ENERGY NORTHWEST People · Vision · Solutions	CALCULATION COVER SHEET	BDC/PDC Page

Equipment Piece No.	Project Columbia	Page 1.0 — Cont'd on Page 1.1
Containment	Discipline Nuclear	Calculation No. NE-02-03-15
		Quality Class 1
	Remarks Non-Proprietary Version	

TITLE/SUBJECT/PURPOSE

Title/Subject

POST-LOCA SUPPRESSION POOL pH

Purpose

The purpose of this calculation is to determine the pH of the Columbia Generating Station containment water pool as a function of time following a DBA-LOCA during the initial phase of the accident prior to the addition of sodium pentaborate via the SLC system (Part A), and out to 30 days after the addition of sodium pentaborate (Part B).

CALCULATION REVISION RECORD

REV NO.	STATUS/ F,P, OR S	REVISION DESCRIPTION	INITIATING DOCUMENTS	TRANSMITTAL NO.
0	F	ORIGINAL ISSUANCE	PDC 2406 2406	

PERFORMANCE/VERIFICATION RECORD

REV NO.	PERFORMED BY/DATE	VERIFIED BY/DATE	APPROVED BY/DATE
0	J. Metcalf James Metcalf 7/21/04	R. Hobbins RR Hobbins 7/23/04	R. Hobbins RR Hobbins 7/23/04

* Study Calculations shall be used only for the purpose of evaluating alternate design options or assisting the engineer in performing assessments.

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Calculation/CMR NE-02-03-15 Revision 0
was verified using the following methods:

☒ Checklist Below ☐ Alternate Calculation(s)

Checklist Item	Verifier Initials
Clear statement of purpose of analysis	RRH
Methodology is clearly stated, sufficiently detailed, and appropriate for the proposed application	RRH
Does the analysis/calculation methodology (including criteria and assumptions) differ from that described in the Plant or ISFSI FSAR or NRC Safety Evaluation Report, or are the results of the analysis/calculation as described in the Plant or ISFSI FSAR or NRC Safety Evaluation Report affected? ☒ Yes ☐ No PIL # 205295	LSW
If Yes, ensure that the requirements of 10 CFR 50.59 and/or 10 CFR 72.48 have been processed in accordance with SWP-LIC-02	LSW
Does the analysis/calculation result require revising any existing output interface document as identified in DES-4-1, Attachment 7.3? ☒ Yes ☐ No	LSW
If Yes, ensure that the appropriate actions are taken to revise the output interface documents per DES-4-1, section 3.1.8 (i.e., document change is initiated in accordance with applicable procedures)	LSW
Logical consistency of analysis	LSW
• Completeness of documenting references	RRH
• Completeness of input	RRH
• Accuracy of input data	RRH
• Consistency of input data with approved criteria	RRH
• Completeness in stating assumptions	RRH
• Validity of assumptions	RRH
• Calculation sufficiently detailed	RRH
• Arithmetical accuracy	RRH
• Physical units specified and correctly used	RRH
• Reasonableness of output conclusion	RRH
Supervisor independency check (if acting as Verifier)	NA
- Did not specify analysis approach - Did not rule out specific analysis options - Did not establish analysis inputs	NA
If a computer program was used:	LSW
- Is the program appropriate for the proposed application? YES - Have the program error notices been reviewed to determine if they pose any limitations for this application? NA - Is the program name, revision number, and date of run inscribed on the output? YES - Is the program identified on the Calculation Method Form? YES If so, is it listed in Chapter 10 of the Engineering Standards Manual? NA	RRH
Other elements considered:	

If separate Verifiers were used for validating these functions or a portion of these functions, each sign and initial below.

Based on the foregoing, the Calculation/CMR is adequate for the purpose intended.

Verifier Signature(s)/Date	Verifier Initials
RR Hobbins 7/23/04	RRH
~~[illegible]~~ [signature] 8/2/04	LSW

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Prepared by / Date: JSM 7/21/04	RRHobbins Verified by/Date: 7/23/04	Revision No.	0

NO	AUTHOR	ISSUE DATE/ EDITION OR REV.	TITLE	DOCUMENT NO.
1	Polestar Applied Technology, Inc.	February 16, 2000	STARpH Code Description and Validation and Verification Report	PSAT C107.02, Revision 4
2	Polestar Applied Technology, Inc.	Revision 0	Dose Calculation Data Base	NE-02-04-01
3	E. C. Beahm, et al.	December, 1992	Iodine Evolution and pH Control	NUREG/CR-5950
4	Arakawa, et al	1986	Radiat. Phys. Chem., Vol. 27, pp. 157-163	
5	Polestar Applied Technology, Inc.	April, 1996	Calculation of Fraction of Containment Aerosol Deposited in Water (Perry)	PSAT 04202H.12
6	US Nuclear Regulatory Commission	July 2000	Alternative Radiological Source Terms For Evaluating Design Basis Accidents At Nuclear Power Reactors	RG 1.183
7	R. R. Hobbins	October 23, 1997	Chemical Forms of Iodine and Cesium in the Reactor Coolant System	Polestar Applied Technology, Inc., Proprietary Memorandum
8	R. R. Hobbins	April, 2001	Effect of Boric Acid on Cesium Chemistry and pH	Polestar Applied Technology, Inc., Proprietary Memorandum
9	R. R. Hobbins	October 31, 1998	Behavior of Sodium Pentaborate Introduced into a Hot Core	Polestar Applied Technology, Inc., Proprietary Memorandum
10	D. R. Lide, CRC Press	77th Edition, 1996	Handbook of Chemistry and Physics	
11	K. Denbigh, Cambridge University Press	1957	The Principles of Chemical Equilibrium	
12	E. C. Beahm, et al.	April 1992	Iodine Chemical Forms in LWR Severe Accidents	NUREG/CR-5732, ORNL
13	Energy Northwest	November 1998	Columbia Generating Station Final Safety Analysis Report, Figure 6.2-9, Suppression Pool Temperature Response, Long-Term Response – Original Rated Power	Amendment 53

NO	AUTHOR	ISSUE DATE/ EDITION OR REV.	TITLE	DOCUMENT NO.
14	Hill and Petrucci, Prentice-Hall, Inc.	2002	General Chemistry, Third Edition	
15	R. Sher	October 15, 2001	Energy Split 7.xls 1	Polestar Applied Technology, Inc.
16	R. Sher	October 12, 2001	EnergyDeposition.xls	Polestar Applied Technology, Inc.
17	J. Wing	September, 1984	Post-Accident Gas Generation from Radiolysis of Organic Materials	NUREG-1081
18	R. R. Hobbins	September 11, 2000	Effect of Temperature on the Dissociation Constant of a Weak Acid	Polestar Applied Technology, Inc., Proprietary Memorandum
19	C. F. Bonilla, McGraw-Hill	1957	Nuclear Engineering	
20	Robert M. Bernero	May 16, 1984	Enclosure 4 to "Memorandum for February 7-8 NRC/IDCOR Attendees, Summary of NRC/IDCOR Meeting on Fission Product Release and Transport"	
21	J. R. Lamarsh, Addison-Wesley	1983	Introduction to Nuclear Engineering, Second Edition	

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Prepared by / Date: [signature] 7/21/04	RB Hobbs Verified by/Date: 7/23/04	Revision No. 0	

The below listed output interface calculations and/or documents are impacted by the current revision of the subject calculation. The listed output interfaces require revision as a result of this calculation. The documents have been revised, or the revision deferred with Manager approval, as indicated below.

AFFECTED DOCUMENT NO.	CHANGED BY (e.g., BDC, SCN, CMR, Rev.)	CHANGED DEFERRED (e.g., RFTS, LETTER NO.)	DEPT. MANAGER *
FSAR 15.6.5	PDC 2406		

* Required for deferred changes only.

REV BAR.

Discussion of Results

Part A

In the short-term following a DBA-LOCA, the pH of water inside the Columbia Generating Station containment (suppression pool, vessel, and other bodies assumed well-mixed) will be increased from an initial value of 5.3 to a value above 7 due to the addition of fission product cesium. Depending on the form of the fission product cesium (e.g., $CsOH$ or $CsBO_2$), the pH will eventually drop below 7 as HNO_3 (from radiolysis of water) and HCl (from radiolysis of cable) are added to the water. The pH is expected to remain above 7 for sufficient time to permit injection and mixing of the Standby Liquid Control (SLC) sodium pentaborate (see Justification for Assumption 4).

Part B

In the long-term (30 days), the pH of the containment water decreases from a peak of ~8.4 as shown in the following table (assuming all sodium pentaborate in the SLC system is injected but no credit for fission product cesium):

pH results vs. time

Time	pH
18h	8.3
45h	8.2
76h	8.1
112h	8.0
160h	7.9
210h	7.8
275h	7.7
360h	7.6
480h	7.5
600h	7.4
720h	7.3

If as little as 95% of the sodium pentaborate is injected and/or mixes with the containment water, the containment water pH will remain greater than 7 for 30 days.

Conclusions

Part A

The pH of the containment water pool in the Columbia Generating Station will remain above 7 for approximately 8 hours after the release of radioactivity into the containment following a DBA-LOCA without sodium pentaborate credit assuming cesium is released in the form of CsOH. Therefore, there will be sufficient time to inject the sodium pentaborate from the SLC system and to have the sodium pentaborate mix with the containment water.

Part B

The pH of the containment water pool in the Columbia Generating Station decreases from 8.4 to 7.3 over 30 days following the release of fission products into the containment for a DBA-LOCA given the addition of all SLCS sodium pentaborate. Only 95% of the total boron available is necessary to maintain pH $\geq$ 7 for 30 days.

Prepared by / Date: [signature] 7/21/04 | [signature] RR Hobbin Verified by/Date: 7/23/04 | Revision No.

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Analysis Method (Check appropriate boxes)

☐ Manual (As required, document source of equations in Reference List)

☒ Computer ☐ Main Frame ☒ Personal

☐ In-House Program

☐ Computer Service Bureau Program

☐ BCS ☐ CDC ☐ PCC ☐ OTHER ______________

☒ Verified Program: Code name/Revision STARpH, Version 1.04

☐ Unverified Program: ______________

Approach/Methodology

Methodology

There are two parts to this analysis. The first part (Part A) deals with the determination of the short-term pH (prior to injection and mixing of the sodium pentaborate injected by the SLC system). In this part, fission product cesium is credited to be in the form of hydroxide in terms of its effect on maintaining suppression pool pH above 7. The second part (Part B) deals with the determination of the long-term pH (up to 30 days post-accident), crediting the injected sodium pentaborate but not crediting fission produce cesium (except for the minor effect of neutralizing the initial pool pH and fission product HI).

In completing both Parts A and B of the analysis, Steps 1 through 3 are employed. Step 4 is used only for Part B.

1. Calculate the $[HNO_3]$ concentration in the water pool as function of time after reactor scram using the Radiolysis of Water model of the STARpH 1.04 code (Reference 1).
2. Calculate the [HCl] concentration in the water pool as a function of time using the Radiolysis of Cable model of the STARpH 1.04 code (Reference 1).
3. Manually calculate the $[H^+]$ concentration added to the pool as a function of time from the results of the two previous calculations.
4. Calculate the pH of the water pool considering the concentration of sodium pentaborate in the pool and $[H^+]$ additions as a function of time using the Add Acid model of the STARpH 1.04 code (Reference 1).

In both Parts A and B, the following chemical reactions in containment water are considered (in the presence of radiation):

- $[H^+] + [NO_3^-]$ is produced by the radiolysis of water containing dissolved nitrogen, but the exact mechanism is not known (per Section 2.2.4 of Reference 3).
- $2[H_2O] + 2[Cl_2] \rightarrow 2[H+] + 2[Cl-] + 2[HOCl] \rightarrow 4[H+] + 4[Cl-] + [O_2]$ (from chlorine gas being released from radiolysis of fire retardant cable insulation in the containment atmosphere and then dissolving in the water)

In Part A, the following additional chemical reactions are considered:

- $[HXX] \rightarrow [H+] + [XX-]$ (from initial pool pH, where HXX is any acid that may be present)
- $[HI] \rightarrow [H+] + [I-]$ (from fission product iodine being released in the form of HI)
- $[CsOH] \rightarrow [Cs+] + [OH-]$ (from fission product cesium being released in the form of CsOH)

In Part B, the following additional chemical reaction is considered:

- $[Na_2O\text{-}5B_2O_3\text{-}10H_2O] \rightarrow 2[NaBO_2] + 8[HBO_2] + 6[H_2O] \leftrightarrow 2[Na+] + 8[H+] + 10[BO_2\text{-}] + 6[H_2O]$ (from injected sodium pentaborate which mixes with recirculated water from the containment)

NOTE THAT THE EQUATIONS REPRESENTING THE METHODOLOGY DESCRIBED IN THIS SECTION ARE PRESENTED AS THEY ARE USED IN THE CALCULATION SECTION.

REV BAR.

Design Inputs

Items 1-4, and 6-14 are from Reference 2 (Item numbers are stated). Other items are as noted.

1. Reactor power = 3556 MWt (Item 1.1)
2. Volume of water in wetwell = 137,262 ft^3 (Item 3.3)
3. RCS inventory = 6.59E5 lbm (Item 8.22)
4. Pool initial pH = 5.3 (Item 6.1)
5. Fission product inventory, see Assumption 1
6. Mass of jacket = 1.673E6 g of Hypalon, 0.798E6 g of Neoprene (Item 6.2)
7. Density of jacket = 1.55 g/cm^3 for Hypalon, 1.42 g/cm^3 for Neoprene (Reference 30 of Reference 2 and Reference 17)
8. Thickness of jacket = 0.107 cm for Hypalon, 0.106 cm for Neoprene (Item 6.3)
9. Cable OD = 2.980 cm for Hypalon, 0.589 cm for Neoprene (Item 6.3)
10. Drywell free volume = 200,540 ft^3 (Item 3.1)
11. Wetwell free volume = 144,184 ft^3 (Item 3.2)
12. Mass of sodium pentaborate available for injection = 4,062.8 lbm (Item 6.4)
13. Chemical formula for sodium pentaborate = $Na_2O \cdot 5B_2O_3 \cdot 10H_2O$ (Item 6.5)
14. Boron enrichment in sodium pentaborate is natural (Item 6.5)
15. G-factor for Hypalon = 2.1 molecules/100 eV (Reference 3)
16. G-factor for Neoprene = 3.5 molecules/100 eV (Reference 4)

Proprietary Information Deleted

Assumption 3: The SLCS is actuated and the sodium pentaborate is injected and mixed with the pool within ~8 hours of accident initiation.

Justification: A core damage event large enough to release the substantial quantities of fission products in the time frame considered for the alternative source term in Reference 6 will be very evident to the operators (e.g., radiation level in the drywell, pressure and temperature in the drywell, hydrogen level in the drywell) within minutes of the initiating event. Thus it is reasonable to assume for purposes of this calculation that the Columbia EOPs and SAMGs provide for SLCS actuation within a few hours of accident initiation.

If SLCS injection is into the pool (i.e., into the reactor vessel with the vessel communicating with the pool as in a recirculation line break), significant mixing will occur quickly, on the order of a few hours based on an RHR/drywell spray flow rate of ~7450 gpm and a pool volume of ~1E6 gallons per Reference 2 (about 0.5 pool volume/hour).

REV BAR.

If the reactor vessel is not immediately communicating with the pool, some additional hours might be required before the operators flood the vessel up to the break to assure communication with the pool or inject sodium pentaborate to the pool via alternate paths.

Assumption 4: The unbuffered pH of the pool should remain above 7 for a period of time sufficient to accommodate injection and mixing even if some fission product cesium appears in forms other than CsOH (the form assumed by default in STARpH).

Justification:

Proprietary Information Deleted

Assumption 6: Injected sodium pentaborate will remain effective in controlling pool pH even if it is sprayed onto hot surfaces.

Justification:

Proprietary Information Deleted

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Assumption 7: The G value for HNO_3 production by the radiolysis of water containing dissolved nitrogen used in the STARpH 1.04 code is 0.007 molecules per 100 eV absorbed (Reference 3, Equation 1).

Justification:

Proprietary Information Deleted

Assumption 8: Beta radiation from activity deposited directly on cables may be ignored.

Justification:

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Assumption 9: HNO_3 generation in the core may be ignored.

Justification:

Proprietary Information Deleted

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Assumption 10: Sequestering of the injected sodium pentaborate within the reactor vessel does not have to be assumed in the pH analysis.

Justification: The SLC injects boron solution via the HPCS line to the top of the core region. The AST DBA-LOCA analysis assumes an ECCS system recovery after sufficient core damage has occurred. For a DBA-LOCA of the recirculation piping, water level is recovered at least to the top of the jet pumps providing water to 2/3 core height and circulation via the bypass region to the break area. For a break high in the vessel, such as the MSLB inside containment, the operators are instructed to flood the vessel, permitting ECCS flow to communicate through the break, to the downcomers, and to the suppression pool. Mixing in the suppression pool is promoted by the ECCS system suction points being approximately 17 feet below the downcomer outlets. Therefore, the warmer water from the vessel tends to rise while the suction is from the cooler, heavier water in the bottom establishing circulation and mixing in the suppression pool.

Assumption 11: The SLC system is adequately qualified and suitably redundant as a system to be credited in DBA-LOCA dose analysis.

Justification: Equipment Qualification

Based on the ability of the fission product cesium to maintain suppression pool pH above 7 for a period of ~8 hours, it is judged that the SLC system will have completed its DBA-LOCA safety function within that time.

The active components of the SLC system are being qualified to DBA-LOCA with seismic qualification [Reference Columbia MEL]. The system is being qualified to operate 24 hours in a LOCA environment.

Suitable Redundancy

At the time of this calculation, the NRC guidance on the requirements for SLC to be credited in a DBA-LOCA is a draft document to Vermont Yankee. ENW has evaluated these requirements and found SLC meets the draft requirements. A submittal position on the use of SLC will be provided. Since the requirements and submittal position are draft, no reference is provided. Any change to the acceptability of the SLC system upon NRC review may impact this analysis.

Calculation

Computations Common to Parts A and B

Calculation of [HNO_3] in water pool as a function of time

The Radiolysis of Water model in the STARpH 1.04 code (Reference 1) calculates the nitric acid concentration, [HNO_3], in the containment water pool generated by radiolysis.

Inputs to the Radiolysis of Water model are: reactor power = 3556 MWt, initial pH = 5.3, fraction of aerosol in water = 0.90 (Assumption 2), water pool volume = 4.18E6 L (calculated below), and core inventory of fission products (in Table 1 below)

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Table 1. Fission product inventory

Group Title	Elements in Group	Core Inventory (Kg)
I	I, Br	32.7
Cs	Cs, Rb	359
Te	Te, Sb, Se	68.9
Sr	Sr	94.3
Ba	Ba	158
Ru	Ru, Rh, Mo, Tc, Pd	981
Ce	Ce	1,342
La	La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y	1,243

Total containment water volume = water volume of wetwell + RCS volume

Water volume of wetwell = 137,262 ft^3 • 2.83E1 L/ft^3 = 3.88E6 L

RCS volume = 6.59E5 lbm / 61.7 lbm/ft^3 • 2.83E1 L/ft^3 = 3.0E5 L

where 61.7 lbm/ft^3 = density of water in the suppression pool at 120 F (a representative value from Reference 13).

Total containment water volume = 3.88E6 L + 3.0E5 L = 4.18E6 L

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The output of the calculation with the Radiolysis of Water model in the form of [HNO_3] as a function of time is provided as Appendix A, Exhibit 1. The time-dependent gamma and beta power added to the pool is shown on Figure F-1 of Appendix F expressed as % of full core power. The integrated 30-day absorbed energy in the containment water (contributing to [HNO_3]) is 261 full-power seconds.

Calculation of [HCl] in water pool as a function of time

The concentration of HCl in the water pool as a result of radiolysis of electrical cable insulation is calculated using the Radiolysis of Cable model of the STARpH 1.04 code (Reference 1). The inputs to the Radiolysis of Cable model are: reactor power = 3556 MWt, water pool volume = 4.18E6 L (calculated above), aerosol fraction in pool = 0.90 (Assumption 2), equivalent mass of Hypalon jacketing = 6,615 lbm (calculated below), containment free volume = 9.76E9 cm^3 (calculated below), **Proprietary Information Deleted**

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Containment free volume = free volume of wetwell + free volume of drywell
$= 144{,}184\ ft^3 + 200{,}540\ ft^3$
$= 344{,}724\ ft^3 \cdot (12\ in/ft)^3 \cdot (2.54\ cm/in)^3$
$= 9.76E9\ cm^3$

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The output of the calculation with the Radiolysis of Cable model in the form of [HCl] as a function of time is provided as Appendix B, Exhibit 2. The time-dependent power absorbed in the cable insulation jacket material (in Rads/hr) is presented in Appendix F, Table F-1. The integrated value over 30 days is 6.1E8 Rads.

<u>Calculation of [H^+] added to the pool</u>

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Table 2. Calculation of [H^+] added to pool (all values in mol/L)

Time	1 [HNO_3]	2 Net [OH^-]	3 [HCl]	4 [H^+] Added	5 Net [H^+] Added
1h	5.79E-06	1.17E-04	1.99E-05	2.57E-05	-9.71E-05
2h	7.95E-06	1.15E-04	3.75E-05	4.54E-05	-7.75E-05
5h	1.24E-05	1.11E-04	8.05E-05	9.29E-05	-3.05E-05
12h	1.97E-05	1.03E-04	0.000153	1.73E-04	5.00E-05
1d	2.94E-05	9.37E-05	0.000243	2.72E-04	1.49E-04
3d	5.67E-05	6.63E-05	0.000489	5.46E-04	4.23E-04
10d	1.07E-04	1.56E-05	0.000818	9.25E-04	8.02E-04
20d	1.40E-04	-1.70E-05	0.000933	1.07E-03	9.50E-04
30d	1.61E-04	-3.80E-05	0.000967	1.13E-03	1.00E-03

Part A – Short-Term pH Calculation

In the short-term, one is interested only in suppression pool pH without injection of sodium pentaborate. Observing Table 2 Column 5 "Net [H^+] Added" (the result of subtracting Column 2 from Column 3), one can see that the [H^+] ions exceed the [OH^-] ions (from fission product cesium) sometime between 5 hours and 12 hours (see Assumption 4 for a further discussion of the impact of fission product cesium on short-term pH).

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Based on Assumption 3, effective boron buffering is assumed to begin by ~8 hours. Thus, for times up to ~8 hours, the pH may be determined from the Net [H^+] Added column in Table 2 (Column 5), keeping in mind that negative values correspond to positive values of [OH^-] ions.

Part B – Long-Term pH Calculation

<u>Calculation of pH of the water pool</u>

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REV BAR.

The concentration of B is calculated as follows:

- The mass of sodium pentaborate in the SLCS is 4,062.8 lbm, or

  454 g/lbm • 4,062.8 lbm = 1.84E6 g.

- The molecular weight of sodium pentaborate ($Na_2O \cdot 5B_2O_3 \cdot 10H_2O$) with boron of natural enrichment is:

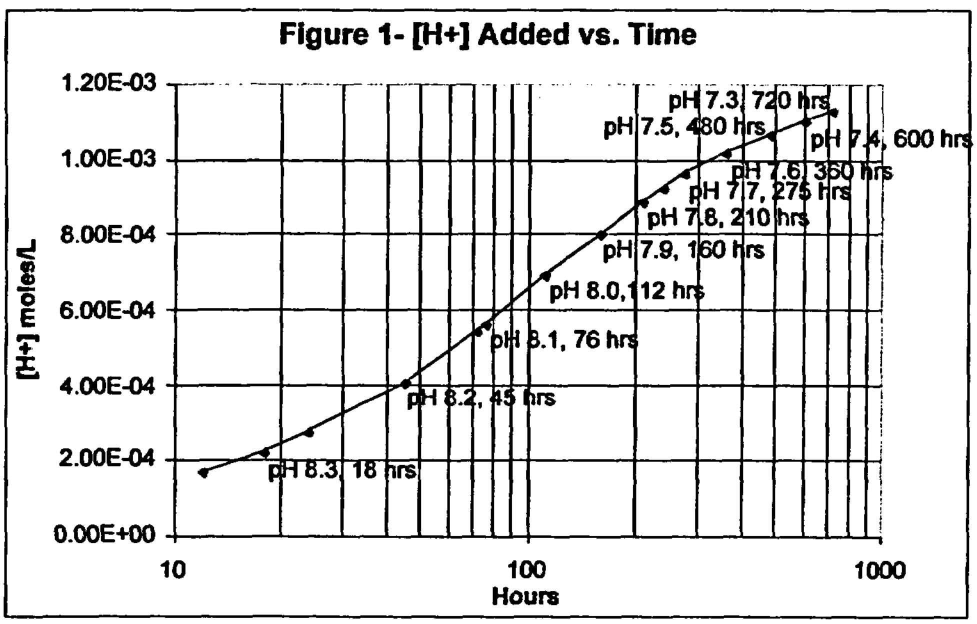
  2 x 22.990 + 10 x 10.811 + 20 x 1.008 + 26 x 15.999 = 590 g/mol

- The moles of sodium pentaborate present are 1.84E6 g/590 g/mol = 3.12E3 mol.

- There are 10 moles of B per mole of sodium pentaborate, so there are 3.12E3 x 10 = 3.12E4 mol of B.

Therefore, the concentration of B is 3.12E4 mol/4.18E6 L = 7.46E-3 mol/L

In Part B, the **(Proprietary Information Deleted)** pH is obtained by **(Proprietary Information Deleted)** Appendix C, Exhibit 3. Figure 1 presents the results.



<u>Calculation of fraction of total boron necessary to maintain pH ≥ 7</u>

The Add Acid model was run in an iterative fashion to determine the fraction of total boron necessary to maintain pH ≥ 7 over 30 days. Appendix D, Exhibit 4 is the STARpH result. It was found that 95% of the total boron available (i.e, a boron concentration = C1 on Appendix D, Exhibit 4 of 7.08E-3 mol/L) is necessary to maintain pH ≥ 7 with the 30 day [H^+] Added from Table 2 (1.13E-3 mol/L).

Results and Conclusions

The pH of the containment water pool in the Columbia Generating Station decreases from 8.4 to 7.3 over 30 days following the release of fission products into the containment in a DBA-LOCA with core damage. However, 95% of the total boron available is necessary to maintain pH ≥ 7 for 30 days.

Exhibit 1: Radiolysis of Water Input and Output

Input:

	A	B	C	D	E	F	G	H	I	J	K
1	Th Power MW	Pool Vol L	Initial pH	FP	Std FP Inv kg	Adj FP Inv kg	FP Rel Fract	FP in Cont kg	Fract in Pool	FP in Pool kg	BurnupMWd/t
2	3556	4.18E+06	5.3	I	16.6	32.7	0.3	9.81	0.9	8.829	33000
3	BWR			Cs	230.3	359	0.25	89.75		80.775	
4				Te	34.9	68.9	0.05	3.445		3.1005	
5	Version 1.04			Sr	62.7	94.3	0.02	1.886		1.6974	
6				Ba	105	158	0.02	3.16		2.844	
7				Ru	584	981	0.0025	2.4525		2.20725	
8				Ce	992	1342	0.0005	0.671		0.6039	
9				La	836.6	1243	0.0002	0.2486		0.22374	

Output:

		M	N				
1		HI M/L	[H+] initial				
2		8.2165E-07	5.01187E-06				
	AZ	BA	BB	BC	BD	BE	BF
1	[OH-] at 1h	[H+] at 1h	Corr. [H+]	ABS [H+]	pH at 1h	Test pH = 7	HNO3 M/L 1h
2	0.000117264	8.5277E-11	8.52774E-11	8.52774E-11	10.0691659	10.0691659	5.79432E-06
3	2h	2h			2h		2h
4	0.000115107	8.6876E-11	8.68757E-11	8.68757E-11	10.06110149	10.06110149	7.95171E-06
5	5h	5h			5h		5h
6	0.000110661	9.0366E-11	9.03662E-11	9.03662E-11	10.0439939	10.0439939	1.23978E-05
7	12h	12h			12h		12h
8	0.000103364	9.6745E-11	9.67452E-11	9.67452E-11	10.01437036	10.01437036	1.96944E-05
9	1d	1d			1d		1d
10	9.368E-05	1.0675E-10	1.06746E-10	1.06746E-10	9.971646862	9.971646862	2.93786E-05
11	3d	3d			3d		3d
12	6.63488E-05	1.5072E-10	1.50719E-10	1.50719E-10	9.821833109	9.821833109	5.67098E-05
13	10d	10d			10d		10d
14	1.5635E-05	6.3959E-10	6.3959E-10	6.3959E-10	9.194098417	9.194098417	0.000107424
15	20d	20d			20d		20d
16	-1.68531E-05	-5.9336E-10	-1.68531E-05	1.68531E-05	4.773319694	4.773319694	0.000139912
17	30d	30d			30d		30d
18	-3.7987E-05	-2.6325E-10	-3.7987E-05	3.7987E-05	4.420365377	4.420365377	0.000161046

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Input:

	A	B	C	D	E	F	G	H	I
1	Th Power, MW	Cont Vol, cm3	Pool Vol, L	Insulation, lb	Th Power, W	Fract in Pool	1-Gamma Leakage	R-Gamma	R-Beta
2	3556	9.76E+09	4.18E+06	6615	3556000000	0.9	1.0	1.49E-15	2.75E-15

3
4 Hypalon
5
6 Version 1.04

Output:

	AK	AL	AM	AN
1	HCl P Hyp M 1h	HCl P Hyp M/L 1h	HCl B Hyp M 1h	HCl B Hyp M/L 1h
2	99.7220932	2.3857E-05	83.36767	1.9944E-05
3	2h	2h	2h	2h
4	187.953562	4.4965E-05	156.565317	3.7456E-05
5	5h	5h	5h	5h
6	406.949443	9.7356E-05	336.547189	8.0514E-05
7	12h	12h	12h	12h
8	774.573999	0.0001853	637.474402	0.00015251
9	1d	1d	1d	1d
10	1242.66894	0.00029729	1016.50319	0.00024318
11	3d	3d	3d	3d
12	2508.07922	0.00060002	2044.08457	0.00048902
13	10d	10d	10d	10d
14	4133.38366	0.00098885	3418.30829	0.00081778
15	20d	20d	20d	20d
16	4609.24853	0.00110269	3899.42425	0.00093288
17	30d	30d	30d	30d
18	4775.58668	0.00114248	4040.14634	0.00096654

Exhibit 2: Radiolysis of Cable Input and Output

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Appendix B

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Calculation No. NE-02-03-15

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REV BAR.

Input:

	A	B	C	D
	Add Ac 1.04 pH	[H+]	C1	K1
56	8.6	2.51E-09	0.00746	9E-10
57	8.5	3.16E-09	0.00746	9E-10
58	8.4	3.98E-09	0.00746	9E-10
59	8.3	5.01E-09	0.00746	9E-10
60	8.2	6.31E-09	0.00746	9E-10
61	8.1	7.94E-09	0.00746	9E-10
62	8	1.00E-08	0.00746	9E-10
63	7.9	1.26E-08	0.00746	9E-10
64	7.8	1.58E-08	0.00746	9E-10
65	7.7	2.00E-08	0.00746	9E-10
66	7.6	2.51E-08	0.00746	9E-10
67	7.5	3.16E-08	0.00746	9E-10
68	7.4	3.98E-08	0.00746	9E-10
69	7.3	5.01E-08	0.00746	9E-10
70	7.2	6.31E-08	0.00746	9E-10
71	7.1	7.94E-08	0.00746	9E-10
72	7	1.00E-07	0.00746	9E-10

Output:

O	P	Q
db	SUMdb	Acid Added
0.00033376	0.0056565	-0.00055484
0.00029642	0.00595292	-0.00025842
0.00025842	0.00621134	0
0.00022179	0.00643313	0.00022179
0.00018769	0.00662081	0.00040947
0.00015711	0.00677792	0.00056658
0.00013014	0.00690806	0.00069672
0.0001069	0.00701496	0.00080362
8.7599E-05	0.00710256	0.00089122
7.0797E-05	0.00717336	0.00096202
5.7412E-05	0.00723077	0.00101943
4.6259E-05	0.00727703	0.00106569
3.7151E-05	0.00731418	0.00110284
2.9783E-05	0.00734396	0.00113262
2.382E-05	0.00736778	0.00115644
1.904E-05	0.00738682	0.00117548
1.5188E-05	0.00740201	0.00119067

Exhibit 3: Add Acid Input and Output - Base Case

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Appendix D

Prepared by / Date: [signature] 7/21/04 Verified by/Date: [signature] 7/23/04

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Exhibit 4: Add Acid Input and Output - Reduced Boron Case

	Input:				Output:		
	A	B	C	D	O	P	Q
	Add Ac 1.04 pH	[H+]	C1	K1	db	SUMdb	Acid Added
56	8.6	2.51E-09	0.00708	9E-10	0.00031676	0.00536837	-0.00052657
57	8.5	3.16E-09	0.00708	9E-10	0.00028132	0.00564969	-0.00024525
58	8.4	3.98E-09	0.00708	9E-10	0.00024525	0.00589494	0
59	8.3	5.01E-09	0.00708	9E-10	0.00021049	0.00610543	0.00021049
60	8.2	6.31E-09	0.00708	9E-10	0.00017813	0.00628356	0.00038862
61	8.1	7.94E-09	0.00708	9E-10	0.0001491	0.00643266	0.00053772
62	8	1.00E-08	0.00708	9E-10	0.00012351	0.00655618	0.00066123
63	7.9	1.26E-08	0.00708	9E-10	0.00010145	0.00665763	0.00076269
64	7.8	1.58E-08	0.00708	9E-10	8.3137E-05	0.00674077	0.00084583
65	7.7	2.00E-08	0.00708	9E-10	6.719E-05	0.00680796	0.00091302
66	7.6	2.51E-08	0.00708	9E-10	5.4487E-05	0.00686245	0.0009675
67	7.5	3.16E-08	0.00708	9E-10	4.3903E-05	0.00690635	0.00101141
68	7.4	3.98E-08	0.00708	9E-10	3.5259E-05	0.00694161	0.00104666
69	7.3	5.01E-08	0.00708	9E-10	2.8266E-05	0.00696987	0.00107493
70	7.2	6.31E-08	0.00708	9E-10	2.2607E-05	0.00699248	0.00109754
71	7.1	7.94E-08	0.00708	9E-10	1.807E-05	0.00701055	0.00111561
72	7	1.00E-07	0.00708	9E-10	1.4414E-05	0.00702496	0.00113002

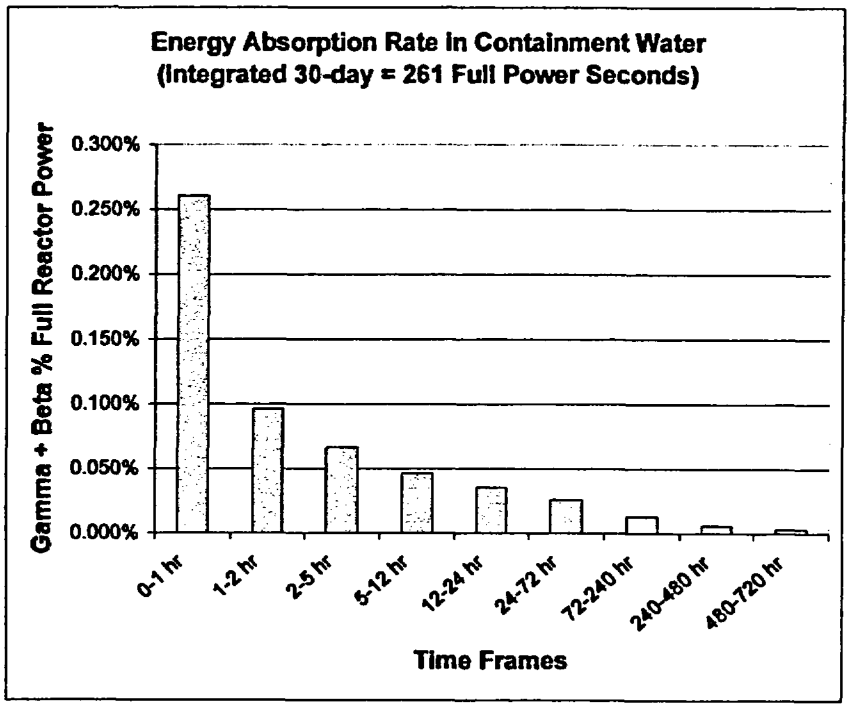
Proprietary Information Deleted

Proprietary Information Deleted

Gamma + Beta Power Added to Containment Water and Insulation Jacket Material

The combined gamma and beta power added to the containment water by activity deposited in the water is shown as a function of time in Figure F-1 **(Proprietary Information Deleted)**

Figure F-1



The radiation dose rate (rads/hour) for exposure of cable insulation jacket material to radiation in the gas space of the containment is shown in the following table individually for gamma and beta radiation. The corresponding integrated radiation exposure (gamma and beta radiation combined) over 30 days is 6.1E8 rads.

Table F-1
Energy Absorption Rate in Cable Insulation Jacket Material

Time Interval	Gamma Rads/hr	Beta Rads/hr
0-1 hr	6.54E+06	6.10E+06
1-2 hr	5.73E+06	5.37E+06
2-5 hr	4.74E+06	4.36E+06
5-12 hr	3.41E+06	3.11E+06
12-24 hr	2.50E+06	2.29E+06
24-72 hr	1.67E+06	1.58E+06
72-240 hr	6.01E+05	6.40E+05
240-480 hr	1.44E+05	1.60E+05
480-720 hr	4.18E+04	4.72E+04

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