and cooldown. For modes 5 and 6, a lower amount (900 gal) is required to counteract volume shrinkage. This value is conservatively increased to 5000 gallons. Therefore, technical specification 3.1.2.7 is changed to reflect the change in volume and concentration.

The rate at which the borated water is injected into the RCS is increased from 10 gpm to 34 gpm. The calculations discussed in section 3.5 justify the acceptability of the change to the higher flow rate.

The requirement for heat tracing of the flow paths from the BAST is deleted and replaced with a requirement to monitor the ambient air temperature of the rooms containing the flow path components from the boric acid tank to the blending tee. The area temperature is to be greater than 63°F and is to be monitored once per 7 days.

A new flow rate surveillance requirement is introduced in T/S 3.1.2.2. Once per 18 months, the flow rate is to be verified to be greater than 34 gpm.

5.4 Modification to the Plant

The flow diagram for the boron makeup portion of the CVCS depicting the normal and emergency boration paths is shown in figure 5.4-1 (Unit 1) and figure 5.4-2 (Unit 2). Since the flow rate requirements (34 gpm) are higher at the reduced boron concentration, calculations were performed to determine whether the normal boration flow path (1" line) could tolerate the increased flow. The investigation showed high pressure drop at the control valve 1-QRV-411 (Unit 1) and 2-QRV-421 (Unit 2). These valves will, therefore, be modified to accommodate the increased flow rate. Other modifications to install area temperature monitoring will be also performed.

It should be noted that the electric heaters in the BAST and steam heating of the boric acid batching tank will no longer be required for system functionality but they may be maintained for other operational considerations.

5.5 Implementation

The reduction in the boric acid concentration of the BAST will be implemented once the T/S changes are approved and the valve modifications discussed in the previous section are completed. The reduction in boron concentration can be accomplished while the units are operating since the emergency boration paths are still available.

6.0 Summary

Boration calculations were performed for Units 1 and 2. Several cycles of operation was considered. The amount of borated water (at 6550 ppm) required to increase the RCS boron concentration to satisfy shutdown margin requirements was calculated. Also the required flow rate of the system was calculated.

7.0 References

1) U.S. Borax tech data sheet IP-14
   Boric Acid H_3BO_3 (Orthoboric Acid)

2) Personnel Computer D. C. Cook Operations Package user Manual, WCAP-10913

3) BAST Boron Concentration Reduction Project Calculation, FA-95-04

4) BAST Boron Concentration Reduction Project Calculation, FA-95-05

5) Technical Specification - Unit 1

6) Technical Specification - Unit 2

Table 4.4-1

Unit 1, Cycle 14 (BOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron - 1186 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1186	1186	6550(BAST)	0.0
350	1301	1376	2400(RWST)	12428
200	1318	1453	2400(RWST)	6820
68	1331	1485	2400(RWST)	3264

Total BAST volume used - 0.0 gal
Total RWST volume used - 22512 gal

Table 4.4-2

Unit 1, Cycle 14 (MOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 624 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	745	745	6550(BAST)	1383
350	932	1004	2400(RWST)	12428
200	958	1108	2400(RWST)	6820
68	979	1153	2400(RWST)	3264

Total BAST volume used = 1383 gal
Total RWST volume used = 22512 gal

Table 4.4-3

Unit 1, Cycle 14 (EOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 8 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	57	57	6550(BAST)	504
350	337	424	2400(RWST)	12428
200	393	572	2400(RWST)	6820
68	440	635	2400(RWST)	3264

Total BAST volume used = 504 gal
Total RWST volume used = 22512 gal

Table 4.4-4

Unit 2, Cycle 10 (BOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 1271 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1350	1350	6550(BAST)	1013
350	1424	1512	2400(RWST)	12264
200	1429	1579	2400(RWST)	6820
68	1429	1607	2400(RWST)	3264

Total BAST volume used = 1013 gal
Total RWST volume used = 22348 gal

Table 4.4-5

Unit 2, Cycle 10 (MOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 897 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1139	1139	6550(BAST)	2939
350	1284	1334	2400(RWST)	12264
200	1297	1414	2400(RWST)	6820
68	1307	1448	2400(RWST)	3264

Total BAST volume used = 2939 gal
Total RWST volume used = 22348 gal

Table 4.4-6

Unit 2, Cycle 10 (EOL)
Feed & Bleed from BAST/Refill from RWST
Critical Boron = 6 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	185	185	6550(BAST)	1863
350	460	527	2400(RWST)	12264
200	512	667	2400(RWST)	6820
68	554	727	2400(RWST)	3264

Total BAST volume used = 1863 gal
Total RWST volume used = 22348 gal

Table 4.5-1

Unit 1, Cycle 14 (BOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP; Peak Xenon
Critical Boron = 930 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1179	1179	6550(BAST)	3037
350	1301	1370	2400(RWST)	12428
200	1318	1447	2400(RWST)	6820
68	1331	1480	2400(RWST)	3264

Total BAST volume used = 3037 gal
Total RWST volume used = 22512 gal

Table 4.5-2

Unit 1, Cycle 14 (MOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Peak Xenon
Critical Boron = 350 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	745	745	6550(BAST)	4411
350	932	1004	2400(RWST)	12428
200	958	1108	2400(RWST)	6820
68	979	1153	2400(RWST)	3264

Total BAST volume used = 4411 gal
Total RWST volume used = 22512 gal

Table 4.5-3

Unit 1, Cycle 14 (EOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Peak Xenon
Critical Boron = 8 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	369	369	6550(BAST)	3804
350	369	687	2400(RWST)	12428
200	393	815	2400(RWST)	6820
68	440	870	2400(RWST)	3264

Total BAST volume used = 3804 gal
Total RWST volume used = 22512 gal

Table 4.5-4

Unit 2, Cycle 10 (BOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Peak Xenon
Critical Boron - 1044 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1350	1350	6550(BAST)	3841
350	1429	1512	2400(RWST)	12264
200	1429	1579	2400(RWST)	6820
68	1429	1607	2400(RWST)	3264

Total BAST volume used - 3841 gal
Total RWST volume used - 22348 gal

Table 4.5-5

Unit 2, Cycle 10 (MOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Peak Xenon
Critical Boron = 632 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1139	1139	6550(BAST)	6017
350	1284	1334	2400(RWST)	12264
200	1297	1414	2400(RWST)	6820
68	1307	1448	2400(RWST)	3264

Total BAST volume used = 6017 gal
Total RWST volume used = 22348 gal

Table 4.5-6

Unit 2, Cycle 10 (EOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Peak Xenon
Critical Boron = 6 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	518	518	6550(BAST)	5473
350	518	808	2400(RWST)	12264
200	518	928	2400(RWST)	6820
68	554	979	2400(RWST)	3264

Total BAST volume used = 5473 gal
Total RWST volume used = 22348 gal

Table 4.6-1

Unit 1, Cycle 14 (BOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 1186 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1552	1552	6550(BAST)	4736
350	1552	1685	2400(RWST)	12428
200	1552	1738	2400(RWST)	6820
68	1552	1761	2400(RWST)	3264

Total BAST volume used = 4736 gal
Total RWST volume used = 22512 gal

Table 4.6-2

Unit 1, Cycle 14 (MOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 624 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1067	1067	6550(BAST)	5207
350	1067	1276	2400(RWST)	12428
200	1067	1360	2400(RWST)	6820
68	1067	1396	2400(RWST)	3264

Total BAST volume used = 5207 gal
Total RWST volume used = 22512 gal

Table 4.6-3

Unit 1, Cycle 14 (EOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 8 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	440	440	6550(BAST)	4578
350	440	747	2400(RWST)	12428
200	440	870	2400(RWST)	6820
68	440	923	2400(RWST)	3264

Total BAST volume used = 4578 gal
Total RWST volume used = 22512 gal

Table 4.6-4

Unit 2, Cycle 10 (BOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 1271 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1667	1667	6550(BAST)	5238
350	1667	1780	2400(RWST)	12264
200	1667	1827	2400(RWST)	6820
68	1667	1846	2400(RWST)	3264

Total BAST volume used = 5238 gal
Total RWST volume used = 22348 gal

Table 4.6-5

Unit 2, Cycle 10 (MOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 897 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	1494	1494	6550(BAST)	7498
350	1494	1634	2400(RWST)	12264
200	1494	1691	2400(RWST)	6820
68	1494	1716	2400(RWST)	3264

Total BAST volume used = 7498 gal
Total RWST volume used = 22348 gal

Table 4.6-6

Unit 2, Cycle 10 (EOL)
Feed & Bleed from BAST/Refill from RWST
Reactor Trip from 100% RTP, Equilibrium Xenon
Critical Boron = 6 ppm

RCS Tave °F	Required Shutdown Boron Concentration ppm	RCS Boron Concentration after Feed & Bleed/Refill ppm	Source Boron Concentration ppm	Amount of Source Boric Acid Used Gal
547	554	554	6550(BAST)	5875
350	554	839	2400(RWST)	12264
200	554	956	2400(RWST)	6820
68	554	1006	2400(RWST)	3264

Total BAST volume used = 5875 gal
Total RWST volume used = 22348 gal

Table 4.7-1
Unit 2
Reactor Trip from 100% hr., Equilibrium Xenon
Xenon Decay Rate

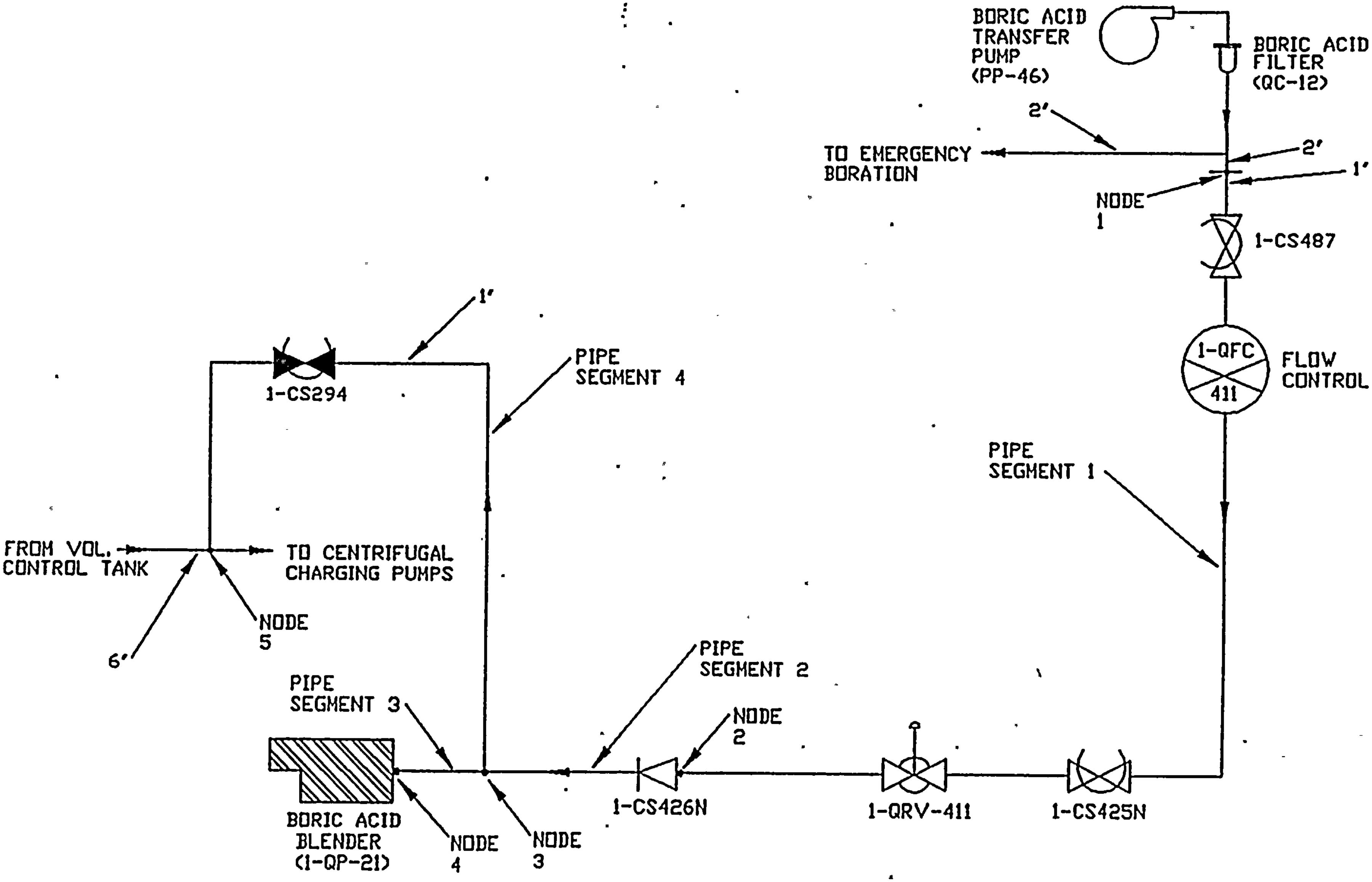
Cycle No./Burnup	Reactivity Increase due to Xenon Decay - pcm/hr	Required Boration ppm/hr
10/BOL	145	19.
10/MOL	159	20.
10/EOL	183	24.

Table 4.7-2
Unit 2
Reactor Startup at Peak Xenon Conditions
BAST Boration Rate

Cycle No./Burnup	Reactivity Increase due to Burnup pcm/hr	Required Boration ppm/hr
10/BOL	914	117
10/MOL	1079	127
10/EOL	1391	137

Fig 5.4-1

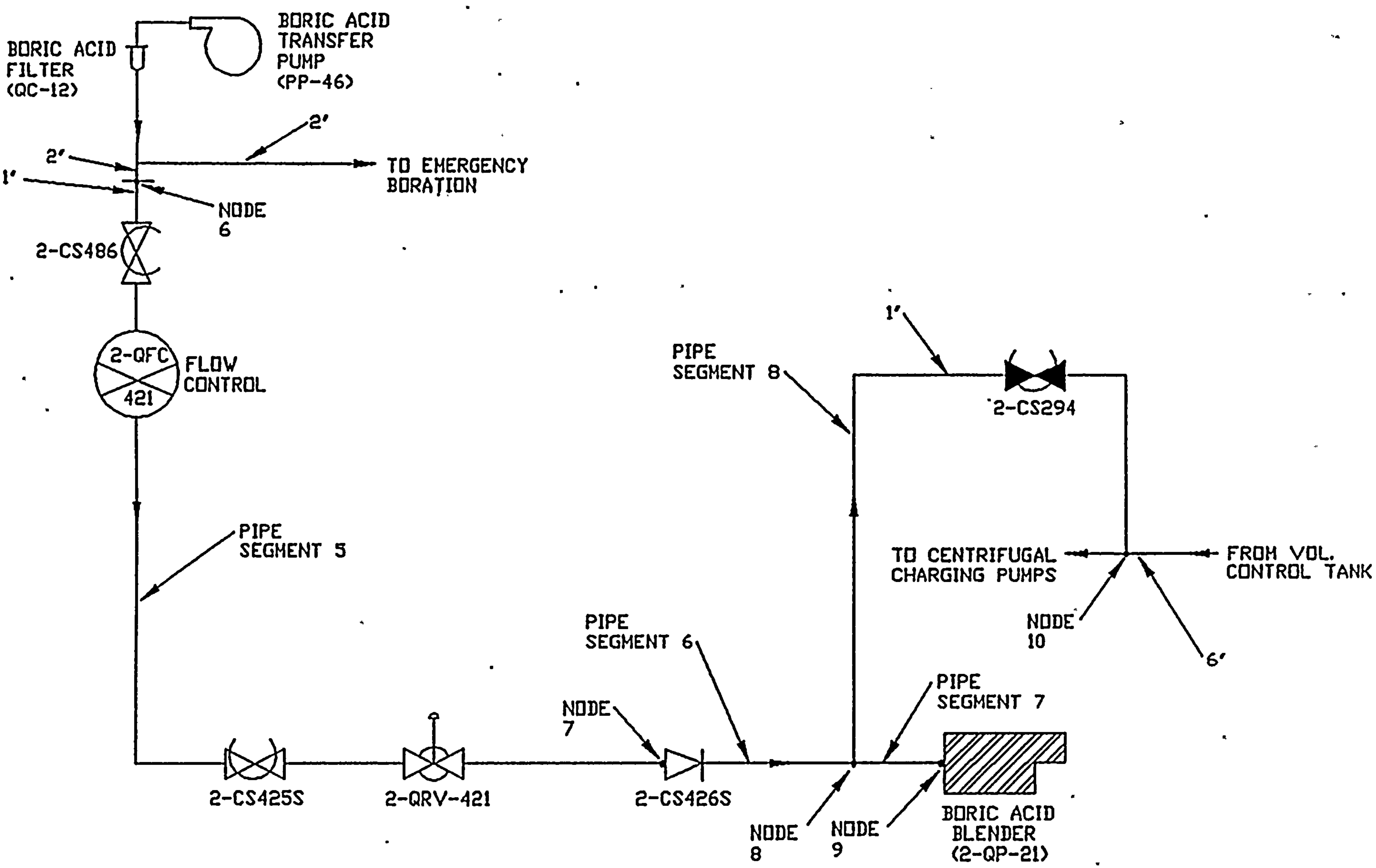
UNIT 1 - CVCS
(FLOW DIAGRAMS 12-5131, 1-5129)



SYSTEM ENGINEER: J. SATIN
SKETCHED BY: B. HANNIGAN

Fig 5.4-2

UNIT 2 - CVCS
(FLOW DIAGRAMS 12-5131, 2-5129)



SYSTEM ENGINEER: J. SATIN
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