Nine Mile Point Unit 1
Alternative Source Term

Calculation H21C084

"Post-LOCA Suppression Chamber (Torus) Water pH Analysis"

ORIGINAL

ENGINEERING SERVICES

CALCULATION COVER SHEET

Project: NINE MILE POINT NUCLEAR STATION **Unit** (1, 2 or 0=Both) : 1 **Discipline :** MECHANICAL

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1.0 Purpose

The purpose of this calculation is to demonstrate that the pH of the suppression chamber (torus) water remains continuously above 7.0 following a Loss of Coolant Accident (LOCA) for the 30-day duration of the accident. Based on Section 6.5.2 of the Standard Review Plan, NUREG-0800 (Ref. 7.20), long-term iodine retention may be assumed only when the equilibrium suppression chamber water pH is above 7.0. The pH transient of the suppression chamber water is evaluated in this calculation to determine whether the uncontrolled suppression chamber water pH remains above 7.0. If not, the effect on final pH of adding sodium pentaborate to the suppression chamber via the Liquid Poison System (LPS) is subsequently determined to verify that the suppression chamber water pH can be maintained above 7.0.

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2.0 Methodology and Acceptance Criteria

2.1 Methodology

The suppression chamber water pH is calculated using the methodology described in NUREG/CR-5950 and in Grand Gulf Nuclear Station Engineering Report GGNS-98-0039. Grand Gulf was one of the NRC's Alternate Source Term pilot plants.

This methodology considers the addition of the following acids and bases to the post-LOCA suppression chamber in the pH calculation:

1. Carbon Dioxide – Carbon dioxide is absorbed from the air to form the weak acid carbonic acid. This acid can reduce pH to a limiting value of approximately 5.65 (Ref. 7.13, §2.2.3) and is bounded in the initial condition selected for the suppression chamber water pH. Therefore, carbonic acid is not explicitly computed but is accounted for in the pH calculation.

2. Hydriodic Acid – Hydriodic acid is produced by the release of iodine from the reactor core as fuel failure occurs. Hydriodic acid is added to the suppression chamber during the Gap Release Phase and during the Early In-Vessel Phase only. This occurs for a two-hour period at the beginning of the LOCA per Regulatory Guide 1.183 (Ref. 7.10.2).

3. Cesium Hydroxide – Cesium hydroxide is produced by the release of cesium from the reactor core as fuel failure occurs. Cesium hydroxide is added to the suppression chamber during the Gap Release Phase and during the Early In-Vessel Phase only. This occurs for a two-hour period at the beginning of the LOCA per Regulatory Guide 1.183 (Ref. 7.10.2).

4. Nitric Acid – Nitric acid is produced by irradiation of water and air during the LOCA. Nitric acid is added to the suppression chamber continuously during the LOCA.

5. Hydrochloric Acid – Hydrochloric acid is produced by radiolysis of chlorine-bearing electrical insulation/jacketing during a LOCA. Only electrical cable exposed to free air or in cable trays is considered. Hydrogen chloride formed from cable enclosed in conduit or enclosures will be contained in the conduit or enclosure and will not be available to form acid in the suppression chamber. Hydrochloric acid is added to the suppression chamber continuously during the LOCA. Hydrochloric acid can also be produced by pyrolysis of chlorine-bearing electrical insulation/jacketing at temperatures near 572°F (Ref. 7.13, §2.2.5.3); however, since post-LOCA containment temperatures are much lower than this, pyrolysis is not considered herein.

6. Concrete Core Aerosols – Per NUREG/CR-5950 (Ref. 7.13, §2.3.2), aerosols from limestone concrete will contain the basic oxides CaO, Na_2O, and K_2O. However, the aerosols are produced from the interaction of a molten core with concrete and, per SECY-94-302 (Ref. 7.21), core damage can be assumed to cease after the Early In-Vessel Phase. Therefore, concrete core aerosols are not considered in this calculation.

The acids and bases are combined in the suppression chamber water and the resulting pH transient response is calculated for a 30-day period. This pH is the unbuffered suppression chamber water pH.

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A final pH after 30 days is then recalculated considering the addition of sodium pentaborate from the LPS. This injection is manually initiated, so the pH transient is subject to the timing of the injection. Since only acids are added to the suppression chamber water after the initial two-hour release of cesium hydroxide, the final pH is the lowest pH that will be attained in the suppression chamber water.

2.2 Computer Programs

The analysis performed herein utilizes Microsoft Excel® (Ref. 7.1), which is commercially available. The validation of Excel is implicit in the detailed review of all spreadsheets used in this analysis. All computer runs were performed using PC No. 9098 under the Windows NT operating system.

2.3 Acceptance Criteria

The acceptance criterion is that the suppression chamber water pH is at or above 7.0 for the 30-day period of the LOCA so that iodine re-evolution is not a source term.

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3.0 Assumptions

3.1 Hydrogen ion activity coefficients are ignored when calculating the pH of the suppression chamber water. Because the suppression chamber is initially filled with demineralized water, the ionic strength is low and any deviation from ideality is negligible for purposes of this calculation.

3.2 The reduction in reactor coolant system (RCS)/suppression chamber water mass due to steam addition to the post-LOCA containment is neglected. This is acceptable since the mass of steam in containment is a small fraction of the total mass of water in the suppression chamber.

3.3 The initial pH in the suppression chamber water and in the RCS is assumed to be at the minimum suppression chamber water value, 5.5 (Design Input 4.1), expected during normal operation. Although the RCS generally operates at a minimum pH of 5.6, this assumption is conservative because it leads to the lowest calculated pH.

3.4 The suppression chamber water is assumed to be sufficiently mixed so a single pH adequately represents the pool contents. Per Design Input 4.14, there are at least 0.3 complete exchanges of water in the suppression chamber per hour. This is judged to provide adequate mixing.

3.5 The Cesium-133 reactor core inventory is conservatively not included in this analysis. Cesium-133 would form additional cesium hydroxide in the suppression chamber water, increasing the pH. Exclusion of this stable isotope of cesium leads to a lower suppression chamber water pH. Also note that the stable nuclide inventory is not provided in Reference 7.7. However, Reference 7.7 does include products from the activation of Cs-133 such as Cs-134, which is included in this calculation (see Attachment 1, Tables 1-2 and 1-4).

3.6 Since Reference 7.7 does not provide the reactor core inventory of stable isotopes, it is assumed that the quantity of Iodine-127 is 30% of the quantity of Iodine-129. Based on the cumulative fission yields presented in Reference 7.26 for thermal neutron fission of U^{235}, U^{238}, Pu^{239}, and Pu^{241}, this value is greater than will actually occur in the reactor core. The ratio of Iodine-127 to Iodine-129 is computed in the table below based on Reference 7.26. Note that U^{238} does not undergo thermal neutron fission.

	U^{235} Fission	Pu^{239} Fission	Pu^{241} Fission
% Cumulative Yield I-127[1]	0.137	0.46	0.25
% Cumulative Yield I-129[1]	1.0	1.7	1.02
n_{I-127}/n_{I-129} [= $\%_{I-127}/\%_{I-129}$]	**13.7%**	**27.1%**	**24.5%**

1) Recommended values from Reference 7.26 used herein.

Since iodine contributes to the post-LOCA suppression chamber water acidity, this assumption is conservative as it bounds the actual amount of Iodine-127 which may be in the reactor core.

3.7 It is conservatively assumed that 5% of the iodine released into containment produces hydriodic acid. Per Regulatory Guide 1.183 (Ref. 7.10.2), 95% of the iodine released from the RCS is in the form of cesium iodide (CsI), 4.85% is in the form of elemental iodine, and 0.15% is in the form of organic iodide. NUREG-1465 (Ref. 7.14) indicates that at least 95% of the iodine entering containment from the RCS is in the form of cesium iodide with no more than 5% as I plus HI. Therefore, for this calculation, it is conservatively assumed that the combined I plus HI

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quantity is the maximum 5% in order to maximize the acid contribution from iodine to the suppression chamber water.

3.8 Radiation dose calculations for gamma and beta total integrated dose (TID) in the drywell used as input are assumed to apply at electrical cable surfaces. If attenuation of air was not taken into account in the TID calculations (Ref. 7.6.2/7.6.3), this assumption is conservative in that it uses a higher radiation flux and computes a higher hydrochloric acid production rate. If attenuation of air was taken into account in the TID calculations (Ref. 7.6.2/7.6.3), this assumption is moot.

3.9 Assumptions made in the determination of the exposed cable inventory are listed in Attachment 3 and repeated (with minor changes) below for convenience.

- All combustible cable insulation is actually cable jacketing; therefore, the entire mass of cable is exposed to both gamma and beta radiation since no credit is taken for shielding of the insulation from beta radiation.
- All cable is free-air routed and not in cable trays; thus, no credit can be taken for shielding of some of the cables from beta radiation in cable trays (this assumption conflicts with the combustible loading calculation, Reference 7.6.7, which assumes all cable is in trays; however, since Reference 7.6.7 *assumes* the cable location, the assumption of free-air routing is acceptable).
- There is no cable in the suppression chamber (torus); this is acceptable since little, if any, cable is expected in the suppression chamber.
- Medium and high voltage cables are not considered when determining the typical cable size; this is acceptable since small cables maximize HCl production and the medium to high voltage power cables are larger than the cables identified in Reference 7.23. In addition, the quantity of medium and high voltage power cables inside primary containment is small as the only 5 kV (medium/large) cables in containment feed the reactor recirculation pumps (Ref. 7.29).
- The chlorine content of the rubber hose and plastic covers is unknown; therefore, it is assumed that these materials are PVC.
- Filler material in the cables is included in the combustible load provided in Reference 7.6.7. Therefore, the filler material is accounted for as chlorine bearing material in this calculation.
- Oil in primary containment is confined and therefore any chlorine which could evolve from the oil to form HCl need not be accounted for in this calculation.

3.10 The amount of sodium pentaborate added to the suppression chamber as a buffer is conservatively assumed to be the minimum mass contained by the LPS injection tank

3.11 The minimum suppression chamber water temperature is modeled as 60°F. This temperature is used to determine the maximum suppression chamber water mass, given the volume. Given that containment is located within the environmentally controlled reactor building, this value is judged to be acceptable for a minimum temperature.

3.12 The gamma radiation dose used herein is increased by 5% to account for bremsstrahlung. This conservative increase is justified as follows:

The fraction of beta energy that is converted to bremsstrahlung (or gamma radiation) is estimated using the equation (Ref. 7.24, p. 110):

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Fraction = k * Z * E

where:
Fraction = the fraction of beta energy converted to bremsstrahlung
$k = 0.7 \times 10^{-3}$ per MeV
Z = atomic number of the absorber
E = energy of the beta particle [MeV]

For this calculation, absorption in air, water, or PVC is considered, so a conservative value for Z would be 20. Similar to gamma energy, the beta energy is different for each radionuclide. Assuming the average beta energy per decay is the same as the average gamma energy per decay, and using a typical gamma energy of 1 MeV, the fraction converted to bremsstrahlung would be:

Fraction = $0.7 \times 10^{-3} * 20 * 1 = 1.4\%$

Inspection of the beta energies for noble gases, iodines, and cesiums in Reference 7.25 indicates that, for most radionuclides, the gamma energy per decay is higher than the beta energy per decay. Using a fraction of 5% is large enough to account for the cases where the beta energy per decay is larger than the gamma energy per decay, and to account for bremsstrahlung from pure beta emitting radionuclides. Therefore, the assumption that the bremsstrahlung contribution to the dose is equal to 5% of the gamma dose is considered conservative.

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4.0 Design Input

4.1 The initial suppression chamber water pH is maintained between 5.5 and 8.0 (Ref. 7.3.1). The suppression chamber water pH is no longer monitored at NMP1 per Reference 7.3.3; therefore, this value is taken from a prior (c. 2001) revision of the NMP1 Chemistry Manual.

4.2 For Reactor Conditions 3 (reactor thermal power > 25%) and 2 (reactor water bulk temperature > 212°F), the Action Level 1 acceptable RCS pH range is 5.6 < pH < 8.6. The Action Level 2 pH range is 4.9 < pH < 9.3 and the Action Level 3 pH range is 4.6 < pH < 9.6 (Ref. 7.3.2, p. 9).

4.3 The mass of water (liquid and steam) in the RCS during normal operation is 501,500 lbm (Ref. 7.2.1).

4.4 Linear absorption coefficients and density for PVC jacketed/insulated cable are determined in Attachment 3 and are repeated below. The σ/ρ values are taken from NUREG-1081 (Ref. 7.15).

Linear absorption coefficient for gamma radiation, σ_γ:

$$\sigma_\gamma/\rho = 0.0637\ cm^2/g$$

$$\rho_{PVC} = 1.16\ g/cm^3$$

$$\sigma_{\gamma,PVC} = 0.0637 \times 1.16 = 0.0739\ cm^{-1}$$

Linear absorption coefficient for beta radiation, σ_β:

$$\sigma_\beta/\rho = 33.6\ cm^2/g$$

$$\rho_{PVC} = 1.16\ g/cm^3$$

$$\sigma_{\beta,PVC} = 33.6 \times 1.16 = 38.976\ cm^{-1}$$

4.5 The 100% rated thermal reactor core power level is 1,850 MWt (Ref. 7.5, p. 3).

4.6 The maximum and minimum suppression chamber water level (referenced to mean sea level) and volume for normal operation are given below.

Suppression Chamber Water Level	Downcomer Submergence (Ref. 7.2.2)	Suppression Chamber Water Level (Ref. 7.6.1, p. 20-22)	Suppression Chamber Water Level – Elevation (Ref. 7.6.1, p. 20-22)	Volume [ft^3]
Maximum	4.25 ft	11.25 ft	211.75 ft	86,000(1)
Minimum	3.5 ft	10.5 ft	211 ft	79,800(2)

1) Interpolated using "Vsp()" column in Table 1 of Reference 7.6.1. Interpolated value (85,599 ft^3) conservatively rounded up.
2) Value obtained from UFSAR Table XV-32a (Ref. 7.11.1); note that this is not consistent with Table 1 of Reference 7.6.1. However, this is acceptable based on the following observation in Reference 7.6.1 (p. 19): "The EOP calculations are not the design basis calculations and therefore the values for Vsp [suppression pool water

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volume] may be slightly different than those used in the Design Basis Containment Suppression Chamber Heatup Analysis (Reference: UFSAR Table XV-32a & Calculation S0TORUS009, Rev. 1).

4.7 The suppression chamber water temperature range is 60°F ≤ T ≤ 85°F for continuous plant operation (Assumption 3.11 and Ref. 7.2.2). However, the maximum temperature can rise to 110°F before reactor shutdown is required (Ref. 7.2.2).

4.8 The initial suppression chamber / drywell pressure is 14.7 psia, consistent with the original DBR containment suppression chamber heatup analysis as documented in UFSAR Table XV-32a (Ref. 7.11.1).

4.9 The reactor core cesium and iodine inventories are determined in Attachment 1, and are repeated below for convenience since they are input to the pH analysis. These quantities are conservatively based on the activities at time t=0 following a LOCA.

Iodines: 43.2 gram-moles
Cesiums: 268.6 gram-moles

The above core inventories are based on a core thermal power of 1,887 MWt (102% of licensed core thermal power, 1,850 MWt), consistent with Regulatory Guide 1.49 (Ref. 7.10.1).

It should be noted that the quantity of cesium given above excludes Cesium-133, which is stable, since it is not provided in Reference 7.7. The exclusion of the stable isotope is conservative as it would form cesium hydroxide (CsOH) which would raise the pH of the post-LOCA suppression chamber water. The stable cesium would form cesium hydroxide since the number of moles of non-stable cesium is greater than 95% of the number of moles of iodine (95% of cesium is released as cesium iodide, CsI – see Assumption 3.7).

4.10 The gamma (γ) dose in the drywell, wetwell, and suppression chamber water is determined in Attachment 2 and is repeated below for convenience since it is input to the pH analysis. The submersion dose is calculated for both the minimum and maximum suppression chamber water volume since it is dependent on the dilution volume. The dose provided below is based on the core thermal power of 1,850 MWt and includes a 5% increase to account for bremsstrahlung (see Assumption 3.12).

Time [hr]	Drywell & Wetwell Airborne γ Dose [rad]	Suppression Chamber Submersion γ TID – Min Vol [rad]	Suppression Chamber Submersion γ TID – Max Vol [rad]
1	1.035E+06	4.454E+05	3.779E+05
6	3.150E+06	1.641E+06	1.392E+06
24	4.950E+06	3.282E+06	2.785E+06
720	1.350E+07	1.875E+07	1.591E+07
2400	2.115E+07	4.219E+07	3.580E+07
4320	2.835E+07	6.446E+07	5.470E+07
8760	4.275E+07	1.102E+08	9.349E+07

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4.11 The beta (β) dose in the drywell is determined in Attachment 2 and is repeated below for convenience since it is input to the pH analysis. The dose provided below is based on the core thermal power of 1,850 MWt.

Time [hr]	Drywell Airborne β Dose [rad]
1	3.011E+07
28	2.121E+08
2400	6.134E+08

4.12 Liquid Poison System (LPS) Parameters

The liquid poison tank contains a minimum of 1,325 gallons of boron bearing solution per Technical Specification 3.1.2 (Ref. 7.2.1). Sodium pentaborate solution with a minimum concentration of 9.423 weight % is used for the liquid poison (Ref. 7.6.4.a, p. 6). The specific gravity (SG) of this solution is 1.048 per Figure 1 of Reference 7.22. However, Reference 7.22 is for Unit 2 which uses boron with less B-10 enrichment than Unit 1 (≥25 atom % for Unit 2 vs. ≥62.5 atom % for Unit 1). Therefore, Unit 1 will actually have a lower specific gravity. To account for this, a specific gravity of 1.0 is conservatively used for the LPS solution.

The above weight percentage (9.423 wt %) is only valid for sodium pentaborate enrichments greater than or equal to 62.5 atom percent B-10 (Ref. 7.6.4.a, p. 6).

Sodium pentaborate decahydrate has the chemical formula $Na_2B_{10}O_{16} \cdot 10H_2O$ (Ref. 7.22, §3.3.1) and a molecular weight of 585.984. This molecular weight is determined using a boron molecular weight of 10.387 [(0.625*10.013)+(0.375*11.009)] to account for the 62.5 atom percent B-10 enrichment (see Ref. 7.9 for isotopic masses of B-10 and B-11). In this calculation, "sodium pentaborate" actually refers to sodium pentaborate decahydrate for consistency with plant documentation.

The sodium pentaborate solution shall be maintained between 70°F and 105°F per the operating procedure (Ref. 7.3.4, p. 3). The low and high temperature annunciators are set at 65°F and 85°F, respectively (Ref. 7.4, §2.7). Note that the minimum temperatures bound the Technical Specification minimum allowable solution temperature of 40°F (Ref. 7.2.1, Figure 3.1.2b).

Each sodium pentaborate pump (NP02A and NP02B) has a 33 gpm rated capacity at 1,300 to 1,670 psig (Ref. 7.4, §2.1). However, the nominal capacity is 30 gpm per the Technical Specification (Ref. 7.2.1) and operating procedure (Ref. 7.3.4, p. 3).

4.13 The chloride bearing cable inventory in primary containment is determined to be 1,400 lbm of free-air routed PVC jacketed cable with an outer diameter of 0.22 inches and a jacket thickness of 0.030 inches in Attachment 3. This mass also includes the mass of any cable insulation and filler material.

4.14 The limiting Design Basis Accident (DBA) LOCA is identified in UFSAR Section VI-B.1.2 (Ref. 7.11.2) as an instantaneous double ended rupture (DER) of the RCS recirculation line (largest line in containment). For this case, a diesel generator failure is the limiting single failure as it

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results in only one core spray pump and one core spray topping pump being available per UFSAR Table XV-11 (Ref. 7.11.4). Given that the reactor vessel depressurizes reasonably quickly for a large break LOCA, the minimum flow rate from one core spray pump and one topping pump is expected to be between 2,000 to 3,000 gpm per UFSAR Table XV-9a (Ref. 7.11.3). In addition, at least one containment spray pump will be operable with a minimum flow rate of 3,600 gpm per UFSAR Table XV-32a (Ref. 7.11.1; also see p. VII-14a of UFSAR). Thus, a minimum flow rate of 5,600 gpm is expected when core spray is actuated. This flow rate equates to approximately 0.5 complete exchanges of the water in the torus per hour (1 complete exchange in approximately 2 hours). If core spray is not actuated, the minimum expected flow rate is 3,600 gpm which equates to approximately 0.3 complete exchanges of water in the torus per hour (1 complete exchange in approximately 3 hours). These mixing times are based on the maximum suppression chamber water volume.

4.15 The post-LOCA suppression chamber water temperature response for an RCS recirculation line break for the DBA LOCA is provided below. The short-term temperature response (t=0 to 4.2 hours) is taken from the Calculation S0-TORUS-M009 (Ref. 7.6.5), which is the torus pool heat-up analysis. Case 4 of the heat-up analysis is selected since it is consistent with the original design basis (Ref. 7.6.5, §2.4). The suppression chamber water temperature profile for Case 4 is presented in Figure 6-13 of Reference 7.6.5 (p. 42), but the values are taken from the computer output in Attachment 2 of Reference 7.6.5 (p. 47-53). Cases 1-3 are sensitivity analyses (Ref. 7.6.5, §2.0) and Case 5 is run to determine NPSH margins (Ref. 7.6.5, §2.5); therefore, these cases are not used. It should be noted that the suppression chamber water temperature response for Cases 1-5 is similar and therefore the case selection has negligible impact on the results of this calculation.

Time [sec (hr)]	T_{pool} [°F]	Time [sec (hr)]	T_{pool} [°F]	Time [sec (hr)]	T_{pool} [°F]
0.0 (0.0)	85	15.2 (4.2×10^{-3})	114.7	2622.58 (0.73)	154.3
2.81 (7.8×10^{-4})	89.1	30.83 (8.6×10^{-3})	122.1	8349.58 (2.3)	160.3
5.83 (1.6×10^{-3})	95.77	99.58 (0.028)	126.5	9574.08 (2.7)	160.3
8.95 (2.5×10^{-3})	102.7	296.2 (0.082)	133.7	14925.33 (4.1)	158.7
12.08 (3.4×10^{-3})	109.4	910.58 (0.25)	143.5		

The long-term suppression chamber water temperature response (t > 4.2 hours) is not provided in Reference 7.6.5 or the UFSAR. Since water temperature has negligible impact on the pH calculation, the temperature at 4.2 hours (158.7°F) is maintained from that point until the end of the transient at 30 days.

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5.0 Calculations

5.1 Suppression Chamber Water Initial Conditions

5.1.1 Suppression Chamber Water Volume

The maximum and minimum suppression chamber water volume are used in this calculation. The total suppression chamber water volume for this calculation is the sum of the initial suppression chamber water volume plus the added RCS volume. The complete RCS mass is added to the suppression chamber at the start of the LOCA for the maximum volume case. The RCS mass is not added to the suppression chamber for the minimum volume case.

The suppression chamber water volume at the maximum water level is 86,000 ft^3. The Reactor Coolant System (RCS) has a total mass of 501,500 lbm. Once the RCS mass is added to the suppression chamber, the total suppression chamber water volume is approximately 94,000 ft^3 (Attachment 4, Table 4-9). The mixed water volume is based on the initial density of the suppression chamber water. The suppression chamber water volume at the minimum water level is 79,800 ft^3.

5.1.2 Initial pH

The suppression chamber water is maintained at a pH between 5.5 and 8.0. Lower pH levels are conservative for this analysis, so an initial pH of 5.5 is used. This pH also accounts for dissolved carbon dioxide.

The RCS pH is maintained at a pH between 5.6 and 8.6 for Reactor Conditions 2 and 3, and between 5.3 and 8.6 for Reactor Condition 1 (reactor water bulk temperature < 212°F). Since the large break LOCA in which the entire RCS inventory is spilled to the suppression chamber is postulated to occur at full power, the pH at Reactor Condition 1 is not used. A conservative initial RCS pH of 5.5 (bounds 5.6) is used for this analysis. The choice of this conservative input does not impact the final result of this calculation due to the small (<10%) RCS water mass relative to the suppression chamber water mass.

The pH of the suppression chamber contents after addition of the RCS is 5.5.

5.2 Hydriodic Acid (HI)

Hydriodic acid is formed by the post-LOCA release of elemental iodine (I) and hydrogen iodide (HI) from the reactor core and its absorption in the suppression chamber water.

Per Regulatory Guide 1.183, Table 1 (Ref. 7.10.2), 5% of the iodine core inventory is released into containment during the Gap Release Phase and an additional 25% of the iodine core inventory is released into containment during the Early In-Vessel (EIV) Phase. The Gap Release Phase has an onset of 2 minutes and a duration of 30 minutes and is followed by the EIV Phase with a duration of 90 minutes per Table 4 of Regulatory Guide 1.183 (Ref. 7.10.2).

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The reactor core inventory of iodine, the Gap Release Phase iodine release, and the EIV Phase iodine release are determined in Attachment 1 and listed in Attachment 1, Table 1-1.

Per Section 3.5 of Regulatory Guide 1.183 (Ref. 7.10.2), 95% of the iodine released from the RCS is in the form of cesium iodide, 4.85% is in the form of elemental iodine, and 0.15% is in the form of organic iodide. Section 3.5 of NUREG-1465 (Ref. 7.14) and Section 4.2 of NUREG/CR-5732 (Ref. 7.16) indicate that at least 95% of the iodine entering containment from the RCS is in the form of cesium iodide with no more than 5% as I plus HI. For this calculation, it will be conservatively assumed that the combined I plus HI is the maximum 5% in order to maximize the acid contribution from iodine to the suppression chamber water.

The formation of hydriodic acid in the suppression chamber water is equal to the molar addition of iodine. Computations are shown in Attachments 4 and 6, Tables 4-2 and 6-2. During the Gap Release Phase, 5% of the Gap Release Phase iodine release produces hydriodic acid in the suppression chamber water. During the EIV Phase, 5% of the EIV Phase iodine release produces additional hydriodic acid in the suppression chamber water. The concentrations are determined at the end of the Gap Release Phase, at one hour, and at the end of the EIV Phase. The rates of addition during the Gap Release Phase and during the EIV Phase are linear per Section 3.3 of Regulatory Guide 1.183 (Ref. 7.10.2). No additional hydriodic acid is formed after the EIV Phase.

5.3 Cesium Hydroxide (CsOH)

Cesium hydroxide is formed by the release of cesium from the reactor core and its absorption in the suppression chamber water.

Per Regulatory Guide 1.183, Table 1 (Ref. 7.10.2), 5% of the cesium core inventory is released into containment during the Gap Release Phase and an additional 20% of the cesium core inventory is released into containment during the Early In-Vessel (EIV) Phase. The Gap Release Phase has an onset of 2 minutes and a duration of 30 minutes and is followed by the EIV phase with a duration of 90 minutes per Table 4 of Regulatory Guide 1.183 (Ref. 7.10.2).

The reactor core inventory of cesium, the Gap Phase cesium release, and the EIV Phase cesium release are determined in Attachment 1 and listed in Attachment 1, Table 1-2.

Cesium released in the form of cesium iodide does not contribute to formation of cesium hydroxide. The quantity of cesium iodide is 95% of the molar quantity of iodine released, consistent with the determination of hydriodic acid production (see Section 5.2). The amount of cesium as cesium iodide is subtracted from the Gap Phase cesium release and the EIV Phase cesium release to obtain the quantity of cesium hydroxide in the post-LOCA suppression chamber water.

The formation of cesium hydroxide in the suppression chamber water is equal to the molar addition of cesium not in the form of cesium iodide. Computations are shown in Attachments 4 and 6, Tables 4-5 and 6-5. The concentrations are determined at the end of the Gap Release Phase, at one hour, and at the end of the EIV Phase. The rates of addition during the Gap Release Phase and during the EIV Phase are linear per Section 3.3 of Regulatory Guide 1.183 (Ref. 7.10.2). No additional cesium hydroxide is formed after the EIV Phase.

Ref.

5.4 Nitric Acid (HNO_3)

Nitric acid is formed by irradiation of air and water in the suppression chamber by gamma radiation. Per Section 2.2.4 of NUREG/CR-5950 (Ref. 7.13), the generation rate of HNO_3, G, is 0.007 molecules HNO_3 per 100 eV. This generation rate converts to 7.3×10^{-6} g-mole/liter per MegaRad as follows:

$$G = \frac{0.007\,\text{molecule}}{100\,\text{eV}} \times \frac{\text{mole}}{6.022\times10^{23}\,\text{molecule}} \times \frac{6.241\times10^{11}\,\text{eV}}{\text{erg}} \times \frac{100\times10^{6}\,\text{erg}}{\text{MegaRad}\,\text{g}} \times \frac{1000\,\text{g}}{\text{liter}}$$

Total integrated suppression chamber gamma radiation doses were multiplied by this value to compute the nitric acid concentration at varying times. Computations are shown in Attachments 4 and 6, Tables 4-3 and 6-3.

5.5 Hydrochloric Acid (HCl)

Hydrochloric acid is formed by radiolysis of chloride-bearing electrical cable in the drywell.

The chlorine bearing cable inventory is determined in Attachment 3. The cable inventory is based on the NMP Unit 1 combustible loading calculation, S0.0-FPE-002 (Ref. 7.6.7).

The methodology for computing hydrochloric acid production in GGNS-98-0039, Revision 1 (Ref. 7.12.1) differs from that used in GGNS-98-0039, Revision 3 (Ref. 7.12.2). The hydrochloric acid production rate in GGNS-98-0039, Revision 1, is based on the mass of cable jacket and on the radiation dose rate at the cable jacket surface multiplied by a flux averaging factor. However, the hydrochloric acid production rate in GGNS-98-0039, Revision 3, is based on the cable jacket surface area and on the energy release per unit volume of containment, diminished by attenuation in air between the center of containment and the cable surface. Both methodologies use the same G value (with units converted to rads in GGNS-98-0039, Revision 1) and the same expression for energy absorption fraction in the cable jacket. Consistent with Assumption 3.8, which is conservative, the GGNS-98-0039, Revision 1, methodology for hydrochloric acid production is used herein. The benchmark (§5.8) demonstrates that both methodologies yield very similar results, and therefore the choice of the GGNS-98-0039, Revision 1, methodology used in this calculation is considered acceptable.

Hydrochloric acid generation in chlorine-bearing material in the cable is determined using the following equation from Appendix B of NUREG/CR-5950 (Ref. 7.13) and further developments from Grand Gulf Engineering Report GGNS-98-0039, Revision 1, Appendix A (Ref. 7.12.1):

$$R = G \times S \times \bar{\phi} \times A$$

where:

R = HCl production rate
G = radiolysis yield

S = cable jacket surface area
$\bar{\phi}$ = average radiation energy flux in the cable jacket
A = absorption fraction of energy flux in the cable jacket

A factor for computing the average radiation energy flux, $\bar{\phi}$, in the jacket is developed based on attenuation of radiation flux at radius r in the cable jacket (Reference 7.12.1, Appendix A, Section A.2):

$$\phi(r) = \phi(R_o) \times e^{-\mu(R_o - r)}$$

where:

r = cable radius
R_o = outside cable radius
μ = linear absorption coefficient

Integration of this equation over the cable jacket thickness leads to an expression for a flux averaging factor that can be multiplied by the flux at the cable jacket surface to give the average flux in the cable jacket:

$$\bar{\phi} = \phi(R_o) \times \frac{\frac{1}{\mu^2}\left[e^{-\mu y}(\mu y + 1) - 1\right] - \frac{R_o}{\mu}\left(e^{-\mu y} - 1\right)}{R_o y - \frac{y^2}{2}}$$

where:

$\bar{\phi}$ = average radiation energy flux in the cable jacket
$\phi(R_o)$ = radiation energy flux at the cable jacket surface
μ = linear absorption coefficient
y = thickness of cable jacket

The absorption fraction of energy flux is calculated as follows per Section 4.2 of NUREG-1081 (Ref. 7.15):

$$A = 1 - e^{-\mu \times y}$$

where:

A = fraction of radiation energy flux absorbed by cable jacket
μ = linear absorption coefficient
y = thickness of cable jacket

The HCl generation equation then becomes:

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Ref.

$$R = G \times S \times \phi(R_o) \times \frac{\frac{1}{\mu^2}\left[e^{-\mu y}(\mu y + 1) - 1\right] - \frac{R_o}{\mu}\left(e^{-\mu y} - 1\right)}{R_o y - \frac{y^2}{2}} \times \left(1 - e^{-\mu x y}\right)$$

The last two terms are the previously developed flux averaging factor and the absorption fraction, respectively.

Grand Gulf Engineering Report GGNS-98-0039, Revision 1, Appendix A (Ref. 7.12.1), then derives from this the following equation in order to use radiation dose reported in units of MegaRad per hour (or MegaRad when integrated over time) as is typically available:

$$R = G \times m_H \times \dot{X}(R_o) \times \frac{\frac{1}{\mu^2}\left[e^{-\mu y}(\mu y + 1) - 1\right] - \frac{R_o}{\mu}\left(e^{-\mu y} - 1\right)}{R_o y - \frac{y^2}{2}} \times \left(1 - e^{-\mu x y}\right)$$

where:

R = HCl production rate
G = radiolysis yield
m_H = mass of cable jacket
$\dot{X}(R_o)$ = radiation dose rate at the surface of the cable jacket
R_o = outside cable radius
μ = linear absorption coefficient
y = thickness of cable jacket

The following linear absorption coefficients are determined for PVC (see Design Input 4.4):

$\mu = 0.0739\ cm^{-1}$ for gamma radiation
$\mu = 38.976\ cm^{-1}$ for beta radiation

Per NUREG/CR-5950 (Ref. 7.13) the G value for PVC is 7.7 molecules HCl per 100 eV (in a vacuum). This corresponds to 7.98×10^{-6} g-mole HCl/g PVC per MegaRad:

$$G = \frac{7.7\,\text{molecule}}{100\,\text{eV}} \times \frac{\text{mole}}{6.022 \times 10^{23}\ \text{molecule}} \times \frac{6.241 \times 10^{11}\ \text{eV}}{\text{erg}} \times \frac{100 \times 10^{6}\ \text{erg}}{\text{MegaRad}\,\text{g}}$$

The basis for the selection of this G value is provided in Attachment 3.

Hydrochloric acid formed by gamma radiation is computed at varying times using the TID for gamma radiation in the drywell multiplied by the generation rate. The total mass of cable jacketing is determined and then used in the computation.

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Hydrochloric acid formed by beta radiation is computed at varying times using the TID for beta radiation in the drywell multiplied by the generation rate. Since all cable is modeled as free-air routed, no localized shielding from beta radiation for cables in cable tray is included.

The mass of hydrochloric acid generated by gamma and beta radiation is divided by the post-LOCA suppression chamber water volume to determine the total concentration of HCl formed by irradiation of electrical cable as a function of time.

The computations determining the hydrochloric acid generation are presented in Attachments 4 and 6, Tables 4-4 and 6-4.

5.6 Transient pH Calculation

The transient pH was computed by combining the contributions of acids and bases. The concentrations of $[H^+]$ and $[OH^-]$ were summed and the net resultant concentrations from self-neutralization determined by the relationship:

$$\left(\sum[H^+]-x\right)\times\left(\sum[OH^-]-x\right)=K_w$$

where:

K_w = dissociation constant for water
x = $[H^+]$ and $[OH^-]$ self-neutralized
$\Sigma[H^+]$ = sum of acids added [g-mole/liter]
$\Sigma[OH^-]$ = sum of bases added [g-mole/liter]

Solving for x:

$$x = \frac{[OH^-]+[H^+]-\sqrt{([OH^-]+[H^+])^2-4\times([OH^-][H^+]-K_w)}}{2}$$

The dissociation constant is temperature dependent, and the temperature function is per the CRC Handbook (Ref. 7.17, consistent with correlation used in Ref. 7.12):

$$-\log(K_w) = 15.5129 - 2.24\times10^{-2}T + 3.352\times10^{-5}T^2$$

where:

T = temperature, °F

Finally, the suppression chamber water pH is determined:

$$[H^+] = [H^+]_{sum} - x$$

$$pH = -\log([H^+])$$

Ref.

5.7 Sodium Pentaborate Addition

Sodium pentaborate can be added via the Liquid Poison System (LPS) to buffer the suppression chamber water, resulting in higher pH values.

The LPS contains an aqueous solution of sodium pentaborate ($Na_2B_{10}O_{16}\bullet10H_2O$). The solution is prepared by mixing borax ($Na_2B_4O_7\bullet10H_2O$) and boric acid (H_3BO_3) in a 1:6 stoichiometric molar ratio in distilled water (Ref. 7.22, §4.4). This yields sodium pentaborate ($Na_2B_{10}O_{16}$ or $Na_2O\bullet5B_2O_3$) and water.

Sodium pentaborate dissociates in water in accordance with the following equilibrium:

$$Na_2B_{10}O_{16}\bullet10H_2O + 6H_2O \leftrightarrow 2Na^+ + 2B(OH)_4^- + 8B(OH)_3$$

This buffers the pH in accordance with:

$$pH = pK_a + \log\frac{[anion]}{[acid]}$$

$$pH = pK_a + \log\frac{[B(OH)_4^-]}{[B(OH)_3]}$$

where:

K_a = equilibrium constant for the sodium pentaborate dissociation

The sodium pentaborate dissociation constant is temperature dependent in accordance with the following correlation (Ref. 7.12.2, §6.1):

$K_a = (0.0585\ T + 1.309) * 10^{-10}$ temperature in °F

This correlation is based on temperature data from 5-10°C (41-122°F). However, Reference 7.12.2 states the following regarding the correlation: "...linear extrapolation of this data to temperatures above 50°C is expected to result in conservatively high dissociation constants and correspondingly lower pool pH values." Therefore, use of this correlation with suppression chamber water temperatures greater than 122°F is conservative.

Due to the nature of the correlation for the pentaborate dissociation constant, a bounding 30-day suppression chamber water temperature of 200°F is used. Use of a higher temperature results in a lower final pH.

The minimum volume of the LPS injection tank is 1,325 gallons and the concentration of the sodium pentaborate solution is 9.423% at that volume based on the decahydrate (includes water of hydration) as defined in Technical Specification 3.1.2 (Ref. 7.2.1) and Reference 7.6.4.a. The specific gravity of this solution is 1.048 (Ref. 7.22, Figure 1). The minimum mass of sodium pentaborate can be calculated:

Ref.

Mass = volume * density * concentration

where the density is taken at the maximum LPS injection tank temperature, 105°F (Ref. 7.3.4, p. 3).

The number of moles of sodium pentaborate added to the suppression chamber is determined using a molecular weight of 590.224 since the concentration is based on the decahydrate. The amounts of anion and acid are 2 and 8 times this amount, respectively, by stoichiometry.

The equivalents of acid in the unbuffered suppression chamber water neutralize the equivalents of conjugate base and shift the equilibrium, so, by mass balance,

$$pH = pK_a + \log \frac{2 \times \text{mole SP} - \text{mole H}^+}{8 \times \text{mole SP} + \text{mole H}^+}$$

where:

mole SP = moles of sodium pentaborate added to the suppression chamber water
mole H^+ = moles of acid in unbuffered suppression chamber water

5.8 Benchmark

5.8.1 Input for pH Calculation Benchmark

The pH transient developed in this calculation is determined using a Microsoft Excel (Ref. 7.1) spreadsheet. In order to benchmark the spreadsheets, the design input from Grand Gulf Nuclear Station (GGNS) Calculation No. XC-Q1111-98013, Revision 2, "Suppression Pool pH Analysis," (Ref. 7.12.3) is input into the spreadsheets developed herein. Since Grand Gulf was an NRC pilot plant for Alternate Source Term implementation, the calculation has been accepted by the NRC and is part of the public record.

Case 1 of this GGNS calculation is used to benchmark the model herein. This case assumes that all source terms (except noble gases) are deposited upon release into the suppression pool water. This maximizes the suppression pool dose and the generation of nitric acid.

The design input taken from the Grand Gulf post-LOCA suppression pool pH calculation (Ref. 7.12.3) is provided in the following table. Input which is unchanged in the benchmark (e.g. core inventory fractions released into containment, etc.) is not re-stated.

Ref.

Table 5.8.1-1: Design Input from GGNS Post-LOCA Suppression Pool pH Analysis

Parameter	Value	Source
Suppression Pool (SP):		
SP volume	4.841×10^6 liters	Ref. 7.12.3, p. 2
SP initial pH	5.3	Ref. 7.12.3, p. 2
RCS initial pH	5.3	Ref. 7.12.3, p. 2
SP temperature profile	see Att. 5, Table 5-8	Ref. 7.12.3, Att. 3, p. 1
Reactor Core Inventory:		
Iodine inventory	325 g-atoms[2]	Ref. 7.12.3, p. 4
Cesium inventory	2,400 g-atoms[2]	Ref. 7.12.3, p. 4
Radiation Dose:		
Suppression pool gamma dose	Correlations provided in Att. 5, Table 5-7. SP γ dose correlation is in Mrad; other γ & β doses are in MeV/cc.	Ref. 7.12.3, Att. 2, Case 1
Drywell gamma dose[1]		Ref. 7.12.3, Att. 2, Case 1
Containment gamma dose[1]		Ref. 7.12.3, Att. 2, Case 1
Drywell beta dose[1]		Ref. 7.12.3, Att. 2, Case 1
Containment beta dose[1]		Ref. 7.12.3, Att. 2, Case 1
Cables:		
Cable material	Hypalon®	
Hypalon® density	1.55 g/cm^3	Ref. 7.15, p. 13
G value for Hypalon®	2.115 molecules HCl per 100 eV	Ref. 7.13, App. B, p. B.3
Typical/modeled cable outer radius	0.35 inches	Ref. 7.12.3, p. 8
Typical/modeled cable jacket thickness	0.28 inches	Ref. 7.12.3, p. 8
Drywell cable masses:		
mass of jacket and insulation (combined) in exposed cable trays	873.65 lbm	Ref. 7.12.3, p. 3
mass of jacket and insulation (combined) in free air drops	873.65 lbm	Ref. 7.12.3, p. 3
Containment cable masses:		
mass of jacket and insulation (combined) in exposed cable trays	14,049.27 lbm	Ref. 7.12.3, p. 3
mass of jacket and insulation (combined) in free air drops	1,561.03 lbm	Ref. 7.12.3, p. 3
SLCS:		
Neutron absorber	anhydrous sodium pentaborate	
Molecular weight ($Na_2B_{10}O_{16}$)	410	Ref. 7.12.3, p. 15
Final suppression pool temperature	120°F	Ref. 7.12.3, p. 16
Mass of sodium pentaborate injected	5,800 lbm	Ref. 7.12.3, p. 15

1) Dose in MeV/cc converted to rad using 1 rad = 8.071×10^4 MeV/cc for air at S.T.P. (Ref. 7.8, p. 23).
2) Per the CRC handbook (Ref. 7.17), a gram-atom is defined as "the mass in grams numerically equal to the atomic weight," which is essentially the same as the definition for a gram-mole. The CRC handbook defines a gram-mole as the "mass in grams numerically equal to the molecular weight." The inventories presented above are given in gram-atoms to be consistent with Reference 7.12.3.

The benchmark is performed in Attachment 5 by utilizing the above design input in the spreadsheets developed for the current calculation in Attachment 4. Wherever an input has been changed or added, the cell is italicized. Similarly, additional information/equations which are added are italicized. The addition of new equations/cells

Ref.

is necessary since, in some instances, the input provided in Reference 7.12.3 is in a different form than used herein.

5.8.2 Benchmark Results

The results of the benchmark provided in Attachment 5 are compared to the results reported in Reference 7.12.3. This comparison is illustrated in Figure 5-1, repeated below for convenience.

Figure 5-1: GGNS Benchmark
Post-LOCA Suppression Pool pH Analysis
pH Response without SLCS

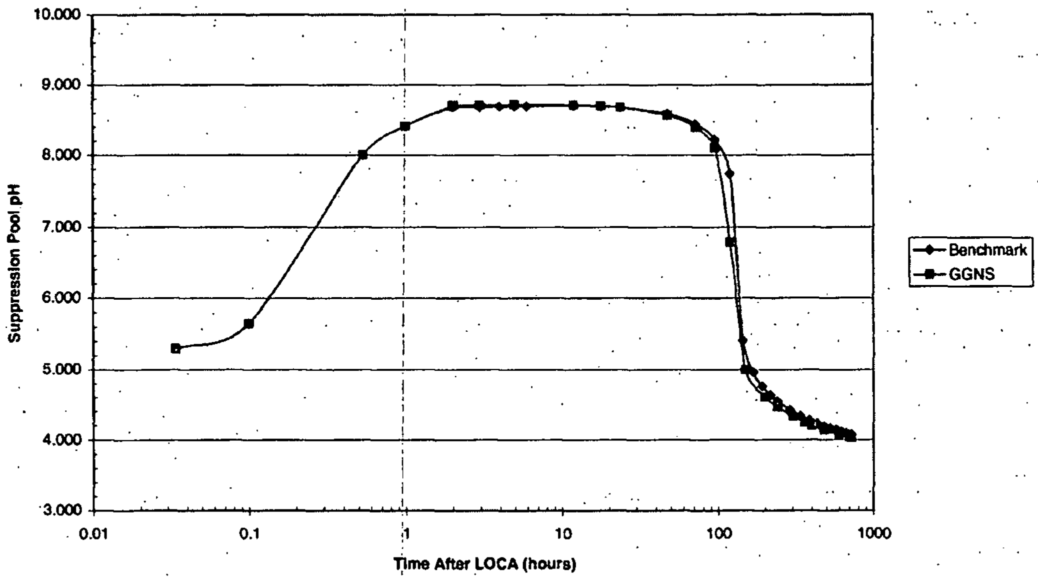

Figure 5-1 demonstrates the successful benchmarking of the model developed herein. The results are identical to 2 hours post-LOCA, thus indicating that the gap release phase and early in-vessel release phases are modeled in the same manner for both GGNS and the benchmark. Beyond 2 hours, nitric acid and hydrochloric acid are produced as a result of radiolysis. The nitric acid contribution is the same for GGNS and the benchmark.

Slight differences between the benchmark and GGNS curves beyond 2 hours are attributed to differences in methodologies between GGNS-98-0039, Revision 1 (Ref. 7.12.1), adopted in this calculation, and GGNS-98-0039, Revision 3 (Ref. 7.12.2), which is the basis for Reference 7.12.3 (the benchmark), for computing hydrochloric acid production. The hydrochloric acid production rate in GGNS-98-0039, Revision 1, is based on the mass of cable jacket and on the radiation dose rate at the cable jacket surface multiplied by a flux averaging factor. However, the hydrochloric acid production rate in GGNS-98-0039, Revision 3, is based on the cable jacket surface area and on the

Ref.

energy release per unit volume of containment, diminished by attenuation in air between the center of containment and the cable surface. Both methodologies use the same G value (with units converted to rads in GGNS-98-0039, Revision 1) and the same expression for energy absorption fraction in the cable jacket. The benchmark also demonstrates that both methodologies yield very similar results.

The final suppression pool pH calculated by the spreadsheets herein is 4.07 in comparison to 4.03 in the GGNS calculation. This is considered sufficiently accurate to benchmark the model developed for this calculation.

Similarly, the model determining the final suppression pool pH following SLCS addition is benchmarked. Both the model herein and the GGNS calculation predict a final pH of 8.46.

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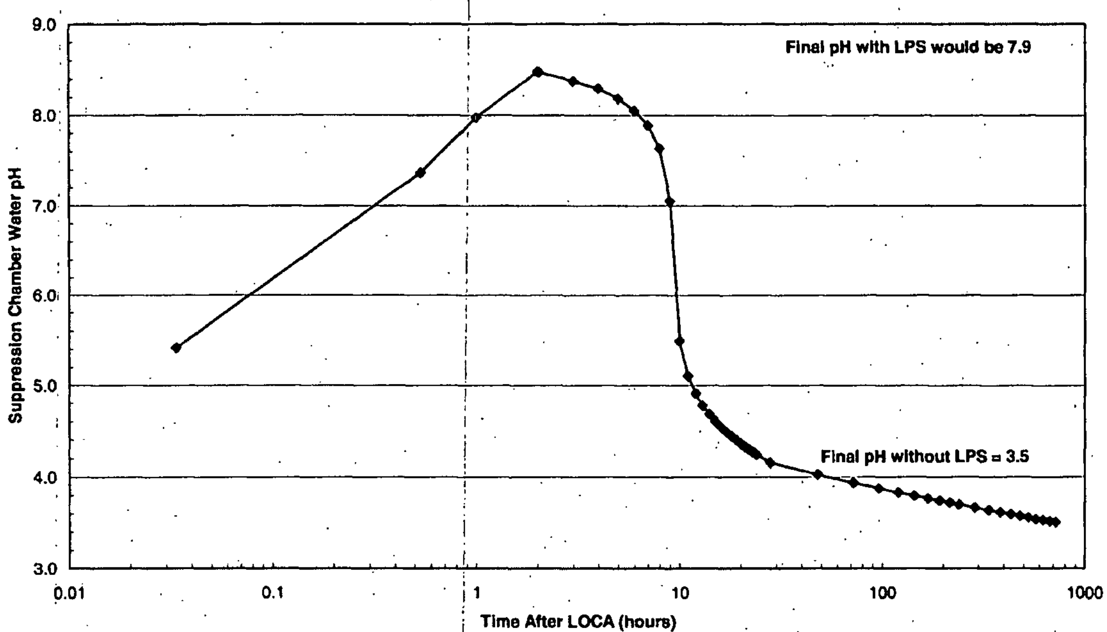
6.0 Results

6.1 Maximum Suppression Chamber Water Volume Case

6.1.1 The pH in the unbuffered post-LOCA suppression chamber water initially rises due to the influence of cesium hydroxide addition at the beginning of the LOCA, but falls to below a pH 7.0 between approximately 9 to 10 hours (see Figure 4-1, repeated below for convenience). The final pH at 30 days without buffering is 3.5, so the suppression chamber water pH does not satisfy the Acceptance Criterion of a pH greater than 7.0.

6.1.2 Addition of sodium pentaborate via the Liquid Poison System (LPS) buffers the suppression chamber water and results in a final pH at 30 days of 7.9. The suppression chamber water pH will satisfy the Acceptance Criterion of a pH greater than 7.0 with use of the LPS. The LPS should be used prior to the suppression chamber water pH falling below 7.0. When determining the appropriate time to inject the sodium pentaborate, the duration of injection should be considered as well as the amount of time to achieve a homogenous mixture in the suppression chamber water.

Figure 4-1: Nine Mile Point Unit 1
Post-LOCA Suppression Chamber Water pH Analysis
Maximum Suppression Chamber Water Volume Case
pH Response without LPS



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H. R. Kopke	M. B. Cooper	H21C0824	0

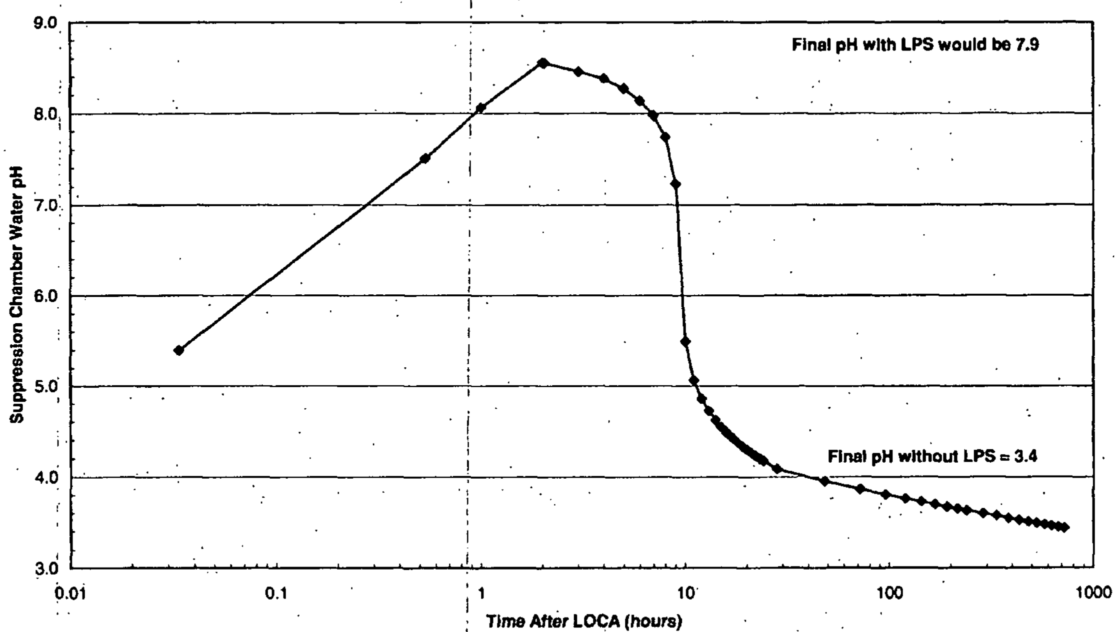
Ref.

6.2 Minimum Suppression Chamber Water Volume Case

6.2.1 The pH in the unbuffered post-LOCA suppression chamber water initially rises due to the influence of cesium hydroxide addition at the beginning of the LOCA, but falls to below a pH 7.0 between approximately 9 to 10 hours (see Figure 6-1, repeated below for convenience). The final pH at 30 days without buffering is 3.4, so the suppression chamber water pH does not satisfy the Acceptance Criterion of a pH greater than 7.0.

6.2.2 Addition of sodium pentaborate via the Liquid Poison System (LPS) buffers the suppression chamber water and results in a final pH at 30 days of 7.9. The suppression chamber water pH will satisfy the Acceptance Criterion of a pH greater than 7.0 with use of the LPS. The LPS should be used prior to the suppression chamber water pH falling below 7.0. When determining the appropriate time to inject the sodium pentaborate, the duration of injection should be considered as well as the amount of time to achieve a homogenous mixture in the suppression chamber water.

Figure 6-1: Nine Mile Point Unit 1
Post-LOCA Suppression Chamber Water pH Analysis
Minimum Suppression Chamber Water Volume Case
pH Response without LPS



6.3 Inherent Conservatisms in this Calculation

This calculation contains conservatisms which have an impact on the final pH determined herein. Several of the significant conservatisms are as follows:

Ref.

- All cable in primary containment is modeled as PVC although it is probable that a great deal of this cable is a chlorosulfonated polyethylene (CSPE) such as Hypalon. The hydrochloric acid production rate for PVC is 3.7 times greater than for Hypalon.
- All cable in primary containment is modeled as being free air routed. Thus, self shielding of cable from beta radiation is ignored. This has a significant impact as beta radiation is the main source of HCl production due to its high (~1) absorption factor into the cable.
- The core inventory of cesium-133 is not included in this analysis. This stable isotope would increase the pH in the post-LOCA suppression chamber water since it would form cesium hydroxide.

6.4 Conclusions

Therefore, based on the results presented in Sections 6.1 and 6.2, the LPS is required at NMP Unit 1 to control the post-LOCA suppression chamber water pH. The LPS will not be required until approximately 9 hours post LOCA, even postulating the worst case scenario, i.e. with the conservatisms listed in Section 6.3.

Ref.

7.0 References

7.1 Microsoft Excel 97 SR-2, S&L Program No. 03.2.081-1.0, dated 04/28/1999.

7.2 NMPNS Unit 1 Technical Specifications
- 7.2.1 TS 3.1.2, Amendment 166, "Liquid Poison System."
- 7.2.2 TS 3.3.2, Amendment 170, "Pressure Suppression System Pressure and Suppression Chamber Water Temperature and Level."

7.3 NMPNS Unit 1 Procedures
- 7.3.1 Chemistry Manual, Revision 3, Attachment 10, "Chemistry Control Levels." (Historical)
- 7.3.2 GAP-CHE-01, Revision 09, "BWR Water Chemistry Operating Limits."
- 7.3.3 S-CTP-V666, Revision 01, "Auxiliary Chemistry System."
- 7.3.4 N1-OP-12, Revision 27, "Liquid Poison System."

7.4 NMPNS Unit 1 Design Basis Document N1-SD-022, "Liquid Poison System," Revision 3.

7.5 NMPNS Unit 1 Facility Operating License, Docket No. 50-220, Amendment 172.

7.6 NMPNS Calculations
- 7.6.1 S0TORUSM003, Revision 2, "Volume of Air Displaced by Torus Internals Above 207.5' Elevation." (Unit 1)
- 7.6.2 S3.11-DWLOCA-BETA, Revision 0, "Beta Dose Calc. for Containment Post-LOCA." (Unit 1)
- 7.6.3 PR-C-21-Q, Revision 1, "Post-LOCA Radiation Environment (Gamma) in Drywell and Wetwell due to Airborne and Liquid Sources." (Unit 2)
- 7.6.4 S14-41-M002, Revision 2, "LPS Enriched Boron." (Unit 1)
  - 7.6.4.a S14-41-M002, Revision 2, Disposition 02A.
- 7.6.5 S0-TORUS-M009, Revision 2, "NMP-1 TORUS Pool Heat Up Analysis." (Unit 1)
- 7.6.6 PR-C-20-F, Revision 3, "Dose Rates versus Distance and Dose Rate to Dose Conversion Factors for Piping Containing Post-LOCA Fluids." (Unit 2)
- 7.6.7 S0.0-FPE-002, Revision 1, "Unit 1 Combustible Loading Calculation." (Unit 1)
- 7.6.8 H21C-097, Revision 0, "Post-LOCA Suppression Pool pH Analysis." (Unit 2)

7.7 GE Nuclear Energy (GENE) Document No. GE-NE-A41-00097-00-01. DRF A41-00097-00, Class III, "Nine Mile Point Unit 2 24-Month Cycle Fission Product Inventory Evaluation," dated February 1999.

7.8 Radiological Health Handbook, U.S. Department of Health, Education, and Welfare, Public Health Service, Compiled and Edited by the Bureau of Radiological Health and the Training Institute Environmental Control Administration, Revised Edition, 1970.

7.9 "Nuclides and Isotopes – Chart of the Nuclides," 15th Edition, GE Nuclear Energy, 1996.

7.10 U.S. Nuclear Regulatory Commission Regulatory Guides
- 7.10.1 Regulatory Guide 1.49, Revision 1, "Power Levels of Nuclear Power Plants," dated December 1973.

Ref.

7.10.2 Regulatory Guide 1.183, Revision 0, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," dated July 2000.

7.11 NMPNS Unit 1 Updated Final Safety Analysis Report (UFSAR).
7.11.1 UFSAR Revision 16, Table XV-32a, "Significant Input Parameters to the DBR Containment Suppression Chamber Heatup Analysis."
7.11.2 UFSAR Revision 15, Section VI-B.1.2, "Design Basis Accident."
7.11.3 UFSAR Revision 17, Table XV-9a, "Core Spray System Flow Performance Assumed in LOCA Analysis."
7.11.4 UFSAR Revision 16, Table XV-11, "Single Failures Considered in LOCA Analysis."
7.11.5 UFSAR Revision 15, Section IX-B.3.4, "Types of Cables."
7.11.6 UFSAR Revision 16, Table 3.1.1-1, "Fire Hazard/Fire Loading," in Appendix 10A (Fire Hazards Analysis).
7.11.7 UFSAR Revision 17, Section VI-E, "Containment Ventilation System," Sub-Section VI-E.1.1, "Design Bases."
7.11.8 UFSAR Revision 15, Section IV, "Reactor," Sub-Section IV-A.1.0, "General."

7.12 Grand Gulf Nuclear Station Documents
7.12.1 Engineering Report No. GGNS-98-0039, Revision 1, "Suppression Pool pH and Iodine Re-Evolution Methodology." (included as Attachment 7 to Letter GNRO-2000/20005 from GGNS to the NRC)
7.12.2 Engineering Report No. GGNS-98-0039, Revision 3, " Suppression Pool pH and Iodine Re-Evolution Methodology." (included as Attachment 1 to Letter GNRO-2000/00100 from GGNS to the NRC)
7.12.3 Calculation No. XC-Q1111-98013, Revision 2, "Suppression Pool pH Analysis." (included as Attachment 2 to Letter GNRO-2000/00100 from GGNS to the NRC)

7.13 NUREG/CR-5950, "Iodine Evolution and pH Control", Published December, 1992.

7.14 NUREG-1465, "Accident Source Terms for Light Water Nuclear Power Plants", Published February, 1995.

7.15 NUREG-1081, "Post Accident Gas Generation from Radiolysis of Organic Materials", Published September, 1984.

7.16 NUREG/CR-5732, "Iodine Chemical Forms in LWR Severe Accidents", Published April, 1992.

7.17 CRC Handbook of Chemistry and Physics, 73rd Edition.

7.18 ASME Steam Tables, 4th Edition, The American Society of Mechanical Engineers, New York, NY, 1979.

7.19 Avallone, E.A. and T. Baumeister III, Editors, Marks' Standard Handbook for Mechanical Engineers, 10th Edition, McGraw-Hill, New York, NY, 1996. ISBN 0-07-004997-1.

7.20 U.S. Nuclear Regulatory Commission Standard Review Plan, NUREG-0800, Revision 2, Section 6.5.2, "Containment Spray as a Fission Product Cleanup System."

Project: Nine Mile Point Nuclear Station Unit: 1 Disposition: ____

Originator/Date	Reviewer/Date	Calculation No.	Revision
H. R. Kopke	M. B. Cooper	H21C0824	0

Ref.

7.21 Commission Paper No. SECY-94-302, "Source Term Related Technical and Licensing Issues Pertaining to Evolutionary and Passive Light Water Reactor Designs," December 19, 1994.

7.22 General Electric Design Specification 22A7641, Revision 1, "Standby Liquid Control System."

7.23 NMPNS Unit 1 Cable Specifications
7.23.1 Spec. No. E-1106, "600V Flame and Radiation Resistant Instrumentation Cable."
7.23.2 Spec. No. E-1107, "600V Flame and Radiation Resistant Control Cable."
7.23.3 Spec. No. E-1108, "600V Flame and Radiation Resistant Low Voltage Power Cable."

7.24 Chilton, A. B., Shultis, J. K., and Faw, R. E., Principles of Radiation Shielding, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1984. ISBN 0-13-709907-X

7.25 NUREG/CR-1413, "A Radionuclide Decay Data Base - Index and Summary Table," May 1980.

7.26 GE Document No. APED-5398-A, "Summary of Fission Product Yields for U^{235}, U^{238}, Pu^{239}, and Pu^{241} at Thermal, Fission Spectrum and 14 MeV Neutron Energies," Class I, Revised, dated October 1, 1968.

7.27 GE Document No. NEDO-24290, 80NED289, NSE-47-0880, DRF A00-960, Class I, "Results of Qualification Data Search for Nine Mile Point Nuclear Station Unit 1 – Response to IE Bulletin 79-01 & 01B," dated October 1980.

7.28 National Institute of Standards and Technology (NIST) Chemistry WebBook. (http://webbook.nist.gov/chemistry/)

7.29 TRAK 2000 Database

Attachment 1

Determination of Reactor Core Inventories

Purpose

The purpose of this attachment is to document the inventory of all iodine and cesium isotopes in the reactor core.

Methodology

The reactor core inventory is calculated using GE document GE-NE-A41-00097-00-01, DRF A41-00097-00, "Nine Mile Point Unit 2 24-Month Cycle Fission Product Inventory Evaluation," (Ref. 7.7 in main body). Case 3, which addresses a single batch core with 1,400 Effective Full Power Days (EFPD) and 34,000 MWd/ST Expected Core Average Exposure (CAVEX), is conservatively used to determine the inventories. The inventory at both t=0 and t=30 days (720 hours) is calculated to demonstrate that the values at t=0 are conservative.

The use of the Unit 2 fission product inventory is considered bounding for Unit 1 for the following reasons. First, the inventory of short lived nuclides is nearly proportional to power level, so that for these nuclides normalized activities (Ci/MWt) generated at a power level of 3,467 MWt would be essentially identical to normalized activities generated at a power level of 1,850 MWt. Second, the inventory of long lived nuclides is more dependent on burnup. The average burnup at the end of cycle for Unit 1 is approximately 30,000 MWd/ST [(44,000 MWd/ST)*(2/3)] based on an equilibrium reload batch discharge exposure of 44,000 MWd/ST and the replacement of approximately 1/3 of the core during each refueling (UFSAR Section IV-A.1.0, main body Reference 7.11.8). Therefore, the use of the 34,000 MWd/ST Unit 2 activities is bounding for long lived nuclides.

GE-NE-A41-00097-00-01 presents the activity in Ci/MWt. To convert this to core inventory, the methodology on p. 29 of the Radiological Health Handbook (Ref. 7.8 in the main body) is used.

$$\lambda N = \frac{\ln(2)\cdot N}{t_{1/2}} = \frac{\ln(2)\cdot N_a}{M\cdot t_{1/2}} \quad \Rightarrow \quad \frac{\lambda N}{3.7\times10^{10}}\left[\frac{Ci}{gm}\right] = \frac{\ln(2)\cdot N_a}{3.7\times10^{10}\cdot M\cdot t_{1/2}}$$

where:

λN	specific activity [dis/sec/gm]
N	number of atoms per gram [atoms/gm]
$t_{1/2}$	half life [sec]
N_a	Avogadro constant [atoms/mole]
M	molecular weight [gm/mole] = [amu]
3.7×10^{10}	disintegrations per second per Curie

Once the total core inventory is known, the fractions released during the gap release phase and early in-vessel (EIV) phase are determined in accordance with the guidance provided in Table 1 of Regulatory Guide 1.183 (Ref. 7.10.2 in main body). This table is summarized below for alkali metals such as cesium and halogens such as iodine.

Group	Core Inventory Fraction Released into Containment		
	Gap Release Phase	Early In-Vessel Phase	Total
Halogens	0.05	0.25	0.30
Alkali Metals	0.05	0.20	0.25

Notes/Assumptions

See the text in the main body for the basis for these items.

1. Stable cesium is conservatively not included in the cesium inventory.
2. The mass of iodine-127 is assumed to be 30% of the mass of iodine-129.

Results

The results below are taken from Tables 1-1 through 1-4.

Element	Reactor Core Inventory [gram-moles]					
	t=0			t=30 days		
	Gap Release	EIV	Total	Gap Release	EIV	Total
Iodine	7.2	36.0	43.2	7.0	35.1	42.1
Cesium	53.7	214.9	268.6	53.5	214.0	267.6

It can be seen that the reactor core inventory of both iodine and cesium does not change appreciably during the duration of the accident. Therefore, use of the values at time=0 is both reasonable and conservative.

Table 1-1: Core Iodine Inventory Determination (t=0 Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

Time post-LOCA	0 sec	
Neutron Mass	1.008665 amu	(Ref. 1)
Core Thermal Power (100%)	1,850 MWt	(Ref. 5)
Core Thermal Power (102%)	1,887 MWt	(Ref. 6)
1 Curie	3.70E+10 dis/sec	(Ref. 1)
Avogadro's Number	6.022137E+23 atoms/mole	(Ref. 2)

Core Inventory Fraction Released in Containment for Halogens

Gap Release Phase	0.05	(Ref. 4, Tbl 1)
Early In-Vessel Phase	0.25	(Ref. 4, Tbl 1)

Isotope	Atomic Mass (Ref. 1) [amu]	Half Life (Ref. 2)	$t_{1/2}$ units	Half Life [sec]	Activity (Ref. 3) [Ci/MWt]	Activity per Core [Ci/core]	Specific Activity [Ci/gm]	Core Inventory [gm/core]	Gap Release [mole]	EIV Release [mole]	Total Release [mole]
I-127[2]	126.904470	stable							1.61E+00	8.07E+00	9.69E+00
I-128	127.905838	25.00	m	1,500	4.28E+02	8.08E+05	5.88E+07	1.37E-02	5.37E-06	2.68E-05	3.22E-05
I-129	128.904987	1.57E+07	a	4.95E+14	1.30E-03	2.45E+00	1.77E-04	1.39E+04	5.38E+00	2.69E+01	3.23E+01
I-130	129.906676	12.36	h	44,496	1.09E+03	2.06E+06	1.95E+06	1.05E+00	4.06E-04	2.03E-03	2.43E-03
I-130M	129.906676	9.0	m	540	4.23E+02	7.98E+05	1.61E+08	4.96E-03	1.91E-06	9.55E-06	1.15E-05
I-131	130.906127	8.020	d	692,928	2.71E+04	5.11E+07	1.24E+05	4.11E+02	1.57E-01	7.85E-01	9.42E-01
I-132	131.907981	2.28	h	8,208	3.92E+04	7.40E+07	1.04E+07	7.10E+00	2.69E-03	1.35E-02	1.61E-02
I-133	132.907750	20.8	h	74,880	5.51E+04	1.04E+08	1.13E+06	9.17E+01	3.45E-02	1.73E-01	2.07E-01
I-133M	132.907750	9	s	9	1.70E+03	3.21E+06	9.43E+09	3.40E-04	1.28E-07	6.40E-07	7.68E-07
I-134	133.909850	52.6	m	3,156	6.03E+04	1.14E+08	2.67E+07	4.26E+00	1.59E-03	7.96E-03	9.55E-03
I-134M	133.909850	3.7	m	222	6.00E+03	1.13E+07	3.79E+08	2.98E-02	1.11E-05	5.57E-05	6.68E-05
I-135	134.910020	6.57	h	23,652	5.16E+04	9.74E+07	3.54E+06	2.75E+01	1.02E-02	5.10E-02	6.12E-02
I-136	135.914740	1.39	m	83	2.44E+04	4.60E+07	9.95E+08	4.63E-02	1.70E-05	8.51E-05	1.02E-04
I-136M	135.914740	47	s	47	1.43E+04	2.70E+07	1.77E+09	1.53E-02	5.62E-06	2.81E-05	3.37E-05
I-137[1]	136.923405	24.5	s	24.5	2.38E+04	4.49E+07	3.36E+09	1.34E-02	4.88E-06	2.44E-05	2.93E-05
I-138[1]	137.932070	6.5	s	6.5	1.18E+04	2.23E+07	1.26E+10	1.77E-03	6.41E-07	3.21E-06	3.85E-06
I-139[1]	138.940735	2.30	s	2.30	5.22E+03	9.85E+06	3.53E+10	2.79E-04	1.00E-07	5.02E-07	6.02E-07
I-140[1]	139.949400	0.86	s	0.86	1.47E+03	2.77E+06	9.37E+10	2.96E-05	1.06E-08	5.29E-08	6.34E-08
I-141[1]	140.958065	0.45	s	0.45	2.43E+02	4.59E+05	1.78E+11	2.58E-06	9.15E-10	4.57E-09	5.49E-09
I-142[1]	141.966730	0.2	s	0.2	3.53E+01	6.66E+04	3.97E+11	1.68E-07	5.90E-11	2.95E-10	3.54E-10
I-143[1][3]	142.975395			n/a	2.33E+00	4.40E+03					
I-144[1][3]	143.984060			n/a	1.90E-01	3.59E+02					
							Total	1.44E+04	7.20	36.02	43.23

Notes
1) Atomic mass not given for these isotopes in Reference 1; therefore, a multiple of the neutron mass is added to the atomic mass of I-136M.
2) Since I-127 is a stable element, its quantity is not presented in Reference 3. The mass of I-127 is assumed to be 30% of the mass of I-129.
3) Half-life information not available in Reference 2.

References
1. Radiological Health Handbook, 1970 (main body Reference 7.8)
2. Chart of the Nuclides, 15th Edition (main body Reference 7.9)
3. GE-NE-A41-00097-00-01, NMP2 24-month Cycle Fission Product Inventory Evaluation (main body Reference 7.7)
4. Regulatory Guide 1.183 (main body Reference 7.10.2)
5. NMP1 Site License (main body Reference 7.5)
6. Regulatory Guide 1.49 (main body Reference 7.10.1)

Table 1-2: Core Cesium Inventory Determination (t=0 Post-LOCA) (Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

Time post-LOCA	0 sec	
Neutron Mass	1.008665 amu	(Ref. 1)
Core Thermal Power (100%)	1,850 MWt	(Ref. 5)
Core Thermal Power (102%)	1,887 MWt	(Ref. 6)
1 Curie	3.70E+10 dis/sec	(Ref. 1)
Avogadro's Number	6.022137E+23 atoms/mole	(Ref. 2)

Core Inventory Fraction Released in Containment for Alkalis

Gap Release Phase	0.05	(Ref. 4, Tbl 1)
Early In-Vessel Phase	0.20	(Ref. 4, Tbl 1)

Isotope	Atomic Mass (Ref. 1) [amu]	Half Life (Ref. 2)	$t_{1/2}$ units	Half Life [sec]	Activity (Ref. 3) [Ci/MWt]	Activity per Core [Ci/core]	Specific Activity [Ci/gm]	Core Inventory [gm/core]	Gap Release [mole]	EIV Release [mole]	Total Release [mole]
CS-132	131.906393	6.48	d	559,872	7.96E+00	1.50E+04	1.53E+05	9.83E-02	3.73E-05	1.49E-04	1.86E-04
CS-133(1)											
CS-134	133.906823	2.065	a	65,121,840	7.29E+03	1.38E+07	1.29E+03	1.06E+04	3.97E+00	1.59E+01	1.99E+01
CS-134M	133.906823	2.90	h	10,440	1.70E+03	3.21E+06	8.07E+06	3.98E-01	1.48E-04	5.94E-04	7.42E-04
CS-135	134.905770	2.30E+06	a	7.25E+13	2.51E-02	4.74E+01	1.15E-03	4.11E+04	1.52E+01	6.09E+01	7.61E+01
CS-135M	134.905770	53	m	3,180	8.81E+02	1.66E+06	2.63E+07	6.32E-02	2.34E-05	9.37E-05	1.17E-04
CS-136	135.907340	13.16	d	1,137,024	2.28E+03	4.30E+06	7.30E+04	5.89E+01	2.17E-02	8.67E-02	1.08E-01
CS-137	136.906770	30.07	a	9.48E+08	4.35E+03	8.21E+06	8.69E+01	9.45E+04	3.45E+01	1.38E+02	1.72E+02
CS-138	137.910800	32.2	m	1,932	5.00E+04	9.44E+07	4.23E+07	2.23E+00	8.08E-04	3.23E-03	4.04E-03
CS-138M	137.910800	2.9	m	174	2.39E+03	4.51E+06	4.70E+08	9.59E-03	3.48E-06	1.39E-05	1.74E-05
CS-139	138.912900	9.3	m	558	4.73E+04	8.93E+07	1.46E+08	6.13E-01	2.21E-04	8.83E-04	1.10E-03
CS-140	139.917110	1.06	m	64	4.26E+04	8.04E+07	1.27E+09	6.34E-02	2.27E-05	9.06E-05	1.13E-04
CS-141(2)	140.925775	24.9	s	24.9	3.16E+04	5.96E+07	3.22E+09	1.85E-02	6.58E-06	2.63E-05	3.29E-05
CS-142(2)	141.934440	1.8	s	1.8	1.91E+04	3.60E+07	4.42E+10	8.16E-04	2.88E-07	1.15E-06	1.44E-06
CS-143(2)	142.943105	1.78	s	1.78	9.33E+03	1.76E+07	4.43E+10	3.97E-04	1.39E-07	5.56E-07	6.94E-07
CS-144(2)	143.951770	1.01	s	1.01	2.70E+03	5.09E+06	7.76E+10	6.57E-05	2.28E-08	9.12E-08	1.14E-07
CS-145(2)	144.960435	0.59	s	0.59	6.79E+02	1.28E+06	1.32E+11	9.71E-06	3.35E-09	1.34E-08	1.68E-08
CS-146(2)	145.969100	0.322	s	0.322	9.96E+01	1.88E+05	2.40E+11	7.83E-07	2.68E-10	1.07E-09	1.34E-09
CS-147(2)	146.977765	0.227	s	0.227	1.65E+01	3.11E+04	3.38E+11	9.21E-08	3.13E-11	1.25E-10	1.57E-10
CS-148(2)	147.986430	0.15	s	0.15	1.07E+00	2.02E+03	5.08E+11	3.97E-09	1.34E-12	5.37E-12	6.71E-12
							Total	**1.462E+05**	**53.72**	**214.87**	**268.59**

Notes
1) Stable cesium is conservatively not accounted for in this analysis as it forms cesium hydroxide (CsOH).
2) Atomic mass not given for these isotopes in Reference 1; therefore, a multiple of the neutron mass is added to the atomic mass of CS-140.

References
1. Radiological Health Handbook, 1970 (main body Reference 7.8)
2. Chart of the Nuclides, 15th Edition (main body Reference 7.9)
3. GE-NE-A41-00097-00-01, NMP2 24-month Cycle Fission Product Inventory Evaluation (main body Reference 7.7)
4. Regulatory Guide 1.183 (main body Reference 7.10.2)
5. NMP1 Site License (main body Reference 7.5)
6. Regulatory Guide 1.49 (main body Reference 7.10.1)

Table 1-3: Core Iodine Inventory Determination (t=30 days Post-LOCA) (Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

Time post-LOCA	30 days	
Neutron Mass	1.008665 amu	(Ref. 1)
Core Thermal Power (100%)	1,850 MWt	(Ref. 5)
Core Thermal Power (102%)	1,887 MWt	(Ref. 6)
1 Curie	3.70E+10 dis/sec	(Ref. 1)
Avogadro's Number	6.022137E+23 atoms/mole	(Ref. 2)

<u>Core Inventory Fraction Released in Containment for Halogens</u>

Gap Release Phase	0.05	(Ref. 4, Tbl 1)
Early In-Vessel Phase	0.25	(Ref. 4, Tbl 1)

Isotope	Atomic Mass (Ref. 1) [amu]	Half Life (Ref. 2)	$t_{1/2}$ units	Half Life [sec]	Activity (Ref. 3) [Ci/MWt]	Activity per Core [Ci/core]	Specific Activity [Ci/gm]	Core Inventory [gm/core]	Gap Release [mole]	EIV Release [mole]	Total Release [mole]
I-127[(2)]	126.904470	stable							1.61E+00	8.07E+00	9.69E+00
I-128	127.905838	25.00	m	1,500	0.00E+00	0.00E+00	5.88E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-129	128.904987	1.57E+07	a	4.95E+14	1.30E-03	2.45E+00	1.77E-04	1.39E+04	5.38E+00	2.69E+01	3.23E+01
I-130	129.906676	12.36	h	44,496	3.18E-15	6.00E-12	1.95E+06	3.07E-18	1.18E-21	5.92E-21	7.10E-21
I-130M	129.906676	9.0	m	540	0.00E+00	0.00E+00	1.61E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-131	130.906127	8.020	d	692,928	2.10E+03	3.96E+06	1.24E+05	3.19E+01	1.22E-02	6.08E-02	7.30E-02
I-132	131.907981	2.28	h	8,208	6.71E+01	1.27E+05	1.04E+07	1.22E-02	4.61E-06	2.30E-05	2.76E-05
I-133	132.907750	20.8	h	74,880	2.14E-06	4.04E-03	1.13E+06	3.56E-09	1.34E-12	6.70E-12	8.04E-12
I-133M	132.907750	9	s	9	0.00E+00	0.00E+00	9.43E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-134	133.909850	52.6	m	3,156	0.00E+00	0.00E+00	2.67E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-134M	133.909850	3.7	m	222	0.00E+00	0.00E+00	3.79E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135	134.910020	6.57	h	23,652	0.00E+00	0.00E+00	3.54E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-136	135.914740	1.39	m	83	0.00E+00	0.00E+00	9.95E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-136M	135.914740	47	s	47	0.00E+00	0.00E+00	1.77E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-137[(1)]	136.923405	24.5	s	24.5	0.00E+00	0.00E+00	3.36E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-138[(1)]	137.932070	6.5	s	6.5	0.00E+00	0.00E+00	1.26E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-139[(1)]	138.940735	2.30	s	2.30	0.00E+00	0.00E+00	3.53E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-140[(1)]	139.949400	0.86	s	0.86	0.00E+00	0.00E+00	9.37E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-141[(1)]	140.958065	0.45	s	0.45	0.00E+00	0.00E+00	1.78E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-142[(1)]	141.966730	0.2	s	0.2	0.00E+00	0.00E+00	3.97E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-143[(1)(3)]	142.975395			n/a	0.00E+00	0.00E+00					
I-144[(1)(3)]	143.984060			n/a		0.00E+00					
							Total	1.39E+04	7.01	35.05	42.06

<u>Notes</u>

1) Atomic mass not given for these isotopes in Reference 1; therefore, a multiple of the neutron mass is added to the atomic mass of I-136M.
2) Since I-127 is a stable element, its quantity is not presented in Reference 3. The mass of I-127 is assumed to be 30% of the mass of I-129.
3) Half-life information not available in Reference 2.

<u>References</u>

1. Radiological Health Handbook, 1970 (main body Reference 7.8)
2. *Chart of the Nuclides, 15th Edition* (main body Reference 7.9)
3. GE-NE-A41-00097-00-01, NMP2 24-month Cycle Fission Product Inventory Evaluation (main body Reference 7.7)
4. Regulatory Guide 1.183 (main body Reference 7.10.2)
5. NMP1 Site License (main body Reference 7.5)
6. Regulatory Guide 1.49 (main body Reference 7.10.1)

Table 1-4: Core Cesium Inventory Determination (t=30 days Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

Time post-LOCA	30 days		
Neutron Mass	1.008665 amu	(Ref. 1)	
Core Thermal Power (100%)	1,850 MWt	(Ref. 5)	
Core Thermal Power (102%)	1,887 MWt	(Ref. 6)	
1 Curie	3.70E+10 dis/sec	(Ref. 1)	
Avogadro's Number	6.022137E+23 atoms/mole	(Ref. 2)	

<u>Core Inventory Fraction Released in Containment for Alkalis</u>

Gap Release Phase	0.05	(Ref. 4, Tbl 1)
Early In-Vessel Phase	0.20	(Ref. 4, Tbl 1)

Isotope	Atomic Mass (Ref. 1) [amu]	Half Life (Ref. 2)	$t_{1/2}$ units	Half Life [sec]	Activity (Ref. 3) [Ci/MWt]	Activity per Core [Ci/core]	Specific Activity [Ci/gm]	Core Inventory [gm/core]	Gap Release [mole]	EIV Release [mole]	Total Release [mole]
CS-132	131.906393	6.48	d	559,872	3.21E-01	6.06E+02	1.53E+05	3.97E-03	1.50E-06	6.01E-06	7.52E-06
CS-133(1)											
CS-134	133.906823	2.065	a	65,121,840	7.09E+03	1.34E+07	1.29E+03	1.03E+04	3.86E+00	1.54E+01	1.93E+01
CS-134M	133.906823	2.90	h	10,440	0.00E+00	0.00E+00	8.07E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-135	134.905770	2.30E+06	a	7.25E+13	2.51E-02	4.74E+01	1.15E-03	4.11E+04	1.52E+01	6.09E+01	7.61E+01
CS-135M	134.905770	53	m	3,180	0.00E+00	0.00E+00	2.63E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-136	135.907340	13.16	d	1,137,024	4.66E+02	8.79E+05	7.30E+04	1.20E+01	4.43E-03	1.77E-02	2.22E-02
CS-137	136.906770	30.07	a	9.48E+08	4.34E+03	8.19E+06	8.69E+01	9.42E+04	3.44E+01	1.38E+02	1.72E+02
CS-138	137.910800	32.2	m	1,932	0.00E+00	0.00E+00	4.23E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-138M	137.910800	2.9	m	174	0.00E+00	0.00E+00	4.70E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-139	138.912900	9.3	m	558	0.00E+00	0.00E+00	1.46E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-140	139.917110	1.06	m	64	0.00E+00	0.00E+00	1.27E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-141(2)	140.925775	24.9	s	24.9	0.00E+00	0.00E+00	3.22E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-142(2)	141.934440	1.8	s	1.8	0.00E+00	0.00E+00	4.42E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-143(2)	142.943105	1.78	s	1.78	0.00E+00	0.00E+00	4.43E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-144(2)	143.951770	1.01	s	1.01	0.00E+00	0.00E+00	7.76E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-145(2)	144.960435	0.59	s	0.59	0.00E+00	0.00E+00	1.32E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-146(2)	145.969100	0.322	s	0.322	0.00E+00	0.00E+00	2.40E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-147(2)	146.977765	0.227	s	0.227	0.00E+00	0.00E+00	3.38E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-148(2)	147.986430	0.15	s	0.15	0.00E+00	0.00E+00	5.08E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
							Total	**1.457E+05**	**53.5**	**214.0**	**267.6**

<u>Notes</u>

1) Stable cesium is conservatively not accounted for in this analysis as it forms cesium hydroxide (CsOH).
2) Atomic mass not given for these isotopes in Reference 1; therefore, a multiple of the neutron mass is added to the atomic mass of CS-140.

<u>References</u>

1. Radiological Health Handbook, 1970 (main body Reference 7.8)
2. Chart of the Nuclides, 15th Edition (main body Reference 7.9)
3. GE-NE-A41-00097-00-01, NMP2 24-month Cycle Fission Product Inventory Evaluation (main body Reference 7.7)
4. Regulatory Guide 1.183 (main body Reference 7.10.2)
5. NMP1 Site License (main body Reference 7.5)
6. Regulatory Guide 1.49 (main body Reference 7.10.1)

Table 1-1 Equations: Core Iodine Inventory Determination (t=0 Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

1/10/05

	A	B	C	D	E
1	Time post-LOCA			0	sec
2	Neutron Mass			1.008665	amu
3	Core Thermal Power (100%)			1850	MWt
4	Core Thermal Power (102%)			=D3*1.02	MWt
5	1 Curie			37000000000	dis/sec
6	Avogadro's Number			6.022137E+23	atoms/mole
7					
8	Isotope	Atomic Mass (Ref. 1)	Half Life (Ref. 2)	$t_{1/2}$ units	Half Life
9		[amu]			[sec]
10	I-127[2]	126.90447	stable		
11	I-128	127.905838	25	m	=IF(D11="s",C11,IF(D11="m",C11*60,IF(D11="h",C11*60*60,IF(D11="d",C11*24*60*60,IF(D11="a",C11*365*24*60*60,"n/a")))))
12	I-129	128.904987	15700000	a	=IF(D12="s",C12,IF(D12="m",C12*60,IF(D12="h",C12*60*60,IF(D12="d",C12*24*60*60,IF(D12="a",C12*365*24*60*60,"n/a")))))
13	I-130	129.906676	12.36	h	=IF(D13="s",C13,IF(D13="m",C13*60,IF(D13="h",C13*60*60,IF(D13="d",C13*24*60*60,IF(D13="a",C13*365*24*60*60,"n/a")))))
14	I-130M	129.906676	9	m	=IF(D14="s",C14,IF(D14="m",C14*60,IF(D14="h",C14*60*60,IF(D14="d",C14*24*60*60,IF(D14="a",C14*365*24*60*60,"n/a")))))
15	I-131	130.906127	8.02	d	=IF(D15="s",C15,IF(D15="m",C15*60,IF(D15="h",C15*60*60,IF(D15="d",C15*24*60*60,IF(D15="a",C15*365*24*60*60,"n/a")))))
16	I-132	131.907981	2.28	h	=IF(D16="s",C16,IF(D16="m",C16*60,IF(D16="h",C16*60*60,IF(D16="d",C16*24*60*60,IF(D16="a",C16*365*24*60*60,"n/a")))))
17	I-133	132.90775	20.8	h	=IF(D17="s",C17,IF(D17="m",C17*60,IF(D17="h",C17*60*60,IF(D17="d",C17*24*60*60,IF(D17="a",C17*365*24*60*60,"n/a")))))
18	I-133M	132.90775	9	s	=IF(D18="s",C18,IF(D18="m",C18*60,IF(D18="h",C18*60*60,IF(D18="d",C18*24*60*60,IF(D18="a",C18*365*24*60*60,"n/a")))))
19	I-134	133.90985	52.6	m	=IF(D19="s",C19,IF(D19="m",C19*60,IF(D19="h",C19*60*60,IF(D19="d",C19*24*60*60,IF(D19="a",C19*365*24*60*60,"n/a")))))
20	I-134M	133.90985	3.7	m	=IF(D20="s",C20,IF(D20="m",C20*60,IF(D20="h",C20*60*60,IF(D20="d",C20*24*60*60,IF(D20="a",C20*365*24*60*60,"n/a")))))
21	I-135	134.91002	6.57	h	=IF(D21="s",C21,IF(D21="m",C21*60,IF(D21="h",C21*60*60,IF(D21="d",C21*24*60*60,IF(D21="a",C21*365*24*60*60,"n/a")))))
22	I-136	135.91474	1.39	m	=IF(D22="s",C22,IF(D22="m",C22*60,IF(D22="h",C22*60*60,IF(D22="d",C22*24*60*60,IF(D22="a",C22*365*24*60*60,"n/a")))))
23	I-136M	135.91474	47	s	=IF(D23="s",C23,IF(D23="m",C23*60,IF(D23="h",C23*60*60,IF(D23="d",C23*24*60*60,IF(D23="a",C23*365*24*60*60,"n/a")))))
24	I-137[1]	=B23+1*D$2	24.5	s	=IF(D24="s",C24,IF(D24="m",C24*60,IF(D24="h",C24*60*60,IF(D24="d",C24*24*60*60,IF(D24="a",C24*365*24*60*60,"n/a")))))
25	I-138[1]	=B24+1*D$2	6.5	s	=IF(D25="s",C25,IF(D25="m",C25*60,IF(D25="h",C25*60*60,IF(D25="d",C25*24*60*60,IF(D25="a",C25*365*24*60*60,"n/a")))))
26	I-139[1]	=B25+1*D$2	2.3	s	=IF(D26="s",C26,IF(D26="m",C26*60,IF(D26="h",C26*60*60,IF(D26="d",C26*24*60*60,IF(D26="a",C26*365*24*60*60,"n/a")))))
27	I-140[1]	=B26+1*D$2	0.86	s	=IF(D27="s",C27,IF(D27="m",C27*60,IF(D27="h",C27*60*60,IF(D27="d",C27*24*60*60,IF(D27="a",C27*365*24*60*60,"n/a")))))
28	I-141[1]	=B27+1*D$2	0.45	s	=IF(D28="s",C28,IF(D28="m",C28*60,IF(D28="h",C28*60*60,IF(D28="d",C28*24*60*60,IF(D28="a",C28*365*24*60*60,"n/a")))))
29	I-142[1]	=B28+1*D$2	0.2	s	=IF(D29="s",C29,IF(D29="m",C29*60,IF(D29="h",C29*60*60,IF(D29="d",C29*24*60*60,IF(D29="a",C29*365*24*60*60,"n/a")))))
30	I-143[1][3]	=B29+1*D$2			=IF(D30="s",C30,IF(D30="m",C30*60,IF(D30="h",C30*60*60,IF(D30="d",C30*24*60*60,IF(D30="a",C30*365*24*60*60,"n/a")))))
31	I-144[1][3]	=B30+1*D$2			=IF(D31="s",C31,IF(D31="m",C31*60,IF(D31="h",C31*60*60,IF(D31="d",C31*24*60*60,IF(D31="a",C31*365*24*60*60,"n/a")))))
32					
33	Notes				
34	1) Atomic mass not given for these isotopes in Reference 1; therefore, a multiple of the neutron mass is added to the atomic mass of I-136M.				
35	2) Since I-127 is a stable element, its quantity is not presented in Reference 3. The mass of I-127 is assumed to be 30% of the mass of I-129.				
36	3) Half-life information not available in Reference 2.				
37					
38	References				
39	1. Radiological Health Handbook, 1970 (main body Reference 7.8)				
40	2. Chart of the Nuclides, 15th Edition (main body Reference 7.9)				
41	3. GE-NE-A41-00097-00-01, NMP2 24-month Cycle Fission Product Inventory Evaluation (main body Reference 7.7)				
42	4. Regulatory Guide 1.183 (main body Reference 7.10.2)				
43	5. NMP1 Site License (main body Reference 7.5)				
44	6. Regulatory Guide 1.49 (main body Reference 7.10.1)				

Table 1-1 Equations: Core Iodine Inventory Determination (t=0 Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

	F	G	H	I	J	K	L
1			Core Inventory Fraction Released in Containment for Halogens				
2	(Ref. 1)		Gap Release Phase		0.05	(Ref. 4, Tbl 1)	
3	(Ref. 5)		Early In-Vessel Phase		0.25	(Ref. 4, Tbl 1)	
4	(Ref. 6)						
5	(Ref. 1)						
6	(Ref. 2)						
7							
8	Activity (Ref. 3)	Activity per Core	Specific Activity	Core Inventory	Gap Release	EIV Release	Total Release
9	[Ci/MWt]	[Ci/core]	[Ci/gm]	[gm/core]	[mole]	[mole]	[mole]
10					=0.3*J12	=0.3*K12	=J10+K10
11	428	=F11*D$4	=LN(2)*D$6/(D$5*B11*E11)	=G11/H11	=I11*J$2/B11	=I11*J$3/B11	=J11+K11
12	0.0013	=F12*D$4	=LN(2)*D$6/(D$5*B12*E12)	=G12/H12	=I12*J$2/B12	=I12*J$3/B12	=J12+K12
13	1090	=F13*D$4	=LN(2)*D$6/(D$5*B13*E13)	=G13/H13	=I13*J$2/B13	=I13*J$3/B13	=J13+K13
14	423	=F14*D$4	=LN(2)*D$6/(D$5*B14*E14)	=G14/H14	=I14*J$2/B14	=I14*J$3/B14	=J14+K14
15	27100	=F15*D$4	=LN(2)*D$6/(D$5*B15*E15)	=G15/H15	=I15*J$2/B15	=I15*J$3/B15	=J15+K15
16	39200	=F16*D$4	=LN(2)*D$6/(D$5*B16*E16)	=G16/H16	=I16*J$2/B16	=I16*J$3/B16	=J16+K16
17	55100	=F17*D$4	=LN(2)*D$6/(D$5*B17*E17)	=G17/H17	=I17*J$2/B17	=I17*J$3/B17	=J17+K17
18	1700	=F18*D$4	=LN(2)*D$6/(D$5*B18*E18)	=G18/H18	=I18*J$2/B18	=I18*J$3/B18	=J18+K18
19	60300	=F19*D$4	=LN(2)*D$6/(D$5*B19*E19)	=G19/H19	=I19*J$2/B19	=I19*J$3/B19	=J19+K19
20	6000	=F20*D$4	=LN(2)*D$6/(D$5*B20*E20)	=G20/H20	=I20*J$2/B20	=I20*J$3/B20	=J20+K20
21	51600	=F21*D$4	=LN(2)*D$6/(D$5*B21*E21)	=G21/H21	=I21*J$2/B21	=I21*J$3/B21	=J21+K21
22	24400	=F22*D$4	=LN(2)*D$6/(D$5*B22*E22)	=G22/H22	=I22*J$2/B22	=I22*J$3/B22	=J22+K22
23	14300	=F23*D$4	=LN(2)*D$6/(D$5*B23*E23)	=G23/H23	=I23*J$2/B23	=I23*J$3/B23	=J23+K23
24	23800	=F24*D$4	=LN(2)*D$6/(D$5*B24*E24)	=G24/H24	=I24*J$2/B24	=I24*J$3/B24	=J24+K24
25	11800	=F25*D$4	=LN(2)*D$6/(D$5*B25*E25)	=G25/H25	=I25*J$2/B25	=I25*J$3/B25	=J25+K25
26	5220	=F26*D$4	=LN(2)*D$6/(D$5*B26*E26)	=G26/H26	=I26*J$2/B26	=I26*J$3/B26	=J26+K26
27	1470	=F27*D$4	=LN(2)*D$6/(D$5*B27*E27)	=G27/H27	=I27*J$2/B27	=I27*J$3/B27	=J27+K27
28	243	=F28*D$4	=LN(2)*D$6/(D$5*B28*E28)	=G28/H28	=I28*J$2/B28	=I28*J$3/B28	=J28+K28
29	35.3	=F29*D$4	=LN(2)*D$6/(D$5*B29*E29)	=G29/H29	=I29*J$2/B29	=I29*J$3/B29	=J29+K29
30	2.33	=F30*D$4					
31	0.19	=F31*D$4					
32			Total	=SUM(I10:I31)	=SUM(J10:J31)	=SUM(K10:K31)	=SUM(L10:L31)
33							
34							
35							
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42							
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amh 1/10/05

Table 1-2 Equations: Core Cesium Inventory Determination (t=0 Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

	A	B	C	D	E
1	Time post-LOCA			0	sec
2	Neutron Mass			1.008665	amu
3	Core Thermal Power (100%)			1850	MWt
4	Core Thermal Power (102%)			=D3*1.02	MWt
5	1 Curie			37000000000	dis/sec
6	Avogadro's Number			6.022137E+23	atoms/mole
7					
8	Isotope	Atomic Mass (Ref. 1)	Half Life (Ref. 2)	$t_{1/2}$ units	Half Life
9		[amu]			[sec]
10	CS-132	131.906393	6.48	d	=IF(D10="s",C10,IF(D10="m",C10*60,IF(D10="h",C10*60*60,IF(D10="d",C10*24*60*60,IF(D10="a",C10*365*24*60*60,"n/a")))))
11	CS-133(1)				
12	CS-134	133.906823	2.065	a	=IF(D12="s",C12,IF(D12="m",C12*60,IF(D12="h",C12*60*60,IF(D12="d",C12*24*60*60,IF(D12="a",C12*365*24*60*60,"n/a")))))
13	CS-134M	133.906823	2.9	h	=IF(D13="s",C13,IF(D13="m",C13*60,IF(D13="h",C13*60*60,IF(D13="d",C13*24*60*60,IF(D13="a",C13*365*24*60*60,"n/a")))))
14	CS-135	134.90577	2300000	a	=IF(D14="s",C14,IF(D14="m",C14*60,IF(D14="h",C14*60*60,IF(D14="d",C14*24*60*60,IF(D14="a",C14*365*24*60*60,"n/a")))))
15	CS-135M	134.90577	53	m	=IF(D15="s",C15,IF(D15="m",C15*60,IF(D15="h",C15*60*60,IF(D15="d",C15*24*60*60,IF(D15="a",C15*365*24*60*60,"n/a")))))
16	CS-136	135.90734	13.16	d	=IF(D16="s",C16,IF(D16="m",C16*60,IF(D16="h",C16*60*60,IF(D16="d",C16*24*60*60,IF(D16="a",C16*365*24*60*60,"n/a")))))
17	CS-137	136.90677	30.07	a	=IF(D17="s",C17,IF(D17="m",C17*60,IF(D17="h",C17*60*60,IF(D17="d",C17*24*60*60,IF(D17="a",C17*365*24*60*60,"n/a")))))
18	CS-138	137.9108	32.2	m	=IF(D18="s",C18,IF(D18="m",C18*60,IF(D18="h",C18*60*60,IF(D18="d",C18*24*60*60,IF(D18="a",C18*365*24*60*60,"n/a")))))
19	CS-138M	137.9108	2.9	m	=IF(D19="s",C19,IF(D19="m",C19*60,IF(D19="h",C19*60*60,IF(D19="d",C19*24*60*60,IF(D19="a",C19*365*24*60*60,"n/a")))))
20	CS-139	138.9129	9.3	m	=IF(D20="s",C20,IF(D20="m",C20*60,IF(D20="h",C20*60*60,IF(D20="d",C20*24*60*60,IF(D20="a",C20*365*24*60*60,"n/a")))))
21	CS-140	139.91711	1.06	m	=IF(D21="s",C21,IF(D21="m",C21*60,IF(D21="h",C21*60*60,IF(D21="d",C21*24*60*60,IF(D21="a",C21*365*24*60*60,"n/a")))))
22	CS-141(2)	=B21+1*D$2	24.9	s	=IF(D22="s",C22,IF(D22="m",C22*60,IF(D22="h",C22*60*60,IF(D22="d",C22*24*60*60,IF(D22="a",C22*365*24*60*60,"n/a")))))
23	CS-142(2)	=B22+1*D$2	1.8	s	=IF(D23="s",C23,IF(D23="m",C23*60,IF(D23="h",C23*60*60,IF(D23="d",C23*24*60*60,IF(D23="a",C23*365*24*60*60,"n/a")))))
24	CS-143(2)	=B23+1*D$2	1.78	s	=IF(D24="s",C24,IF(D24="m",C24*60,IF(D24="h",C24*60*60,IF(D24="d",C24*24*60*60,IF(D24="a",C24*365*24*60*60,"n/a")))))
25	CS-144(2)	=B24+1*D$2	1.01	s	=IF(D25="s",C25,IF(D25="m",C25*60,IF(D25="h",C25*60*60,IF(D25="d",C25*24*60*60,IF(D25="a",C25*365*24*60*60,"n/a")))))
26	CS-145(2)	=B25+1*D$2	0.59	s	=IF(D26="s",C26,IF(D26="m",C26*60,IF(D26="h",C26*60*60,IF(D26="d",C26*24*60*60,IF(D26="a",C26*365*24*60*60,"n/a")))))
27	CS-146(2)	=B26+1*D$2	0.322	s	=IF(D27="s",C27,IF(D27="m",C27*60,IF(D27="h",C27*60*60,IF(D27="d",C27*24*60*60,IF(D27="a",C27*365*24*60*60,"n/a")))))
28	CS-147(2)	=B27+1*D$2	0.227	s	=IF(D28="s",C28,IF(D28="m",C28*60,IF(D28="h",C28*60*60,IF(D28="d",C28*24*60*60,IF(D28="a",C28*365*24*60*60,"n/a")))))
29	CS-148(2)	=B28+1*D$2	0.15	s	=IF(D29="s",C29,IF(D29="m",C29*60,IF(D29="h",C29*60*60,IF(D29="d",C29*24*60*60,IF(D29="a",C29*365*24*60*60,"n/a")))))
30					
31	Notes				
32	1) Stable cesium is conservatively not accounted for in this analysis as it forms cesium hydroxide (CsOH).				
33	2) Atomic mass not given for these isotopes in Reference 1; therefore, a multiple of the neutron mass is added to the atomic mass of CS-140.				
34					
35	References				
36	1. Radiological Health Handbook, 1970 (main body Reference 7.8)				
37	2. *Chart of the Nuclides, 15th Edition (main body Reference 7.9)*				
38	3. GE-NE-A41-00097-00-01, NMP2 24-month Cycle Fission Product Inventory Evaluation (main body Reference 7.7)				
39	4. Regulatory Guide 1.183 (main body Reference 7.10.2)				
40	5. NMP1 Site License (main body Reference 7.5)				
41	6. Regulatory Guide 1.49 (main body Reference 7.10.1)				

Table 1-2 Equations: Core Cesium Inventory Determination (t=0 Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

	F	G	H	I	J	K	L
1			Core Inventory Fraction Released in Containment for Alkalis				
2	(Ref. 1)		Gap Release Phase		0.05	(Ref. 4, Tbl 1)	
3	(Ref. 5)		Early In-Vessel Phase		0.2	(Ref. 4, Tbl 1)	
4	(Ref. 6)						
5	(Ref. 1)						
6	(Ref. 2)						
7							
8	Activity (Ref. 3)	Activity per Core	Specific Activity	Core Inventory	Gap Release	EIV Release	Total Release
9	[Ci/MWt]	[Ci/core]	[Ci/gm]	[gm/core]	[mole]	[mole]	[mole]
10	7.96	=F10*D$4	=LN(2)*D$6/(D$5*B10*E10)	=G10/H10	=I10*J$2/B10	=I10*J$3/B10	=J10+K10
11							
12	7290	=F12*D$4	=LN(2)*D$6/(D$5*B12*E12)	=G12/H12	=I12*J$2/B12	=I12*J$3/B12	=J12+K12
13	1700	=F13*D$4	=LN(2)*D$6/(D$5*B13*E13)	=G13/H13	=I13*J$2/B13	=I13*J$3/B13	=J13+K13
14	0.0251	=F14*D$4	=LN(2)*D$6/(D$5*B14*E14)	=G14/H14	=I14*J$2/B14	=I14*J$3/B14	=J14+K14
15	881	=F15*D$4	=LN(2)*D$6/(D$5*B15*E15)	=G15/H15	=I15*J$2/B15	=I15*J$3/B15	=J15+K15
16	2280	=F16*D$4	=LN(2)*D$6/(D$5*B16*E16)	=G16/H16	=I16*J$2/B16	=I16*J$3/B16	=J16+K16
17	4350	=F17*D$4	=LN(2)*D$6/(D$5*B17*E17)	=G17/H17	=I17*J$2/B17	=I17*J$3/B17	=J17+K17
18	50000	=F18*D$4	=LN(2)*D$6/(D$5*B18*E18)	=G18/H18	=I18*J$2/B18	=I18*J$3/B18	=J18+K18
19	2390	=F19*D$4	=LN(2)*D$6/(D$5*B19*E19)	=G19/H19	=I19*J$2/B19	=I19*J$3/B19	=J19+K19
20	47300	=F20*D$4	=LN(2)*D$6/(D$5*B20*E20)	=G20/H20	=I20*J$2/B20	=I20*J$3/B20	=J20+K20
21	42600	=F21*D$4	=LN(2)*D$6/(D$5*B21*E21)	=G21/H21	=I21*J$2/B21	=I21*J$3/B21	=J21+K21
22	31600	=F22*D$4	=LN(2)*D$6/(D$5*B22*E22)	=G22/H22	=I22*J$2/B22	=I22*J$3/B22	=J22+K22
23	19100	=F23*D$4	=LN(2)*D$6/(D$5*B23*E23)	=G23/H23	=I23*J$2/B23	=I23*J$3/B23	=J23+K23
24	9330	=F24*D$4	=LN(2)*D$6/(D$5*B24*E24)	=G24/H24	=I24*J$2/B24	=I24*J$3/B24	=J24+K24
25	2700	=F25*D$4	=LN(2)*D$6/(D$5*B25*E25)	=G25/H25	=I25*J$2/B25	=I25*J$3/B25	=J25+K25
26	679	=F26*D$4	=LN(2)*D$6/(D$5*B26*E26)	=G26/H26	=I26*J$2/B26	=I26*J$3/B26	=J26+K26
27	99.6	=F27*D$4	=LN(2)*D$6/(D$5*B27*E27)	=G27/H27	=I27*J$2/B27	=I27*J$3/B27	=J27+K27
28	16.5	=F28*D$4	=LN(2)*D$6/(D$5*B28*E28)	=G28/H28	=I28*J$2/B28	=I28*J$3/B28	=J28+K28
29	1.07	=F29*D$4	=LN(2)*D$6/(D$5*B29*E29)	=G29/H29	=I29*J$2/B29	=I29*J$3/B29	=J29+K29
30			**Total**	**=SUM(I10:I29)**	**=SUM(J10:J29)**	**=SUM(K10:K29)**	**=SUM(L10:L29)**
31							
32							
33							
34							
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Table 1-3 Eqs: Core Iodine Inventory Determination (t=30 days Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

	A	B	C	D	E
1	Time post-LOCA			30	days
2	Neutron Mass			1.008665	amu
3	Core Thermal Power (100%)			1850	MWt
4	Core Thermal Power (102%)			=D3*1.02	MWt
5	1 Curie			37000000000	dis/sec
6	Avogadro's Number			6.022137E+23	atoms/mole
7					
8	Isotope	Atomic Mass (Ref. 1)	Half Life (Ref. 2)	$t_{1/2}$ units	Half Life
9		[amu]			[sec]
10	I-127[2]	126.90447	stable		
11	I-128	127.905838	25	m	=IF(D11="s",C11,IF(D11="m",C11*60,IF(D11="h",C11*60*60,IF(D11="d",C11*24*60*60,IF(D11="a",C11*365*24*60*60,"n/a")))))
12	I-129	128.904987	15700000	a	=IF(D12="s",C12,IF(D12="m",C12*60,IF(D12="h",C12*60*60,IF(D12="d",C12*24*60*60,IF(D12="a",C12*365*24*60*60,"n/a")))))
13	I-130	129.906676	12.36	h	=IF(D13="s",C13,IF(D13="m",C13*60,IF(D13="h",C13*60*60,IF(D13="d",C13*24*60*60,IF(D13="a",C13*365*24*60*60,"n/a")))))
14	I-130M	129.906676	9	m	=IF(D14="s",C14,IF(D14="m",C14*60,IF(D14="h",C14*60*60,IF(D14="d",C14*24*60*60,IF(D14="a",C14*365*24*60*60,"n/a")))))
15	I-131	130.906127	8.02	d	=IF(D15="s",C15,IF(D15="m",C15*60,IF(D15="h",C15*60*60,IF(D15="d",C15*24*60*60,IF(D15="a",C15*365*24*60*60,"n/a")))))
16	I-132	131.907981	2.28	h	=IF(D16="s",C16,IF(D16="m",C16*60,IF(D16="h",C16*60*60,IF(D16="d",C16*24*60*60,IF(D16="a",C16*365*24*60*60,"n/a")))))
17	I-133	132.90775	20.8	h	=IF(D17="s",C17,IF(D17="m",C17*60,IF(D17="h",C17*60*60,IF(D17="d",C17*24*60*60,IF(D17="a",C17*365*24*60*60,"n/a")))))
18	I-133M	132.90775	9	s	=IF(D18="s",C18,IF(D18="m",C18*60,IF(D18="h",C18*60*60,IF(D18="d",C18*24*60*60,IF(D18="a",C18*365*24*60*60,"n/a")))))
19	I-134	133.90985	52.6	m	=IF(D19="s",C19,IF(D19="m",C19*60,IF(D19="h",C19*60*60,IF(D19="d",C19*24*60*60,IF(D19="a",C19*365*24*60*60,"n/a")))))
20	I-134M	133.90985	3.7	m	=IF(D20="s",C20,IF(D20="m",C20*60,IF(D20="h",C20*60*60,IF(D20="d",C20*24*60*60,IF(D20="a",C20*365*24*60*60,"n/a")))))
21	I-135	134.91002	6.57	h	=IF(D21="s",C21,IF(D21="m",C21*60,IF(D21="h",C21*60*60,IF(D21="d",C21*24*60*60,IF(D21="a",C21*365*24*60*60,"n/a")))))
22	I-136	135.91474	1.39	m	=IF(D22="s",C22,IF(D22="m",C22*60,IF(D22="h",C22*60*60,IF(D22="d",C22*24*60*60,IF(D22="a",C22*365*24*60*60,"n/a")))))
23	I-136M	135.91474	47	s	=IF(D23="s",C23,IF(D23="m",C23*60,IF(D23="h",C23*60*60,IF(D23="d",C23*24*60*60,IF(D23="a",C23*365*24*60*60,"n/a")))))
24	I-137[1]	=B23+1*D$2	24.5	s	=IF(D24="s",C24,IF(D24="m",C24*60,IF(D24="h",C24*60*60,IF(D24="d",C24*24*60*60,IF(D24="a",C24*365*24*60*60,"n/a")))))
25	I-138[1]	=B24+1*D$2	6.5	s	=IF(D25="s",C25,IF(D25="m",C25*60,IF(D25="h",C25*60*60,IF(D25="d",C25*24*60*60,IF(D25="a",C25*365*24*60*60,"n/a")))))
26	I-139[1]	=B25+1*D$2	2.3	s	=IF(D26="s",C26,IF(D26="m",C26*60,IF(D26="h",C26*60*60,IF(D26="d",C26*24*60*60,IF(D26="a",C26*365*24*60*60,"n/a")))))
27	I-140[1]	=B26+1*D$2	0.86	s	=IF(D27="s",C27,IF(D27="m",C27*60,IF(D27="h",C27*60*60,IF(D27="d",C27*24*60*60,IF(D27="a",C27*365*24*60*60,"n/a")))))
28	I-141[1]	=B27+1*D$2	0.45	s	=IF(D28="s",C28,IF(D28="m",C28*60,IF(D28="h",C28*60*60,IF(D28="d",C28*24*60*60,IF(D28="a",C28*365*24*60*60,"n/a")))))
29	I-142[1]	=B28+1*D$2	0.2	s	=IF(D29="s",C29,IF(D29="m",C29*60,IF(D29="h",C29*60*60,IF(D29="d",C29*24*60*60,IF(D29="a",C29*365*24*60*60,"n/a")))))
30	I-143[1][3]	=B29+1*D$2			=IF(D30="s",C30,IF(D30="m",C30*60,IF(D30="h",C30*60*60,IF(D30="d",C30*24*60*60,IF(D30="a",C30*365*24*60*60,"n/a")))))
31	I-144[1][3]	=B30+1*D$2			=IF(D31="s",C31,IF(D31="m",C31*60,IF(D31="h",C31*60*60,IF(D31="d",C31*24*60*60,IF(D31="a",C31*365*24*60*60,"n/a")))))
32					
33	Notes				
34	1) Atomic mass not given for these isotopes in Reference 1; therefore, a multiple of the neutron mass is added to the atomic mass of I-136M.				
35	2) Since I-127 is a stable element, its quantity is not presented in Reference 3. The mass of I-127 is assumed to be 30% of the mass of I-129.				
36	3) Half-life information not available in Reference 2.				
37					
38	References				
39	1. Radiological Health Handbook, 1970 (main body Reference 7.8)				
40	2. Chart of the Nuclides, 15th Edition (main body Reference 7.9)				
41	3. GE-NE-A41-00097-00-01, NMP2 24-month Cycle Fission Product Inventory Evaluation (main body Reference 7.7)				
42	4. Regulatory Guide 1.183 (main body Reference 7.10.2)				
43	5. NMP1 Site License (main body Reference 7.5)				
44	6. Regulatory Guide 1.49 (main body Reference 7.10.1)				

Table 1-3 Eqs: Core Iodine Inventory Determination (t=30 days Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

amh 1/10/05

	F	G	H	I	J	K	L
1			Core Inventory Fraction Released in Containment for Halogens				
2	(Ref. 1)		Gap Release Phase		0.05	(Ref. 4, Tbl 1)	
3	(Ref. 5)		Early In-Vessel Phase		0.25	(Ref. 4, Tbl 1)	
4	(Ref. 6)						
5	(Ref. 1)						
6	(Ref. 2)						
7							
8	Activity (Ref. 3)	Activity per Core	Specific Activity	Core Inventory	Gap Release	EIV Release	Total Release
9	[Ci/MWt]	[Ci/core]	[Ci/gm]	[gm/core]	[mole]	[mole]	[mole]
10					=0.3*J12	=0.3*K12	=J10+K10
11	0	=F11*D$4	=LN(2)*D$6/(D$5*B11*E11)	=G11/H11	=I11*J$2/B11	=I11*J$3/B11	=J11+K11
12	0.0013	=F12*D$4	=LN(2)*D$6/(D$5*B12*E12)	=G12/H12	=I12*J$2/B12	=I12*J$3/B12	=J12+K12
13	0.00000000000000318	=F13*D$4	=LN(2)*D$6/(D$5*B13*E13)	=G13/H13	=I13*J$2/B13	=I13*J$3/B13	=J13+K13
14	0	=F14*D$4	=LN(2)*D$6/(D$5*B14*E14)	=G14/H14	=I14*J$2/B14	=I14*J$3/B14	=J14+K14
15	2100	=F15*D$4	=LN(2)*D$6/(D$5*B15*E15)	=G15/H15	=I15*J$2/B15	=I15*J$3/B15	=J15+K15
16	67.1	=F16*D$4	=LN(2)*D$6/(D$5*B16*E16)	=G16/H16	=I16*J$2/B16	=I16*J$3/B16	=J16+K16
17	0.00000214	=F17*D$4	=LN(2)*D$6/(D$5*B17*E17)	=G17/H17	=I17*J$2/B17	=I17*J$3/B17	=J17+K17
18	0	=F18*D$4	=LN(2)*D$6/(D$5*B18*E18)	=G18/H18	=I18*J$2/B18	=I18*J$3/B18	=J18+K18
19	0	=F19*D$4	=LN(2)*D$6/(D$5*B19*E19)	=G19/H19	=I19*J$2/B19	=I19*J$3/B19	=J19+K19
20	0	=F20*D$4	=LN(2)*D$6/(D$5*B20*E20)	=G20/H20	=I20*J$2/B20	=I20*J$3/B20	=J20+K20
21	0	=F21*D$4	=LN(2)*D$6/(D$5*B21*E21)	=G21/H21	=I21*J$2/B21	=I21*J$3/B21	=J21+K21
22	0	=F22*D$4	=LN(2)*D$6/(D$5*B22*E22)	=G22/H22	=I22*J$2/B22	=I22*J$3/B22	=J22+K22
23	0	=F23*D$4	=LN(2)*D$6/(D$5*B23*E23)	=G23/H23	=I23*J$2/B23	=I23*J$3/B23	=J23+K23
24	0	=F24*D$4	=LN(2)*D$6/(D$5*B24*E24)	=G24/H24	=I24*J$2/B24	=I24*J$3/B24	=J24+K24
25	0	=F25*D$4	=LN(2)*D$6/(D$5*B25*E25)	=G25/H25	=I25*J$2/B25	=I25*J$3/B25	=J25+K25
26	0	=F26*D$4	=LN(2)*D$6/(D$5*B26*E26)	=G26/H26	=I26*J$2/B26	=I26*J$3/B26	=J26+K26
27	0	=F27*D$4	=LN(2)*D$6/(D$5*B27*E27)	=G27/H27	=I27*J$2/B27	=I27*J$3/B27	=J27+K27
28	0	=F28*D$4	=LN(2)*D$6/(D$5*B28*E28)	=G28/H28	=I28*J$2/B28	=I28*J$3/B28	=J28+K28
29	0	=F29*D$4	=LN(2)*D$6/(D$5*B29*E29)	=G29/H29	=I29*J$2/B29	=I29*J$3/B29	=J29+K29
30	0	=F30*D$4					
31		=F31*D$4					
32			Total	=SUM(I10:I31)	=SUM(J10:J31)	=SUM(K10:K31)	=SUM(L10:L31)
33							
34							
35							
36							
37							
38							
39							
40							
41							
42							
43							
44							

Table 1-4 Eqs: Core Cesium Inventory Determination (t=30 days Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

	A	B	C	D	E
1	Time post-LOCA			30	days
2	Neutron Mass			1.008665	amu
3	Core Thermal Power (100%)			1850	MWt
4	Core Thermal Power (102%)			=D3*1.02	MWt
5	1 Curie			37000000000	dis/sec
6	Avogadro's Number			6.022137E+23	atoms/mole
7					
8	Isotope	Atomic Mass (Ref. 1)	Half Life (Ref. 2)	$t_{1/2}$ units	Half Life
9		[amu]			[sec]
10	CS-132	131.906393	6.48	d	=IF(D10="s",C10,IF(D10="m",C10*60,IF(D10="h",C10*60*60,IF(D10="d",C10*24*60*60,IF(D10="a",C10*365*24*60*60,"n/a")))))
11	CS-133[(1)]				
12	CS-134	133.906823	2.065	a	=IF(D12="s",C12,IF(D12="m",C12*60,IF(D12="h",C12*60*60,IF(D12="d",C12*24*60*60,IF(D12="a",C12*365*24*60*60,"n/a")))))
13	CS-134M	133.906823	2.9	h	=IF(D13="s",C13,IF(D13="m",C13*60,IF(D13="h",C13*60*60,IF(D13="d",C13*24*60*60,IF(D13="a",C13*365*24*60*60,"n/a")))))
14	CS-135	134.90577	2300000	a	=IF(D14="s",C14,IF(D14="m",C14*60,IF(D14="h",C14*60*60,IF(D14="d",C14*24*60*60,IF(D14="a",C14*365*24*60*60,"n/a")))))
15	CS-135M	134.90577	53	m	=IF(D15="s",C15,IF(D15="m",C15*60,IF(D15="h",C15*60*60,IF(D15="d",C15*24*60*60,IF(D15="a",C15*365*24*60*60,"n/a")))))
16	CS-136	135.90734	13.16	d	=IF(D16="s",C16,IF(D16="m",C16*60,IF(D16="h",C16*60*60,IF(D16="d",C16*24*60*60,IF(D16="a",C16*365*24*60*60,"n/a")))))
17	CS-137	136.90677	30.07	a	=IF(D17="s",C17,IF(D17="m",C17*60,IF(D17="h",C17*60*60,IF(D17="d",C17*24*60*60,IF(D17="a",C17*365*24*60*60,"n/a")))))
18	CS-138	137.9108	32.2	m	=IF(D18="s",C18,IF(D18="m",C18*60,IF(D18="h",C18*60*60,IF(D18="d",C18*24*60*60,IF(D18="a",C18*365*24*60*60,"n/a")))))
19	CS-138M	137.9108	2.9	m	=IF(D19="s",C19,IF(D19="m",C19*60,IF(D19="h",C19*60*60,IF(D19="d",C19*24*60*60,IF(D19="a",C19*365*24*60*60,"n/a")))))
20	CS-139	138.9129	9.3	m	=IF(D20="s",C20,IF(D20="m",C20*60,IF(D20="h",C20*60*60,IF(D20="d",C20*24*60*60,IF(D20="a",C20*365*24*60*60,"n/a")))))
21	CS-140	139.91711	1.06	m	=IF(D21="s",C21,IF(D21="m",C21*60,IF(D21="h",C21*60*60,IF(D21="d",C21*24*60*60,IF(D21="a",C21*365*24*60*60,"n/a")))))
22	CS-141[(2)]	=B21+1*D$2	24.9	s	=IF(D22="s",C22,IF(D22="m",C22*60,IF(D22="h",C22*60*60,IF(D22="d",C22*24*60*60,IF(D22="a",C22*365*24*60*60,"n/a")))))
23	CS-142[(2)]	=B22+1*D$2	1.8	s	=IF(D23="s",C23,IF(D23="m",C23*60,IF(D23="h",C23*60*60,IF(D23="d",C23*24*60*60,IF(D23="a",C23*365*24*60*60,"n/a")))))
24	CS-143[(2)]	=B23+1*D$2	1.78	s	=IF(D24="s",C24,IF(D24="m",C24*60,IF(D24="h",C24*60*60,IF(D24="d",C24*24*60*60,IF(D24="a",C24*365*24*60*60,"n/a")))))
25	CS-144[(2)]	=B24+1*D$2	1.01	s	=IF(D25="s",C25,IF(D25="m",C25*60,IF(D25="h",C25*60*60,IF(D25="d",C25*24*60*60,IF(D25="a",C25*365*24*60*60,"n/a")))))
26	CS-145[(2)]	=B25+1*D$2	0.59	s	=IF(D26="s",C26,IF(D26="m",C26*60,IF(D26="h",C26*60*60,IF(D26="d",C26*24*60*60,IF(D26="a",C26*365*24*60*60,"n/a")))))
27	CS-146[(2)]	=B26+1*D$2	0.322	s	=IF(D27="s",C27,IF(D27="m",C27*60,IF(D27="h",C27*60*60,IF(D27="d",C27*24*60*60,IF(D27="a",C27*365*24*60*60,"n/a")))))
28	CS-147[(2)]	=B27+1*D$2	0.227	s	=IF(D28="s",C28,IF(D28="m",C28*60,IF(D28="h",C28*60*60,IF(D28="d",C28*24*60*60,IF(D28="a",C28*365*24*60*60,"n/a")))))
29	CS-148[(2)]	=B28+1*D$2	0.15	s	=IF(D29="s",C29,IF(D29="m",C29*60,IF(D29="h",C29*60*60,IF(D29="d",C29*24*60*60,IF(D29="a",C29*365*24*60*60,"n/a")))))
30					
31	Notes				
32	1) Stable cesium is conservatively not accounted for in this analysis as it forms cesium hydroxide (CsOH).				
33	2) Atomic mass not given for these isotopes in Reference 1; therefore, a multiple of the neutron mass is added to the atomic mass of CS-140.				
34					
35	References				
36	1. Radiological Health Handbook, 1970 (main body Reference 7.8)				
37	2. Chart of the Nuclides, 15th Edition (main body Reference 7.9)				
38	3. GE-NE-A41-00097-00-01, NMP2 24-month Cycle Fission Product Inventory Evaluation (main body Reference 7.7)				
39	4. Regulatory Guide 1.183 (main body Reference 7.10.2)				
40	5. NMP1 Site License (main body Reference 7.5)				
41	6. Regulatory Guide 1.49 (main body Reference 7.10.1)				

Table 1-4 Eqs: Core Cesium Inventory Determination (t=30 days Post-LOCA)
(Single Batch Core with 1400 EFPD and 34,000 MWd/ST CAVEX)

	F	G	H	I	J	K	L
1			Core Inventory Fraction Released in Containment for Alkalis				
2	(Ref. 1)		Gap Release Phase		0.05	(Ref. 4, Tbl 1)	
3	(Ref. 5)		Early In-Vessel Phase		0.2	(Ref. 4, Tbl 1)	
4	(Ref. 6)						
5	(Ref. 1)						
6	(Ref. 2)						
7							
8	Activity (Ref. 3)	Activity per Core	Specific Activity	Core Inventory	Gap Release	EIV Release	Total Release
9	[Ci/MWt]	[Ci/core]	[Ci/gm]	[gm/core]	[mole]	[mole]	[mole]
10	0.321	=F10*D$4	=LN(2)*D$6/(D$5*B10*E10)	=G10/H10	=I10*J$2/B10	=I10*J$3/B10	=J10+K10
11							
12	7090	=F12*D$4	=LN(2)*D$6/(D$5*B12*E12)	=G12/H12	=I12*J$2/B12	=I12*J$3/B12	=J12+K12
13	0	=F13*D$4	=LN(2)*D$6/(D$5*B13*E13)	=G13/H13	=I13*J$2/B13	=I13*J$3/B13	=J13+K13
14	0.0251	=F14*D$4	=LN(2)*D$6/(D$5*B14*E14)	=G14/H14	=I14*J$2/B14	=I14*J$3/B14	=J14+K14
15	0	=F15*D$4	=LN(2)*D$6/(D$5*B15*E15)	=G15/H15	=I15*J$2/B15	=I15*J$3/B15	=J15+K15
16	466	=F16*D$4	=LN(2)*D$6/(D$5*B16*E16)	=G16/H16	=I16*J$2/B16	=I16*J$3/B16	=J16+K16
17	4340	=F17*D$4	=LN(2)*D$6/(D$5*B17*E17)	=G17/H17	=I17*J$2/B17	=I17*J$3/B17	=J17+K17
18	0	=F18*D$4	=LN(2)*D$6/(D$5*B18*E18)	=G18/H18	=I18*J$2/B18	=I18*J$3/B18	=J18+K18
19	0	=F19*D$4	=LN(2)*D$6/(D$5*B19*E19)	=G19/H19	=I19*J$2/B19	=I19*J$3/B19	=J19+K19
20	0	=F20*D$4	=LN(2)*D$6/(D$5*B20*E20)	=G20/H20	=I20*J$2/B20	=I20*J$3/B20	=J20+K20
21	0	=F21*D$4	=LN(2)*D$6/(D$5*B21*E21)	=G21/H21	=I21*J$2/B21	=I21*J$3/B21	=J21+K21
22	0	=F22*D$4	=LN(2)*D$6/(D$5*B22*E22)	=G22/H22	=I22*J$2/B22	=I22*J$3/B22	=J22+K22
23	0	=F23*D$4	=LN(2)*D$6/(D$5*B23*E23)	=G23/H23	=I23*J$2/B23	=I23*J$3/B23	=J23+K23
24	0	=F24*D$4	=LN(2)*D$6/(D$5*B24*E24)	=G24/H24	=I24*J$2/B24	=I24*J$3/B24	=J24+K24
25	0	=F25*D$4	=LN(2)*D$6/(D$5*B25*E25)	=G25/H25	=I25*J$2/B25	=I25*J$3/B25	=J25+K25
26	0	=F26*D$4	=LN(2)*D$6/(D$5*B26*E26)	=G26/H26	=I26*J$2/B26	=I26*J$3/B26	=J26+K26
27	0	=F27*D$4	=LN(2)*D$6/(D$5*B27*E27)	=G27/H27	=I27*J$2/B27	=I27*J$3/B27	=J27+K27
28	0	=F28*D$4	=LN(2)*D$6/(D$5*B28*E28)	=G28/H28	=I28*J$2/B28	=I28*J$3/B28	=J28+K28
29	0	=F29*D$4	=LN(2)*D$6/(D$5*B29*E29)	=G29/H29	=I29*J$2/B29	=I29*J$3/B29	=J29+K29
30			Total	=SUM(I10:I29)	=SUM(J10:J29)	=SUM(K10:K29)	=SUM(L10:L29)
31							
32							
33							
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41							

Attachment 2

Determination of Radiation Doses

Purpose

The purpose of this attachment is to document the gamma and beta radiation dose in the drywell, wetwell, and suppression chamber water.

Methodology

Beta Dose

The beta radiation dose is taken from Calculation S3.11-DWLOCA-BETA, Revision 0 (main body Reference 7.6.2).

The beta dose in S3.11-DWLOCA-BETA is presented for three scenarios:

1. No halogen plate-out (p. 41)
2. For plate-out of elemental iodines (p. 48), and
3. For instantaneous plate-out (p. 50).

Since the values for the scenario with no halogen plate-out are greater than the other two scenarios and hence more conservative, they are used herein. The values reduced by 50% to account for self shielding are used herein.

The beta dose for Unit 2 is smaller than for Unit 1 because Unit 2 assumes all halogen activity is plated out while Unit 1 assumes it is airborne. For the Unit 2 beta dose calculation, 100% of the noble gases are airborne, iodines are reduced by suppression pool scrubbing, and 100% of remaining iodines are plated out (Calculation PR-C-19-C, p. 5). For Unit 1, 50% of the iodines are assumed to remain airborne along with 100% of the noble gases in the beta dose calculation (Calculation S3.11-DWLOCA-BETA, p. 3).

Since the penetrating ability of beta radiation is orders of magnitude less than that of gamma radiation, the beta dose from the suppression chamber water is considered negligible in comparison to the suppression chamber submersion gamma dose. Therefore, the suppression chamber submersion beta dose is not modeled.

Drywell and Wetwell Airborne Gamma Dose

The gamma radiation dose is formulated using the total integrated dose (TID) from NEDO-24290 (main body Reference 7.27) and the Unit 2 gamma radiation dose profile from Calculation PR-C-21-Q, Revision 1 (main body Reference 7.6.3). The Unit 1 gamma radiation dose is obtained by normalizing the Unit 2 profile to the Unit 1 6 month TID (provided in Table 4-3 of NEDO-24290) as follows:

$$TID_{U1\_airborne} = TID_{U2\_airborne} * (TID_{U1\_6mo} / TID_{U2\_6mo})$$

The drywell and wetwell airborne accident gamma TID is taken from Zone 1 in Table 4-3 of NEDO-24290. The Zone 1 TID is for the drywell with no vessel shield and bounds all other zones analyzed in NEDO-24290, including the wetwell, and therefore is conservative.

Suppression Chamber Water Submersion Gamma Dose

The Unit 1 suppression chamber water submersion gamma dose is scaled from the Unit 2 suppression pool submersion gamma dose provided in PR-C-21-Q. The Unit 2 submersion gamma dose is taken from environmental zones PC 175101, PC 196112, and PC 215121, which represent the suppression pool, in PR-C-21-Q.

The Unit 1 submersion gamma dose is scaled by the core thermal power (P) and dilution volumes (V). This scaling is consistent with PR-C-21-Q, where the TID is determined as follows:

$$TID = DCF * (A/V)$$

The DCF is a dose conversion factor [rad/(Ci/cc)], A is the amount of activity released to the suppression pool [Ci], and V is the dilution volume (volume of the suppression chamber water) [cc]. From this expression it is clear that the TID can be scaled.

$$TID_1 / TID_2 = [DCF * (A_1/V_1)] / [DCF * (A_2/V_2)]$$

or, since the DCF is a constant,

$$TID_2 = TID_1 * (A_2/A_1) * (V_1/V_2)$$

Since activity is directly proportional to core thermal power level (see Attachment 1), P, the above expression is also equivalent to:

$$TID_{U1\_sub} = TID_{U2\_sub} * (P_{U1}/P_{U2}) * (V_{U2}/V_{U1})$$

General Comments on Gamma Dose Determinations

It should be noted that all Unit 2 radiation dose profiles used herein are for the originally analyzed core thermal power level of 3,323 MWt, not the uprated core thermal power level of 3,467 MWt. This has no impact on the results of this analysis.

Both the drywell/wetwell airborne gamma dose and the suppression pool submersion gamma dose are increased by 5% to account for bremsstrahlung.

Results

The radiation doses to be used are shown in Tables 2-1 and 2-2.

Table 2-1: Beta Dose

Time [hr]	Drywell Airborne Beta Dose (No Plate-Out) TID @ 1,850 MWt [rad]
1	3.011E+07
28	2.121E+08
2400	6.134E+08

Notes
1) Suppression pool beta dose is negligible and is therefore not included.

References
1) S3.11-DWLOCA-BETA, Rev. 0 (main body Reference 7.6.2)

amp 1/10/05

Bremsstrahlung Factor (5% incr.)	1.05		Assumption
Unit 1 6 month (4320 hr) Drywell Accident TID	2.7E+07	rad	Reference 2, Table 4-3
Unit 1 minimum dilution volume	79,800	ft^3	Attachment 4, Table 4-9
Unit 1 maximum dilution volume	94,040	ft^3	Attachment 4, Table 4-9
Unit 2 dilution volume for submersion γ dose	160,000	ft^3	Refs. 1, 3 (also see Ref. 4, Att. 2)

Time	Drywell & Wetwell Airborne Gamma Dose		Suppression Pool Submersion Gamma Dose		
[hr]	Unit 2 TID[1] @ 3323 MWt [rad]	Unit 1 TID[2] @ 1850 MWt [rad]	Unit 2 TID[3] @ 3323 MWt [rad]	Unit 1 TID[4] @ 1850 MWt - Min Vol [rad]	Unit 1 TID[4] @ 1850 MWt - Max Vol [rad]
1	2.3E+06	1.035E+06	3.8E+05	4.454E+05	3.779E+05
6	7.0E+06	3.150E+06	1.4E+06	1.641E+06	1.392E+06
24	1.1E+07	4.950E+06	2.8E+06	3.282E+06	2.785E+06
720	3.0E+07	1.350E+07	1.6E+07	1.875E+07	1.591E+07
2400	4.7E+07	2.115E+07	3.6E+07	4.219E+07	3.580E+07
4320	6.3E+07	2.835E+07	5.5E+07	6.446E+07	5.470E+07
8760	9.5E+07	4.275E+07	9.4E+07	1.102E+08	9.349E+07

Notes
1) Maximum environmental zone TID as given in Reference 1 (Zone PC289684, p. 270)
2) $TID_{Unit1}=(1.05)*(TID_{Unit2})*(TID_{6mo\_U1}/TID_{6mo\_U2})$
3) TID for suppression pool environmental zones (PC175101, PC196112, PC215121) in Reference 1 (p. 202)
4) $TID_{Unit1}=(1.05)*(TID_{Unit2})*(1850\ MWt / 3323\ MWt)*(V_{dilution\_U2} / V_{dilution\_U1})$

References
1) PR-C-21-Q, Rev. 1 (main body Reference 7.6.3)
2) NEDO-24290 (main body Reference 7.27)
3) PR-C-20-F, Revision 3 (main body Reference 7.6.6)
4) H21C-097, Revision 0 (main body Reference 7.6.8)

Table 2-2 Equations: Gamma Dose

	A	B	C	D	E	F
1						
2	Bremsstrahlung Factor (5% incr.)		1.05		Assumption	
3	Unit 1 6 month (4320 hr) Drywell Accident TID		27000000	rad	Reference 2, Table 4-3	
4	Unit 1 minimum dilution volume		79800	ft^3	Attachment 4, Table 4-9	
5	Unit 1 maximum dilution volume		94049	ft^3	Attachment 4, Table 4-9	
6	Unit 2 dilution volume for submersion γ dose		160000	ft^3	Refs. 1, 3 (also see Ref. 4, Att. 2)	
7						
8		Drywell & Wetwell Airborne Gamma Dose		Suppression Pool Submersion Gamma Dose		
9	Time	Unit 2 TID(1) @ 3323 MWt	Unit 1 TID(2) @ 1850 MWt	Unit 2 TID(3) @ 3323 MWt	Unit 1 TID(4) @ 1850 MWt - Min Vol	Unit 1 TID(4) @ 1850 MWt - Max Vol
10	[hr]	[rad]	[rad]	[rad]	[rad]	[rad]
11	1	2300000	=B11*(C$3/B$16)*C$2	380000	=D11*(1850/3323)*(C$6/C$4)*C$2	=D11*(1850/3323)*(C$6/C$5)*C$2
12	6	7000000	=B12*(C$3/B$16)*C$2	1400000	=D12*(1850/3323)*(C$6/C$4)*C$2	=D12*(1850/3323)*(C$6/C$5)*C$2
13	24	11000000	=B13*(C$3/B$16)*C$2	2800000	=D13*(1850/3323)*(C$6/C$4)*C$2	=D13*(1850/3323)*(C$6/C$5)*C$2
14	720	30000000	=B14*(C$3/B$16)*C$2	16000000	=D14*(1850/3323)*(C$6/C$4)*C$2	=D14*(1850/3323)*(C$6/C$5)*C$2
15	2400	47000000	=B15*(C$3/B$16)*C$2	36000000	=D15*(1850/3323)*(C$6/C$4)*C$2	=D15*(1850/3323)*(C$6/C$5)*C$2
16	4320	63000000	=B16*(C$3/B$16)*C$2	55000000	=D16*(1850/3323)*(C$6/C$4)*C$2	=D16*(1850/3323)*(C$6/C$5)*C$2
17	8760	95000000	=B17*(C$3/B$16)*C$2	94000000	=D17*(1850/3323)*(C$6/C$4)*C$2	=D17*(1850/3323)*(C$6/C$5)*C$2
18	Notes					
19	1) Maximum environmental zone TID as given in Reference 1 (Zone PC289684, p. 270)					
20	2) $TID_{Unit1}=(1.05)*(TID_{Unit2})*(TID_{6mo\_U1}/TID_{6mo\_U2})$					
21	3) TID for suppression pool environmental zones (PC175101, PC196112, PC215121) in Reference 1 (p. 202)					
22	4) $TID_{Unit1}=(1.05)*(TID_{Unit2})*(1850\ MWt / 3323\ MWt)*(V_{dilution\_U2} / V_{dilution\_U1})$					
23						
24	References					
25	1) PR-C-21-Q, Rev. 1 (main body Reference 7.6.3)					
26	2) NEDO-24290 (main body Reference 7.27)					
27	3) PR-C-20-F, Revision 3 (main body Reference 7.6.6)					
28	4) H21C-097, Revision 0 (main body Reference 7.6.8)					

Attachment 3

Determination of Primary Containment Exposed Cable Inventory

Purpose

The purpose of this attachment is to determine the primary containment exposed cable inventory.

It is expected that NMP Unit 1 will require use of the Liquid Poison System (LPS) based on previous experience, regardless of how the cable inventory is determined. Therefore, use of the conservative methodology presented herein is considered acceptable.

Mass of Cable Insulation/Jacketing in Primary Containment

Since cable insulation and jacketing is combustible, it is included in the combustible load for fire area/zone FA3/R1, "RB 225' to el. 332' Primary Containment Torus Area" (Ref. 1, p. B5). The total combustible load for FA3/R1 is given in the following table. Quantities from the combustible loading calculation (Ref. 1) and Table 3.1.1 of Appendix 10A (Fire Hazards Analysis) to the UFSAR are presented since they are different. For the purposes of the post-LOCA suppression chamber water pH calculation, the calculation (Ref. 1) values are used.

Combustible Material	Quantity (Ref. 1)	Quantity (Ref. 3 – UFSAR)
Cable insulation	744	744
Rubber	36	n/a
Oil	1,104	1,310
Wire insulation	41	25
Plastic	180	n/a
Motor insulation	363	250

Of the combustible loads listed above, the cable insulation, wire insulation, motor insulation, rubber, and plastic *could* be chlorine-bearing material. The total weight of these materials is 1,364 lbm [744+36+41+180+363], of which 1,148 lbm [744+41+363] is insulation. This inventory excludes cable routed in conduit and junction boxes (Ref. 1, p. 5, Assumption 1), which is consistent with the methodology used to determine HCl production for pH analyses. The rubber hoses and plastic covers on lead blankets (Ref. 1, p. A25) are included since they may contain chlorine and therefore may contribute to HCl production. The mass of the rubber and plastic are modeled the same as cable jacketing. Oil may include chlorine-bearing compounds such as chlorinated solvents, but is enclosed and would contain any HCl that might be formed.

Note that the total chlorine bearing material weight for Unit 1 (1,364 lbm) is greater than that for Unit 2 (~620 lbm per Ref. 2, p. 4-7). For conservatism, 1,400 lbm is used for the post-LOCA suppression chamber water pH calculation.

Chemical Composition of Cable Insulation/Jacketing

There are three types of cables used at Nine Mile Point Unit 1: power cable, control cable, and instrumentation cable. All of these cable types can contain a chlorine bearing insulation or jacket material. Per Section IX-B.3.4 of the UFSAR (Ref. 3), some of the possible chlorine bearing insulation and jacket materials are neoprene, polyvinyl chloride (PVC), chlorosulfonated polyethylene (CSPE), and Hypalon® (a CSPE). It is noted that this differs slightly from the 600V cable specifications (Refs. 6-8) which state that the cable jacketing is all black CSPE. The chemical properties of these materials are provided below:

Material	Formula	Molecular Weight	% Chlorine by wt.	Reference
Neoprene	$(C_4H_5Cl)_n$	88.5	40%	Ref. 5
PVC	$(C_2H_3Cl)_n$	62.5	57%	Ref. 5
Hypalon®	$C_{85}H_{157}Cl_{13}SO_2$	1,702.5	27%*	Ref. 4, §2.2.5.1
Kerite CSPE	n/a	n/a	18%	Ref. 2, p. 3-28

* *Weight % chlorine varies from 24-43% per NUREG/CR-5950 for commercial product with filler.*

Thus, based on the above information, it is conservative to model all cable insulation and jacketing in containment as PVC. Note that this differs from NMP Unit 2 in which the majority of cable in containment is Kerite CSPE, conservatively modeled as Hypalon®.

The rubber hose and plastic covers are also modeled as PVC since more detailed information regarding their chlorine content is not available.

Properties of PVC Insulation/Jacketing

The properties of cable insulation/jacketing required for the post-LOCA suppression chamber water pH analysis are as follows: density, linear absorption coefficient, and radiation G value. These properties are provided below for PVC.

Per Reference 10 (p. 6-200), the specific gravity of flexible PVC ranges from 1.16 to 1.7; thus, the density ranges from 1.16 to 1.7 g/cm^3. Note that the density of Hypalon®, 1.55 g/cm^3, is similar (Ref. 11, p. 13).

Since carbon is a major constituent of PVC, $(C_2H_3Cl)_n$, the following values relating the linear absorption coefficient (σ) to material density (ρ) from Reference 11 (p. 13) can be used:

$\sigma_\gamma/\rho = 0.0637\ cm^2/g$
$\sigma_\beta/\rho = 33.6\ cm^2/g$

For the purposes of this calculation, a smaller linear absorption coefficient is conservative since it leads to greater radiation penetration and hence a greater quantity of insulation/jacketing affected by radiation. Therefore, when determining the linear absorption coefficient, the lower bound PVC density (1.16 g/cm^3) is used. This leads to the following linear absorption coefficients for PVC:

$\sigma_\gamma = 0.0739\ cm^{-1}$ [(0.0637 cm^2/g)*(1.16 g/cm^3)]
$\sigma_\beta = 38.976\ cm^{1}$ [(33.6 cm^2/g)*(1.16 g/cm^3)]

The G value for PVC is 7.7 molecules HCl per 100 eV in a vacuum at room temperature, which is greater than the 2.1 molecules HCl per 100 eV G value for Hypalon® in a vacuum at room temperature (Ref. 4, §2.2.5.2). The G value in a vacuum at room temperature is meant to represent a balance between the increased HCl production at elevated temperatures expected during accidents and the neutralization potential of fillers in the cables. Although the neutralization potential of fillers in PVC jacketed/insulated cable is less than in Hypalon® jacketed/insulated cable per NUREG/CR-5950, the G value in a vacuum at room temperatures is still considered acceptable for the following reasons:

- The NMP Unit 1 primary containment vessels (drywell and pressure suppression chamber) are purged with nitrogen to maintain less than 4% oxygen per UFSAR Section VI-E.1.1 (Ref. 3). Therefore, the G value in a vacuum is realistic for NMP Unit 1
- Since all 600V cable jacketing is actually CSPE per the cable specifications (Refs. 6-8), it is probable that much of the insulation combustible load is CSPE or Hypalon®. Therefore, the application of the PVC G value to the entire insulation mass is conservative.

Thus, the G value to be used herein for PVC is 7.7 molecules HCl per 100 eV. Note that this represents an HCl production 3.7 [7.7/2.1] times greater for the radiolysis of PVC than for the radiolysis of Hypalon®. This is the primary difference between the use of PVC versus Hypalon®.

It should also be noted that the use of the G value in a vacuum at room temperature is consistent with the G value suggested for use with Hypalon® in NUREG/CR-5950 (Ref. 7.13). Grand Gulf, an NRC pilot plant for AST implementation, also adopted the G value in a vacuum at room temperature for Hypalon® in Engineering Report GGNS-98-0039 (Ref. 12, Appendix A).

Selection of Typical Cable Size

The typical cable size is selected based on the NMP Unit 1 cable specifications (Refs. 6-8). Typical cable sizes are presented in the following table.

NMPC Item No. [-]	Approximate Outer Diameter [in]	Avg Overall Jacket Thickness [in]	Reference [-]
600V Twisted Pair Instrumentation Cable with Individual Pair Shielding			
N3A101	0.35	0.045	Ref. 6, Tbl. IA/B
N3A102	0.65	0.060	Ref. 6, Tbl. IA/B
N3A103	0.89	0.080	Ref. 6, Tbl. IA/B
N3A104	1.17	0.080	Ref. 6, Tbl. IA/B
600V Twisted Pair Instrumentation Cable with Overall Shielding			
N3A105	0.62	0.060	Ref. 6, Tbl. IIA/B
N3A106	0.77	0.060	Ref. 6, Tbl. IIA/B
N3A107	1.03	0.080	Ref. 6, Tbl. IIA/B
600V Non-Shielded Control Cable			
N3A1	0.22	0.030*	Ref. 7, Tbl. IA/B
N3A2	0.42	0.045	Ref. 7, Tbl. IA/B
N3A3	0.44	0.045	Ref. 7, Tbl. IA/B
N3A4A	0.52	0.045	Ref. 7, Tbl. IA/B
N3A4B	0.60	0.060	Ref. 7, Tbl. IA/B
N3A5	0.70	0.060	Ref. 7, Tbl. IA/B
N3A6	0.78	0.060	Ref. 7, Tbl. IA/B
N3A7	0.95	0.080	Ref. 7, Tbl. IA/B
N3A8	0.25	0.030*	Ref. 7, Tbl. IA/B
N3A10	0.49	0.045	Ref. 7, Tbl. IA/B
N3A11	0.62	0.060	Ref. 7, Tbl. IA/B
600V Shielded Control Cable			
N3A20	0.47	0.045	Ref. 7, Tbl. IIA/B
N3A21	0.60	0.060	Ref. 7, Tbl. IIA/B
N3A22	0.74	0.060	Ref. 7, Tbl. IIA/B
N3A23	0.82	0.060	Ref. 7, Tbl. IIA/B
N3A24	0.51	0.045	Ref. 7, Tbl. IIA/B

NMPC Item No. [-]	Approximate Outer Diameter [in]	Avg Overall Jacket Thickness [in]	Reference [-]
N3A25	0.66	0.060	Ref. 7, Tbl. IIA/B
N3A26	0.83	0.060	Ref. 7, Tbl. IIA/B
N3A27	0.97	0.080	Ref. 7, Tbl. IIA/B
600V Shielded Twisted Pair Control Cable			
N3A32	0.88	0.080*	Ref. 7, Tbl. IIIA/B
N3A35	0.98	0.080*	Ref. 7, Tbl. IIIA/B
600V Multiple Conductor Low-Voltage Power Cable			
N5A1	0.698	0.065	Ref. 8, Tbl. IA/B
N5A2	0.962	0.080	Ref. 8, Tbl. IA/B
600V Triplexed with Ground Low-Voltage Power Cable**			
N5B	0.545	0.065	Ref. 8, Tbl. IIA
N5D	0.688	0.065	Ref. 8, Tbl. IIA
N5E	0.794	0.065	Ref. 8, Tbl. IIA
N5F	0.976	0.065	Ref. 8, Tbl. IIA
N5G	1.105	0.065	Ref. 8, Tbl. IIA
Cable Type Summary			
Maximum	1.17	0.08	
Minimum	0.22	0.03	

* *average individual cable jacket thickness*

** values for individual cables presented (conservative for HCl production purposes)

A typical cable size is selected which maximizes predicted HCl production. Based on the flux averaging factor and absorption fraction (Ref. 2, §5.5), the minimum cable outer diameter and minimum jacket thickness yield conservative results. For smaller cables with thin jacketing, the amount of radiation applied to the jacket is nearly equal to the incident radiation on the surface; hence HCl production is greatest with said cables.

Therefore, a cable with an outer diameter of 0.22 inches and a jacket thickness of 0.030 inches is used for the pH analysis.

Modeling Assumptions

The following assumptions are used in the determination of the primary containment cable inventory. The cumulative effect of these assumptions is extremely conservative.

- Assume all combustible cable insulation is actually cable jacketing; therefore, the entire mass of cable is exposed to both gamma and beta radiation since no credit is taken for shielding of the insulation from beta radiation
- Assume all cable is free-air routed and not in cable trays; thus, no credit can be taken for shielding of some of the cables from beta radiation in cable trays (this assumption conflicts with the combustible loading calculation, Reference 1, which assumes all cable is in trays; however, since Reference 1 *assumes* the cable location, the assumption of free-air routing is acceptable)
- No cable is assumed in the suppression chamber (torus); this is acceptable since little, if any, cable is expected in the suppression chamber

- Medium and high voltage cables are not considered when determining the typical cable size; this is acceptable since small cables maximize HCl production and the medium to high voltage power cables are larger than the cables identified in References 6-8. In addition, the quantity of medium and high voltage power cables inside primary containment is small as the only 5 kV (medium/large) cables in containment feed the reactor recirculation pumps (Ref. 9).
- The chlorine content of the rubber hose and plastic covers is unknown; therefore, it is assumed that these materials are PVC.
- It is assumed that any filler material in the cables is included in the combustible load provided in Reference 1. Therefore, the filler material would be accounted for as chlorine bearing material in this calculation.
- It is assumed that the oil in primary containment is confined and therefore any chlorine which could evolve from the oil to form HCl need not be accounted for in this calculation.

Summary of Cable Inventory in Primary Containment

For the post-LOCA suppression chamber water pH analysis, the primary containment cable inventory is as follows:

- 1,400 lbm of free-air routed PVC jacketed cable with an outer diameter of 0.22 inches and a jacket thickness of 0.030 inches

References

1. NMP Unit 1 Calculation No. S0.0-FPE-002, Revision 1, "Unit 1 Combustible Loading Calculation." (main body Reference 7.6.7)
2. NMP Unit 2 Calculation No. H21C-097, Revision 0, "Post-LOCA Suppression Pool pH Analysis." (main body Reference 7.6.8)
3. Nine Mile Point Unit 1 UFSAR. (main body References 7.11.5, 7.11.6, and 7.11.7)
4. NUREG/CR-5950, "Iodine Evolution and pH Control." (main body Reference 7.13)
5. National Institute of Standards and Technology (NIST) Chemistry WebBook. (http://webbook.nist.gov/chemistry/) (main body Reference 7.28)
6. NMP Unit 1 Specification No. E-1106, "600V Flame and Radiation Resistant Instrumentation Cable." (main body Reference 7.23.1)
7. NMP Unit 1 Specification No. E-1107, "600V Flame and Radiation Resistant Control Cable." (main body Reference 7.23.2)
8. NMP Unit 1 Specification No. E-1108, "600V Flame and Radiation Resistant Low Voltage Power Cable." (main body Reference 7.23.3)
9. TRAK 2000 Database (main body Reference 7.29)
10. Avallone, E.A. and T. Baumeister III, Editors, Marks' Standard Handbook for Mechanical Engineers, 10th Edition, McGraw-Hill, New York, NY, 1996. ISBN 0-07-004997-1. (main body Reference 7.19)
11. NUREG-1081, "Post-Accident Gas Generation from Radiolysis of Organic Materials," September 1984. (main body Reference 7.15)
12. Grand Gulf Engineering Report No. GGNS-98-0039, Revision 3, " Suppression Pool pH and Iodine Re-Evolution Methodology." (main body Reference 7.12.1)

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Attachment 4

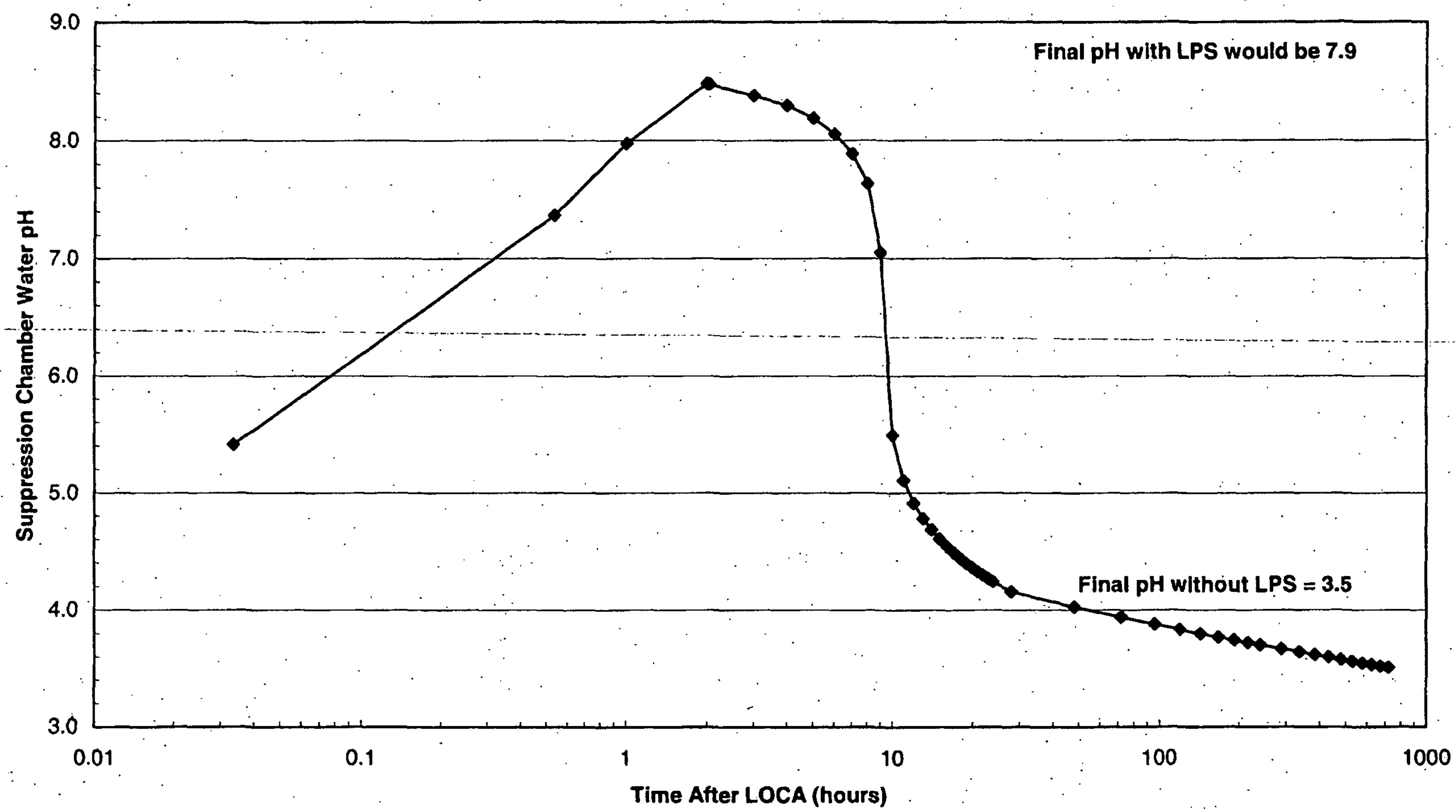
Calculations Determining Post-LOCA Suppression Chamber Water pH

Maximum Suppression Chamber Water Volume Case

Table of Contents

Note that each table in this attachment has been developed using Microsoft Excel. Some tables reference each other; for these references, see the "tab" name at the bottom of each sheet.

**Figure 4-1: Nine Mile Point Unit 1
Post-LOCA Suppression Chamber Water pH Analysis
Maximum Suppression Chamber Water Volume Case
pH Response without LPS**



Pool pH

Table 4-1: Post-LOCA pH Calculation without LPS

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Initial conditions

SC water mass	5,364,128 lbm	Table 4.9 (maximum values)
RCS mass	501,500 lbm	Table 4.9 (maximum values)
Total post-LOCA SC mass	5,865,628 lbm	
suppression chamber water pH	5.5	Design Input 4.1 (minimum value)
reactor coolant pH	5.5	Design Input 4.2 (minimum value)
initial [H^+]	3.16E-06 g-mole/l	weighted average
initial [OH^-]	3.16E-09 g-mole/l	weighted average

Time (hr)	Pool Volume[1] (liter)	[HI][2] (g-moles/l)	[HNO_3][3] (g-moles/l)	[HCl][2] (g-moles/l)	[CsOH][2] (g-moles/l)	Total [H^+] (g-moles/l)	Total [OH^-] (g-moles/l)	Pool Temp (°F)	Water Density (lbm/ft^3)	K_w at Pool Temp (-)	x (g-moles/l)	[H^+] (g-moles/l)	Pool pH (-)
0	2,671,619					3.16E-06	3.16E-09	85.0	62.17	1.409E-14	-1.29E-09	3.16E-06	5.5
0.034	2,696,573		9.15E-08	6.163E-07		3.87E-06	3.16E-09	127.3	61.60	6.240E-14	-1.29E-08	3.88E-06	5.4
0.534	2,714,331	1.33E-07	1.44E-06	9.72E-06	1.73E-05	1.45E-05	1.73E-05	149.9	61.19	1.234E-13	1.44E-05	4.32E-08	7.4
1	2,719,033	3.38E-07	2.70E-06	1.818E-05	3.79E-05	2.44E-05	3.79E-05	155.3	61.09	1.438E-13	2.44E-05	1.06E-08	8.0
2	2,722,378	7.94E-07	4.46E-06	2.726E-05	8.36E-05	3.57E-05	8.36E-05	159.1	61.01	1.594E-13	3.57E-05	3.33E-09	8.5
2.034	2,722,492	7.94E-07	4.52E-06	2.753E-05	8.36E-05	3.60E-05	8.36E-05	159.2	61.01	1.599E-13	3.60E-05	3.36E-09	8.5
3	2,723,132	7.94E-07	6.00E-06	3.456E-05	8.36E-05	4.45E-05	8.36E-05	159.9	60.99	1.63E-13	4.45E-05	4.17E-09	8.4
4	2,722,165	7.94E-07	7.39E-06	4.092E-05	8.36E-05	5.23E-05	8.36E-05	158.9	61.02	1.583E-13	5.23E-05	5.06E-09	8.3
5	2,722,024	7.94E-07	8.70E-06	4.664E-05	8.36E-05	5.93E-05	8.36E-05	158.7	61.02	1.577E-13	5.93E-05	6.49E-09	8.2
6	2,722,024	7.94E-07	9.93E-06	5.189E-05	8.36E-05	6.58E-05	8.36E-05	158.7	61.02	1.577E-13	6.58E-05	8.85E-09	8.1
7	2,722,024	7.94E-07	1.07E-05	5.68E-05	8.36E-05	7.15E-05	8.36E-05	158.7	61.02	1.577E-13	7.15E-05	1.30E-08	7.9
8	2,722,024	7.94E-07	1.15E-05	6.142E-05	8.36E-05	7.68E-05	8.36E-05	158.7	61.02	1.577E-13	7.68E-05	2.33E-08	7.6
9	2,722,024	7.94E-07	1.22E-05	6.58E-05	8.36E-05	8.19E-05	8.36E-05	158.7	61.02	1.577E-13	8.18E-05	8.98E-08	7.0
10	2,722,024	7.94E-07	1.28E-05	6.999E-05	8.36E-05	8.68E-05	8.36E-05	158.7	61.02	1.577E-13	8.35E-05	3.23E-06	5.5
11	2,722,024	7.94E-07	1.35E-05	7.401E-05	8.36E-05	9.14E-05	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	7.85E-06	5.1
12	2,722,024	7.94E-07	1.40E-05	7.788E-05	8.36E-05	9.59E-05	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.23E-05	4.9
13	2,722,024	7.94E-07	1.46E-05	8.162E-05	8.36E-05	1.00E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.66E-05	4.8
14	2,722,024	7.94E-07	1.52E-05	8.524E-05	8.36E-05	1.04E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.08E-05	4.7
15	2,722,024	7.94E-07	1.57E-05	8.875E-05	8.36E-05	1.08E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.48E-05	4.6
16	2,722,024	7.94E-07	1.62E-05	9.217E-05	8.36E-05	1.12E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.88E-05	4.5
17	2,722,024	7.94E-07	1.67E-05	9.551E-05	8.36E-05	1.16E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	3.26E-05	4.5
18	2,722,024	7.94E-07	1.72E-05	9.876E-05	8.36E-05	1.20E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	3.63E-05	4.4
19	2,722,024	7.94E-07	1.77E-05	0.0001019	8.36E-05	1.24E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	4.00E-05	4.4
20	2,722,024	7.94E-07	1.81E-05	0.000105	8.36E-05	1.27E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	4.36E-05	4.4
21	2,722,024	7.94E-07	1.86E-05	0.0001081	8.36E-05	1.31E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	4.70E-05	4.3

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Table 4-1: Post-LOCA pH Calculation without LPS

Time (hr)	Pool Volume[1] (liter)	[HI][2] (g-moles/l)	[HNO_3][3] (g-moles/l)	[HCl][2] (g-moles/l)	[CsOH][2] (g-moles/l)	Total [H^+] (g-moles/l)	Total [OH^-] (g-moles/l)	Pool Temp (°F)	Water Density (lbm/ft^3)	K_w at Pool Temp (-)	x (g-moles/l)	[H^+] (g-moles/l)	Pool pH (-)
22	2,722,024	7.94E-07	1.90E-05	0.0001111	8.36E-05	1.34E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	5.05E-05	4.3
23	2,722,024	7.94E-07	1.95E-05	0.000114	8.36E-05	1.37E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	5.38E-05	4.3
24	2,722,024	7.94E-07	1.99E-05	0.0001169	8.36E-05	1.41E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	5.71E-05	4.2
28	2,722,024	7.94E-07	2.15E-05	0.0001279	8.36E-05	1.53E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	6.98E-05	4.2
48	2,722,024	7.94E-07	2.83E-05	0.0001455	8.36E-05	1.78E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	9.42E-05	4.0
72	2,722,024	7.94E-07	3.49E-05	0.0001603	8.36E-05	1.99E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.16E-04	3.9
96	2,722,024	7.94E-07	4.04E-05	0.0001717	8.36E-05	2.16E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.32E-04	3.9
120	2,722,024	7.94E-07	4.53E-05	0.000181	8.36E-05	2.30E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.47E-04	3.8
144	2,722,024	7.94E-07	4.98E-05	0.0001891	8.36E-05	2.43E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.59E-04	3.8
168	2,722,024	7.94E-07	5.39E-05	0.0001962	8.36E-05	2.54E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.70E-04	3.8
192	2,722,024	7.94E-07	5.77E-05	0.0002025	8.36E-05	2.64E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.81E-04	3.7
216	2,722,024	7.94E-07	6.13E-05	0.0002083	8.36E-05	2.74E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.90E-04	3.7
240	2,722,024	7.94E-07	6.47E-05	0.0002136	8.36E-05	2.82E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	1.99E-04	3.7
288	2,722,024	7.94E-07	7.10E-05	0.0002231	8.36E-05	2.98E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.14E-04	3.7
336	2,722,024	7.94E-07	7.68E-05	0.0002315	8.36E-05	3.12E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.29E-04	3.6
384	2,722,024	7.94E-07	8.23E-05	0.0002389	8.36E-05	3.25E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.42E-04	3.6
432	2,722,024	7.94E-07	8.74E-05	0.0002458	8.36E-05	3.37E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.54E-04	3.6
480	2,722,024	7.94E-07	9.22E-05	0.000252	8.36E-05	3.48E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.65E-04	3.6
528	2,722,024	7.94E-07	9.68E-05	0.0002578	8.36E-05	3.59E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.75E-04	3.6
576	2,722,024	7.94E-07	1.01E-04	0.0002632	8.36E-05	3.68E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.85E-04	3.5
624	2,722,024	7.94E-07	1.05E-04	0.0002683	8.36E-05	3.78E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	2.94E-04	3.5
672	2,722,024	7.94E-07	1.10E-04	0.0002731	8.36E-05	3.87E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	3.03E-04	3.5
720	2,722,024	7.94E-07	1.14E-04	0.0002776	8.36E-05	3.95E-04	8.36E-05	158.7	61.02	1.577E-13	8.36E-05	3.12E-04	3.5

Notes

1) Pool volume is computed as follows: (m_{SP} / ρ_{SP})*28.31685 l/ft^3

2) The HI, HCl, and CsOH concentrations calculated in Tables 4-2, 4-4, and 4-5 are based on the SP volume from Table 4-9.
To adjust for the SP volume as it changes throughout the LOCA, the concentration from Tables 4-2, 4-4, and 4-5 is multiplied by the following factor: V_{basis}/V_{SP}
where V_{basis} is the volume in Table 4-9 and VSP is calculated in this sheet.

3) The HNO_3 concentration does not directly utilize the SP volume and therefore is not adjusted as described in Note 2. However, the HNO_3 generation is based on ρ_{H2O}=1000 g/l. To account for the density in the post-LOCA SP, the concentration from Table 4-3 is multiplied by ρ_{SP} / 1000 g/l * 453.6 g/lbm / 28.31685 l/ft^3

Table 4-2: Hydriodic Acid (HI) Production

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<u>Core iodine inventory</u>			
Core iodine - gap release	7.20	g-mole	Attachment 1, Table 1-1
Core iodine - EIV release	36.02	g-mole	Attachment 1, Table 1-1
Fraction of release as HI	0.05	max	Reg Guide 1.183 (main body Ref. 7.10.2)
Gap release onset	2	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)

	Time (hr)	cumulative HI (g-mole)	suppression chamber water volume (liter)	cumulative HI (g-mole/l)
onset	0.033	0.00	2,662,924	0.00E+00
end of gap release	0.533	0.36	2,662,924	1.35E-07
	1.000	0.92	2,662,924	3.46E-07
end of EIV	2.033	2.16	2,662,924	8.12E-07

Table 4-3: Nitric Acid (HNO_3) Production

HNO_3 generation 7.3E-06 g-mole/l per MRad NUREG/CR-5950 (main body Ref. 7.13)

	Time (hr)	Suppression Chamber Water TID @ 1,850 MWt (rad)	cumulative HNO_3 (g-mole/l)
onset	0.034	1.27E+04	9.27E-08
end of gap release	0.534	2.02E+05	1.47E-06
	1	3.78E+05	2.76E-06
end of EIV	2	6.26E+05	4.57E-06
	2.034	6.33E+05	4.62E-06
	3	8.41E+05	6.14E-06
	4	1.04E+06	7.57E-06
	5	1.22E+06	8.90E-06
	6	1.39E+06	1.02E-05
	7	1.50E+06	1.10E-05
	8	1.61E+06	1.17E-05
	9	1.71E+06	1.24E-05
	10	1.80E+06	1.31E-05
	11	1.89E+06	1.38E-05
	12	1.97E+06	1.44E-05
	13	2.05E+06	1.50E-05
	14	2.13E+06	1.55E-05
	15	2.20E+06	1.61E-05
	16	2.27E+06	1.66E-05
	17	2.34E+06	1.71E-05
	18	2.41E+06	1.76E-05
	19	2.48E+06	1.81E-05
	20	2.54E+06	1.86E-05
	21	2.61E+06	1.90E-05
	22	2.67E+06	1.95E-05
	23	2.73E+06	1.99E-05
	24	2.79E+06	2.03E-05
	28	3.01E+06	2.20E-05
	48	3.97E+06	2.90E-05
	72	4.89E+06	3.57E-05
	96	5.67E+06	4.14E-05
	120	6.35E+06	4.64E-05
	144	6.97E+06	5.09E-05
	168	7.55E+06	5.51E-05
	192	8.08E+06	5.90E-05
	216	8.59E+06	6.27E-05
	240	9.06E+06	6.61E-05
	288	9.95E+06	7.26E-05
	336	1.08E+07	7.86E-05
	384	1.15E+07	8.42E-05
	432	1.22E+07	8.94E-05
	480	1.29E+07	9.44E-05
	528	1.36E+07	9.91E-05
	576	1.42E+07	1.04E-04
	624	1.48E+07	1.08E-04
	672	1.54E+07	1.12E-04
	720	1.59E+07	1.16E-04

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Cables

PVC properties:

radiolysis yield, G	7.980E-06	g-mole HCl per MRad-g	main body §5.5
linear absorption coefficient	38.976	cm^{-1} for beta radiation	Attachment 3
linear absorption coefficient	0.0739	cm^{-1} for gamma radiation	Attachment 3

Cable jacket and insulation:

	Typical Cable	
cable OD	0.22	in
jacket thickness	30	mil
jacket material	PVC	
insulation thickness	0	mil
insulation material	n/a	

chlorine-bearing material:

mass in free air	1,400.0	lbm
mass in tray	0.0	lbm
mass in free air	635,026.0	gram
mass in tray	0.0	gram

Irradiation:

	Typical Cable		
		beta	
	gamma	free air	tray
cable radius (cm)	0.2794	0.2794	0.2794
jacket thickness (cm)	0.0762	0.0762	0.0762
mass irradiated (g)	635,026.0	635,026.0	0.0
flux averaging factor	0.997337	0.341356	0.341356
absorption factor	0.005615	0.948695	0.948695

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Time (hr)	pool volume (liter)	gamma TID (rad)	beta TID (rad)	Drywell HCl gamma (g-mole)	Drywell HCl beta (g-mole)	HCl (g-mole/l)
0.034	2,662,924	3.48E+04	1.01E+06	9.87E-04	1.66E+00	6.24E-07
0.534	2,662,924	5.52E+05	1.61E+07	1.57E-02	2.64E+01	9.91E-06
1	2,662,924	1.04E+06	3.01E+07	2.94E-02	4.94E+01	1.86E-05
2	2,662,924	1.59E+06	4.52E+07	4.52E-02	7.42E+01	2.79E-05
2.034	2,662,924	1.61E+06	4.56E+07	4.57E-02	7.49E+01	2.81E-05
3	2,662,924	2.05E+06	5.73E+07	5.81E-02	9.41E+01	3.53E-05
4	2,662,924	2.45E+06	6.78E+07	6.95E-02	1.11E+02	4.18E-05
5	2,662,924	2.81E+06	7.73E+07	7.98E-02	1.27E+02	4.77E-05
6	2,662,924	3.15E+06	8.60E+07	8.94E-02	1.41E+02	5.3E-05
7	2,662,924	3.31E+06	9.41E+07	9.40E-02	1.55E+02	5.81E-05
8	2,662,924	3.46E+06	1.02E+08	9.82E-02	1.67E+02	6.28E-05
9	2,662,924	3.60E+06	1.09E+08	1.02E-01	1.79E+02	6.73E-05
10	2,662,924	3.72E+06	1.16E+08	1.06E-01	1.90E+02	7.15E-05
11	2,662,924	3.84E+06	1.23E+08	1.09E-01	2.01E+02	7.57E-05
12	2,662,924	3.95E+06	1.29E+08	1.12E-01	2.12E+02	7.96E-05
13	2,662,924	4.05E+06	1.35E+08	1.15E-01	2.22E+02	8.34E-05
14	2,662,924	4.15E+06	1.41E+08	1.18E-01	2.32E+02	8.71E-05
15	2,662,924	4.25E+06	1.47E+08	1.21E-01	2.41E+02	9.07E-05
16	2,662,924	4.34E+06	1.53E+08	1.23E-01	2.51E+02	9.42E-05
17	2,662,924	4.42E+06	1.58E+08	1.26E-01	2.60E+02	9.76E-05
18	2,662,924	4.51E+06	1.64E+08	1.28E-01	2.69E+02	0.000101
19	2,662,924	4.59E+06	1.69E+08	1.30E-01	2.77E+02	0.000104
20	2,662,924	4.66E+06	1.74E+08	1.32E-01	2.86E+02	0.000107
21	2,662,924	4.74E+06	1.79E+08	1.34E-01	2.94E+02	0.00011
22	2,662,924	4.81E+06	1.84E+08	1.37E-01	3.02E+02	0.000114
23	2,662,924	4.88E+06	1.89E+08	1.39E-01	3.10E+02	0.000117
24	2,662,924	4.95E+06	1.94E+08	1.40E-01	3.18E+02	0.000119
28	2,662,924	5.18E+06	2.12E+08	1.47E-01	3.48E+02	0.000131
48	2,662,924	6.07E+06	2.41E+08	1.72E-01	3.96E+02	0.000149
72	2,662,924	6.84E+06	2.66E+08	1.94E-01	4.36E+02	0.000164
96	2,662,924	7.45E+06	2.85E+08	2.11E-01	4.67E+02	0.000175
120	2,662,924	7.96E+06	3.00E+08	2.26E-01	4.93E+02	0.000185
144	2,662,924	8.40E+06	3.13E+08	2.38E-01	5.14E+02	0.000193
168	2,662,924	8.79E+06	3.25E+08	2.49E-01	5.34E+02	0.000201
192	2,662,924	9.14E+06	3.36E+08	2.59E-01	5.51E+02	0.000207
216	2,662,924	9.46E+06	3.45E+08	2.69E-01	5.67E+02	0.000213
240	2,662,924	9.76E+06	3.54E+08	2.77E-01	5.81E+02	0.000218
288	2,662,924	1.03E+07	3.70E+08	2.92E-01	6.07E+02	0.000228
336	2,662,924	1.08E+07	3.84E+08	3.06E-01	6.30E+02	0.000237
384	2,662,924	1.12E+07	3.96E+08	3.18E-01	6.50E+02	0.000244
432	2,662,924	1.16E+07	4.07E+08	3.30E-01	6.69E+02	0.000251
480	2,662,924	1.20E+07	4.18E+08	3.40E-01	6.86E+02	0.000258
528	2,662,924	1.23E+07	4.27E+08	3.50E-01	7.01E+02	0.000264
576	2,662,924	1.26E+07	4.36E+08	3.59E-01	7.16E+02	0.000269
624	2,662,924	1.29E+07	4.45E+08	3.67E-01	7.30E+02	0.000274
672	2,662,924	1.32E+07	4.53E+08	3.75E-01	7.43E+02	0.000279
720	2,662,924	1.35E+07	4.60E+08	3.83E-01	7.55E+02	0.000284

Table 4-5: Cesium Hydroxide (CsOH) Production

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Core cesium - gap release	53.72	g-mole	Attachment 1, Table 1-2
Core cesium - EIV release	214.87	g-mole	Attachment 1, Table 1-2
CsI - gap release	6.84	g-mole	fraction iodine release in form of CsI
CsI - EIV release	34.22	g-mole	fraction iodine release in form of CsI
CsOH - gap release	46.88	g-mole	
CsOH - EIV release	180.65	g-mole	
Gap release onset	2	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)

	Time (Hr)	cumulative CsOH (g-mole)	suppression pool volume (liter)	cumulative CsOH (g-mole/l)
onset	0.033	0.00	2,662,924	0.00E+00
end of gap release	0.533	46.88	2,662,924	1.76E-05
	1.000	103.08	2,662,924	3.87E-05
end of EIV	2.033	227.53	2,662,924	8.54E-05

Buffering by Liquid Poison System

LPS:			
Nominal LPS pump flow rate	30	gpm	Design Input 4.12
Min LPS injection tank volume	1,325	gal	Design Input 4.12
Max LPS temp	105	°F	Design Input 4.12
Min LPS temp	70	°F	Design Input 4.12
LPS SPB concentration by weight	9.423%		Design Input 4.12
Specific gravity	1.0		Design Input 4.12
Water density at max LPS temperature	61.93		Ref. 7.18
LPS solution density at max temperature	61.93	lbm/ft^3	
Final suppression pool temp (bounding)	200	°F	
Boric acid K	1.30E-09	at	200 °F
MW sodium pentaborate ($Na_2B_{10}O_{16}*10H_2O$)	585.984		Design Input 4.12
Volume sodium pentaborate	177.1	ft^3	
Mass sodium pentaborate	1,033.6	lbm	
Mass sodium pentaborate	800.1	g-mole	
Unbuffered pH	3.51		
Unbuffered [H^+]	3.115E-04	g-mole/l	
Suppression chamber water volume	2,662,924	liter	
Equivalents unbuffered [H^+]	829.5	g-mole	
Final pH	7.91		
Time to inject boron	44.2	minutes	

Table 4-7: Gamma and Beta Radiation Dose used to Determine Post-LOCA pH

	gamma dose		beta dose		
Time [hr]	Torus Water TID @ 1850 MWt [rad]	Drywell & Wetwell TID @ 1850 MWt [rad]	Drywell TID @ 1850 MWt [rad]	Source for γ Values [-]	Source for β Values [-]
0					
0.034	1.3E+04	3.5E+04	1.0E+06	linear interpolation	linear interpolation
0.534	2.0E+05	5.5E+05	1.6E+07	linear interpolation	linear interpolation
1	3.779E+05	1.035E+06	3.011E+07	Attachment 2, Table 2-2	Attachment 2, Table 2-1
2	6.3E+05	1.6E+06	4.5E+07	log-log interpolation	log-log interpolation
2.034	6.3E+05	1.6E+06	4.6E+07	log-log interpolation	log-log interpolation
3	8.4E+05	2.0E+06	5.7E+07	log-log interpolation	log-log interpolation
4	1.0E+06	2.4E+06	6.8E+07	log-log interpolation	log-log interpolation
5	1.2E+06	2.8E+06	7.7E+07	log-log interpolation	log-log interpolation
6	1.392E+06	3.150E+06	8.6E+07	Attachment 2, Table 2-2	log-log interpolation
7	1.5E+06	3.3E+06	9.4E+07	log-log interpolation	log-log interpolation
8	1.6E+06	3.5E+06	1.0E+08	log-log interpolation	log-log interpolation
9	1.7E+06	3.6E+06	1.1E+08	log-log interpolation	log-log interpolation
10	1.8E+06	3.7E+06	1.2E+08	log-log interpolation	log-log interpolation
11	1.9E+06	3.8E+06	1.2E+08	log-log interpolation	log-log interpolation
12	2.0E+06	3.9E+06	1.3E+08	log-log interpolation	log-log interpolation
13	2.0E+06	4.1E+06	1.4E+08	log-log interpolation	log-log interpolation
14	2.1E+06	4.2E+06	1.4E+08	log-log interpolation	log-log interpolation
15	2.2E+06	4.2E+06	1.5E+08	log-log interpolation	log-log interpolation
16	2.3E+06	4.3E+06	1.5E+08	log-log interpolation	log-log interpolation
17	2.3E+06	4.4E+06	1.6E+08	log-log interpolation	log-log interpolation
18	2.4E+06	4.5E+06	1.6E+08	log-log interpolation	log-log interpolation
19	2.5E+06	4.6E+06	1.7E+08	log-log interpolation	log-log interpolation
20	2.5E+06	4.7E+06	1.7E+08	log-log interpolation	log-log interpolation
21	2.6E+06	4.7E+06	1.8E+08	log-log interpolation	log-log interpolation
22	2.7E+06	4.8E+06	1.8E+08	log-log interpolation	log-log interpolation
23	2.7E+06	4.9E+06	1.9E+08	log-log interpolation	log-log interpolation
24	2.785E+06	4.950E+06	1.9E+08	Attachment 2, Table 2-2	log-log interpolation
28	3.0E+06	5.2E+06	2.121E+08	log-log interpolation	Attachment 2, Table 2-1
48	4.0E+06	6.1E+06	2.4E+08	log-log interpolation	log-log interpolation
72	4.9E+06	6.8E+06	2.7E+08	log-log interpolation	log-log interpolation
96	5.7E+06	7.5E+06	2.8E+08	log-log interpolation	log-log interpolation
120	6.4E+06	8.0E+06	3.0E+08	log-log interpolation	log-log interpolation
144	7.0E+06	8.4E+06	3.1E+08	log-log interpolation	log-log interpolation
168	7.5E+06	8.8E+06	3.3E+08	log-log interpolation	log-log interpolation
192	8.1E+06	9.1E+06	3.4E+08	log-log interpolation	log-log interpolation
216	8.6E+06	9.5E+06	3.5E+08	log-log interpolation	log-log interpolation
240	9.1E+06	9.8E+06	3.5E+08	log-log interpolation	log-log interpolation
288	9.9E+06	1.0E+07	3.7E+08	log-log interpolation	log-log interpolation
336	1.1E+07	1.1E+07	3.8E+08	log-log interpolation	log-log interpolation
384	1.2E+07	1.1E+07	4.0E+08	log-log interpolation	log-log interpolation
432	1.2E+07	1.2E+07	4.1E+08	log-log interpolation	log-log interpolation
480	1.3E+07	1.2E+07	4.2E+08	log-log interpolation	log-log interpolation
528	1.4E+07	1.2E+07	4.3E+08	log-log interpolation	log-log interpolation
576	1.4E+07	1.3E+07	4.4E+08	log-log interpolation	log-log interpolation
624	1.5E+07	1.3E+07	4.4E+08	log-log interpolation	log-log interpolation
672	1.5E+07	1.3E+07	4.5E+08	log-log interpolation	log-log interpolation
720	1.591E+07	1.350E+07	4.6E+08	Attachment 2, Table 2-2	log-log interpolation
2400	3.580E+07	2.115E+07	6.134E+08	Attachment 2, Table 2-2	Attachment 2, Table 2-1

Note: Shaded values taken from Attachment 2.

Table 4-8: Post-LOCA Suppression Chamber Water Temperature Response

From Data (Ref. 7.6.5)

Time Post-LOCA (sec/days)*	(hr)	Temp (°F)
0	0	85
2.81	7.81E-04	89.1
5.83	1.62E-03	95.77
8.95	2.49E-03	102.7
12.08	3.36E-03	109.4
15.2	4.22E-03	114.7
30.83	8.56E-03	122.1
99.58	0.028	126.5
	0.034	127.3
296.2	0.082	133.7
910.58	0.253	143.5
	0.534	149.9
2,622.58	0.728	154.3
	1	155.3
	2	159.1
	2.034	159.2
8,349.58	2.319	160.3
9,574.08	2.659	160.3
	3	159.9
	4	158.9
14,925.33	4.146	158.7
	5	158.7
	6	158.7
	7	158.7
	8	158.7
	9	158.7
	10	158.7
	11	158.7
	12	158.7
	13	158.7
	14	158.7
	15	158.7
	16	158.7
	17	158.7
	18	158.7
	19	158.7
	20	158.7
	21	158.7
	22	158.7
	23	158.7
	24	158.7
	28	158.7
2	48	158.7
3	72	158.7
4	96	158.7
5	120	158.7
6	144	158.7
7	168	158.7
8	192	158.7
9	216	158.7
10	240	158.7
12	288	158.7
14	336	158.7
15	360	158.7
	384	158.7
	432	158.7
20	480	158.7
	528	158.7
	576	158.7
25	600	158.7
	624	158.7
	672	158.7
30	720	158.7

* Seconds are the units for t=0 to 24 hours; days are the units for t=48 to 720 hours.

Used for pH Analysis

Time (hr)	Temp (°F)
0	85.0
0.034	127.3
0.534	149.9
1	155.3
2	159.1
2.034	159.2
3	159.9
4	158.9
5	158.7
6	158.7
7	158.7
8	158.7
9	158.7
10	158.7
11	158.7
12	158.7
13	158.7
14	158.7
15	158.7
16	158.7
17	158.7
18	158.7
19	158.7
20	158.7
21	158.7
22	158.7
23	158.7
24	158.7
28	158.7
48	158.7
72	158.7
96	158.7
120	158.7
144	158.7
168	158.7
192	158.7
216	158.7
240	158.7
288	158.7
336	158.7
384	158.7
432	158.7
480	158.7
528	158.7
576	158.7
624	158.7
672	158.7
720	158.7

The shaded values are taken from Reference 7.6.5 (Design Input 4.15). Other other values are either interpolated or extrapolated. The long term temperature is maintained at 158.7°F.

Table 4-9: Post-LOCA Suppression Chamber Water Volumes

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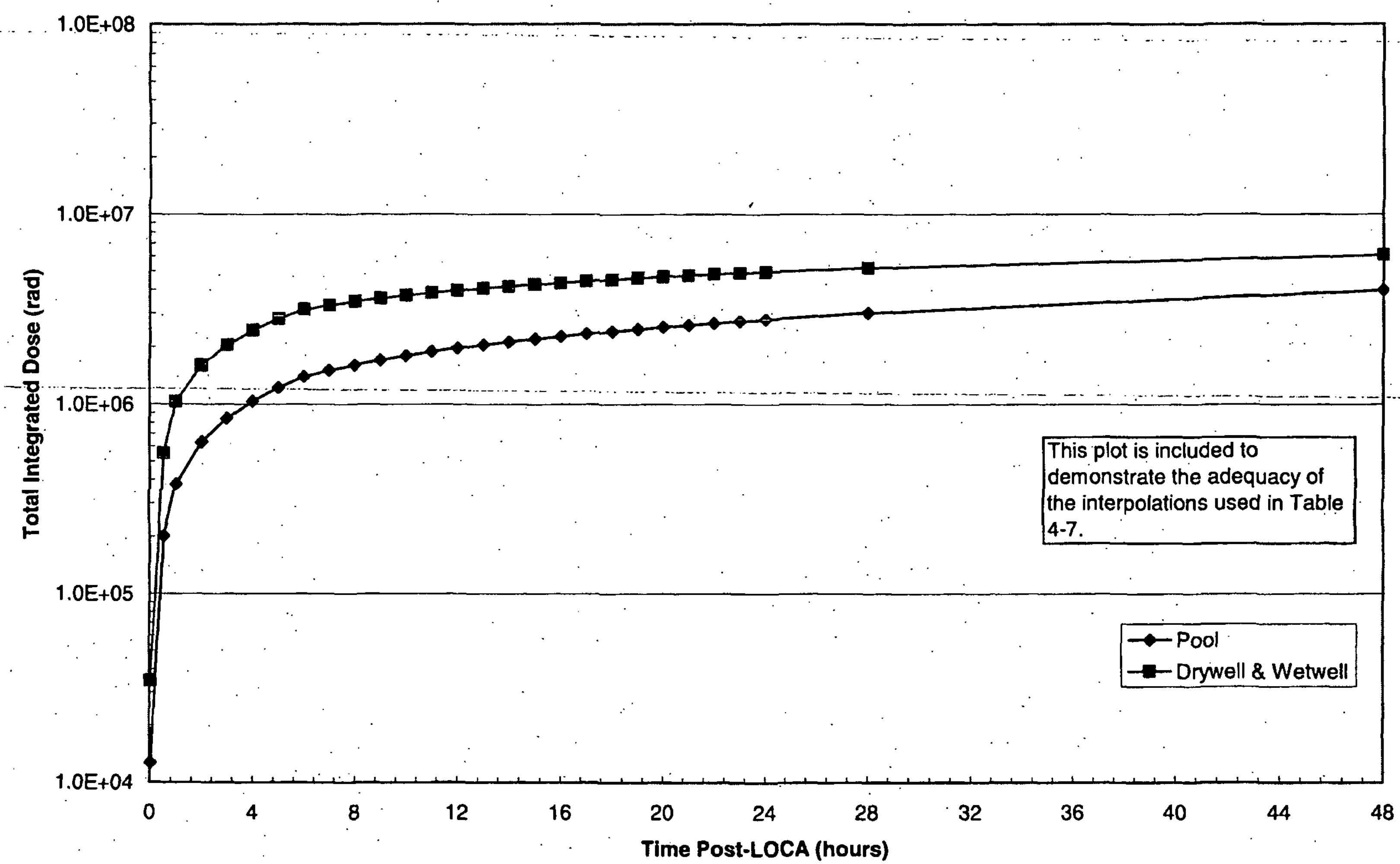
Parameter	Symbol	Unit	Minimum SC Mass	Maximum SC Mass	Reference
Suppression Chamber Water (SC)					
Suppression chamber water volume	V_{SC}	ft^3	79,800	86,000	Design Input 4.6
Suppression chamber water temperature	T_{SC}	°F	85	60	Design Input 4.7
Suppression chamber pressure	P_{SC}	psia	14.7	14.7	Design Input 4.8
Density of suppression chamber water	ρ_{SC}	lbm/ft^3	62.17	62.37	Ref. 7.18
Mass of water in suppression chamber	m_{SC}	lbm	4,961,429	5,364,128	$= V_{SC}*\rho_{SC}$
Reactor Coolant System (RCS)					
RCS mass	m_{RCS}	ft^3	501,500	501,500	Design Input 4.3
Post-LOCA (SC+RCS)					
RCS mass added to SC	$m_{RCS,tot}$	lbm	0	501,500	no RCS mass included in SC for min; all steam condenses in SC for max
Total water mass in SC	$m_{PL\_SC,tot}$	lbm	4,961,429	5,865,628	$= m_{SC} + m_{RCS}$
Total volume of water in SC	$V_{PL\_SC,tot}$	ft^3	79,800	94,040	$= m_{PL\_SC,tot} / \rho_{SC}$
Total volume of water in SC	$V_{PL\_SC,tot}$	liters	2,259,685	2,662,924	$= V_{PL\_SC,tot}\ [ft^3] * 28.31685\ liter/ft^3$

Figure 4-2a: Gamma (γ) Dose vs. Time Post-LOCA (Short Term)



ST gamma TID

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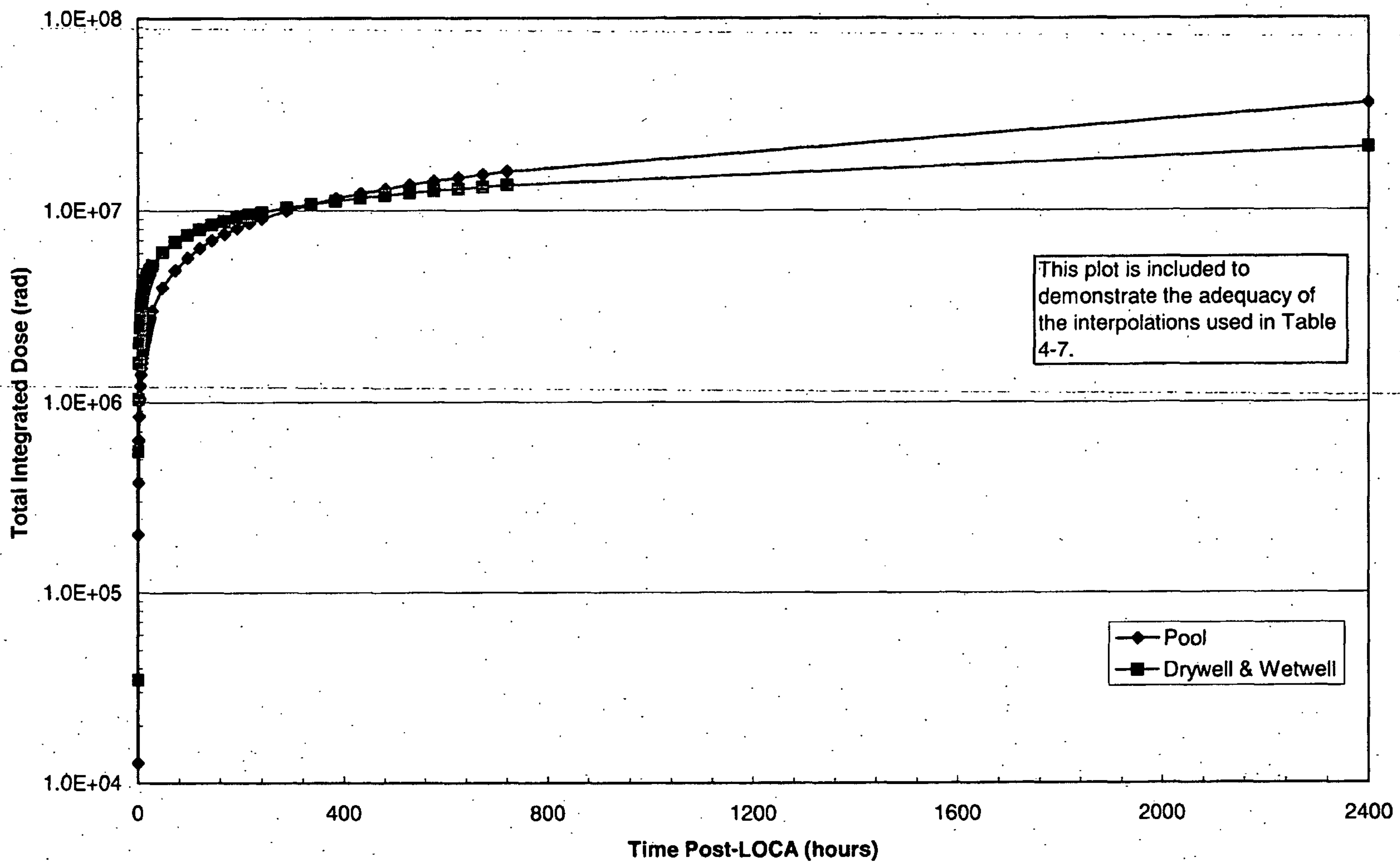
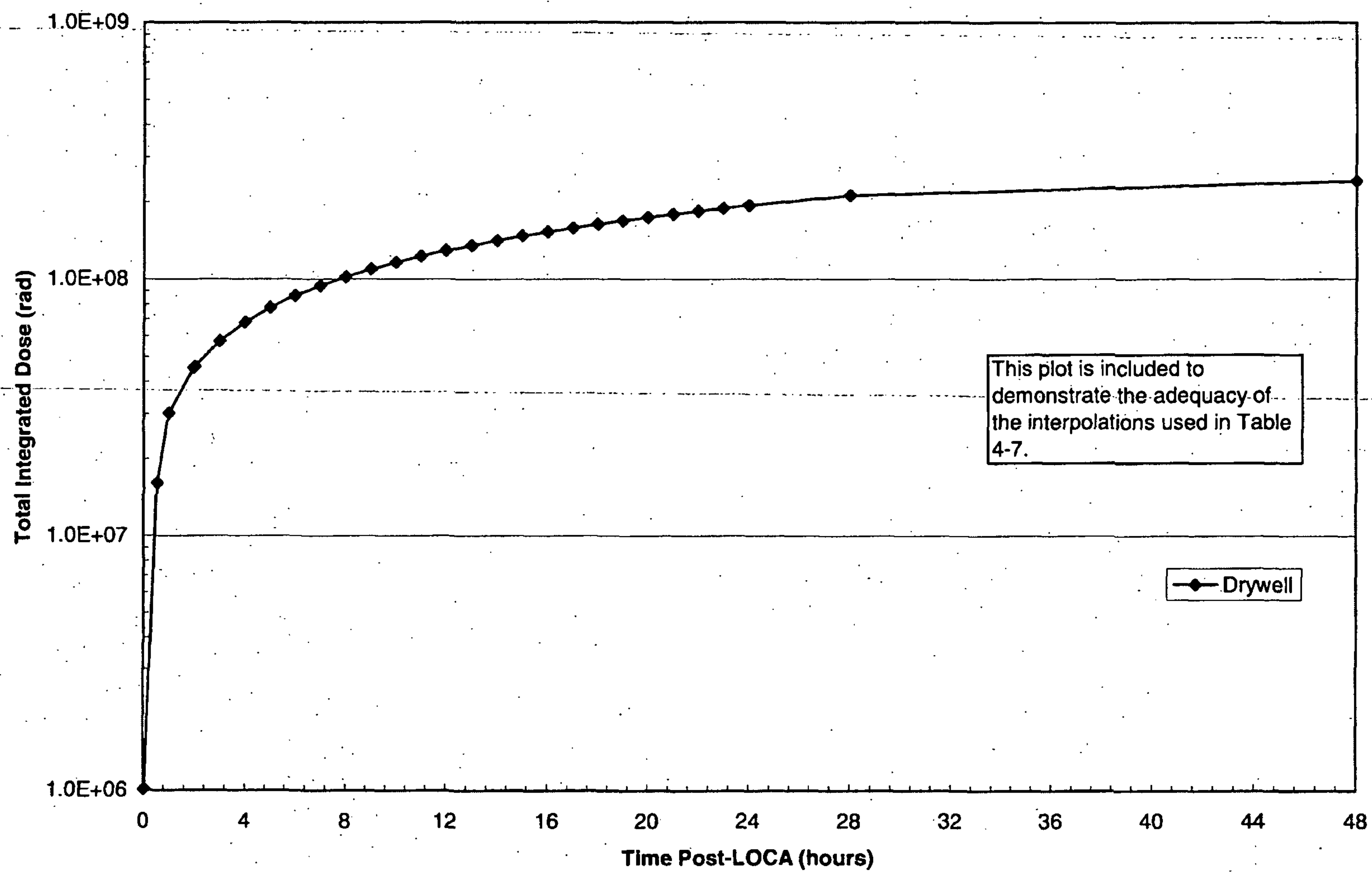
Figure 4-2b: Gamma (γ) Dose vs. Time Post-LOCA (Long Term)



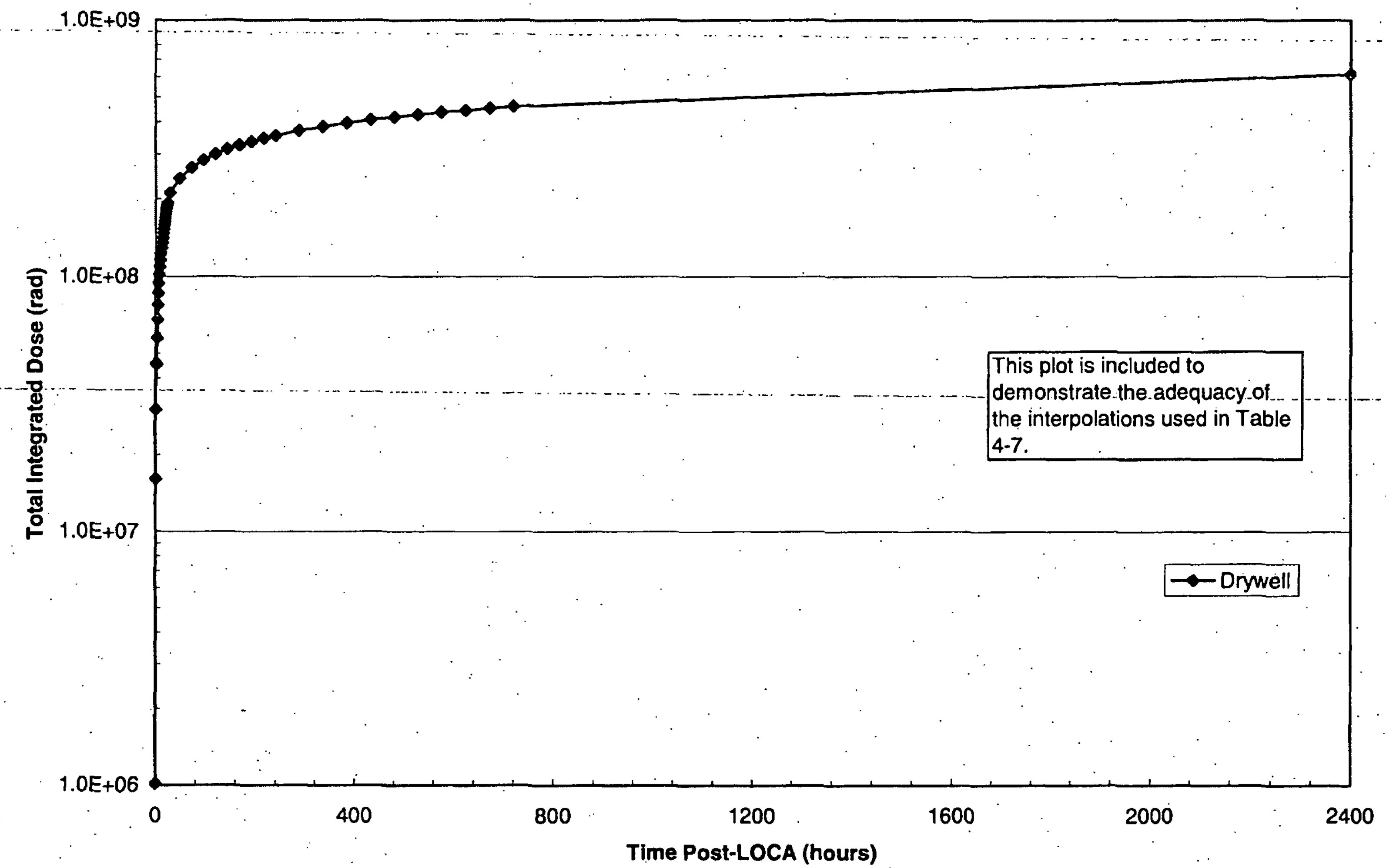
LT gamma TID

Figure 4-3a: Beta (β) Dose vs. Time Post-LOCA (Short Term)



ST beta TID

Figure 4-3b: Beta (β) Dose vs. Time Post-LOCA (Long Term)



LT beta TID

	A	B	C	D	E	F
1	**Initial conditions**					
2						
3	SC water mass			='SP Mass (eqs)'!E8	lbm	Table 4.9 (maximum values)
4	RCS mass			='SP Mass (eqs)'!E12	lbm	Table 4.9 (maximum values)
5	Total post-LOCA SC mass			=D3+D4	lbm	
6						
7	suppression chamber water pH			5.5		Design Input 4.1 (minimum value)
8	reactor coolant pH			5.5		Design Input 4.2 (minimum value)
9						
10	initial $[H^+]$			=(D3*10^(-D7)+D4*10^(-D8))/D5	g-mole/l	weighted average
11	initial $[OH^-]$			=(D3*10^(-14+D7)+D4*10^(-14+D8))/D5	g-mole/l	weighted average
12						
13		Pool	[HI][2]	$[HNO_3]$[3]	[HCl][2]	[CsOH][2]
14	Time	Volume[1]				
15	(hr)	(liter)	(g-moles/l)	(g-moles/l)	(g-moles/l)	(g-moles/l)
16	='Rad Dose (eqs)'!A8	=D$5/J16*28.31685				
17	='Rad Dose (eqs)'!A9	=D$5/J17*28.31685		='HNO3 (eqs)'!D8*J17*453.6/(1000*28.31685)	='HCl (eqs)'!H42*'SP Mass (eqs)'!$E$15/$B17	
18	='Rad Dose (eqs)'!A10	=D$5/J18*28.31685	='HI (eqs)'!E16*'SP Mass (eqs)'!$E$15/$B18	='HNO3 (eqs)'!D9*J18*453.6/(1000*28.31685)	='HCl (eqs)'!H43*'SP Mass (eqs)'!$E$15/$B18	='CsOH (eqs)'!E19*'SP Mass (eqs)'!$E$15/$B18
19	='Rad Dose (eqs)'!A11	=D$5/J19*28.31685	='HI (eqs)'!E17*'SP Mass (eqs)'!$E$15/$B19	='HNO3 (eqs)'!D10*J19*453.6/(1000*28.31685)	='HCl (eqs)'!H44*'SP Mass (eqs)'!$E$15/$B19	='CsOH (eqs)'!E20*'SP Mass (eqs)'!$E$15/$B19
20	='Rad Dose (eqs)'!A12	=D$5/J20*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B20	='HNO3 (eqs)'!D11*J20*453.6/(1000*28.31685)	='HCl (eqs)'!H45*'SP Mass (eqs)'!$E$15/$B20	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B20
21	='Rad Dose (eqs)'!A13	=D$5/J21*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B21	='HNO3 (eqs)'!D12*J21*453.6/(1000*28.31685)	='HCl (eqs)'!H46*'SP Mass (eqs)'!$E$15/$B21	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B21
22	='Rad Dose (eqs)'!A14	=D$5/J22*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B22	='HNO3 (eqs)'!D13*J22*453.6/(1000*28.31685)	='HCl (eqs)'!H47*'SP Mass (eqs)'!$E$15/$B22	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B22
23	='Rad Dose (eqs)'!A15	=D$5/J23*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B23	='HNO3 (eqs)'!D14*J23*453.6/(1000*28.31685)	='HCl (eqs)'!H48*'SP Mass (eqs)'!$E$15/$B23	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B23
24	='Rad Dose (eqs)'!A16	=D$5/J24*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B24	='HNO3 (eqs)'!D15*J24*453.6/(1000*28.31685)	='HCl (eqs)'!H49*'SP Mass (eqs)'!$E$15/$B24	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B24
25	='Rad Dose (eqs)'!A17	=D$5/J25*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B25	='HNO3 (eqs)'!D16*J25*453.6/(1000*28.31685)	='HCl (eqs)'!H50*'SP Mass (eqs)'!$E$15/$B25	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B25
26	='Rad Dose (eqs)'!A18	=D$5/J26*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B26	='HNO3 (eqs)'!D17*J26*453.6/(1000*28.31685)	='HCl (eqs)'!H51*'SP Mass (eqs)'!$E$15/$B26	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B26
27	='Rad Dose (eqs)'!A19	=D$5/J27*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B27	='HNO3 (eqs)'!D18*J27*453.6/(1000*28.31685)	='HCl (eqs)'!H52*'SP Mass (eqs)'!$E$15/$B27	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B27
28	='Rad Dose (eqs)'!A20	=D$5/J28*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B28	='HNO3 (eqs)'!D19*J28*453.6/(1000*28.31685)	='HCl (eqs)'!H53*'SP Mass (eqs)'!$E$15/$B28	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B28
29	='Rad Dose (eqs)'!A21	=D$5/J29*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B29	='HNO3 (eqs)'!D20*J29*453.6/(1000*28.31685)	='HCl (eqs)'!H54*'SP Mass (eqs)'!$E$15/$B29	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B29
30	='Rad Dose (eqs)'!A22	=D$5/J30*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B30	='HNO3 (eqs)'!D21*J30*453.6/(1000*28.31685)	='HCl (eqs)'!H55*'SP Mass (eqs)'!$E$15/$B30	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B30
31	='Rad Dose (eqs)'!A23	=D$5/J31*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B31	='HNO3 (eqs)'!D22*J31*453.6/(1000*28.31685)	='HCl (eqs)'!H56*'SP Mass (eqs)'!$E$15/$B31	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B31
32	='Rad Dose (eqs)'!A24	=D$5/J32*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B32	='HNO3 (eqs)'!D23*J32*453.6/(1000*28.31685)	='HCl (eqs)'!H57*'SP Mass (eqs)'!$E$15/$B32	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B32
33	='Rad Dose (eqs)'!A25	=D$5/J33*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B33	='HNO3 (eqs)'!D24*J33*453.6/(1000*28.31685)	='HCl (eqs)'!H58*'SP Mass (eqs)'!$E$15/$B33	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B33
34	='Rad Dose (eqs)'!A26	=D$5/J34*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B34	='HNO3 (eqs)'!D25*J34*453.6/(1000*28.31685)	='HCl (eqs)'!H59*'SP Mass (eqs)'!$E$15/$B34	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B34
35	='Rad Dose (eqs)'!A27	=D$5/J35*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B35	='HNO3 (eqs)'!D26*J35*453.6/(1000*28.31685)	='HCl (eqs)'!H60*'SP Mass (eqs)'!$E$15/$B35	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B35
36	='Rad Dose (eqs)'!A28	=D$5/J36*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B36	='HNO3 (eqs)'!D27*J36*453.6/(1000*28.31685)	='HCl (eqs)'!H61*'SP Mass (eqs)'!$E$15/$B36	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B36
37	='Rad Dose (eqs)'!A29	=D$5/J37*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B37	='HNO3 (eqs)'!D28*J37*453.6/(1000*28.31685)	='HCl (eqs)'!H62*'SP Mass (eqs)'!$E$15/$B37	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B37
38	='Rad Dose (eqs)'!A30	=D$5/J38*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B38	='HNO3 (eqs)'!D29*J38*453.6/(1000*28.31685)	='HCl (eqs)'!H63*'SP Mass (eqs)'!$E$15/$B38	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B38
39	='Rad Dose (eqs)'!A31	=D$5/J39*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B39	='HNO3 (eqs)'!D30*J39*453.6/(1000*28.31685)	='HCl (eqs)'!H64*'SP Mass (eqs)'!$E$15/$B39	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B39
40	='Rad Dose (eqs)'!A32	=D$5/J40*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B40	='HNO3 (eqs)'!D31*J40*453.6/(1000*28.31685)	='HCl (eqs)'!H65*'SP Mass (eqs)'!$E$15/$B40	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B40
41	='Rad Dose (eqs)'!A33	=D$5/J41*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B41	='HNO3 (eqs)'!D32*J41*453.6/(1000*28.31685)	='HCl (eqs)'!H66*'SP Mass (eqs)'!$E$15/$B41	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B41
42	='Rad Dose (eqs)'!A34	=D$5/J42*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B42	='HNO3 (eqs)'!D33*J42*453.6/(1000*28.31685)	='HCl (eqs)'!H67*'SP Mass (eqs)'!$E$15/$B42	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B42
43	='Rad Dose (eqs)'!A35	=D$5/J43*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B43	='HNO3 (eqs)'!D34*J43*453.6/(1000*28.31685)	='HCl (eqs)'!H68*'SP Mass (eqs)'!$E$15/$B43	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B43
44	='Rad Dose (eqs)'!A36	=D$5/J44*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B44	='HNO3 (eqs)'!D35*J44*453.6/(1000*28.31685)	='HCl (eqs)'!H69*'SP Mass (eqs)'!$E$15/$B44	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B44
45	='Rad Dose (eqs)'!A37	=D$5/J45*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B45	='HNO3 (eqs)'!D36*J45*453.6/(1000*28.31685)	='HCl (eqs)'!H70*'SP Mass (eqs)'!$E$15/$B45	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B45
46	='Rad Dose (eqs)'!A38	=D$5/J46*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B46	='HNO3 (eqs)'!D37*J46*453.6/(1000*28.31685)	='HCl (eqs)'!H71*'SP Mass (eqs)'!$E$15/$B46	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B46
47	='Rad Dose (eqs)'!A39	=D$5/J47*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B47	='HNO3 (eqs)'!D38*J47*453.6/(1000*28.31685)	='HCl (eqs)'!H72*'SP Mass (eqs)'!$E$15/$B47	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B47
48	='Rad Dose (eqs)'!A40	=D$5/J48*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B48	='HNO3 (eqs)'!D39*J48*453.6/(1000*28.31685)	='HCl (eqs)'!H73*'SP Mass (eqs)'!$E$15/$B48	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B48
49	='Rad Dose (eqs)'!A41	=D$5/J49*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B49	='HNO3 (eqs)'!D40*J49*453.6/(1000*28.31685)	='HCl (eqs)'!H74*'SP Mass (eqs)'!$E$15/$B49	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B49
50	='Rad Dose (eqs)'!A42	=D$5/J50*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B50	='HNO3 (eqs)'!D41*J50*453.6/(1000*28.31685)	='HCl (eqs)'!H75*'SP Mass (eqs)'!$E$15/$B50	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B50
51	='Rad Dose (eqs)'!A43	=D$5/J51*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B51	='HNO3 (eqs)'!D42*J51*453.6/(1000*28.31685)	='HCl (eqs)'!H76*'SP Mass (eqs)'!$E$15/$B51	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B51
52	='Rad Dose (eqs)'!A44	=D$5/J52*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B52	='HNO3 (eqs)'!D43*J52*453.6/(1000*28.31685)	='HCl (eqs)'!H77*'SP Mass (eqs)'!$E$15/$B52	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B52
53	='Rad Dose (eqs)'!A45	=D$5/J53*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B53	='HNO3 (eqs)'!D44*J53*453.6/(1000*28.31685)	='HCl (eqs)'!H78*'SP Mass (eqs)'!$E$15/$B53	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B53
54	='Rad Dose (eqs)'!A46	=D$5/J54*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B54	='HNO3 (eqs)'!D45*J54*453.6/(1000*28.31685)	='HCl (eqs)'!H79*'SP Mass (eqs)'!$E$15/$B54	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B54
55	='Rad Dose (eqs)'!A47	=D$5/J55*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B55	='HNO3 (eqs)'!D46*J55*453.6/(1000*28.31685)	='HCl (eqs)'!H80*'SP Mass (eqs)'!$E$15/$B55	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B55

	A	B	C	D	E	F
13		Pool	[HI][2]	[HNO_3][3]	[HCl][2]	[CsOH][2]
14	Time	Volume[1]				
15	(hr)	(liter)	(g-moles/l)	(g-moles/l)	(g-moles/l)	(g-moles/l)
56	='Rad Dose (eqs)'!A48	=D$5/J56*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B56	='HNO3 (eqs)'!D47*J56*453.6/(1000*28.31685)	='HCl (eqs)'!H81*'SP Mass (eqs)'!$E$15/$B56	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B56
57	='Rad Dose (eqs)'!A49	=D$5/J57*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B57	='HNO3 (eqs)'!D48*J57*453.6/(1000*28.31685)	='HCl (eqs)'!H82*'SP Mass (eqs)'!$E$15/$B57	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B57
58	='Rad Dose (eqs)'!A50	=D$5/J58*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B58	='HNO3 (eqs)'!D49*J58*453.6/(1000*28.31685)	='HCl (eqs)'!H83*'SP Mass (eqs)'!$E$15/$B58	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B58
59	='Rad Dose (eqs)'!A51	=D$5/J59*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B59	='HNO3 (eqs)'!D50*J59*453.6/(1000*28.31685)	='HCl (eqs)'!H84*'SP Mass (eqs)'!$E$15/$B59	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B59
60	='Rad Dose (eqs)'!A52	=D$5/J60*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B60	='HNO3 (eqs)'!D51*J60*453.6/(1000*28.31685)	='HCl (eqs)'!H85*'SP Mass (eqs)'!$E$15/$B60	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B60
61	='Rad Dose (eqs)'!A53	=D$5/J61*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B61	='HNO3 (eqs)'!D52*J61*453.6/(1000*28.31685)	='HCl (eqs)'!H86*'SP Mass (eqs)'!$E$15/$B61	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B61
62	='Rad Dose (eqs)'!A54	=D$5/J62*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B62	='HNO3 (eqs)'!D53*J62*453.6/(1000*28.31685)	='HCl (eqs)'!H87*'SP Mass (eqs)'!$E$15/$B62	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B62
63	='Rad Dose (eqs)'!A55	=D$5/J63*28.31685	='HI (eqs)'!E$18*'SP Mass (eqs)'!$E$15/$B63	='HNO3 (eqs)'!D54*J63*453.6/(1000*28.31685)	='HCl (eqs)'!H88*'SP Mass (eqs)'!$E$15/$B63	='CsOH (eqs)'!E$21*'SP Mass (eqs)'!$E$15/$B63
64	Notes					
65	1) Pool volume is computed as follows: (m_{SP} / ρ_{SP})*28.31685 l/ft^3					
66	2) The HI, HCl, and CsOH concentrations calculated in Tables 4-2, 4-4, and 4-5 are based on the SP volume from Table 4-9.					
67	To adjust for the SP volume as it changes throughout the LOCA, the concentration from Tables 4-2, 4-4, and 4-5 is multiplied by the following factor: V_{basis}/V_{SP}					
68	where V_{basis} is the volume in Table 4-9 and VSP is calculated in this sheet.					
69	3) The HNO_3 concentration does not directly utilize the SP volume and therefore is not adjusted as described in Note 2. However,					
70	the HNO_3 generation is based on ρ_{H2O}=1000 g/l. To account for the density in the post-LOCA SP, the concentration from Table 4-3					
71	is multiplied by ρ_{SP} / 1000 g/l * 453.6 g/lbm / 28.31685 l/ft^3					
72						

	G	H	I	J	K	L	M	N
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13	Total [H⁺]	Total [OH⁻]	Pool	Water	K_w at	x	[H⁺]	Pool
14			Temp	Density	Pool Temp			pH
15	(g-moles/l)	(g-moles/l)	(°F)	(lbm/ft³)	(-)	(g-moles/l)	(g-moles/l)	(-)
16	=D$10+SUM(C16:E16)	=D$11+F16	='SP Temp (eqs)'!F5	62.17	=10^-(15.5129-0.0224*I16+0.00003352*I16^2)	=(H16+G16-SQRT((H16+G16)^2-4*(H16*G16-K16)))/2	=G16-L16	=-LOG(M16)
17	=D$10+SUM(C17:E17)	=D$11+F17	='SP Temp (eqs)'!F6	61.6	=10^-(15.5129-0.0224*I17+0.00003352*I17^2)	=(H17+G17-SQRT((H17+G17)^2-4*(H17*G17-K17)))/2	=G17-L17	=-LOG(M17)
18	=D$10+SUM(C18:E18)	=D$11+F18	='SP Temp (eqs)'!F7	61.19	=10^-(15.5129-0.0224*I18+0.00003352*I18^2)	=(H18+G18-SQRT((H18+G18)^2-4*(H18*G18-K18)))/2	=G18-L18	=-LOG(M18)
19	=D$10+SUM(C19:E19)	=D$11+F19	='SP Temp (eqs)'!F8	61.09	=10^-(15.5129-0.0224*I19+0.00003352*I19^2)	=(H19+G19-SQRT((H19+G19)^2-4*(H19*G19-K19)))/2	=G19-L19	=-LOG(M19)
20	=D$10+SUM(C20:E20)	=D$11+F20	='SP Temp (eqs)'!F9	61.01	=10^-(15.5129-0.0224*I20+0.00003352*I20^2)	=(H20+G20-SQRT((H20+G20)^2-4*(H20*G20-K20)))/2	=G20-L20	=-LOG(M20)
21	=D$10+SUM(C21:E21)	=D$11+F21	='SP Temp (eqs)'!F10	61.01	=10^-(15.5129-0.0224*I21+0.00003352*I21^2)	=(H21+G21-SQRT((H21+G21)^2-4*(H21*G21-K21)))/2	=G21-L21	=-LOG(M21)
22	=D$10+SUM(C22:E22)	=D$11+F22	='SP Temp (eqs)'!F11	60.99	=10^-(15.5129-0.0224*I22+0.00003352*I22^2)	=(H22+G22-SQRT((H22+G22)^2-4*(H22*G22-K22)))/2	=G22-L22	=-LOG(M22)
23	=D$10+SUM(C23:E23)	=D$11+F23	='SP Temp (eqs)'!F12	61.02	=10^-(15.5129-0.0224*I23+0.00003352*I23^2)	=(H23+G23-SQRT((H23+G23)^2-4*(H23*G23-K23)))/2	=G23-L23	=-LOG(M23)
24	=D$10+SUM(C24:E24)	=D$11+F24	='SP Temp (eqs)'!F13	61.02	=10^-(15.5129-0.0224*I24+0.00003352*I24^2)	=(H24+G24-SQRT((H24+G24)^2-4*(H24*G24-K24)))/2	=G24-L24	=-LOG(M24)
25	=D$10+SUM(C25:E25)	=D$11+F25	='SP Temp (eqs)'!F14	61.02	=10^-(15.5129-0.0224*I25+0.00003352*I25^2)	=(H25+G25-SQRT((H25+G25)^2-4*(H25*G25-K25)))/2	=G25-L25	=-LOG(M25)
26	=D$10+SUM(C26:E26)	=D$11+F26	='SP Temp (eqs)'!F15	61.02	=10^-(15.5129-0.0224*I26+0.00003352*I26^2)	=(H26+G26-SQRT((H26+G26)^2-4*(H26*G26-K26)))/2	=G26-L26	=-LOG(M26)
27	=D$10+SUM(C27:E27)	=D$11+F27	='SP Temp (eqs)'!F16	61.02	=10^-(15.5129-0.0224*I27+0.00003352*I27^2)	=(H27+G27-SQRT((H27+G27)^2-4*(H27*G27-K27)))/2	=G27-L27	=-LOG(M27)
28	=D$10+SUM(C28:E28)	=D$11+F28	='SP Temp (eqs)'!F17	61.02	=10^-(15.5129-0.0224*I28+0.00003352*I28^2)	=(H28+G28-SQRT((H28+G28)^2-4*(H28*G28-K28)))/2	=G28-L28	=-LOG(M28)
29	=D$10+SUM(C29:E29)	=D$11+F29	='SP Temp (eqs)'!F18	61.02	=10^-(15.5129-0.0224*I29+0.00003352*I29^2)	=(H29+G29-SQRT((H29+G29)^2-4*(H29*G29-K29)))/2	=G29-L29	=-LOG(M29)
30	=D$10+SUM(C30:E30)	=D$11+F30	='SP Temp (eqs)'!F19	61.02	=10^-(15.5129-0.0224*I30+0.00003352*I30^2)	=(H30+G30-SQRT((H30+G30)^2-4*(H30*G30-K30)))/2	=G30-L30	=-LOG(M30)
31	=D$10+SUM(C31:E31)	=D$11+F31	='SP Temp (eqs)'!F20	61.02	=10^-(15.5129-0.0224*I31+0.00003352*I31^2)	=(H31+G31-SQRT((H31+G31)^2-4*(H31*G31-K31)))/2	=G31-L31	=-LOG(M31)
32	=D$10+SUM(C32:E32)	=D$11+F32	='SP Temp (eqs)'!F21	61.02	=10^-(15.5129-0.0224*I32+0.00003352*I32^2)	=(H32+G32-SQRT((H32+G32)^2-4*(H32*G32-K32)))/2	=G32-L32	=-LOG(M32)
33	=D$10+SUM(C33:E33)	=D$11+F33	='SP Temp (eqs)'!F22	61.02	=10^-(15.5129-0.0224*I33+0.00003352*I33^2)	=(H33+G33-SQRT((H33+G33)^2-4*(H33*G33-K33)))/2	=G33-L33	=-LOG(M33)
34	=D$10+SUM(C34:E34)	=D$11+F34	='SP Temp (eqs)'!F23	61.02	=10^-(15.5129-0.0224*I34+0.00003352*I34^2)	=(H34+G34-SQRT((H34+G34)^2-4*(H34*G34-K34)))/2	=G34-L34	=-LOG(M34)
35	=D$10+SUM(C35:E35)	=D$11+F35	='SP Temp (eqs)'!F24	61.02	=10^-(15.5129-0.0224*I35+0.00003352*I35^2)	=(H35+G35-SQRT((H35+G35)^2-4*(H35*G35-K35)))/2	=G35-L35	=-LOG(M35)
36	=D$10+SUM(C36:E36)	=D$11+F36	='SP Temp (eqs)'!F25	61.02	=10^-(15.5129-0.0224*I36+0.00003352*I36^2)	=(H36+G36-SQRT((H36+G36)^2-4*(H36*G36-K36)))/2	=G36-L36	=-LOG(M36)
37	=D$10+SUM(C37:E37)	=D$11+F37	='SP Temp (eqs)'!F26	61.02	=10^-(15.5129-0.0224*I37+0.00003352*I37^2)	=(H37+G37-SQRT((H37+G37)^2-4*(H37*G37-K37)))/2	=G37-L37	=-LOG(M37)
38	=D$10+SUM(C38:E38)	=D$11+F38	='SP Temp (eqs)'!F27	61.02	=10^-(15.5129-0.0224*I38+0.00003352*I38^2)	=(H38+G38-SQRT((H38+G38)^2-4*(H38*G38-K38)))/2	=G38-L38	=-LOG(M38)
39	=D$10+SUM(C39:E39)	=D$11+F39	='SP Temp (eqs)'!F28	61.02	=10^-(15.5129-0.0224*I39+0.00003352*I39^2)	=(H39+G39-SQRT((H39+G39)^2-4*(H39*G39-K39)))/2	=G39-L39	=-LOG(M39)
40	=D$10+SUM(C40:E40)	=D$11+F40	='SP Temp (eqs)'!F29	61.02	=10^-(15.5129-0.0224*I40+0.00003352*I40^2)	=(H40+G40-SQRT((H40+G40)^2-4*(H40*G40-K40)))/2	=G40-L40	=-LOG(M40)
41	=D$10+SUM(C41:E41)	=D$11+F41	='SP Temp (eqs)'!F30	61.02	=10^-(15.5129-0.0224*I41+0.00003352*I41^2)	=(H41+G41-SQRT((H41+G41)^2-4*(H41*G41-K41)))/2	=G41-L41	=-LOG(M41)
42	=D$10+SUM(C42:E42)	=D$11+F42	='SP Temp (eqs)'!F31	61.02	=10^-(15.5129-0.0224*I42+0.00003352*I42^2)	=(H42+G42-SQRT((H42+G42)^2-4*(H42*G42-K42)))/2	=G42-L42	=-LOG(M42)
43	=D$10+SUM(C43:E43)	=D$11+F43	='SP Temp (eqs)'!F32	61.02	=10^-(15.5129-0.0224*I43+0.00003352*I43^2)	=(H43+G43-SQRT((H43+G43)^2-4*(H43*G43-K43)))/2	=G43-L43	=-LOG(M43)
44	=D$10+SUM(C44:E44)	=D$11+F44	='SP Temp (eqs)'!F33	61.02	=10^-(15.5129-0.0224*I44+0.00003352*I44^2)	=(H44+G44-SQRT((H44+G44)^2-4*(H44*G44-K44)))/2	=G44-L44	=-LOG(M44)
45	=D$10+SUM(C45:E45)	=D$11+F45	='SP Temp (eqs)'!F34	61.02	=10^-(15.5129-0.0224*I45+0.00003352*I45^2)	=(H45+G45-SQRT((H45+G45)^2-4*(H45*G45-K45)))/2	=G45-L45	=-LOG(M45)
46	=D$10+SUM(C46:E46)	=D$11+F46	='SP Temp (eqs)'!F35	61.02	=10^-(15.5129-0.0224*I46+0.00003352*I46^2)	=(H46+G46-SQRT((H46+G46)^2-4*(H46*G46-K46)))/2	=G46-L46	=-LOG(M46)
47	=D$10+SUM(C47:E47)	=D$11+F47	='SP Temp (eqs)'!F36	61.02	=10^-(15.5129-0.0224*I47+0.00003352*I47^2)	=(H47+G47-SQRT((H47+G47)^2-4*(H47*G47-K47)))/2	=G47-L47	=-LOG(M47)
48	=D$10+SUM(C48:E48)	=D$11+F48	='SP Temp (eqs)'!F37	61.02	=10^-(15.5129-0.0224*I48+0.00003352*I48^2)	=(H48+G48-SQRT((H48+G48)^2-4*(H48*G48-K48)))/2	=G48-L48	=-LOG(M48)
49	=D$10+SUM(C49:E49)	=D$11+F49	='SP Temp (eqs)'!F38	61.02	=10^-(15.5129-0.0224*I49+0.00003352*I49^2)	=(H49+G49-SQRT((H49+G49)^2-4*(H49*G49-K49)))/2	=G49-L49	=-LOG(M49)
50	=D$10+SUM(C50:E50)	=D$11+F50	='SP Temp (eqs)'!F39	61.02	=10^-(15.5129-0.0224*I50+0.00003352*I50^2)	=(H50+G50-SQRT((H50+G50)^2-4*(H50*G50-K50)))/2	=G50-L50	=-LOG(M50)
51	=D$10+SUM(C51:E51)	=D$11+F51	='SP Temp (eqs)'!F40	61.02	=10^-(15.5129-0.0224*I51+0.00003352*I51^2)	=(H51+G51-SQRT((H51+G51)^2-4*(H51*G51-K51)))/2	=G51-L51	=-LOG(M51)
52	=D$10+SUM(C52:E52)	=D$11+F52	='SP Temp (eqs)'!F41	61.02	=10^-(15.5129-0.0224*I52+0.00003352*I52^2)	=(H52+G52-SQRT((H52+G52)^2-4*(H52*G52-K52)))/2	=G52-L52	=-LOG(M52)
53	=D$10+SUM(C53:E53)	=D$11+F53	='SP Temp (eqs)'!F42	61.02	=10^-(15.5129-0.0224*I53+0.00003352*I53^2)	=(H53+G53-SQRT((H53+G53)^2-4*(H53*G53-K53)))/2	=G53-L53	=-LOG(M53)
54	=D$10+SUM(C54:E54)	=D$11+F54	='SP Temp (eqs)'!F43	61.02	=10^-(15.5129-0.0224*I54+0.00003352*I54^2)	=(H54+G54-SQRT((H54+G54)^2-4*(H54*G54-K54)))/2	=G54-L54	=-LOG(M54)
55	=D$10+SUM(C55:E55)	=D$11+F55	='SP Temp (eqs)'!F44	61.02	=10^-(15.5129-0.0224*I55+0.00003352*I55^2)	=(H55+G55-SQRT((H55+G55)^2-4*(H55*G55-K55)))/2	=G55-L55	=-LOG(M55)

Table 4-1 Eqs: Post-LOCA pH Calculation without LPS

	G	H	I	J	K	L	M	N
13	Total [H⁺]	Total [OH⁻]	Pool	Water	K_w at	x	[H⁺]	Pool
14			Temp	Density	Pool Temp			pH
15	(g-moles/l)	(g-moles/l)	(°F)	(lbm/ft³)	(-)	(g-moles/l)	(g-moles/l)	(-)
56	=D$10+SUM(C56:E56)	=D$11+F56	='SP Temp (eqs)'!F45	61.02	=10^-(15.5129-0.0224*I56+0.00003352*I56^2)	=(H56+G56-SQRT((H56+G56)^2-4*(H56*G56-K56)))/2	=G56-L56	=-LOG(M56)
57	=D$10+SUM(C57:E57)	=D$11+F57	='SP Temp (eqs)'!F46	61.02	=10^-(15.5129-0.0224*I57+0.00003352*I57^2)	=(H57+G57-SQRT((H57+G57)^2-4*(H57*G57-K57)))/2	=G57-L57	=-LOG(M57)
58	=D$10+SUM(C58:E58)	=D$11+F58	='SP Temp (eqs)'!F47	61.02	=10^-(15.5129-0.0224*I58+0.00003352*I58^2)	=(H58+G58-SQRT((H58+G58)^2-4*(H58*G58-K58)))/2	=G58-L58	=-LOG(M58)
59	=D$10+SUM(C59:E59)	=D$11+F59	='SP Temp (eqs)'!F48	61.02	=10^-(15.5129-0.0224*I59+0.00003352*I59^2)	=(H59+G59-SQRT((H59+G59)^2-4*(H59*G59-K59)))/2	=G59-L59	=-LOG(M59)
60	=D$10+SUM(C60:E60)	=D$11+F60	='SP Temp (eqs)'!F49	61.02	=10^-(15.5129-0.0224*I60+0.00003352*I60^2)	=(H60+G60-SQRT((H60+G60)^2-4*(H60*G60-K60)))/2	=G60-L60	=-LOG(M60)
61	=D$10+SUM(C61:E61)	=D$11+F61	='SP Temp (eqs)'!F50	61.02	=10^-(15.5129-0.0224*I61+0.00003352*I61^2)	=(H61+G61-SQRT((H61+G61)^2-4*(H61*G61-K61)))/2	=G61-L61	=-LOG(M61)
62	=D$10+SUM(C62:E62)	=D$11+F62	='SP Temp (eqs)'!F51	61.02	=10^-(15.5129-0.0224*I62+0.00003352*I62^2)	=(H62+G62-SQRT((H62+G62)^2-4*(H62*G62-K62)))/2	=G62-L62	=-LOG(M62)
63	=D$10+SUM(C63:E63)	=D$11+F63	='SP Temp (eqs)'!F52	61.02	=10^-(15.5129-0.0224*I63+0.00003352*I63^2)	=(H63+G63-SQRT((H63+G63)^2-4*(H63*G63-K63)))/2	=G63-L63	=-LOG(M63)
64								
65								
66								
67								
68								
69								
70								
71								
72								

Table 4-2 Eqs: Hydriodic Acid (HI) Production

	A	B	C	D	E
1	Core iodine inventory				
2	Core iodine - gap release	7.2	g-mole	Attachment 1, Table 1-1	
3	Core iodine - EIV release	36.02	g-mole	Attachment 1, Table 1-1	
4					
5	Fraction of release as HI	0.05	max	Reg Guide 1.183 (main body Ref. 7.10.2)	
6					
7	Gap release onset	2	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
8	Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
9	EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
10					
11				suppression	
12			cumulative	chamber water	cumulative
13		Time	HI	volume	HI
14		(hr)	(g-mole)	(liter)	(g-mole/l)
15	onset	=B7/60	0	='SP Mass (eqs)'!$E$15	=C15/D15
16	*end of gap release*	=B15+B8/60	=B2*B5	='SP Mass (eqs)'!$E$15	=C16/D16
17		1	=C16+(B17-B16)/(B9/60)*B3*B5	='SP Mass (eqs)'!$E$15	=C17/D17
18	end of EIV	=B16+B9/60	=C16+B3*B5	='SP Mass (eqs)'!$E$15	=C18/D18

	A	B	C	D	E	F
1	HNO_3 generation	0.0000073	g-mole/l per MRad		NUREG/CR-5950 (main body Ref. 7.13)	
2						
3						
4			Suppression			
5			Chamber Water	cumulative		
6		Time	TID @ 1,850 MWt	HNO_3		
7		(hr)	(rad)	(g-mole/l)		
8	onset	='Rad Dose (eqs)'!A9	='Rad Dose (eqs)'!B9	=$B$1*C8/1000000		
9	end of gap release	='Rad Dose (eqs)'!A10	='Rad Dose (eqs)'!B10	=$B$1*C9/1000000		
10		='Rad Dose (eqs)'!A11	='Rad Dose (eqs)'!B11	=$B$1*C10/1000000		
11	end of EIV	='Rad Dose (eqs)'!A12	='Rad Dose (eqs)'!B12	=$B$1*C11/1000000		
12		='Rad Dose (eqs)'!A13	='Rad Dose (eqs)'!B13	=$B$1*C12/1000000		
13		='Rad Dose (eqs)'!A14	='Rad Dose (eqs)'!B14	=$B$1*C13/1000000		
14		='Rad Dose (eqs)'!A15	='Rad Dose (eqs)'!B15	=$B$1*C14/1000000		
15		='Rad Dose (eqs)'!A16	='Rad Dose (eqs)'!B16	=$B$1*C15/1000000		
16		='Rad Dose (eqs)'!A17	='Rad Dose (eqs)'!B17	=$B$1*C16/1000000		
17		='Rad Dose (eqs)'!A18	='Rad Dose (eqs)'!B18	=$B$1*C17/1000000		
18		='Rad Dose (eqs)'!A19	='Rad Dose (eqs)'!B19	=$B$1*C18/1000000		
19		='Rad Dose (eqs)'!A20	='Rad Dose (eqs)'!B20	=$B$1*C19/1000000		
20		='Rad Dose (eqs)'!A21	='Rad Dose (eqs)'!B21	=$B$1*C20/1000000		
21		='Rad Dose (eqs)'!A22	='Rad Dose (eqs)'!B22	=$B$1*C21/1000000		
22		='Rad Dose (eqs)'!A23	='Rad Dose (eqs)'!B23	=$B$1*C22/1000000		
23		='Rad Dose (eqs)'!A24	='Rad Dose (eqs)'!B24	=$B$1*C23/1000000		
24		='Rad Dose (eqs)'!A25	='Rad Dose (eqs)'!B25	=$B$1*C24/1000000		
25		='Rad Dose (eqs)'!A26	='Rad Dose (eqs)'!B26	=$B$1*C25/1000000		
26		='Rad Dose (eqs)'!A27	='Rad Dose (eqs)'!B27	=$B$1*C26/1000000		
27		='Rad Dose (eqs)'!A28	='Rad Dose (eqs)'!B28	=$B$1*C27/1000000		
28		='Rad Dose (eqs)'!A29	='Rad Dose (eqs)'!B29	=$B$1*C28/1000000		
29		='Rad Dose (eqs)'!A30	='Rad Dose (eqs)'!B30	=$B$1*C29/1000000		
30		='Rad Dose (eqs)'!A31	='Rad Dose (eqs)'!B31	=$B$1*C30/1000000		
31		='Rad Dose (eqs)'!A32	='Rad Dose (eqs)'!B32	=$B$1*C31/1000000		
32		='Rad Dose (eqs)'!A33	='Rad Dose (eqs)'!B33	=$B$1*C32/1000000		
33		='Rad Dose (eqs)'!A34	='Rad Dose (eqs)'!B34	=$B$1*C33/1000000		
34		='Rad Dose (eqs)'!A35	='Rad Dose (eqs)'!B35	=$B$1*C34/1000000		
35		='Rad Dose (eqs)'!A36	='Rad Dose (eqs)'!B36	=$B$1*C35/1000000		
36		='Rad Dose (eqs)'!A37	='Rad Dose (eqs)'!B37	=$B$1*C36/1000000		
37		='Rad Dose (eqs)'!A38	='Rad Dose (eqs)'!B38	=$B$1*C37/1000000		
38		='Rad Dose (eqs)'!A39	='Rad Dose (eqs)'!B39	=$B$1*C38/1000000		
39		='Rad Dose (eqs)'!A40	='Rad Dose (eqs)'!B40	=$B$1*C39/1000000		
40		='Rad Dose (eqs)'!A41	='Rad Dose (eqs)'!B41	=$B$1*C40/1000000		
41		='Rad Dose (eqs)'!A42	='Rad Dose (eqs)'!B42	=$B$1*C41/1000000		
42		='Rad Dose (eqs)'!A43	='Rad Dose (eqs)'!B43	=$B$1*C42/1000000		
43		='Rad Dose (eqs)'!A44	='Rad Dose (eqs)'!B44	=$B$1*C43/1000000		
44		='Rad Dose (eqs)'!A45	='Rad Dose (eqs)'!B45	=$B$1*C44/1000000		
45		='Rad Dose (eqs)'!A46	='Rad Dose (eqs)'!B46	=$B$1*C45/1000000		
46		='Rad Dose (eqs)'!A47	='Rad Dose (eqs)'!B47	=$B$1*C46/1000000		
47		='Rad Dose (eqs)'!A48	='Rad Dose (eqs)'!B48	=$B$1*C47/1000000		
48		='Rad Dose (eqs)'!A49	='Rad Dose (eqs)'!B49	=$B$1*C48/1000000		
49		='Rad Dose (eqs)'!A50	='Rad Dose (eqs)'!B50	=$B$1*C49/1000000		
50		='Rad Dose (eqs)'!A51	='Rad Dose (eqs)'!B51	=$B$1*C50/1000000		
51		='Rad Dose (eqs)'!A52	='Rad Dose (eqs)'!B52	=$B$1*C51/1000000		
52		='Rad Dose (eqs)'!A53	='Rad Dose (eqs)'!B53	=$B$1*C52/1000000		
53		='Rad Dose (eqs)'!A54	='Rad Dose (eqs)'!B54	=$B$1*C53/1000000		
54		='Rad Dose (eqs)'!A55	='Rad Dose (eqs)'!B55	=$B$1*C54/1000000		

	A	B	C	D	E	F
1	Cables					
2						
3	PVC properties:					
4	radiolysis yield, G	0.00000798	g-mole HCl per MRad-g			main body §5.5
5	linear absorption coefficient	38.976	cm^{-1} for beta radiation			Attachment 3
6	linear absorption coefficient	0.0739	cm^{-1} for gamma radiation			Attachment 3
7						
8	Cable jacket and insulation:					
9						
10		Typical Cable				
11						
12	cable OD	0.22	in			
13	jacket thickness	30	mil			
14	jacket material	PVC				
15	insulation thickness	0	mil			
16	insulation material	n/a				
17						
18	chlorine-bearing material:					
19						
20	mass in free air	1400	lbm			
21	mass in tray	0	lbm			
22	mass in free air	=B20*453.59	gram			
23	mass in tray	=B21*453.59	gram			
24						
25	Irradiation:					
26						
27			=B10			
28			beta			
29		gamma	free air	tray		
30						
31	cable radius (cm)	=$B12*2.54/2	=$B12*2.54/2	=$B12*2.54/2		
32	jacket thickness (cm)	=($B13)/1000*2.54	=($B13)/1000*2.54	=($B13)/1000*2.54		
33	mass irradiated (g)	=B22+B23	=B22	=0.5*B23		
34						
35	flux averaging factor	=(1/($B$6^2)*(EXP(-$B$6*B32)*($B$6*B32+1)-1)-B31/$B$6*(EXP(-$B$6*B32)-1))/(B31*B32-B32^2/2)	=(1/($B$5^2)*(EXP(-$B$5*C32)*($B$5*C32+1)-1)-C31/$B$5*(EXP(-$B$5*C32)-1))/(C31*C32-C32^2/2)	=(1/($B$5^2)*(EXP(-$B$5*D32)*($B$5*D32+1)-1)-D31/$B$5*(EXP(-$B$5*D32)-1))/(D31*D32-D32^2/2)		
36	absorption factor	=1-EXP(-$B$6*B32)	=1-EXP(-$B$5*C32)	=1-EXP(-$B$5*D32)		
37						

	A	B	C	D	E	F
38						
39			pool	gamma	beta	
40		Time	volume	TID	TID	gamma
41		(hr)	(liter)	(rad)	(rad)	(g-mole)
42		='Rad Dose (eqs)'!A9	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C9	='Rad Dose (eqs)'!D9	=$B$4*($B$33*$B$35*$B$36)*D42/1000000
43		='Rad Dose (eqs)'!A10	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C10	='Rad Dose (eqs)'!D10	=$B$4*($B$33*$B$35*$B$36)*D43/1000000
44		='Rad Dose (eqs)'!A11	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C11	='Rad Dose (eqs)'!D11	=$B$4*($B$33*$B$35*$B$36)*D44/1000000
45		='Rad Dose (eqs)'!A12	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C12	='Rad Dose (eqs)'!D12	=$B$4*($B$33*$B$35*$B$36)*D45/1000000
46		='Rad Dose (eqs)'!A13	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C13	='Rad Dose (eqs)'!D13	=$B$4*($B$33*$B$35*$B$36)*D46/1000000
47		='Rad Dose (eqs)'!A14	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C14	='Rad Dose (eqs)'!D14	=$B$4*($B$33*$B$35*$B$36)*D47/1000000
48		='Rad Dose (eqs)'!A15	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C15	='Rad Dose (eqs)'!D15	=$B$4*($B$33*$B$35*$B$36)*D48/1000000
49		='Rad Dose (eqs)'!A16	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C16	='Rad Dose (eqs)'!D16	=$B$4*($B$33*$B$35*$B$36)*D49/1000000
50		='Rad Dose (eqs)'!A17	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C17	='Rad Dose (eqs)'!D17	=$B$4*($B$33*$B$35*$B$36)*D50/1000000
51		='Rad Dose (eqs)'!A18	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C18	='Rad Dose (eqs)'!D18	=$B$4*($B$33*$B$35*$B$36)*D51/1000000
52		='Rad Dose (eqs)'!A19	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C19	='Rad Dose (eqs)'!D19	=$B$4*($B$33*$B$35*$B$36)*D52/1000000
53		='Rad Dose (eqs)'!A20	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C20	='Rad Dose (eqs)'!D20	=$B$4*($B$33*$B$35*$B$36)*D53/1000000
54		='Rad Dose (eqs)'!A21	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C21	='Rad Dose (eqs)'!D21	=$B$4*($B$33*$B$35*$B$36)*D54/1000000
55		='Rad Dose (eqs)'!A22	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C22	='Rad Dose (eqs)'!D22	=$B$4*($B$33*$B$35*$B$36)*D55/1000000
56		='Rad Dose (eqs)'!A23	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C23	='Rad Dose (eqs)'!D23	=$B$4*($B$33*$B$35*$B$36)*D56/1000000
57		='Rad Dose (eqs)'!A24	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C24	='Rad Dose (eqs)'!D24	=$B$4*($B$33*$B$35*$B$36)*D57/1000000
58		='Rad Dose (eqs)'!A25	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C25	='Rad Dose (eqs)'!D25	=$B$4*($B$33*$B$35*$B$36)*D58/1000000
59		='Rad Dose (eqs)'!A26	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C26	='Rad Dose (eqs)'!D26	=$B$4*($B$33*$B$35*$B$36)*D59/1000000
60		='Rad Dose (eqs)'!A27	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C27	='Rad Dose (eqs)'!D27	=$B$4*($B$33*$B$35*$B$36)*D60/1000000
61		='Rad Dose (eqs)'!A28	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C28	='Rad Dose (eqs)'!D28	=$B$4*($B$33*$B$35*$B$36)*D61/1000000
62		='Rad Dose (eqs)'!A29	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C29	='Rad Dose (eqs)'!D29	=$B$4*($B$33*$B$35*$B$36)*D62/1000000
63		='Rad Dose (eqs)'!A30	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C30	='Rad Dose (eqs)'!D30	=$B$4*($B$33*$B$35*$B$36)*D63/1000000
64		='Rad Dose (eqs)'!A31	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C31	='Rad Dose (eqs)'!D31	=$B$4*($B$33*$B$35*$B$36)*D64/1000000
65		='Rad Dose (eqs)'!A32	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C32	='Rad Dose (eqs)'!D32	=$B$4*($B$33*$B$35*$B$36)*D65/1000000
66		='Rad Dose (eqs)'!A33	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C33	='Rad Dose (eqs)'!D33	=$B$4*($B$33*$B$35*$B$36)*D66/1000000
67		='Rad Dose (eqs)'!A34	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C34	='Rad Dose (eqs)'!D34	=$B$4*($B$33*$B$35*$B$36)*D67/1000000
68		='Rad Dose (eqs)'!A35	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C35	='Rad Dose (eqs)'!D35	=$B$4*($B$33*$B$35*$B$36)*D68/1000000
69		='Rad Dose (eqs)'!A36	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C36	='Rad Dose (eqs)'!D36	=$B$4*($B$33*$B$35*$B$36)*D69/1000000
70		='Rad Dose (eqs)'!A37	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C37	='Rad Dose (eqs)'!D37	=$B$4*($B$33*$B$35*$B$36)*D70/1000000
71		='Rad Dose (eqs)'!A38	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C38	='Rad Dose (eqs)'!D38	=$B$4*($B$33*$B$35*$B$36)*D71/1000000
72		='Rad Dose (eqs)'!A39	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C39	='Rad Dose (eqs)'!D39	=$B$4*($B$33*$B$35*$B$36)*D72/1000000

	A	B	C	D	E	F
73		='Rad Dose (eqs)'!A40	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C40	='Rad Dose (eqs)'!D40	=$B$4*($B$33*$B$35*$B$36)*D73/1000000
74		='Rad Dose (eqs)'!A41	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C41	='Rad Dose (eqs)'!D41	=$B$4*($B$33*$B$35*$B$36)*D74/1000000
75		='Rad Dose (eqs)'!A42	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C42	='Rad Dose (eqs)'!D42	=$B$4*($B$33*$B$35*$B$36)*D75/1000000
76		='Rad Dose (eqs)'!A43	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C43	='Rad Dose (eqs)'!D43	=$B$4*($B$33*$B$35*$B$36)*D76/1000000
77		='Rad Dose (eqs)'!A44	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C44	='Rad Dose (eqs)'!D44	=$B$4*($B$33*$B$35*$B$36)*D77/1000000
78		='Rad Dose (eqs)'!A45	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C45	='Rad Dose (eqs)'!D45	=$B$4*($B$33*$B$35*$B$36)*D78/1000000
79		='Rad Dose (eqs)'!A46	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C46	='Rad Dose (eqs)'!D46	=$B$4*($B$33*$B$35*$B$36)*D79/1000000
80		='Rad Dose (eqs)'!A47	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C47	='Rad Dose (eqs)'!D47	=$B$4*($B$33*$B$35*$B$36)*D80/1000000
81		='Rad Dose (eqs)'!A48	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C48	='Rad Dose (eqs)'!D48	=$B$4*($B$33*$B$35*$B$36)*D81/1000000
82		='Rad Dose (eqs)'!A49	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C49	='Rad Dose (eqs)'!D49	=$B$4*($B$33*$B$35*$B$36)*D82/1000000
83		='Rad Dose (eqs)'!A50	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C50	='Rad Dose (eqs)'!D50	=$B$4*($B$33*$B$35*$B$36)*D83/1000000
84		='Rad Dose (eqs)'!A51	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C51	='Rad Dose (eqs)'!D51	=$B$4*($B$33*$B$35*$B$36)*D84/1000000
85		='Rad Dose (eqs)'!A52	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C52	='Rad Dose (eqs)'!D52	=$B$4*($B$33*$B$35*$B$36)*D85/1000000
86		='Rad Dose (eqs)'!A53	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C53	='Rad Dose (eqs)'!D53	=$B$4*($B$33*$B$35*$B$36)*D86/1000000
87		='Rad Dose (eqs)'!A54	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C54	='Rad Dose (eqs)'!D54	=$B$4*($B$33*$B$35*$B$36)*D87/1000000
88		='Rad Dose (eqs)'!A55	='SP Mass (eqs)'!$E$15	='Rad Dose (eqs)'!C55	='Rad Dose (eqs)'!D55	=$B$4*($B$33*$B$35*$B$36)*D88/1000000

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	G	H	I
38			
39	Drywell HCl		
40	beta	HCl	
41	(g-mole)	(g-mole/l)	
42	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E42/1000000	=(F42+G42)/C42	
43	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E43/1000000	=(F43+G43)/C43	
44	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E44/1000000	=(F44+G44)/C44	
45	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E45/1000000	=(F45+G45)/C45	
46	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E46/1000000	=(F46+G46)/C46	
47	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E47/1000000	=(F47+G47)/C47	
48	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E48/1000000	=(F48+G48)/C48	
49	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E49/1000000	=(F49+G49)/C49	
50	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E50/1000000	=(F50+G50)/C50	
51	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E51/1000000	=(F51+G51)/C51	
52	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E52/1000000	=(F52+G52)/C52	
53	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E53/1000000	=(F53+G53)/C53	
54	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E54/1000000	=(F54+G54)/C54	
55	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E55/1000000	=(F55+G55)/C55	
56	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E56/1000000	=(F56+G56)/C56	
57	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E57/1000000	=(F57+G57)/C57	
58	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E58/1000000	=(F58+G58)/C58	
59	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E59/1000000	=(F59+G59)/C59	
60	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E60/1000000	=(F60+G60)/C60	
61	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E61/1000000	=(F61+G61)/C61	
62	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E62/1000000	=(F62+G62)/C62	
63	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E63/1000000	=(F63+G63)/C63	
64	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E64/1000000	=(F64+G64)/C64	
65	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E65/1000000	=(F65+G65)/C65	
66	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E66/1000000	=(F66+G66)/C66	
67	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E67/1000000	=(F67+G67)/C67	
68	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E68/1000000	=(F68+G68)/C68	
69	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E69/1000000	=(F69+G69)/C69	
70	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E70/1000000	=(F70+G70)/C70	
71	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E71/1000000	=(F71+G71)/C71	
72	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E72/1000000	=(F72+G72)/C72	

	G	H	I
73	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E73/1000000	=(F73+G73)/C73	
74	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E74/1000000	=(F74+G74)/C74	
75	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E75/1000000	=(F75+G75)/C75	
76	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E76/1000000	=(F76+G76)/C76	
77	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E77/1000000	=(F77+G77)/C77	
78	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E78/1000000	=(F78+G78)/C78	
79	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E79/1000000	=(F79+G79)/C79	
80	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E80/1000000	=(F80+G80)/C80	
81	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E81/1000000	=(F81+G81)/C81	
82	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E82/1000000	=(F82+G82)/C82	
83	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E83/1000000	=(F83+G83)/C83	
84	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E84/1000000	=(F84+G84)/C84	
85	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E85/1000000	=(F85+G85)/C85	
86	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E86/1000000	=(F86+G86)/C86	
87	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E87/1000000	=(F87+G87)/C87	
88	=($C$33*$C$35*$C$36+$D$33*$D$35*$D$36)*$B$4*E88/1000000	=(F88+G88)/C88	

Table 4-5 Eqs: Cesium Hydroxide (CsOH) Production

	A	B	C	D	E
1	Core cesium - gap release	53.72	g-mole	Attachment 1, Table 1-2	
2	Core cesium - EIV release	214.87	g-mole	Attachment 1, Table 1-2	
3					
4	CsI - gap release	=(1-'HI (eqs)'!B$5)*'HI (eqs)'!B2	g-mole	fraction iodine release in form of CsI	
5	CsI - EIV release	=(1-'HI (eqs)'!B$5)*'HI (eqs)'!B3	g-mole	fraction iodine release in form of CsI	
6					
7	CsOH - gap release	=B1-B4	g-mole		
8	CsOH - EIV release	=B2-B5	g-mole		
9					
10	Gap release onset	2	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
11	Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
12	EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
13					
14				suppression	
15			cumulative	pool	cumulative
16		Time	CsOH	volume	CsOH
17		(Hr)	(g-mole)	(liter)	(g-mole/l)
18	onset	=B10/60	0	='SP Mass (eqs)'!$E$15	=C18/D18
19	end of gap release	=B18+B11/60	=B7	='SP Mass (eqs)'!$E$15	=C19/D19
20		1	=C19+(B20-B19)/(B21-B19)*B8	='SP Mass (eqs)'!$E$15	=C20/D20
21	end of EIV	=B19+B12/60	=C19+B8	='SP Mass (eqs)'!$E$15	=C21/D21

Table 4-6 Eqs: Effect of LPS Addition on Post-LOCA Suppression Chamber pH

	A	B	C	D	E
1	**Buffering by Liquid Poison System**				
2					
3	LPS:				
4	Nominal LPS pump flow rate	30	gpm	Design Input 4.12	
5	Min LPS injection tank volume	1325	gal	Design Input 4.12	
6	Max LPS temp	105	°F	Design Input 4.12	
7	Min LPS temp	70	°F	Design Input 4.12	
8	LPS SPB concentration by weight	0.09423		Design Input 4.12	
9	Specific gravity	1		Design Input 4.12	
10	Water density at max LPS temperature	61.93		Ref. 7.18	
11	LPS solution density at max temperature	=B9*B10	lbm/ft^3		
12					
13	Final suppression pool temp (bounding)	200	°F		
14					
15	Boric acid K	=(0.0585*B13+1.309)*0.0000000001	at	=B13	°F
16					
17	MW sodium pentaborate ($Na_2B_{10}O_{16}*10H_2O$)	585.984		Design Input 4.12	
18					
19	Volume sodium pentaborate	=B5/7.481	ft^3		
20	Mass sodium pentaborate	=B19*B11*B8	lbm		
21	Mass sodium pentaborate	=B20*453.6/B17	g-mole		
22					
23	Unbuffered pH	='pH (eqs)'!N63			
24	Unbuffered [H^+]	=10^(-B23)	g-mole/l		
25	Suppression chamber water volume	='SP Mass (eqs)'!$E$15	liter		
26	Equivalents unbuffered [H^+]	=B24*B25	g-mole		
27					
28	Final pH	=-LOG(B15)+LOG((2*B21-B26)/(8*B21+B26))			
29					
30	Time to inject boron	=B5/B4	minutes		

	A	B	C
1			
2			
3		gamma dose	
4		Torus	Drywell &
5		Water	Wetwell
6	Time	TID @ 1850 MWt	TID @ 1850 MWt
7	[hr]	[rad]	[rad]
8	0		
9	=121/3600	=A9/A11*B11	=A9/A11*C11
10	=A9+30/60	=A10/A11*B11	=A10/A11*C11
11	1	377900	1035000
12	2	=10^((LOG($A12)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(B$17)-LOG(B$11))+LOG(B$11))	=10^((LOG($A12)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(C$17)-LOG(C$11))+LOG(C$11))
13	=2+121/3600	=10^((LOG($A13)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(B$17)-LOG(B$11))+LOG(B$11))	=10^((LOG($A13)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(C$17)-LOG(C$11))+LOG(C$11))
14	3	=10^((LOG($A14)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(B$17)-LOG(B$11))+LOG(B$11))	=10^((LOG($A14)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(C$17)-LOG(C$11))+LOG(C$11))
15	4	=10^((LOG($A15)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(B$17)-LOG(B$11))+LOG(B$11))	=10^((LOG($A15)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(C$17)-LOG(C$11))+LOG(C$11))
16	5	=10^((LOG($A16)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(B$17)-LOG(B$11))+LOG(B$11))	=10^((LOG($A16)-LOG($A$11))/(LOG($A$17)-LOG($A$11))*(LOG(C$17)-LOG(C$11))+LOG(C$11))
17	6	1392000	3150000
18	7	=10^((LOG($A18)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A18)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
19	8	=10^((LOG($A19)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A19)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
20	9	=10^((LOG($A20)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A20)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
21	10	=10^((LOG($A21)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A21)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
22	11	=10^((LOG($A22)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A22)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
23	12	=10^((LOG($A23)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A23)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
24	13	=10^((LOG($A24)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A24)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
25	14	=10^((LOG($A25)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A25)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
26	15	=10^((LOG($A26)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A26)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
27	16	=10^((LOG($A27)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A27)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
28	17	=10^((LOG($A28)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A28)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
29	18	=10^((LOG($A29)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A29)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
30	19	=10^((LOG($A30)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A30)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
31	20	=10^((LOG($A31)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A31)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
32	21	=10^((LOG($A32)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A32)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
33	22	=10^((LOG($A33)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A33)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
34	23	=10^((LOG($A34)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(B$35)-LOG(B$17))+LOG(B$17))	=10^((LOG($A34)-LOG($A$17))/(LOG($A$35)-LOG($A$17))*(LOG(C$35)-LOG(C$17))+LOG(C$17))
35	24	2785000	4950000
36	28	=10^((LOG($A36)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A36)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
37	=A35+24	=10^((LOG($A37)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A37)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
38	=A37+24	=10^((LOG($A38)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A38)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
39	=A38+24	=10^((LOG($A39)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A39)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
40	=A39+24	=10^((LOG($A40)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A40)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
41	=A40+24	=10^((LOG($A41)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A41)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
42	=A41+24	=10^((LOG($A42)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A42)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
43	=A42+24	=10^((LOG($A43)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A43)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
44	=A43+24	=10^((LOG($A44)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A44)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
45	=A44+24	=10^((LOG($A45)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A45)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
46	=A45+48	=10^((LOG($A46)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A46)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
47	=A46+48	=10^((LOG($A47)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A47)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
48	=A47+48	=10^((LOG($A48)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A48)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
49	=A48+48	=10^((LOG($A49)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A49)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
50	=A49+48	=10^((LOG($A50)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A50)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
51	=A50+48	=10^((LOG($A51)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A51)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
52	=A51+48	=10^((LOG($A52)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A52)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
53	=A52+48	=10^((LOG($A53)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A53)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
54	=A53+48	=10^((LOG($A54)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(B$55)-LOG(B$35))+LOG(B$35))	=10^((LOG($A54)-LOG($A$35))/(LOG($A$55)-LOG($A$35))*(LOG(C$55)-LOG(C$35))+LOG(C$35))
55	720	15910000	13500000
56	2400	35800000	21150000
57	Note: Shaded values taken from Attachment 2.		

Table 4-7 Eqs: Gamma and Beta Radiation Dose used to Determine Post-LOCA pH

	D	E	F
1			
2			
3	beta dose		
4			
5	Drywell		
6	TID @ 1850 MWt	Source for γ Values	Source for β Values
7	[rad]	[-]	[-]
8			
9	=A9/A11*D11	linear interpolation	linear interpolation
10	=A10/A11*D11	linear interpolation	linear interpolation
11	30110000	Attachment 2, Table 2-2	Attachment 2, Table 2-1
12	=10^((LOG($A12)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
13	=10^((LOG($A13)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
14	=10^((LOG($A14)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
15	=10^((LOG($A15)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
16	=10^((LOG($A16)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
17	=10^((LOG($A17)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	Attachment 2, Table 2-2	log-log interpolation
18	=10^((LOG($A18)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
19	=10^((LOG($A19)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
20	=10^((LOG($A20)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
21	=10^((LOG($A21)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
22	=10^((LOG($A22)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
23	=10^((LOG($A23)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
24	=10^((LOG($A24)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
25	=10^((LOG($A25)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
26	=10^((LOG($A26)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
27	=10^((LOG($A27)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
28	=10^((LOG($A28)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
29	=10^((LOG($A29)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
30	=10^((LOG($A30)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
31	=10^((LOG($A31)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
32	=10^((LOG($A32)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
33	=10^((LOG($A33)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
34	=10^((LOG($A34)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	log-log interpolation	log-log interpolation
35	=10^((LOG($A35)-LOG($A$11))/(LOG($A$36)-LOG($A$11))*(LOG(D$36)-LOG(D$11))+LOG(D$11))	Attachment 2, Table 2-2	log-log interpolation
36	212100000	log-log interpolation	Attachment 2, Table 2-1
37	=10^((LOG($A37)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
38	=10^((LOG($A38)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
39	=10^((LOG($A39)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
40	=10^((LOG($A40)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
41	=10^((LOG($A41)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
42	=10^((LOG($A42)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$55)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
43	=10^((LOG($A43)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
44	=10^((LOG($A44)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
45	=10^((LOG($A45)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
46	=10^((LOG($A46)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
47	=10^((LOG($A47)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
48	=10^((LOG($A48)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
49	=10^((LOG($A49)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
50	=10^((LOG($A50)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
51	=10^((LOG($A51)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
52	=10^((LOG($A52)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
53	=10^((LOG($A53)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
54	=10^((LOG($A54)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	log-log interpolation	log-log interpolation
55	=10^((LOG($A55)-LOG($A$36))/(LOG($A$56)-LOG($A$36))*(LOG(D$56)-LOG(D$36))+LOG(D$36))	Attachment 2, Table 2-2	log-log interpolation
56	613400000	Attachment 2, Table 2-2	Attachment 2, Table 2-1
57			

	A	B	C	D	E	F
1	**From Data (Ref. 7.6.5)**				**Used for pH Analysis**	
2						
3	Time Post-LOCA		Temp		Time	Temp
4	(sec/days)*	(hr)	(°F)		(hr)	(°F)
5	0	=A5/3600	85		0	=C5
6	2.81	=A6/3600	89.1		0.0336111111111111	=C13
7	5.83	=A7/3600	95.77		0.533611111111111	=C16
8	8.95	=A8/3600	102.7		1	=C18
9	12.08	=A9/3600	109.4		2	=C19
10	15.2	=A10/3600	114.7		2.03361111111111	=C20
11	30.83	=A11/3600	122.1		3	=C23
12	99.58	=A12/3600	126.5		4	=C24
13		0.0336111111111111	=(B13-B12)/(B14-B12)*(C14-C12)+C12		5	=C26
14	296.2	=A14/3600	133.7		6	=C27
15	910.58	=A15/3600	143.5		7	=C28
16		0.533611111111111	=(B16-B15)/(B17-B15)*(C17-C15)+C15		8	=C29
17	2622.58	=A17/3600	154.3		9	=C30
18		1	=(B18-B$17)/(B$21-B$17)*(C$21-C$17)+C$17		10	=C31
19		2	=(B19-B$17)/(B$21-B$17)*(C$21-C$17)+C$17		11	=C32
20		2.03361111111111	=(B20-B$17)/(B$21-B$17)*(C$21-C$17)+C$17		12	=C33
21	8349.56	=A21/3600	160.3		13	=C34
22	9574.08	=A22/3600	160.3		14	=C35
23		3	=(B23-B$22)/(B$25-B$22)*(C$25-C$22)+C$22		15	=C36
24		4	=(B24-B$22)/(B$25-B$22)*(C$25-C$22)+C$22		16	=C37
25	14925.33	=A25/3600	158.7		17	=C38
26		5	158.7		18	=C39
27		=B26+1	158.7		19	=C40
28		=B27+1	158.7		20	=C41
29		=B28+1	158.7		21	=C42
30		=B29+1	158.7		22	=C43
31		=B30+1	158.7		23	=C44
32		=B31+1	158.7		24	=C45
33		=B32+1	158.7		28	=C46
34		=B33+1	158.7		48	=C47
35		=B34+1	158.7		72	=C48
36		=B35+1	158.7		96	=C49
37		=B36+1	158.7		120	=C50
38		=B37+1	158.7		144	=C51
39		=B38+1	158.7		168	=C52
40		=B39+1	158.7		192	=C53
41		=B40+1	158.7		216	=C54
42		=B41+1	158.7		240	=C55
43		=B42+1	158.7		288	=C56
44		=B43+1	158.7		336	=C57
45		=B44+1	158.7		384	=C59
46		28	158.7		432	=C60
47	=B47/24	48	158.7		480	=C61
48	=B48/24	72	158.7		528	=C62
49	=B49/24	96	158.7		576	=C63
50	=B50/24	120	158.7		624	=C65
51	=B51/24	144	158.7		672	=C66
52	=B52/24	168	158.7		720	=C67
53	=B53/24	192	158.7			
54	=B54/24	216	158.7			
55	=B55/24	240	158.7			
56	=B56/24	288	158.7			
57	=B57/24	336	158.7			
58	=B58/24	360	158.7			
59		384	158.7			
60		432	158.7			
61	=B61/24	480	158.7			
62		528	158.7			
63		576	158.7			
64	=B64/24	600	158.7			
65		624	158.7			
66		672	158.7			
67	=B67/24	720	158.7			
68						
69						
70						
71						

The shaded values are taken from Reference 7.6.5 (Design Input 4.15). Other other values are either interpolated or extrapolated. The long term temperature is maintained at 158.7°F.

* Seconds are the units for t=0 to 24 hours; days are the units for t=48 to 720 hours.

Table 4-9 Eqs: Post-LOCA Suppression Chamber Water Volumes

	A	B	C	D	E	F
1						
2	Parameter	Symbol	Unit	Minimum SC Mass	Maximum SC Mass	Reference
3	**Suppression Chamber Water (SC)**					
4	Suppression chamber water volume	V_{SC}	ft^3	79800	86000	Design Input 4.6
5	Suppression chamber water temperature	T_{SC}	°F	85	60	Design Input 4.7
6	Suppression chamber pressure	P_{SC}	psia	14.7	14.7	Design Input 4.8
7	Density of suppression chamber water	ρ_{SC}	lbm/ft^3	62.17	62.37	Ref. 7.18
8	Mass of water in suppression chamber	m_{SC}	lbm	=D4*D7	=E4*E7	$= V_{SC} * \rho_{SC}$
9	**Reactor Coolant System (RCS)**					
10	RCS mass	m_{RCS}	ft^3	501500	501500	Design Input 4.3
11	**Post-LOCA (SC+RCS)**					
12	RCS mass added to SC	$m_{RCS,tot}$	lbm	0	=E10	no RCS mass included in SC for min; all steam condenses in SC for max
13	Total water mass in SC	$m_{PL\_SC,tot}$	lbm	=D8+D12	=E8+E12	$= m_{SC} + m_{RCS}$
14	Total volume of water in SC	$V_{PL\_SC,tot}$	ft^3	=D13/D7	=E13/E7	$= m_{PL\_SC,tot} / \rho_{SC}$
15	Total volume of water in SC	$V_{PL\_SC,tot}$	liters	=D14*28.31685	=E14*28.31685	$= V_{PL\_SC,tot}$ [ft^3] * 28.31685 liter/ft^3

Attachment 5

Post-LOCA Suppression Chamber Water pH
Benchmark to Grand Gulf Nuclear Station (GGNS)

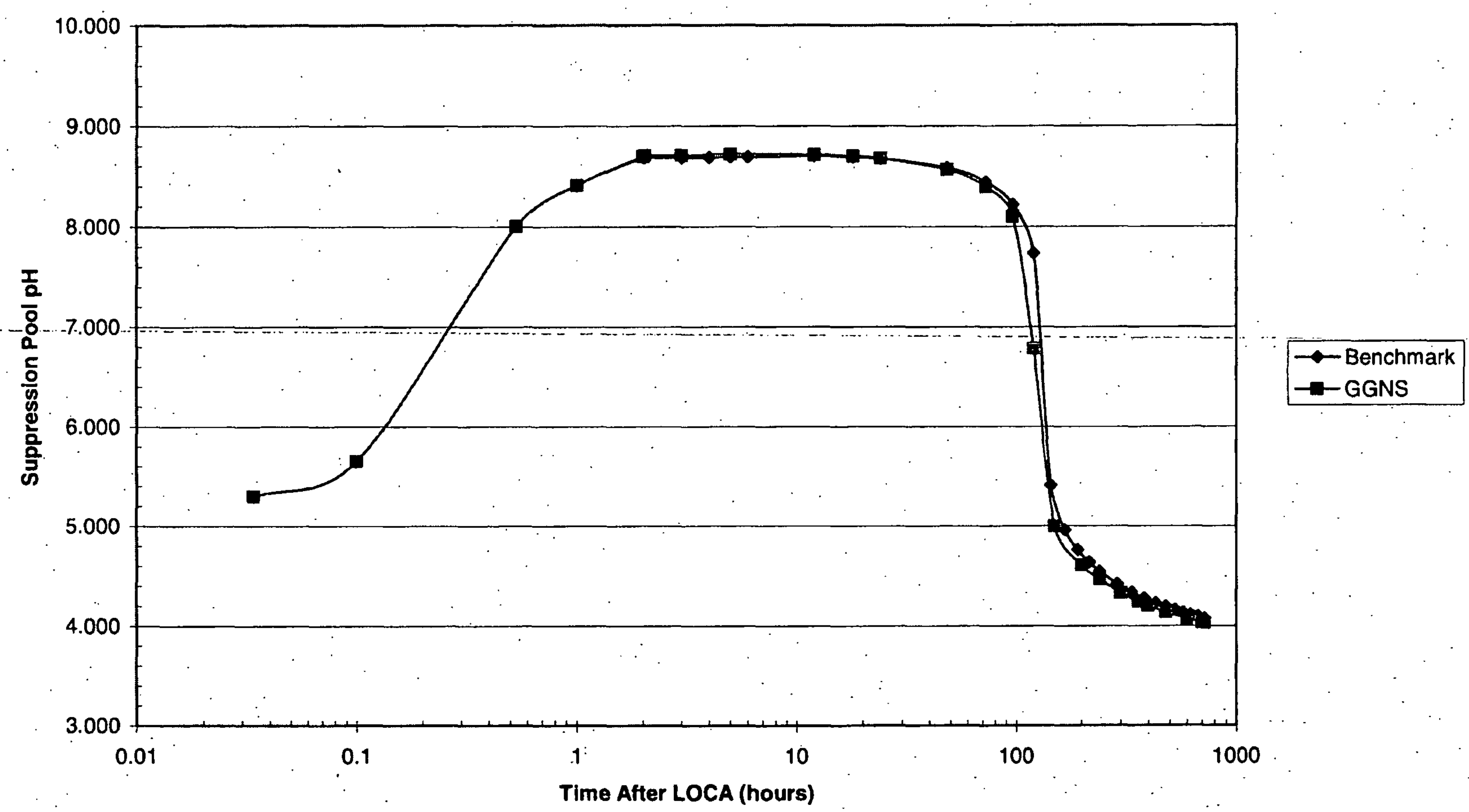
Table of Contents

Note that each table in this attachment has been developed using Microsoft Excel. Some tables reference each other; for these references, see the "tab" name at the bottom of each sheet.

Input in the tables in this attachment is obtained from GGNS Calculation No. XC-Q1111-98013, Revision 2 (main body Ref. 7.12.3). Any input/cells which have changed from the NMP1 tables provided in Attachment 4 are italicized. In some instances, new cells were added and in others, various input was not provided and therefore is left blank in the tables.

This benchmark is also provided in the NMP2 pH calculation, H21C-097 (Ref. 7.6.8). The time steps in this benchmark are not adjusted to the NMP1 time steps. This does not impact the validity of the benchmark.

Figure 5-1: GGNS Benchmark
Post-LOCA Suppression Pool pH Analysis
pH Response without SLCS



Pool pH

Table 5-1: GGNS Benchmark
Post-LOCA pH Calculation without SLCS

Initial conditions

Suppression pool mass	-	lbm
RCS mass	-	lbm
Total post-LOCA SP mass	-	lbm

suppression pool pH	*5.3*
reactor coolant pH	*5.3*

initial [H^+]	*5.01E-06* g-mole/l	*weighted average not required since $pH_{SP,I} = pH_{RCS,I}$*
initial [OH^-]	*2.00E-09* g-mole/l	*weighted average not required since $pH_{SP,I} = pH_{RCS,I}$*

Time (hr)	Pool Volume (liter)	[HI] (g-moles/l)	[HNO_3] (g-moles/l)	[HCl] (g-moles/l)	[CsOH] (g-moles/l)	Total [H^+] (g-moles/l)	Total [OH^-] (g-moles/l)	Pool Temp (°F)	Water Density (lbm/ft^3)	K_w at Pool Temp (-)	x (g-moles/l)	[H^+] (g-moles/l)	Pool pH (-)
0	*4,841,000*					5.01E-06	2.00E-09	90.0	62.12	1.704E-14	-1.40E-09	5.01E-06	5.300
0.034	*4,841,000*					5.01E-06	2.00E-09	160.0	60.99	1.633E-13	-3.04E-08	5.04E-06	5.297
0.100	*4,841,000*	*2.2285E-08*			*2.8679E-06*	*5.03E-06*	*2.87E-06*	*160.0*	*60.99*	*1.633E-13*	*2.80E-06*	*2.24E-06*	*5.650*
0.534	*4,841,000*	*1.6784E-07*			*2.1599E-05*	5.18E-06	2.16E-05	160.0	60.99	1.633E-13	5.17E-06	9.94E-09	8.003
1	*4,841,000*	*4.2876E-07*			*4.7471E-05*	5.44E-06	4.75E-05	160.0	60.99	1.633E-13	5.44E-06	3.88E-09	8.411
2	*4,841,000*	*1.0070E-06*	*1.0061E-05*	*8.6798E-06*	*1.0481E-04*	2.48E-05	1.05E-04	160.0	60.99	1.633E-13	2.48E-05	2.04E-09	8.690
2.034	*4,841,000*	*1.0070E-06*	*1.0068E-05*	*8.7776E-06*	*1.0481E-04*	2.49E-05	1.05E-04	160.0	60.99	1.633E-13	2.49E-05	2.04E-09	8.690
3	*4,841,000*	*1.0070E-06*	*1.0256E-05*	*1.1300E-05*	*1.0481E-04*	2.76E-05	1.05E-04	159.1	61.01	1.594E-13	2.76E-05	2.06E-09	8.685
4	*4,841,000*	*1.0070E-06*	*1.0450E-05*	*1.4047E-05*	*1.0481E-04*	3.05E-05	1.05E-04	157.3	61.05	1.518E-13	3.05E-05	2.04E-09	8.690
5	*4,841,000*	*1.0070E-06*	*1.0644E-05*	*1.6233E-05*	*1.0481E-04*	3.29E-05	1.05E-04	155.5	61.08	1.445E-13	3.29E-05	2.01E-09	8.697
6	*4,841,000*	*1.0070E-06*	*1.0837E-05*	*1.8063E-05*	*1.0481E-04*	3.49E-05	1.05E-04	154.6	61.10	1.409E-13	3.49E-05	2.02E-09	8.695
12	*4,841,000*	*1.0070E-06*	*1.1990E-05*	*2.5535E-05*	*1.0481E-04*	4.35E-05	1.05E-04	149.2	61.21	1.211E-13	4.35E-05	1.98E-09	8.704
18	*4,841,000*	*1.0070E-06*	*1.3129E-05*	*3.0458E-05*	*1.0481E-04*	4.96E-05	1.05E-04	146.4	61.26	1.117E-13	4.96E-05	2.02E-09	8.694
24	*4,841,000*	*1.0070E-06*	*1.4254E-05*	*3.4308E-05*	*1.0481E-04*	5.46E-05	1.05E-04	144.3	61.30	1.051E-13	5.46E-05	2.09E-09	8.680
48	*4,841,000*	*1.0070E-06*	*1.8622E-05*	*4.5256E-05*	*1.0481E-04*	6.99E-05	1.05E-04	139.4	61.39	9.084E-14	6.99E-05	2.60E-09	8.585
72	*4,841,000*	*1.0070E-06*	*2.2785E-05*	*5.3018E-05*	*1.0481E-04*	8.18E-05	1.05E-04	136.5	61.44	8.32E-14	8.18E-05	3.62E-09	8.441
96	*4,841,000*	*1.0070E-06*	*2.6753E-05*	*5.9165E-05*	*1.0481E-04*	9.19E-05	1.05E-04	134.4	61.47	7.801E-14	9.19E-05	6.06E-09	8.218
120	*4,841,000*	*1.0070E-06*	*3.0536E-05*	*6.4242E-05*	*1.0481E-04*	1.01E-04	1.05E-04	132.8	61.50	7.424E-14	1.01E-04	1.84E-08	7.735
144	*4,841,000*	*1.0070E-06*	*3.4141E-05*	*6.8525E-05*	*1.0481E-04*	1.09E-04	1.05E-04	131.6	61.52	7.152E-14	1.05E-04	3.89E-06	5.410
168	*4,841,000*	*1.0070E-06*	*3.7577E-05*	*7.2188E-05*	*1.0481E-04*	1.16E-04	1.05E-04	130.5	61.54	6.919E-14	1.05E-04	1.10E-05	4.959
192	*4,841,000*	*1.0070E-06*	*4.0852E-05*	*7.5347E-05*	*1.0481E-04*	1.22E-04	1.05E-04	129.5	61.56	6.703E-14	1.05E-04	1.74E-05	4.759
216	*4,841,000*	*1.0070E-06*	*4.3973E-05*	*7.8090E-05*	*1.0481E-04*	1.28E-04	1.05E-04	128.7	61.57	6.524E-14	1.05E-04	2.33E-05	4.633
240	*4,841,000*	*1.0070E-06*	*4.6948E-05*	*8.0486E-05*	*1.0481E-04*	1.33E-04	1.05E-04	127.9	61.59	6.364E-14	1.05E-04	2.86E-05	4.543
288	*4,841,000*	*1.0070E-06*	*5.2487E-05*	*8.4442E-05*	*1.0481E-04*	1.43E-04	1.05E-04	126.6	61.61	6.109E-14	1.05E-04	3.81E-05	4.419
336	*4,841,000*	*1.0070E-06*	*5.7519E-05*	*8.7538E-05*	*1.0481E-04*	1.51E-04	1.05E-04	125.5	61.62	5.897E-14	1.05E-04	4.63E-05	4.335
384	*4,841,000*	*1.0070E-06*	*6.2090E-05*	*9.0002E-05*	*1.0481E-04*	1.58E-04	1.05E-04	124.6	61.64	5.721E-14	1.05E-04	5.33E-05	4.273
432	*4,841,000*	*1.0070E-06*	*6.6242E-05*	*9.1991E-05*	*1.0481E-04*	1.64E-04	1.05E-04	123.8	61.65	5.574E-14	1.05E-04	5.94E-05	4.226

Table 5-1: GGNS Benchmark
Post-LOCA pH Calculation without SLCS

Time (hr)	Pool Volume (liter)	[HI] (g-moles/l)	[HNO_3] (g-moles/l)	[HCl] (g-moles/l)	[CsOH] (g-moles/l)	Total [H^+] (g-moles/l)	Total [OH^-] (g-moles/l)	Pool Temp (°F)	Water Density (lbm/ft^3)	K_w at Pool Temp (-)	x (g-moles/l)	[H^+] (g-moles/l)	Pool pH (-)
480	*4,841,000*	*1.0070E-06*	*7.0015E-05*	*9.3624E-05*	*1.0481E-04*	1.70E-04	1.05E-04	123.0	61.66	5.435E-14	1.05E-04	6.48E-05	4.188
528	*4,841,000*	*1.0070E-06*	*7.3442E-05*	*9.4984E-05*	*1.0481E-04*	1.74E-04	1.05E-04	122.4	61.68	5.322E-14	1.05E-04	6.96E-05	4.157
576	*4,841,000*	*1.0070E-06*	*7.6556E-05*	*9.6136E-05*	*1.0481E-04*	1.79E-04	1.05E-04	121.7	61.69	5.212E-14	1.05E-04	7.39E-05	4.131
624	*4,841,000*	*1.0070E-06*	*7.9384E-05*	*9.7125E-05*	*1.0481E-04*	1.83E-04	1.05E-04	121.1	61.69	5.113E-14	1.05E-04	7.77E-05	4.109
672	*4,841,000*	*1.0070E-06*	*8.1954E-05*	*9.7987E-05*	*1.0481E-04*	1.86E-04	1.05E-04	120.6	61.70	5.025E-14	1.05E-04	8.11E-05	4.091
720	*4,841,000*	*1.0070E-06*	*8.4288E-05*	*9.8748E-05*	*1.0481E-04*	1.89E-04	1.05E-04	120.1	61.71	4.941E-14	1.05E-04	8.42E-05	4.074

Notes

Adjustments made in Table 4-1 of Attachment 4 (see Notes 1-3) are not made for the benchmark.

Table 5-1a: GGNS Benchmark Post-LOCA Suppression Pool pH per GGNS Calc. No. XC-Q1111-98013, Rev. 2

Time (hr)	*pH (-)*
0	*5.300*
0.03361	*5.297*
0.1	*5.650*
0.53361	*8.003*
1	*8.411*
2	*8.699*
2.0361	*8.709*
3	*8.711*
5	*8.719*
12	*8.716*
18	*8.701*
24	*8.681*
48	*8.568*
72	*8.395*
96	*8.098*
120	*6.783*
150	*4.995*
200	*4.606*
240	*4.461*
300	*4.327*
360	*4.241*
400	*4.199*
480	*4.135*
600	*4.070*
700	*4.033*
720	*4.027*

The pH values presented in this table are taken from Case 1 in Attachment 3 to XC-Q1111-98013, Revision 1 (main body Ref. 7.12.3).

Table 5-2: GGNS Benchmark
Hydriodic Acid (HI) Production

Core iodine inventory	*325*	*g-mole*	*Ref. 7.12.3*
Core iodine - gap release	*16.25*	g-mole	*=0.05*325 g-mole*
Core iodine - EIV release	*81.25*	g-mole	*=0.25*325 g-mole*
Fraction of release as HI	0.05	max	Reg Guide 1.183 (main body Ref. 7.10.2)
Gap release onset	*121*	*sec*	*Ref. 7.12.3*
Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)

	Time (hr)	cumulative HI (g-mole)	suppression pool volume (liter)	cumulative HI (g-mole/l)
onset	0.034	0.00	*4,841,000*	0.0000E+00
	0.100	*0.11*	*4,841,000*	*2.2285E-08*
end of gap release	0.534	*0.81*	*4,841,000*	1.6784E-07
	1.000	2.08	*4,841,000*	4.2876E-07
end of EIV	2.034	4.88	*4,841,000*	1.0070E-06

HNO_3 generation 7.3E-06 g-mole/l per MRad NUREG/CR-5950 (main body Ref. 7.13)

	Time (hr)	Suppression Pool TID @ 3467 MWt (rad)	cumulative HNO_3 (g-mole/l)
onset	0.034		
end of gap release	0.534		
	1		
end of EIV	2	1.3783E+06	1.0061E-05
	2.034	1.3792E+06	1.0068E-05
	3	1.4049E+06	1.0256E-05
	4	1.4315E+06	1.0450E-05
	5	1.4581E+06	1.0644E-05
	6	1.4846E+06	1.0837E-05
	12	1.6425E+06	1.1990E-05
	18	1.7985E+06	1.3129E-05
	24	1.9526E+06	1.4254E-05
	48	2.5509E+06	1.8622E-05
	72	3.1213E+06	2.2785E-05
	96	3.6648E+06	2.6753E-05
	120	4.1830E+06	3.0536E-05
	144	4.6768E+06	3.4141E-05
	168	5.1475E+06	3.7577E-05
	192	5.5961E+06	4.0852E-05
	216	6.0237E+06	4.3973E-05
	240	6.4313E+06	4.6948E-05
	288	7.1900E+06	5.2487E-05
	336	7.8793E+06	5.7519E-05
	384	8.5054E+06	6.2090E-05
	432	9.0743E+06	6.6242E-05
	480	9.5911E+06	7.0015E-05
	528	1.0061E+07	7.3442E-05
	576	1.0487E+07	7.6556E-05
	624	1.0875E+07	7.9384E-05
	672	1.1227E+07	8.1954E-05
	720	1.1546E+07	8.4288E-05

Cables

hypalon properties:

radiolysis yield, G	2.192E-06 g-mole HCl per MRad-g	NUREG/CR-5950 (main body Ref. 7.13)
linear absorption coefficient	52.08 cm^{-1} for beta radiation	NUREG-1081 (main body Ref. 7.15)
linear absorption coefficient	0.099 cm^{-1} for gamma radiation	NUREG-1081 (main body Ref. 7.15)
density	1.55 g/cm^3	NUREG-1081 (main body Ref. 7.15)

Cable jacket and insulation:

	Drywell Cable Inventory		*Containment Cable Inventory*	
cable outer radius	*0.35*	*in*	*0.35*	*in*
cable OD (max guar.)	*0.7*	in	*0.7*	in
jacket thickness	*280*	mil	*280*	mil
jacket material	hypalon		hypalon	
insulation thickness	-	mil	-	mil
insulation material	-		-	
length in free air	-	linear ft	-	linear ft
length in tray	-	linear ft	-	linear ft

chlorine-bearing material:

	Drywell		Containment	
volume in free air	-	cm^3	-	cm^3
volume in tray	-	cm^3	-	cm^3
mass in free air	*873.65*	*lbm*	*1,561.03*	*lbm*
mass in free air	*396,287.6*	gram	*708,083.2*	gram
mass in tray	*873.65*	*lbm*	*14,049.27*	*lbm*
mass in tray	*396,287.6*	gram	*6,372,748.9*	gram

Irradiation:

	Drywell Cable Inventory			Containment Cable Inventory		
		beta			beta	
	gamma	*free air*	tray	gamma	free air	tray
cable radius (cm)	0.889	0.889	0.889	0.889	0.889	0.889
jacket thickness (cm)	0.7112	0.7112	0.7112	0.7112	0.7112	0.7112
mass irradiated (g)	792,575.3	396,287.6	198,143.8	7,080,832.1	708,083.2	3,186,374.4
flux averaging factor	0.973	0.044	0.044	0.973	0.044	0.044
absorption factor	0.068	1.000	1.000	0.068	1.000	1.000

Table 5-4: GGNS Benchmark
Hydrochloric Acid (HCl) Production

Time (hr)	pool volume (liter)	Drywell γ TID (rad)	Containment γ TID (rad)	Drywell β TID (rad)	Containment β TID (rad)	Drywell HCl gamma (g-mole)	Drywell HCl beta (g-mole)	Drywell HCl Total (g-mole/l)	Containment HCl gamma (g-mole)	Containment HCl beta (g-mole)	Containment HCl Total (g-mole/l)	HCl (g-mole/l)
0.034	4,841,000	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0000E+00
0.534	4,841,000	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0000E+00
1	4,841,000	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.0000E+00
2	4,841,000	1.7595E+07	0.0000E+00	3.5600E+07	1.5019E+07	2.01E+01	1.54E+01	7.34E-06	0.00E+00	6.51E+00	1.34E-06	8.6798E-06
2.034	4,841,000	1.7973E+07	0.0000E+00	3.5663E+07	1.5051E+07	2.05E+01	1.54E+01	7.43E-06	0.00E+00	6.52E+00	1.35E-06	8.7776E-06
3	4,841,000	2.6800E+07	8.2920E+05	3.7461E+07	1.5993E+07	3.06E+01	1.62E+01	9.67E-06	9.47E-01	6.93E+00	1.63E-06	1.1300E-05
4	4,841,000	3.3331E+07	4.8748E+06	3.9309E+07	1.6962E+07	3.81E+01	1.70E+01	1.14E-05	5.57E+00	7.35E+00	2.67E-06	1.4047E-05
5	4,841,000	3.8397E+07	8.0128E+06	4.1145E+07	1.7926E+07	4.38E+01	1.78E+01	1.27E-05	9.15E+00	7.77E+00	3.49E-06	1.6233E-05
6	4,841,000	4.2537E+07	1.0577E+07	4.2969E+07	1.8884E+07	4.86E+01	1.86E+01	1.39E-05	1.21E+01	8.18E+00	4.18E-06	1.8063E-05
12	4,841,000	5.8273E+07	2.0324E+07	5.3664E+07	2.4518E+07	6.65E+01	2.32E+01	1.85E-05	2.32E+01	1.06E+01	6.99E-06	2.5535E-05
18	4,841,000	6.7478E+07	2.6026E+07	6.3944E+07	2.9963E+07	7.71E+01	2.77E+01	2.16E-05	2.97E+01	1.30E+01	8.82E-06	3.0458E-05
24	4,841,000	7.4010E+07	3.0072E+07	7.3824E+07	3.5225E+07	8.45E+01	3.20E+01	2.41E-05	3.43E+01	1.53E+01	1.02E-05	3.4308E-05
48	4,841,000	8.9746E+07	3.9819E+07	1.0966E+08	5.4563E+07	1.02E+02	4.75E+01	3.10E-05	4.55E+01	2.36E+01	1.43E-05	4.5256E-05
72	4,841,000	9.8951E+07	4.5521E+07	1.4024E+08	7.1428E+07	1.13E+02	6.08E+01	3.59E-05	5.20E+01	3.09E+01	1.71E-05	5.3018E-05
96	4,841,000	1.0548E+08	4.9567E+07	1.6634E+08	8.6137E+07	1.20E+02	7.21E+01	3.98E-05	5.66E+01	3.73E+01	1.94E-05	5.9165E-05
120	4,841,000	1.1055E+08	5.2705E+07	1.8862E+08	9.8965E+07	1.26E+02	8.17E+01	4.30E-05	6.02E+01	4.29E+01	2.13E-05	6.4242E-05
144	4,841,000	1.1469E+08	5.5269E+07	2.0764E+08	1.1015E+08	1.31E+02	8.99E+01	4.56E-05	6.31E+01	4.77E+01	2.29E-05	6.8525E-05
168	4,841,000	1.1819E+08	5.7436E+07	2.2387E+08	1.1991E+08	1.35E+02	9.70E+01	4.79E-05	6.56E+01	5.19E+01	2.43E-05	7.2188E-05
192	4,841,000	1.2122E+08	5.9314E+07	2.3772E+08	1.2842E+08	1.38E+02	1.03E+02	4.99E-05	6.77E+01	5.56E+01	2.55E-05	7.5347E-05
216	4,841,000	1.2389E+08	6.0971E+07	2.4954E+08	1.3584E+08	1.41E+02	1.08E+02	5.16E-05	6.96E+01	5.88E+01	2.65E-05	7.8090E-05
240	4,841,000	1.2628E+08	6.2452E+07	2.5963E+08	1.4232E+08	1.44E+02	1.12E+02	5.30E-05	7.13E+01	6.17E+01	2.75E-05	8.0486E-05
288	4,841,000	1.3042E+08	6.5016E+07	2.7559E+08	1.5288E+08	1.49E+02	1.19E+02	5.54E-05	7.42E+01	6.62E+01	2.90E-05	8.4442E-05
336	4,841,000	1.3392E+08	6.7184E+07	2.8722E+08	1.6092E+08	1.53E+02	1.24E+02	5.73E-05	7.67E+01	6.97E+01	3.02E-05	8.7538E-05
384	4,841,000	1.3696E+08	6.9062E+07	2.9570E+08	1.6704E+08	1.56E+02	1.28E+02	5.88E-05	7.89E+01	7.24E+01	3.12E-05	9.0002E-05
432	4,841,000	1.3963E+08	7.0718E+07	3.0187E+08	1.7169E+08	1.59E+02	1.31E+02	5.99E-05	8.08E+01	7.44E+01	3.20E-05	9.1991E-05
480	4,841,000	1.4202E+08	7.2200E+07	3.0636E+08	1.7523E+08	1.62E+02	1.33E+02	6.09E-05	8.24E+01	7.59E+01	3.27E-05	9.3624E-05
528	4,841,000	1.4419E+08	7.3540E+07	3.0964E+08	1.7792E+08	1.65E+02	1.34E+02	6.17E-05	8.40E+01	7.71E+01	3.33E-05	9.4984E-05
576	4,841,000	1.4616E+08	7.4764E+07	3.1202E+08	1.7997E+08	1.67E+02	1.35E+02	6.24E-05	8.54E+01	7.80E+01	3.37E-05	9.6136E-05
624	4,841,000	1.4798E+08	7.5889E+07	3.1376E+08	1.8152E+08	1.69E+02	1.36E+02	6.30E-05	8.67E+01	7.86E+01	3.41E-05	9.7125E-05
672	4,841,000	1.4966E+08	7.6932E+07	3.1503E+08	1.8271E+08	1.71E+02	1.36E+02	6.35E-05	8.78E+01	7.91E+01	3.45E-05	9.7987E-05
720	4,841,000	1.5123E+08	7.7902E+07	3.1595E+08	1.8361E+08	1.73E+02	1.37E+02	6.39E-05	8.90E+01	7.95E+01	3.48E-05	9.8748E-05

Table 5-5: GGNS Benchmark
Cesium Hydroxide (CsOH) Production

Core cesium inventory	*2400*	*g-mole*	*Ref. 7.12.3*
Core cesium - gap release	*120.00*	*g-mole*	*=0.05*2400 g-mole*
Core cesium - EIV release	*480.00*	*g-mole*	*=0.20*2400 g-mole*
CsI - gap release	15.44	g-mole	fraction iodine release in form of CsI
CsI - EIV release	77.19	g-mole	fraction iodine release in form of CsI
CsOH - gap release	104.56	g-mole	
CsOH - EIV release	402.81	g-mole	
Gap release onset	*121*	*sec*	*Ref. 7.12.3*
Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)

	Time (Hr)	cumulative CsOH (g-mole)	suppression pool volume (liter)	cumulative CsOH (g-mole/l)
onset	0.034	0.00	*4,841,000*	0.0000E+00
	0.100	*13.88*	*4,841,000*	2.8679E-06
end of gap release	0.534	*104.56*	*4,841,000*	2.1599E-05
	1.000	229.81	*4,841,000*	4.7471E-05
end of EIV	2.034	507.38	*4,841,000*	1.0481E-04

**Table 5-6: GGNS Benchmark
Effect of SLCS Addition
on Post-LOCA Suppression Pool**

Buffering by SLCS

SLCS:				
Min SLC pump flow rate	-	gpm		
Min SLC injection tank volume	-	gal		
Max SLC temp	-	°F		
Min SLC temp	-	°F		
SLC SPB conc. by weight	-			
Specific gravity	-			
Density (T=85°F)	-	lbm/ft^3		
Final suppression pool temp (bounding)	120	°F		
Boric acid K	8.33E-10	at	120	°F
MW sodium pentaborate ($Na_2B_{10}O_{16}$)	*410*			
Volume sodium pentaborate	-	ft^3		
Mass sodium pentaborate	*5,800.0*	lbm		
Mass sodium pentaborate	6,416.8	g-mole		
unbuffered pH	4.07			
unbuffered [H^+]	8.425E-05	g-mole/l		
Suppression Pool volume	*4,841,000*	liter		
Equivalents unbuffered [H^+]	407.8	g-mole		
Final pH	8.46			
Time to inject boron	-	minutes		

Table 5-7: GGNS Benchmark Gamma and Beta Radiation Dose used to Determine Post-LOCA pH

amd 1/10/05

Time [hr]	Suppression Pool γ TID [rad]	Drywell γ TID [MeV/cc]	Containment γ TID [MeV/cc]	Drywell β TID [MeV/cc]	Containment β TID [MeV/cc]	Drywell γ TID [rad]	Containment γ TID [rad]	Drywell β TID [rad]	Containment β TID [rad]
0	0	0	0	0	0	0	0	0	0
0.034	0	0	0	0	0	0	0	0	0
0.534	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	1.3783E+06	1.4201E+12	0.0000E+00	2.8733E+12	1.2122E+12	1.7595E+07	0.0000E+00	3.5600E+07	1.5019E+07
2.034	1.3792E+06	1.4506E+12	0.0000E+00	2.8784E+12	1.2148E+12	1.7973E+07	0.0000E+00	3.5663E+07	1.5051E+07
3	1.4049E+06	2.1630E+12	6.6925E+10	3.0235E+12	1.2908E+12	2.6800E+07	8.2920E+05	3.7461E+07	1.5993E+07
4	1.4315E+06	2.6902E+12	3.9344E+11	3.1726E+12	1.3690E+12	3.3331E+07	4.8748E+06	3.9309E+07	1.6962E+07
5	1.4581E+06	3.0991E+12	6.4671E+11	3.3208E+12	1.4468E+12	3.8397E+07	8.0128E+06	4.1145E+07	1.7926E+07
6	1.4846E+06	3.4331E+12	8.5365E+11	3.4680E+12	1.5241E+12	4.2537E+07	1.0577E+07	4.2969E+07	1.8884E+07
12	1.6425E+06	4.7032E+12	1.6404E+12	4.3312E+12	1.9789E+12	5.8273E+07	2.0324E+07	5.3664E+07	2.4518E+07
18	1.7985E+06	5.4462E+12	2.1006E+12	5.1609E+12	2.4183E+12	6.7478E+07	2.6026E+07	6.3944E+07	2.9963E+07
24	1.9526E+06	5.9733E+12	2.4271E+12	5.9584E+12	2.8430E+12	7.4010E+07	3.0072E+07	7.3824E+07	3.5225E+07
48	2.5509E+06	7.2434E+12	3.2138E+12	8.8503E+12	4.4038E+12	8.9746E+07	3.9819E+07	1.0966E+08	5.4563E+07
72	3.1213E+06	7.9863E+12	3.6740E+12	1.1319E+13	5.7649E+12	9.8951E+07	4.5521E+07	1.4024E+08	7.1428E+07
96	3.6648E+06	8.5135E+12	4.0005E+12	1.3425E+13	6.9521E+12	1.0548E+08	4.9567E+07	1.6634E+08	8.6137E+07
120	4.1830E+06	8.9224E+12	4.2538E+12	1.5224E+13	7.9874E+12	1.1055E+08	5.2705E+07	1.8862E+08	9.8965E+07
144	4.6768E+06	9.2564E+12	4.4607E+12	1.6758E+13	8.8904E+12	1.1469E+08	5.5269E+07	2.0764E+08	1.1015E+08
168	5.1475E+06	9.5389E+12	4.6357E+12	1.8068E+13	9.6780E+12	1.1819E+08	5.7436E+07	2.2387E+08	1.1991E+08
192	5.5961E+06	9.7836E+12	4.7873E+12	1.9186E+13	1.0365E+13	1.2122E+08	5.9314E+07	2.3772E+08	1.2842E+08
216	6.0237E+06	9.9994E+12	4.9209E+12	2.0140E+13	1.0964E+13	1.2389E+08	6.0971E+07	2.4954E+08	1.3584E+08
240	6.4313E+06	1.0192E+13	5.0405E+12	2.0955E+13	1.1486E+13	1.2628E+08	6.2452E+07	2.5963E+08	1.4232E+08
288	7.1900E+06	1.0527E+13	5.2475E+12	2.2243E+13	1.2339E+13	1.3042E+08	6.5016E+07	2.7559E+08	1.5288E+08
336	7.8793E+06	1.0809E+13	5.4224E+12	2.3182E+13	1.2988E+13	1.3392E+08	6.7184E+07	2.8722E+08	1.6092E+08
384	8.5054E+06	1.1054E+13	5.5740E+12	2.3866E+13	1.3482E+13	1.3696E+08	6.9062E+07	2.9570E+08	1.6704E+08
432	9.0743E+06	1.1269E+13	5.7077E+12	2.4364E+13	1.3857E+13	1.3963E+08	7.0718E+07	3.0187E+08	1.7169E+08
480	9.5911E+06	1.1463E+13	5.8272E+12	2.4727E+13	1.4143E+13	1.4202E+08	7.2200E+07	3.0636E+08	1.7523E+08
528	1.0061E+07	1.1637E+13	5.9354E+12	2.4991E+13	1.4360E+13	1.4419E+08	7.3540E+07	3.0964E+08	1.7792E+08
576	1.0487E+07	1.1797E+13	6.0342E+12	2.5183E+13	1.4525E+13	1.4616E+08	7.4764E+07	3.1202E+08	1.7997E+08
624	1.0875E+07	1.1943E+13	6.1250E+12	2.5324E+13	1.4651E+13	1.4798E+08	7.5889E+07	3.1376E+08	1.8152E+08
672	1.1227E+07	1.2079E+13	6.2091E+12	2.5426E+13	1.4746E+13	1.4966E+08	7.6932E+07	3.1503E+08	1.8271E+08
720	1.1546E+07	1.2205E+13	6.2875E+12	2.5500E+13	1.4819E+13	1.5123E+08	7.7902E+07	3.1595E+08	1.8361E+08
2400	1.4610E+07	1.4412E+13	7.6540E+12	2.5700E+13	1.5050E+13	1.7856E+08	9.4833E+07	3.1842E+08	1.8647E+08
4320	1.4718E+07	1.5489E+13	8.3211E+12	2.5700E+13	1.5050E+13	1.9190E+08	1.0310E+08	3.1842E+08	1.8647E+08
8760	1.4720E+07	1.6784E+13	9.1235E+12	2.5700E+13	1.5050E+13	2.0795E+08	1.1304E+08	3.1842E+08	1.8647E+08

Equations

γ_{SP} [Mrad] = $14.72*[1-0.91*\exp(-0.002*t_{hr})]*10^6$

γ_{DW} [MeV/cc] = $[0.15+1.83235*\ln(t_{hr})]*10^6*10^6$

γ_{CNT} [MeV/cc] = $[-1.18+1.135*\ln(t_{hr})]*10^6*10^6$

β_{DW} [MeV/cc] = $25.7*[1-0.9*\exp(-0.0066*t_{hr})]*10^6*10^6$

β_{CNT} [MeV/cc] = $15.05*[1-0.93*\exp(-0.0057*t_{hr})]*10^6*10^6$

1 rad = 8.071×10^4 MeV/cc for air at S.T.P. per Radiological Health Handbook (main body Ref. 7.8)

Notes

If the curve fits above yield a negative TID due to curve fit inacurracies, the TID is assumed to be zero consistent with Ref. 7.12.3.

Table 5-8: GGNS Benchmark Post-LOCA Suppression Pool Temperature Response

From Data (Ref. 7.12.3)

Time Post-LOCA (sec/days)*	(hr)	Temp (°F)
0	0	77.0
	0.03361	160.0
1	2.778E-04	160.0
8	2.222E-03	160.0
10	2.778E-03	160.0
30	8.333E-03	160.0
100	0.028	160.0
	0.034	160.0
300	0.083	160.0
1,000	0.278	160.0
	0.534	160.0
	1	160.0
	2	160.0
	2.034	160.0
10,000	2.778	159.3
	3	159.1
	4	157.3
	5	155.5
20,000	5.556	155.0
	6	154.6
42,000	11.67	149.5
	12	149.2
60,000	16.67	147.0
	18	146.4
	24	144.3
100,000	27.78	143.5
2	48	139.4
3	72	136.5
4	96	134.4
5	120	132.8
6	144	131.6
	150	131.3
7	168	130.5
8	192	129.5
	200	129.2
9	216	128.7
10	240	127.9
12	288	126.6
	300	126.3
14	336	125.5
15	360	125.0
	384	124.6
	400	124.3
	432	123.8
20	480	123.0
	528	122.4
	576	121.7
25	600	121.4
	624	121.1
	672	120.6
	700	120.3
30	720	120.1

Used for pH Analysis

Time (hr)	Temp (°F)
0	77.0
0.034	160.0
0.534	160.0
1	160.0
2	160.0
2.034	160.0
3	159.1
4	157.3
5	155.5
6	154.6
12	149.2
18	146.4
24	144.3
48	139.4
72	136.5
96	134.4
120	132.8
144	131.6
168	130.5
192	129.5
216	128.7
240	127.9
288	126.6
336	125.5
384	124.6
432	123.8
480	123.0
528	122.4
576	121.7
624	121.1
672	120.6
720	120.1

The shaded values are taken from Reference 7.12.3. Other other values are interpolated.

* Seconds are the units for t=0 to 27.78 hours; days are the units for t=48 to 720 hours.

	A	B	C	D	E	F	G	H
1	**Initial conditions**							
2								
3	Suppression pool mass			-	lbm			
4	RCS mass			-	lbm			
5	Total post-LOCA SP mass			-	lbm			
6								
7	suppression pool pH			5.3				
8	reactor coolant pH			5.3				
9								
10	*initial [H+]*			*=10^(-D7)*	g-mole/l	*weighted average not required since $pH_{SP,I} = pH_{RCS,I}$*		
11	initial [OH-]			*=10^(-14+D7)*	g-mole/l	*weighted average not required since $pH_{SP,I} = pH_{RCS,I}$*		
12								
13		Pool	[HI]	$[HNO_3]$	[HCl]	[CsOH]	Total $[H^+]$	Total $[OH^-]$
14	Time	Volume						
15	(hr)	(liter)	(g-moles/l)	(g-moles/l)	(g-moles/l)	(g-moles/l)	(g-moles/l)	(g-moles/l)
16	='Rad Dose (eqs)'!A6	*4841000*					=D$10+SUM(C16:E16)	=D$11+F16
17	='Rad Dose (eqs)'!A7	*4841000*					=D$10+SUM(C17:E17)	=D$11+F17
18	*0.1*	*4841000*	*='HI (eqs)'!E17*			*='CsOH (eqs)'!E21*	*=D$10+SUM(C18:E18)*	*=D$11+F18*
19	='Rad Dose (eqs)'!A8	*4841000*	*='HI (eqs)'!E18*			*='CsOH (eqs)'!E22*	=D$10+SUM(C19:E19)	=D$11+F19
20	='Rad Dose (eqs)'!A9	*4841000*	*='HI (eqs)'!E19*			*='CsOH (eqs)'!E23*	=D$10+SUM(C20:E20)	=D$11+F20
21	='Rad Dose (eqs)'!A10	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D11*	*='HCl (eqs)'!N50*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C21:E21)	=D$11+F21
22	='Rad Dose (eqs)'!A11	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D12*	*='HCl (eqs)'!N51*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C22:E22)	=D$11+F22
23	='Rad Dose (eqs)'!A12	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D13*	*='HCl (eqs)'!N52*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C23:E23)	=D$11+F23
24	='Rad Dose (eqs)'!A13	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D14*	*='HCl (eqs)'!N53*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C24:E24)	=D$11+F24
25	='Rad Dose (eqs)'!A14	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D15*	*='HCl (eqs)'!N54*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C25:E25)	=D$11+F25
26	='Rad Dose (eqs)'!A15	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D16*	*='HCl (eqs)'!N55*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C26:E26)	=D$11+F26
27	='Rad Dose (eqs)'!A16	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D17*	*='HCl (eqs)'!N56*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C27:E27)	=D$11+F27
28	='Rad Dose (eqs)'!A17	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D18*	*='HCl (eqs)'!N57*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C28:E28)	=D$11+F28
29	='Rad Dose (eqs)'!A18	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D19*	*='HCl (eqs)'!N58*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C29:E29)	=D$11+F29
30	='Rad Dose (eqs)'!A19	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D20*	*='HCl (eqs)'!N59*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C30:E30)	=D$11+F30
31	='Rad Dose (eqs)'!A20	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D21*	*='HCl (eqs)'!N60*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C31:E31)	=D$11+F31
32	='Rad Dose (eqs)'!A21	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D22*	*='HCl (eqs)'!N61*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C32:E32)	=D$11+F32
33	='Rad Dose (eqs)'!A22	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D23*	*='HCl (eqs)'!N62*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C33:E33)	=D$11+F33
34	='Rad Dose (eqs)'!A23	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D24*	*='HCl (eqs)'!N63*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C34:E34)	=D$11+F34
35	='Rad Dose (eqs)'!A24	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D25*	*='HCl (eqs)'!N64*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C35:E35)	=D$11+F35
36	='Rad Dose (eqs)'!A25	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D26*	*='HCl (eqs)'!N65*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C36:E36)	=D$11+F36
37	='Rad Dose (eqs)'!A26	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D27*	*='HCl (eqs)'!N66*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C37:E37)	=D$11+F37
38	='Rad Dose (eqs)'!A27	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D28*	*='HCl (eqs)'!N67*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C38:E38)	=D$11+F38
39	='Rad Dose (eqs)'!A28	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D29*	*='HCl (eqs)'!N68*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C39:E39)	=D$11+F39
40	='Rad Dose (eqs)'!A29	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D30*	*='HCl (eqs)'!N69*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C40:E40)	=D$11+F40
41	='Rad Dose (eqs)'!A30	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D31*	*='HCl (eqs)'!N70*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C41:E41)	=D$11+F41
42	='Rad Dose (eqs)'!A31	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D32*	*='HCl (eqs)'!N71*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C42:E42)	=D$11+F42

Table 5-1 Eqs: GGNS Benchmark
Post-LOCA pH Calculation without SLCS

	A	B	C	D	E	F	G	H
13		Pool	[HI]	[HNO_3]	[HCl]	[CsOH]	Total [H^+]	Total [OH^-]
14	Time	Volume						
15	(hr)	(liter)	(g-moles/l)	(g-moles/l)	(g-moles/l)	(g-moles/l)	(g-moles/l)	(g-moles/l)
43	='Rad Dose (eqs)'!A32	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D33*	*='HCl (eqs)'!N72*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C43:E43)	=D$11+F43
44	='Rad Dose (eqs)'!A33	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D34*	*='HCl (eqs)'!N73*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C44:E44)	=D$11+F44
45	='Rad Dose (eqs)'!A34	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D35*	*='HCl (eqs)'!N74*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C45:E45)	=D$11+F45
46	='Rad Dose (eqs)'!A35	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D36*	*='HCl (eqs)'!N75*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C46:E46)	=D$11+F46
47	='Rad Dose (eqs)'!A36	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D37*	*='HCl (eqs)'!N76*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C47:E47)	=D$11+F47
48	='Rad Dose (eqs)'!A37	*4841000*	*='HI (eqs)'!E$20*	*='HNO3 (eqs)'!D38*	*='HCl (eqs)'!N77*	*='CsOH (eqs)'!E$24*	=D$10+SUM(C48:E48)	=D$11+F48
49	Notes							
50	*Adjustments made in Table 4-1 of Attachment 4 (see Notes 1-3) are not made for the benchmark.*							
51								
52								
53								
54								
55								
56								
57								

Table 5-1 Eqs: GGNS Benchmark
Post-LOCA pH Calculation without SLCS

amk 1/10/05

	I	J	K	L	M	N
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13	Pool	Water	K_w at	x	$[H^+]$	Pool
14	Temp	Density	Pool Temp			pH
15	(°F)	(lbm/ft^3)	(-)	(g-moles/l)	(g-moles/l)	(-)
16	90	=1/vftsat(I16)	=10^-(15.5129-0.0224*I16+0.00003352*I16^2)	=(H16+G16-SQRT((H16+G16)^2-4*(H16*G16-K16)))/2	=G16-L16	=-LOG(M16)
17	='SP Temp (eqs)'!F6	=1/vftsat(I17)	=10^-(15.5129-0.0224*I17+0.00003352*I17^2)	=(H17+G17-SQRT((H17+G17)^2-4*(H17*G17-K17)))/2	=G17-L17	=-LOG(M17)
18	*160*	*=1/vftsat(I18)*	*=10^-(15.5129-0.0224*I18+0.00003352*I18^2)*	*=(H18+G18-SQRT((H18+G18)^2-4*(H18*G18-K18)))/2*	*=G18-L18*	*=-LOG(M18)*
19	='SP Temp (eqs)'!F7	=1/vftsat(I19)	=10^-(15.5129-0.0224*I19+0.00003352*I19^2)	=(H19+G19-SQRT((H19+G19)^2-4*(H19*G19-K19)))/2	=G19-L19	=-LOG(M19)
20	='SP Temp (eqs)'!F8	=1/vftsat(I20)	=10^-(15.5129-0.0224*I20+0.00003352*I20^2)	=(H20+G20-SQRT((H20+G20)^2-4*(H20*G20-K20)))/2	=G20-L20	=-LOG(M20)
21	='SP Temp (eqs)'!F9	=1/vftsat(I21)	=10^-(15.5129-0.0224*I21+0.00003352*I21^2)	=(H21+G21-SQRT((H21+G21)^2-4*(H21*G21-K21)))/2	=G21-L21	=-LOG(M21)
22	='SP Temp (eqs)'!F10	=1/vftsat(I22)	=10^-(15.5129-0.0224*I22+0.00003352*I22^2)	=(H22+G22-SQRT((H22+G22)^2-4*(H22*G22-K22)))/2	=G22-L22	=-LOG(M22)
23	='SP Temp (eqs)'!F11	=1/vftsat(I23)	=10^-(15.5129-0.0224*I23+0.00003352*I23^2)	=(H23+G23-SQRT((H23+G23)^2-4*(H23*G23-K23)))/2	=G23-L23	=-LOG(M23)
24	='SP Temp (eqs)'!F12	=1/vftsat(I24)	=10^-(15.5129-0.0224*I24+0.00003352*I24^2)	=(H24+G24-SQRT((H24+G24)^2-4*(H24*G24-K24)))/2	=G24-L24	=-LOG(M24)
25	='SP Temp (eqs)'!F13	=1/vftsat(I25)	=10^-(15.5129-0.0224*I25+0.00003352*I25^2)	=(H25+G25-SQRT((H25+G25)^2-4*(H25*G25-K25)))/2	=G25-L25	=-LOG(M25)
26	='SP Temp (eqs)'!F14	=1/vftsat(I26)	=10^-(15.5129-0.0224*I26+0.00003352*I26^2)	=(H26+G26-SQRT((H26+G26)^2-4*(H26*G26-K26)))/2	=G26-L26	=-LOG(M26)
27	='SP Temp (eqs)'!F15	=1/vftsat(I27)	=10^-(15.5129-0.0224*I27+0.00003352*I27^2)	=(H27+G27-SQRT((H27+G27)^2-4*(H27*G27-K27)))/2	=G27-L27	=-LOG(M27)
28	='SP Temp (eqs)'!F16	=1/vftsat(I28)	=10^-(15.5129-0.0224*I28+0.00003352*I28^2)	=(H28+G28-SQRT((H28+G28)^2-4*(H28*G28-K28)))/2	=G28-L28	=-LOG(M28)
29	='SP Temp (eqs)'!F17	=1/vftsat(I29)	=10^-(15.5129-0.0224*I29+0.00003352*I29^2)	=(H29+G29-SQRT((H29+G29)^2-4*(H29*G29-K29)))/2	=G29-L29	=-LOG(M29)
30	='SP Temp (eqs)'!F18	=1/vftsat(I30)	=10^-(15.5129-0.0224*I30+0.00003352*I30^2)	=(H30+G30-SQRT((H30+G30)^2-4*(H30*G30-K30)))/2	=G30-L30	=-LOG(M30)
31	='SP Temp (eqs)'!F19	=1/vftsat(I31)	=10^-(15.5129-0.0224*I31+0.00003352*I31^2)	=(H31+G31-SQRT((H31+G31)^2-4*(H31*G31-K31)))/2	=G31-L31	=-LOG(M31)
32	='SP Temp (eqs)'!F20	=1/vftsat(I32)	=10^-(15.5129-0.0224*I32+0.00003352*I32^2)	=(H32+G32-SQRT((H32+G32)^2-4*(H32*G32-K32)))/2	=G32-L32	=-LOG(M32)
33	='SP Temp (eqs)'!F21	=1/vftsat(I33)	=10^-(15.5129-0.0224*I33+0.00003352*I33^2)	=(H33+G33-SQRT((H33+G33)^2-4*(H33*G33-K33)))/2	=G33-L33	=-LOG(M33)
34	='SP Temp (eqs)'!F22	=1/vftsat(I34)	=10^-(15.5129-0.0224*I34+0.00003352*I34^2)	=(H34+G34-SQRT((H34+G34)^2-4*(H34*G34-K34)))/2	=G34-L34	=-LOG(M34)
35	='SP Temp (eqs)'!F23	=1/vftsat(I35)	=10^-(15.5129-0.0224*I35+0.00003352*I35^2)	=(H35+G35-SQRT((H35+G35)^2-4*(H35*G35-K35)))/2	=G35-L35	=-LOG(M35)
36	='SP Temp (eqs)'!F24	=1/vftsat(I36)	=10^-(15.5129-0.0224*I36+0.00003352*I36^2)	=(H36+G36-SQRT((H36+G36)^2-4*(H36*G36-K36)))/2	=G36-L36	=-LOG(M36)
37	='SP Temp (eqs)'!F25	=1/vftsat(I37)	=10^-(15.5129-0.0224*I37+0.00003352*I37^2)	=(H37+G37-SQRT((H37+G37)^2-4*(H37*G37-K37)))/2	=G37-L37	=-LOG(M37)
38	='SP Temp (eqs)'!F26	=1/vftsat(I38)	=10^-(15.5129-0.0224*I38+0.00003352*I38^2)	=(H38+G38-SQRT((H38+G38)^2-4*(H38*G38-K38)))/2	=G38-L38	=-LOG(M38)
39	='SP Temp (eqs)'!F27	=1/vftsat(I39)	=10^-(15.5129-0.0224*I39+0.00003352*I39^2)	=(H39+G39-SQRT((H39+G39)^2-4*(H39*G39-K39)))/2	=G39-L39	=-LOG(M39)
40	='SP Temp (eqs)'!F28	=1/vftsat(I40)	=10^-(15.5129-0.0224*I40+0.00003352*I40^2)	=(H40+G40-SQRT((H40+G40)^2-4*(H40*G40-K40)))/2	=G40-L40	=-LOG(M40)
41	='SP Temp (eqs)'!F29	=1/vftsat(I41)	=10^-(15.5129-0.0224*I41+0.00003352*I41^2)	=(H41+G41-SQRT((H41+G41)^2-4*(H41*G41-K41)))/2	=G41-L41	=-LOG(M41)
42	='SP Temp (eqs)'!F30	=1/vftsat(I42)	=10^-(15.5129-0.0224*I42+0.00003352*I42^2)	=(H42+G42-SQRT((H42+G42)^2-4*(H42*G42-K42)))/2	=G42-L42	=-LOG(M42)

Table 5-1 Eqs: GGNS Benchmark
Post-LOCA pH Calculation without SLCS

	I	J	K	L	M	N
13	Pool	Water	K_w at	x	$[H^+]$	Pool
14	Temp	Density	Pool Temp			pH
15	(°F)	(lbm/ft^3)	(-)	(g-moles/l)	(g-moles/l)	(-)
43	='SP Temp (eqs)'!F31	=1/vftsat(I43)	=10^-(15.5129-0.0224*I43+0.00003352*I43^2)	=(H43+G43-SQRT((H43+G43)^2-4*(H43*G43-K43)))/2	=G43-L43	=-LOG(M43)
44	='SP Temp (eqs)'!F32	=1/vftsat(I44)	=10^-(15.5129-0.0224*I44+0.00003352*I44^2)	=(H44+G44-SQRT((H44+G44)^2-4*(H44*G44-K44)))/2	=G44-L44	=-LOG(M44)
45	='SP Temp (eqs)'!F33	=1/vftsat(I45)	=10^-(15.5129-0.0224*I45+0.00003352*I45^2)	=(H45+G45-SQRT((H45+G45)^2-4*(H45*G45-K45)))/2	=G45-L45	=-LOG(M45)
46	='SP Temp (eqs)'!F34	=1/vftsat(I46)	=10^-(15.5129-0.0224*I46+0.00003352*I46^2)	=(H46+G46-SQRT((H46+G46)^2-4*(H46*G46-K46)))/2	=G46-L46	=-LOG(M46)
47	='SP Temp (eqs)'!F35	=1/vftsat(I47)	=10^-(15.5129-0.0224*I47+0.00003352*I47^2)	=(H47+G47-SQRT((H47+G47)^2-4*(H47*G47-K47)))/2	=G47-L47	=-LOG(M47)
48	='SP Temp (eqs)'!F36	=1/vftsat(I48)	=10^-(15.5129-0.0224*I48+0.00003352*I48^2)	=(H48+G48-SQRT((H48+G48)^2-4*(H48*G48-K48)))/2	=G48-L48	=-LOG(M48)
49						
50						
51						
52						
53						
54						
55						
56						
57						

Table 5-2 Eqs: GGNS Benchmark
Hydriodic Acid (HI) Production

	A	B	C	D	E
1	*Core iodine inventory*	*325*	*g-mole*	*Ref. 7.12.3*	
2					
3	Core iodine - gap release	*=0.05*B1*	g-mole	*=0.05*325 g-mole*	
4	Core iodine - EIV release	*=0.25*B1*	g-mole	*=0.25*325 g-mole*	
5					
6	Fraction of release as HI	0.05	max	Reg Guide 1.183 (main body Ref. 7.10.2)	
7					
8	Gap release onset	*121*	*sec*	*Ref. 7.12.3*	
9	Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
10	EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
11					
12				suppression	
13			cumulative	pool	cumulative
14		Time	HI	volume	HI
15		(hr)	(g-mole)	(liter)	(g-mole/l)
16	onset	=B8/3600	0	*4841000*	=C16/D16
17		*0.1*	*=C16+(B17-B16)/(B9/60)*B3*B6*	*4841000*	*=C17/D17*
18	end of gap release	=B16+B9/60	*=C17+(B18-B17)/(B9/60)*B3*B6*	*4841000*	=C18/D18
19		1	=C18+(B19-B18)/(B10/60)*B4*B6	*4841000*	=C19/D19
20	end of EIV	=B18+B10/60	=C18+B4*B6	*4841000*	=C20/D20

	A	B	C	D	E
1	HNO_3 generation	0.0000073	g-mole/l per MRad		NUREG/CR-5950 (main body Ref. 7.13)
2					
3					
4			Suppression		
5			Pool	cumulative	
6		Time	TID @ 3467 MWt	HNO_3	
7		(hr)	(rad)	(g-mole/l)	
8	onset	='Rad Dose (eqs)'!A7			
9	end of gap release	='Rad Dose (eqs)'!A8			
10		='Rad Dose (eqs)'!A9			
11	end of EIV	='Rad Dose (eqs)'!A10	='Rad Dose (eqs)'!B10	=$B$1*C11/1000000	
12		='Rad Dose (eqs)'!A11	='Rad Dose (eqs)'!B11	=$B$1*C12/1000000	
13		='Rad Dose (eqs)'!A12	='Rad Dose (eqs)'!B12	=$B$1*C13/1000000	
14		='Rad Dose (eqs)'!A13	='Rad Dose (eqs)'!B13	=$B$1*C14/1000000	
15		='Rad Dose (eqs)'!A14	='Rad Dose (eqs)'!B14	=$B$1*C15/1000000	
16		='Rad Dose (eqs)'!A15	='Rad Dose (eqs)'!B15	=$B$1*C16/1000000	
17		='Rad Dose (eqs)'!A16	='Rad Dose (eqs)'!B16	=$B$1*C17/1000000	
18		='Rad Dose (eqs)'!A17	='Rad Dose (eqs)'!B17	=$B$1*C18/1000000	
19		='Rad Dose (eqs)'!A18	='Rad Dose (eqs)'!B18	=$B$1*C19/1000000	
20		='Rad Dose (eqs)'!A19	='Rad Dose (eqs)'!B19	=$B$1*C20/1000000	
21		='Rad Dose (eqs)'!A20	='Rad Dose (eqs)'!B20	=$B$1*C21/1000000	
22		='Rad Dose (eqs)'!A21	='Rad Dose (eqs)'!B21	=$B$1*C22/1000000	
23		='Rad Dose (eqs)'!A22	='Rad Dose (eqs)'!B22	=$B$1*C23/1000000	
24		='Rad Dose (eqs)'!A23	='Rad Dose (eqs)'!B23	=$B$1*C24/1000000	
25		='Rad Dose (eqs)'!A24	='Rad Dose (eqs)'!B24	=$B$1*C25/1000000	
26		='Rad Dose (eqs)'!A25	='Rad Dose (eqs)'!B25	=$B$1*C26/1000000	
27		='Rad Dose (eqs)'!A26	='Rad Dose (eqs)'!B26	=$B$1*C27/1000000	
28		='Rad Dose (eqs)'!A27	='Rad Dose (eqs)'!B27	=$B$1*C28/1000000	
29		='Rad Dose (eqs)'!A28	='Rad Dose (eqs)'!B28	=$B$1*C29/1000000	
30		='Rad Dose (eqs)'!A29	='Rad Dose (eqs)'!B29	=$B$1*C30/1000000	
31		='Rad Dose (eqs)'!A30	='Rad Dose (eqs)'!B30	=$B$1*C31/1000000	
32		='Rad Dose (eqs)'!A31	='Rad Dose (eqs)'!B31	=$B$1*C32/1000000	
33		='Rad Dose (eqs)'!A32	='Rad Dose (eqs)'!B32	=$B$1*C33/1000000	
34		='Rad Dose (eqs)'!A33	='Rad Dose (eqs)'!B33	=$B$1*C34/1000000	
35		='Rad Dose (eqs)'!A34	='Rad Dose (eqs)'!B34	=$B$1*C35/1000000	
36		='Rad Dose (eqs)'!A35	='Rad Dose (eqs)'!B35	=$B$1*C36/1000000	
37		='Rad Dose (eqs)'!A36	='Rad Dose (eqs)'!B36	=$B$1*C37/1000000	
38		='Rad Dose (eqs)'!A37	='Rad Dose (eqs)'!B37	=$B$1*C38/1000000	

Table 5-4 Eqs: GGNS Benchmark
Hydrochloric Acid (HCl) Production

	A	B	C	D	E	F	G
1	Cables						
2							
3	hypalon properties:						
4	radiolysis yield, G	0.000002192	g-mole HCl per MRad-g			NUREG/CR-5950 (main body Ref. 7.13)	
5	linear absorption coefficient	52.08	cm^{-1} for beta radiation			NUREG-1081 (main body Ref. 7.15)	
6	linear absorption coefficient	0.099	cm^{-1} for gamma radiation			NUREG-1081 (main body Ref. 7.15)	
7	density	1.55	g/cm^3			NUREG-1081 (main body Ref. 7.15)	
8							
9	Cable jacket and insulation:						
10							
11		*Drywell Cable Inventory*					*Containment Cable Inventory*
12	*cable outer radius*	*0.35*	*in*			*cable outer radius*	*0.35*
13	cable OD (max guar.)	*=2*B12*	in			cable OD (max guar.)	*=2*G12*
14	jacket thickness	*280*	mil			jacket thickness	*280*
15	jacket material	hypalon				jacket material	hypalon
16	insulation thickness	-	mil			insulation thickness	-
17	insulation material	-				insulation material	-
18	length in free air	-	*linear ft*			length in free air	-
19	length in tray	-	linear ft			length in tray	-
20							
21	chlorine-bearing material:						
22							
23	volume in free air	-	cm^3			volume in free air	-
24	volume in tray	-	cm^3			volume in tray	-
25	*mass in free air*	*873.65*	*lbm*			*mass in free air*	*1561.03*
26	mass in free air	*=B25*453.6*	gram			mass in free air	*=G25*453.6*
27	*mass in tray*	*873.65*	*lbm*			*mass in tray*	*14049.27*
28	mass in tray	*=B27*453.6*	gram			mass in tray	*=G27*453.6*
29							
30	Irradiation:						
31							
32			=B11				
33			beta				
34		gamma	free air	tray			gamma
35							
36	cable radius (cm)	=$B13*2.54/2	=$B13*2.54/2	=$B13*2.54/2			=$G13*2.54/2
37	jacket thickness (cm)	=($B14)/1000*2.54	=($B14)/1000*2.54	=($B14)/1000*2.54			=($G14)/1000*2.54
38	mass irradiated (g)	=B26+B28	=B26	=0.5*B28			=G26+G28
39							
40	flux averaging factor	=(1/($B$6^2)*(EXP(-$B$6*B37)*($B$6*B37+1)-1)-B36/$B$6*(EXP(-$B$6*B37)-1))/(B36*B37-B37^2/2)	=(1/($B$5^2)*(EXP(-$B$5*C37)*($B$5*C37+1)-1)-C36/$B$5*(EXP(-$B$5*C37)-1))/(C36*C37-C37^2/2)	=(1/($B$5^2)*(EXP(-$B$5*D37)*($B$5*D37+1)-1)-D36/$B$5*(EXP(-$B$5*D37)-1))/(D36*D37-D37^2/2)			=(1/($B$6^2)*(EXP(-$B$6*G37)*($B$6*G37+1)-1)-G36/$B$6*(EXP(-$B$6*G37)-1))/(G36*G37-G37^2/2)
41	absorption factor	=1-EXP(-$B$6*B37)	=1-EXP(-$B$5*C37)	=1-EXP(-$B$5*D37)			=1-EXP(-$B$6*G37)
42							
43							

Table 5-4 Eqs: GGNS Benchmark
Hydrochloric Acid (HCl) Production

	A	B	C	D	E	F	G
44			pool	Drywell	Containment	Drywell	Containment
45		Time	volume	γ TID	γ TID	β TID	β TID
46		(hr)	(liter)	(rad)	(rad)	(rad)	(rad)
47		='Rad Dose (eqs)'!A7	*4841000*	*='Rad Dose (eqs)'!G7*	*='Rad Dose (eqs)'!H7*	*='Rad Dose (eqs)'!I7*	*='Rad Dose (eqs)'!J7*
48		='Rad Dose (eqs)'!A8	*4841000*	*='Rad Dose (eqs)'!G8*	*='Rad Dose (eqs)'!H8*	*='Rad Dose (eqs)'!I8*	*='Rad Dose (eqs)'!J8*
49		='Rad Dose (eqs)'!A9	*4841000*	*='Rad Dose (eqs)'!G9*	*='Rad Dose (eqs)'!H9*	*='Rad Dose (eqs)'!I9*	*='Rad Dose (eqs)'!J9*
50		='Rad Dose (eqs)'!A10	*4841000*	*='Rad Dose (eqs)'!G10*	*='Rad Dose (eqs)'!H10*	*='Rad Dose (eqs)'!I10*	*='Rad Dose (eqs)'!J10*
51		='Rad Dose (eqs)'!A11	*4841000*	*='Rad Dose (eqs)'!G11*	*='Rad Dose (eqs)'!H11*	*='Rad Dose (eqs)'!I11*	*='Rad Dose (eqs)'!J11*
52		='Rad Dose (eqs)'!A12	*4841000*	*='Rad Dose (eqs)'!G12*	*='Rad Dose (eqs)'!H12*	*='Rad Dose (eqs)'!I12*	*='Rad Dose (eqs)'!J12*
53		='Rad Dose (eqs)'!A13	*4841000*	*='Rad Dose (eqs)'!G13*	*='Rad Dose (eqs)'!H13*	*='Rad Dose (eqs)'!I13*	*='Rad Dose (eqs)'!J13*
54		='Rad Dose (eqs)'!A14	*4841000*	*='Rad Dose (eqs)'!G14*	*='Rad Dose (eqs)'!H14*	*='Rad Dose (eqs)'!I14*	*='Rad Dose (eqs)'!J14*
55		='Rad Dose (eqs)'!A15	*4841000*	*='Rad Dose (eqs)'!G15*	*='Rad Dose (eqs)'!H15*	*='Rad Dose (eqs)'!I15*	*='Rad Dose (eqs)'!J15*
56		='Rad Dose (eqs)'!A16	*4841000*	*='Rad Dose (eqs)'!G16*	*='Rad Dose (eqs)'!H16*	*='Rad Dose (eqs)'!I16*	*='Rad Dose (eqs)'!J16*
57		='Rad Dose (eqs)'!A17	*4841000*	*='Rad Dose (eqs)'!G17*	*='Rad Dose (eqs)'!H17*	*='Rad Dose (eqs)'!I17*	*='Rad Dose (eqs)'!J17*
58		='Rad Dose (eqs)'!A18	*4841000*	*='Rad Dose (eqs)'!G18*	*='Rad Dose (eqs)'!H18*	*='Rad Dose (eqs)'!I18*	*='Rad Dose (eqs)'!J18*
59		='Rad Dose (eqs)'!A19	*4841000*	*='Rad Dose (eqs)'!G19*	*='Rad Dose (eqs)'!H19*	*='Rad Dose (eqs)'!I19*	*='Rad Dose (eqs)'!J19*
60		='Rad Dose (eqs)'!A20	*4841000*	*='Rad Dose (eqs)'!G20*	*='Rad Dose (eqs)'!H20*	*='Rad Dose (eqs)'!I20*	*='Rad Dose (eqs)'!J20*
61		='Rad Dose (eqs)'!A21	*4841000*	*='Rad Dose (eqs)'!G21*	*='Rad Dose (eqs)'!H21*	*='Rad Dose (eqs)'!I21*	*='Rad Dose (eqs)'!J21*
62		='Rad Dose (eqs)'!A22	*4841000*	*='Rad Dose (eqs)'!G22*	*='Rad Dose (eqs)'!H22*	*='Rad Dose (eqs)'!I22*	*='Rad Dose (eqs)'!J22*
63		='Rad Dose (eqs)'!A23	*4841000*	*='Rad Dose (eqs)'!G23*	*='Rad Dose (eqs)'!H23*	*='Rad Dose (eqs)'!I23*	*='Rad Dose (eqs)'!J23*
64		='Rad Dose (eqs)'!A24	*4841000*	*='Rad Dose (eqs)'!G24*	*='Rad Dose (eqs)'!H24*	*='Rad Dose (eqs)'!I24*	*='Rad Dose (eqs)'!J24*
65		='Rad Dose (eqs)'!A25	*4841000*	*='Rad Dose (eqs)'!G25*	*='Rad Dose (eqs)'!H25*	*='Rad Dose (eqs)'!I25*	*='Rad Dose (eqs)'!J25*
66		='Rad Dose (eqs)'!A26	*4841000*	*='Rad Dose (eqs)'!G26*	*='Rad Dose (eqs)'!H26*	*='Rad Dose (eqs)'!I26*	*='Rad Dose (eqs)'!J26*
67		='Rad Dose (eqs)'!A27	*4841000*	*='Rad Dose (eqs)'!G27*	*='Rad Dose (eqs)'!H27*	*='Rad Dose (eqs)'!I27*	*='Rad Dose (eqs)'!J27*
68		='Rad Dose (eqs)'!A28	*4841000*	*='Rad Dose (eqs)'!G28*	*='Rad Dose (eqs)'!H28*	*='Rad Dose (eqs)'!I28*	*='Rad Dose (eqs)'!J28*
69		='Rad Dose (eqs)'!A29	*4841000*	*='Rad Dose (eqs)'!G29*	*='Rad Dose (eqs)'!H29*	*='Rad Dose (eqs)'!I29*	*='Rad Dose (eqs)'!J29*
70		='Rad Dose (eqs)'!A30	*4841000*	*='Rad Dose (eqs)'!G30*	*='Rad Dose (eqs)'!H30*	*='Rad Dose (eqs)'!I30*	*='Rad Dose (eqs)'!J30*
71		='Rad Dose (eqs)'!A31	*4841000*	*='Rad Dose (eqs)'!G31*	*='Rad Dose (eqs)'!H31*	*='Rad Dose (eqs)'!I31*	*='Rad Dose (eqs)'!J31*
72		='Rad Dose (eqs)'!A32	*4841000*	*='Rad Dose (eqs)'!G32*	*='Rad Dose (eqs)'!H32*	*='Rad Dose (eqs)'!I32*	*='Rad Dose (eqs)'!J32*
73		='Rad Dose (eqs)'!A33	*4841000*	*='Rad Dose (eqs)'!G33*	*='Rad Dose (eqs)'!H33*	*='Rad Dose (eqs)'!I33*	*='Rad Dose (eqs)'!J33*
74		='Rad Dose (eqs)'!A34	*4841000*	*='Rad Dose (eqs)'!G34*	*='Rad Dose (eqs)'!H34*	*='Rad Dose (eqs)'!I34*	*='Rad Dose (eqs)'!J34*
75		='Rad Dose (eqs)'!A35	*4841000*	*='Rad Dose (eqs)'!G35*	*='Rad Dose (eqs)'!H35*	*='Rad Dose (eqs)'!I35*	*='Rad Dose (eqs)'!J35*
76		='Rad Dose (eqs)'!A36	*4841000*	*='Rad Dose (eqs)'!G36*	*='Rad Dose (eqs)'!H36*	*='Rad Dose (eqs)'!I36*	*='Rad Dose (eqs)'!J36*
77		='Rad Dose (eqs)'!A37	*4841000*	*='Rad Dose (eqs)'!G37*	*='Rad Dose (eqs)'!H37*	*='Rad Dose (eqs)'!I37*	*='Rad Dose (eqs)'!J37*

amf 1/10/05

	H	I	J
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12	*in*		
13	in		
14	mil		
15			
16	mil		
17			
18	linear ft		
19	linear ft		
20			
21			
22			
23	cm³		
24	cm³		
25	*lbm*		
26	gram		
27	*lbm*		
28	gram		
29			
30			
31			
32	=G11		
33	beta		
34	free air	tray	
35			
36	=$G13*2.54/2	=$G13*2.54/2	
37	=($G14)/1000*2.54	=($G14)/1000*2.54	
38	=G26	=0.5*G28	
39			
40	=(1/($B$5^2)*(EXP(-$B$5*H37)*($B$5*H37+1)-1)-H36/$B$5*(EXP(-$B$5*H37)-1))/(H36*H37-H37^2/2)	=(1/($B$5^2)*(EXP(-$B$5*I37)*($B$5*I37+1)-1)-I36/$B$5*(EXP(-$B$5*I37)-1))/(I36*I37-I37^2/2)	
41	=1-EXP(-$B$5*H37)	=1-EXP(-$B$5*I37)	
42			
43			

Table 5-4 Eqs: GGNS Benchmark
Hydrochloric Acid (HCl) Production

	H	I	J
44		Drywell HCl	
45	gamma	beta	*Total*
46	(g-mole)	(g-mole)	*(g-mole/l)*
47	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*D47/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F47/1000000	*=(H47+I47)/C47*
48	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D48/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F48/1000000	*=(H48+I48)/C48*
49	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D49/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F49/1000000	*=(H49+I49)/C49*
50	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D50/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F50/1000000	*=(H50+I50)/C50*
51	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D51/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F51/1000000	*=(H51+I51)/C51*
52	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D52/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F52/1000000	*=(H52+I52)/C52*
53	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D53/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F53/1000000	*=(H53+I53)/C53*
54	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D54/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F54/1000000	*=(H54+I54)/C54*
55	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D55/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F55/1000000	*=(H55+I55)/C55*
56	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D56/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F56/1000000	*=(H56+I56)/C56*
57	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D57/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F57/1000000	*=(H57+I57)/C57*
58	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D58/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F58/1000000	*=(H58+I58)/C58*
59	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D59/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F59/1000000	*=(H59+I59)/C59*
60	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D60/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F60/1000000	*=(H60+I60)/C60*
61	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D61/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F61/1000000	*=(H61+I61)/C61*
62	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D62/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F62/1000000	*=(H62+I62)/C62*
63	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D63/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F63/1000000	*=(H63+I63)/C63*
64	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D64/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F64/1000000	*=(H64+I64)/C64*
65	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D65/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F65/1000000	*=(H65+I65)/C65*
66	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D66/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F66/1000000	*=(H66+I66)/C66*
67	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D67/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F67/1000000	*=(H67+I67)/C67*
68	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D68/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F68/1000000	*=(H68+I68)/C68*
69	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D69/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F69/1000000	*=(H69+I69)/C69*
70	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D70/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F70/1000000	*=(H70+I70)/C70*
71	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D71/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F71/1000000	*=(H71+I71)/C71*
72	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D72/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F72/1000000	*=(H72+I72)/C72*
73	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D73/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F73/1000000	*=(H73+I73)/C73*
74	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D74/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F74/1000000	*=(H74+I74)/C74*
75	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D75/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F75/1000000	*=(H75+I75)/C75*
76	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D76/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F76/1000000	*=(H76+I76)/C76*
77	=$B$4*($B$38*$B$40*$B$41+$G$38*$G$40*$G$41)*D77/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*F77/1000000	*=(H77+I77)/C77*

Table 5-4 Eqs: GGNS Benchmark
Hydrochloric Acid (HCl) Production

amL 1/10/05

	K	L	M	N
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				

amp 1/10/05

	K	L	M	N
44		Containment HCl		
45	gamma	beta	Total	HCl
46	(g-mole)	(g-mole)	(g-mole/l)	(g-mole/l)
47	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E47/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G47/1000000	=(K47+L47)/C47	=(H47+I47+K47+L47)/C47
48	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E48/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G48/1000000	=(K48+L48)/C48	=(H48+I48+K48+L48)/C48
49	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E49/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G49/1000000	=(K49+L49)/C49	=(H49+I49+K49+L49)/C49
50	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E50/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G50/1000000	=(K50+L50)/C50	=(H50+I50+K50+L50)/C50
51	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E51/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G51/1000000	=(K51+L51)/C51	=(H51+I51+K51+L51)/C51
52	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E52/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G52/1000000	=(K52+L52)/C52	=(H52+I52+K52+L52)/C52
53	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E53/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G53/1000000	=(K53+L53)/C53	=(H53+I53+K53+L53)/C53
54	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E54/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G54/1000000	=(K54+L54)/C54	=(H54+I54+K54+L54)/C54
55	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E55/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G55/1000000	=(K55+L55)/C55	=(H55+I55+K55+L55)/C55
56	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E56/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G56/1000000	=(K56+L56)/C56	=(H56+I56+K56+L56)/C56
57	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E57/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G57/1000000	=(K57+L57)/C57	=(H57+I57+K57+L57)/C57
58	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E58/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G58/1000000	=(K58+L58)/C58	=(H58+I58+K58+L58)/C58
59	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E59/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G59/1000000	=(K59+L59)/C59	=(H59+I59+K59+L59)/C59
60	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E60/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G60/1000000	=(K60+L60)/C60	=(H60+I60+K60+L60)/C60
61	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E61/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G61/1000000	=(K61+L61)/C61	=(H61+I61+K61+L61)/C61
62	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E62/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G62/1000000	=(K62+L62)/C62	=(H62+I62+K62+L62)/C62
63	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E63/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G63/1000000	=(K63+L63)/C63	=(H63+I63+K63+L63)/C63
64	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E64/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G64/1000000	=(K64+L64)/C64	=(H64+I64+K64+L64)/C64
65	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E65/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G65/1000000	=(K65+L65)/C65	=(H65+I65+K65+L65)/C65
66	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E66/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G66/1000000	=(K66+L66)/C66	=(H66+I66+K66+L66)/C66
67	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E67/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G67/1000000	=(K67+L67)/C67	=(H67+I67+K67+L67)/C67
68	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E68/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G68/1000000	=(K68+L68)/C68	=(H68+I68+K68+L68)/C68
69	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E69/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G69/1000000	=(K69+L69)/C69	=(H69+I69+K69+L69)/C69
70	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E70/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G70/1000000	=(K70+L70)/C70	=(H70+I70+K70+L70)/C70
71	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E71/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G71/1000000	=(K71+L71)/C71	=(H71+I71+K71+L71)/C71
72	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E72/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G72/1000000	=(K72+L72)/C72	=(H72+I72+K72+L72)/C72
73	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E73/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G73/1000000	=(K73+L73)/C73	=(H73+I73+K73+L73)/C73
74	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E74/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G74/1000000	=(K74+L74)/C74	=(H74+I74+K74+L74)/C74
75	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E75/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G75/1000000	=(K75+L75)/C75	=(H75+I75+K75+L75)/C75
76	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E76/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G76/1000000	=(K76+L76)/C76	=(H76+I76+K76+L76)/C76
77	=$B$4*(($B$38*$B$40*$B$41)+($G$38*$G$40*$G$41))*E77/1000000	=(($C$38*$C$40*$C$41+$D$38*$D$40*$D$41)+($H$38*$H$40*$H$41+$I$38*$I$40*$I$41))*$B$4*G77/1000000	=(K77+L77)/C77	=(H77+I77+K77+L77)/C77

Table 5-5 Eqs: GGNS Benchmark
Cesium Hydroxide (CsOH) Production

amL 11/10/00

	A	B	C	D	E
1	*Core cesium inventory*	*2400*	*g-mole*	*Ref. 7.12.3*	
2					
3	Core cesium - gap release	*=0.05*B1*	*g-mole*	*=0.05*2400 g-mole*	
4	Core cesium - EIV release	*=0.2*B1*	*g-mole*	*=0.20*2400 g-mole*	
5					
6	CsI - gap release	=(1-'HI (eqs)'!B$6)*'HI (eqs)'!B3	g-mole	fraction iodine release in form of CsI	
7	CsI - EIV release	=(1-'HI (eqs)'!B$6)*'HI (eqs)'!B4	g-mole	fraction iodine release in form of CsI	
8					
9	CsOH - gap release	=B3-B6	g-mole		
10	CsOH - EIV release	=B4-B7	g-mole		
11					
12	Gap release onset	*121*	*sec*	*Ref. 7.12.3*	
13	Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
14	EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)	
15					
16				suppression	
17			cumulative	pool	cumulative
18		Time	CsOH	volume	CsOH
19		(Hr)	(g-mole)	(liter)	(g-mole/l)
20	onset	=B12/3600	0	*4841000*	=C20/D20
21		*0.1*	*=C20+(B21-B20)/(B13/60)*B9*	*4841000*	=C21/D21
22	end of gap release	=B20+B13/60	*=C21+(B22-B21)/(B13/60)*B9*	*4841000*	=C22/D22
23		1	=C22+(B23-B22)/(B24-B22)*B10	*4841000*	=C23/D23
24	end of EIV	=B22+B14/60	=C22+B10	*4841000*	=C24/D24

**Table 5-6 Eqs: GGNS Benchmark
Effect of SLCS Addition
on Post-LOCA Suppression Pool**

	A	B	C	D	E
1	**Buffering by SLCS**				
2					
3	SLCS:				
4	Min SLC pump flow rate	-	gpm		
5	Min SLC injection tank volume	-	gal		
6	Max SLC temp	-	°F		
7	Min SLC temp	-	°F		
8	SLC SPB conc. by weight	-			
9	Specific gravity	-			
10	Density (T=85°F)	-	lbm/ft^3		
11					
12	Final suppression pool temp (bounding)	120	°F		
13					
14	Boric acid K	=(0.0585*B12+1.309)*0.0000000001	at	=B12	°F
15					
16	*MW sodium pentaborate ($Na_2B_{10}O_{16}$)*	*410*			
17					
18	Volume sodium pentaborate	-	ft^3		
19	Mass sodium pentaborate	*5800*	lbm		
20	Mass sodium pentaborate	=B19*453.6/B16	g-mole		
21					
22	unbuffered pH	='pH (eqs)'!N48			
23	unbuffered $[H^+]$	=10^(-B22)	g-mole/l		
24	Suppression Pool volume	*4841000*	liter		
25	Equivalents unbuffered $[H^+]$	=B23*B24	g-mole		
26					
27	Final pH	=-LOG(B14)+LOG((2*B20-B25)/(8*B20+B25))			
28					
29	Time to inject boron	-	minutes		

	A	B	C	D	E
1					
2					
3		Suppression	Drywell	Containment	Drywell
4	Time	Pool γ TID	γ TID	γ TID	β TID
5	[hr]	[rad]	[MeV/cc]	[MeV/cc]	[MeV/cc]
6	0	0	0	0	0
7	=121/3600	0	0	0	0
8	=A7+30/60	0	0	0	0
9	1	0	0	0	0
10	2	=1000000*(14.72*(1-0.91*EXP(-0.002*A10)))	=1000000*1000000*(0.15+1.83235*LN(A10))	0	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A10)))
11	=2+121/3600	=1000000*(14.72*(1-0.91*EXP(-0.002*A11)))	=1000000*1000000*(0.15+1.83235*LN(A11))	0	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A11)))
12	3	=1000000*(14.72*(1-0.91*EXP(-0.002*A12)))	=1000000*1000000*(0.15+1.83235*LN(A12))	=1000000*1000000*(-1.18+1.135*LN(A12))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A12)))
13	4	=1000000*(14.72*(1-0.91*EXP(-0.002*A13)))	=1000000*1000000*(0.15+1.83235*LN(A13))	=1000000*1000000*(-1.18+1.135*LN(A13))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A13)))
14	5	=1000000*(14.72*(1-0.91*EXP(-0.002*A14)))	=1000000*1000000*(0.15+1.83235*LN(A14))	=1000000*1000000*(-1.18+1.135*LN(A14))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A14)))
15	6	=1000000*(14.72*(1-0.91*EXP(-0.002*A15)))	=1000000*1000000*(0.15+1.83235*LN(A15))	=1000000*1000000*(-1.18+1.135*LN(A15))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A15)))
16	12	=1000000*(14.72*(1-0.91*EXP(-0.002*A16)))	=1000000*1000000*(0.15+1.83235*LN(A16))	=1000000*1000000*(-1.18+1.135*LN(A16))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A16)))
17	18	=1000000*(14.72*(1-0.91*EXP(-0.002*A17)))	=1000000*1000000*(0.15+1.83235*LN(A17))	=1000000*1000000*(-1.18+1.135*LN(A17))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A17)))
18	24	=1000000*(14.72*(1-0.91*EXP(-0.002*A18)))	=1000000*1000000*(0.15+1.83235*LN(A18))	=1000000*1000000*(-1.18+1.135*LN(A18))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A18)))
19	=A18+24	=1000000*(14.72*(1-0.91*EXP(-0.002*A19)))	=1000000*1000000*(0.15+1.83235*LN(A19))	=1000000*1000000*(-1.18+1.135*LN(A19))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A19)))
20	=A19+24	=1000000*(14.72*(1-0.91*EXP(-0.002*A20)))	=1000000*1000000*(0.15+1.83235*LN(A20))	=1000000*1000000*(-1.18+1.135*LN(A20))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A20)))
21	=A20+24	=1000000*(14.72*(1-0.91*EXP(-0.002*A21)))	=1000000*1000000*(0.15+1.83235*LN(A21))	=1000000*1000000*(-1.18+1.135*LN(A21))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A21)))
22	=A21+24	=1000000*(14.72*(1-0.91*EXP(-0.002*A22)))	=1000000*1000000*(0.15+1.83235*LN(A22))	=1000000*1000000*(-1.18+1.135*LN(A22))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A22)))
23	=A22+24	=1000000*(14.72*(1-0.91*EXP(-0.002*A23)))	=1000000*1000000*(0.15+1.83235*LN(A23))	=1000000*1000000*(-1.18+1.135*LN(A23))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A23)))
24	=A23+24	=1000000*(14.72*(1-0.91*EXP(-0.002*A24)))	=1000000*1000000*(0.15+1.83235*LN(A24))	=1000000*1000000*(-1.18+1.135*LN(A24))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A24)))
25	=A24+24	=1000000*(14.72*(1-0.91*EXP(-0.002*A25)))	=1000000*1000000*(0.15+1.83235*LN(A25))	=1000000*1000000*(-1.18+1.135*LN(A25))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A25)))
26	=A25+24	=1000000*(14.72*(1-0.91*EXP(-0.002*A26)))	=1000000*1000000*(0.15+1.83235*LN(A26))	=1000000*1000000*(-1.18+1.135*LN(A26))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A26)))
27	=A26+24	=1000000*(14.72*(1-0.91*EXP(-0.002*A27)))	=1000000*1000000*(0.15+1.83235*LN(A27))	=1000000*1000000*(-1.18+1.135*LN(A27))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A27)))
28	=A27+48	=1000000*(14.72*(1-0.91*EXP(-0.002*A28)))	=1000000*1000000*(0.15+1.83235*LN(A28))	=1000000*1000000*(-1.18+1.135*LN(A28))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A28)))
29	=A28+48	=1000000*(14.72*(1-0.91*EXP(-0.002*A29)))	=1000000*1000000*(0.15+1.83235*LN(A29))	=1000000*1000000*(-1.18+1.135*LN(A29))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A29)))
30	=A29+48	=1000000*(14.72*(1-0.91*EXP(-0.002*A30)))	=1000000*1000000*(0.15+1.83235*LN(A30))	=1000000*1000000*(-1.18+1.135*LN(A30))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A30)))
31	=A30+48	=1000000*(14.72*(1-0.91*EXP(-0.002*A31)))	=1000000*1000000*(0.15+1.83235*LN(A31))	=1000000*1000000*(-1.18+1.135*LN(A31))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A31)))
32	=A31+48	=1000000*(14.72*(1-0.91*EXP(-0.002*A32)))	=1000000*1000000*(0.15+1.83235*LN(A32))	=1000000*1000000*(-1.18+1.135*LN(A32))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A32)))
33	=A32+48	=1000000*(14.72*(1-0.91*EXP(-0.002*A33)))	=1000000*1000000*(0.15+1.83235*LN(A33))	=1000000*1000000*(-1.18+1.135*LN(A33))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A33)))
34	=A33+48	=1000000*(14.72*(1-0.91*EXP(-0.002*A34)))	=1000000*1000000*(0.15+1.83235*LN(A34))	=1000000*1000000*(-1.18+1.135*LN(A34))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A34)))
35	=A34+48	=1000000*(14.72*(1-0.91*EXP(-0.002*A35)))	=1000000*1000000*(0.15+1.83235*LN(A35))	=1000000*1000000*(-1.18+1.135*LN(A35))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A35)))
36	=A35+48	=1000000*(14.72*(1-0.91*EXP(-0.002*A36)))	=1000000*1000000*(0.15+1.83235*LN(A36))	=1000000*1000000*(-1.18+1.135*LN(A36))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A36)))
37	720	=1000000*(14.72*(1-0.91*EXP(-0.002*A37)))	=1000000*1000000*(0.15+1.83235*LN(A37))	=1000000*1000000*(-1.18+1.135*LN(A37))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A37)))
38	2400	=1000000*(14.72*(1-0.91*EXP(-0.002*A38)))	=1000000*1000000*(0.15+1.83235*LN(A38))	=1000000*1000000*(-1.18+1.135*LN(A38))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A38)))
39	4320	=1000000*(14.72*(1-0.91*EXP(-0.002*A39)))	=1000000*1000000*(0.15+1.83235*LN(A39))	=1000000*1000000*(-1.18+1.135*LN(A39))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A39)))
40	8760	=1000000*(14.72*(1-0.91*EXP(-0.002*A40)))	=1000000*1000000*(0.15+1.83235*LN(A40))	=1000000*1000000*(-1.18+1.135*LN(A40))	=1000000*1000000*(25.7*(1-0.9*EXP(-0.0066*A40)))
41	Equations				
42	γ_{SP} [Mrad] = 14.72*[1-0.91*exp(-0.002*t_{hr})]*10^6				
43	γ_{DW} [MeV/cc] = [0.15+1.83235*ln(t_{hr})]*10^6*10^6				
44	γ_{CNT} [MeV/cc] = [-1.18+1.135*ln(t_{hr})]*10^6*10^6				
45	β_{DW} [MeV/cc] = 25.7*[1-0.9*exp(-0.0066*t_{hr})]*10^6*10^6				
46	β_{CNT} [MeV/cc] = 15.05*[1-0.93*exp(-0.0057*t_{hr})]*10^6*10^6				
47	1 rad = 8.071x10^4 MeV/cc for air at S.T.P. per Radiological Health Handbook (main body Ref. 7.8)				
48					
49	Notes				
50	If the curve fits above yield a negative TID due to curve fit inacurracies, the TID is assumed to be zero consistent with Ref. 7.12.3.				

	F	G	H	I	J
1					
2					
3	Containment	Drywell	Containment	Drywell	Containment
4	β TID	γ TID	γ TID	β TID	β TID
5	[MeV/cc]	[rad]	[rad]	[rad]	[rad]
6	0	=C6*80710	=D6*80710	=E6*80710	=F6*80710
7	0	=C7*80710	=D7*80710	=E7*80710	=F7*80710
8	0	=C8*80710	=D8*80710	=E8*80710	=F8*80710
9	0	=C9*80710	=D9*80710	=E9*80710	=F9*80710
10	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A10)))	=C10/80710	=D10/80710	=E10/80710	=F10/80710
11	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A11)))	=C11/80710	=D11/80710	=E11/80710	=F11/80710
12	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A12)))	=C12/80710	=D12/80710	=E12/80710	=F12/80710
13	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A13)))	=C13/80710	=D13/80710	=E13/80710	=F13/80710
14	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A14)))	=C14/80710	=D14/80710	=E14/80710	=F14/80710
15	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A15)))	=C15/80710	=D15/80710	=E15/80710	=F15/80710
16	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A16)))	=C16/80710	=D16/80710	=E16/80710	=F16/80710
17	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A17)))	=C17/80710	=D17/80710	=E17/80710	=F17/80710
18	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A18)))	=C18/80710	=D18/80710	=E18/80710	=F18/80710
19	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A19)))	=C19/80710	=D19/80710	=E19/80710	=F19/80710
20	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A20)))	=C20/80710	=D20/80710	=E20/80710	=F20/80710
21	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A21)))	=C21/80710	=D21/80710	=E21/80710	=F21/80710
22	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A22)))	=C22/80710	=D22/80710	=E22/80710	=F22/80710
23	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A23)))	=C23/80710	=D23/80710	=E23/80710	=F23/80710
24	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A24)))	=C24/80710	=D24/80710	=E24/80710	=F24/80710
25	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A25)))	=C25/80710	=D25/80710	=E25/80710	=F25/80710
26	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A26)))	=C26/80710	=D26/80710	=E26/80710	=F26/80710
27	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A27)))	=C27/80710	=D27/80710	=E27/80710	=F27/80710
28	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A28)))	=C28/80710	=D28/80710	=E28/80710	=F28/80710
29	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A29)))	=C29/80710	=D29/80710	=E29/80710	=F29/80710
30	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A30)))	=C30/80710	=D30/80710	=E30/80710	=F30/80710
31	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A31)))	=C31/80710	=D31/80710	=E31/80710	=F31/80710
32	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A32)))	=C32/80710	=D32/80710	=E32/80710	=F32/80710
33	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A33)))	=C33/80710	=D33/80710	=E33/80710	=F33/80710
34	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A34)))	=C34/80710	=D34/80710	=E34/80710	=F34/80710
35	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A35)))	=C35/80710	=D35/80710	=E35/80710	=F35/80710
36	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A36)))	=C36/80710	=D36/80710	=E36/80710	=F36/80710
37	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A37)))	=C37/80710	=D37/80710	=E37/80710	=F37/80710
38	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A38)))	=C38/80710	=D38/80710	=E38/80710	=F38/80710
39	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A39)))	=C39/80710	=D39/80710	=E39/80710	=F39/80710
40	=1000000*1000000*(15.05*(1-0.93*EXP(-0.0057*A40)))	=C40/80710	=D40/80710	=E40/80710	=F40/80710
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					

	A	B	C	D	E	F	G
1	**From Data (Ref. 7.12.3)**				**Used for pH Analysis**		
2							
3	Time Post-LOCA		Temp		Time	Temp	
4	(sec/days)*	(hr)	(°F)		(hr)	(°F)	
5	0	0	77		0	=C5	
6		0.03361	160		0.0336111111111111	=C12	
7	1	=A7/3600	160		0.533611111111111	=C15	
8	8	=A8/3600	160		1	=C16	
9	10	=A9/3600	160		2	=C17	
10	30	=A10/3600	160		2.03361111111111	=C18	
11	100	=A11/3600	160		3	=C20	
12		0.0336111111111111	160		4	=C21	
13	300	=A13/3600	160		5	=C22	
14	1000	=A14/3600	160		6	=C24	
15		0.533611111111111	160		12	=C26	
16		1	160		18	=C28	
17		2	160		24	=C29	
18		2.03361111111111	160		48	=C31	
19	10000	=A19/3600	=(B19-B18)/(B20-B18)*(C20-C18)+C18		72	=C32	
20		3	159.1		96	=C33	
21		4	=(B21-B20)/(B22-B20)*(C22-C20)+C20		120	=C34	
22		5	155.5		144	=C35	
23	20000	=A23/3600	=(B23-B22)/(B26-B22)*(C26-C22)+C22		168	=C37	
24		6	=(B24-B22)/(B26-B22)*(C26-C22)+C22		192	=C38	
25	42000	=A25/3600	=(B25-B22)/(B26-B22)*(C26-C22)+C22		216	=C40	
26		12	149.2		240	=C41	
27	60000	=A27/3600	=(B27-B26)/(B28-B26)*(C28-C26)+C26		288	=C42	
28		18	146.4		336	=C44	
29		24	144.3		384	=C46	
30	100000	=A30/3600	=(B30-B29)/(B31-B29)*(C31-C29)+C29		432	=C48	
31	=B31/24	48	139.4		480	=C49	
32	=B32/24	72	136.5		528	=C50	
33	=B33/24	96	134.4		576	=C51	
34	=B34/24	120	132.8		624	=C53	
35	=B35/24	144	=(B35-B34)/(B36-B34)*(C36-C34)+C34		672	=C54	
36		150	131.3		720	=C56	
37	=B37/24	168	=(B37-B36)/(B39-B36)*(C39-C36)+C36				
38	=B38/24	192	=(B38-B36)/(B39-B36)*(C39-C36)+C36		The shaded values are taken from either Reference 7.12.3. Other other values are interpolated.		
39		200	129.2				
40	=B40/24	216	=(B40-B39)/(B41-B39)*(C41-C39)+C39				
41	=B41/24	240	127.9				
42	=B42/24	288	=(B42-B41)/(B43-B41)*(C43-C41)+C41				
43		300	126.3				
44	=B44/24	336	=(B44-B43)/(B45-B43)*(C45-C43)+C43				
45	=B45/24	360	125				
46		384	=(B46-B45)/(B47-B45)*(C47-C45)+C45				
47		400	124.3				
48		432	=(B48-B47)/(B49-B47)*(C49-C47)+C47				
49	=B49/24	480	123				
50		528	=(B50-B49)/(B52-B49)*(C52-C49)+C49				
51		576	=(B51-B49)/(B52-B49)*(C52-C49)+C49				
52	=B52/24	600	121.4				
53		624	=(B53-B52)/(B55-B52)*(C55-C52)+C52		* Seconds are the units for t=0 to 27.78 hours; days are the units for t=48 to 720 hours.		
54		672	=(B54-B52)/(B55-B52)*(C55-C52)+C52				
55		700	120.3				
56	=B56/24	720	120.1				

Attachment 6

Calculations Determining Post-LOCA Suppression Chamber Water pH

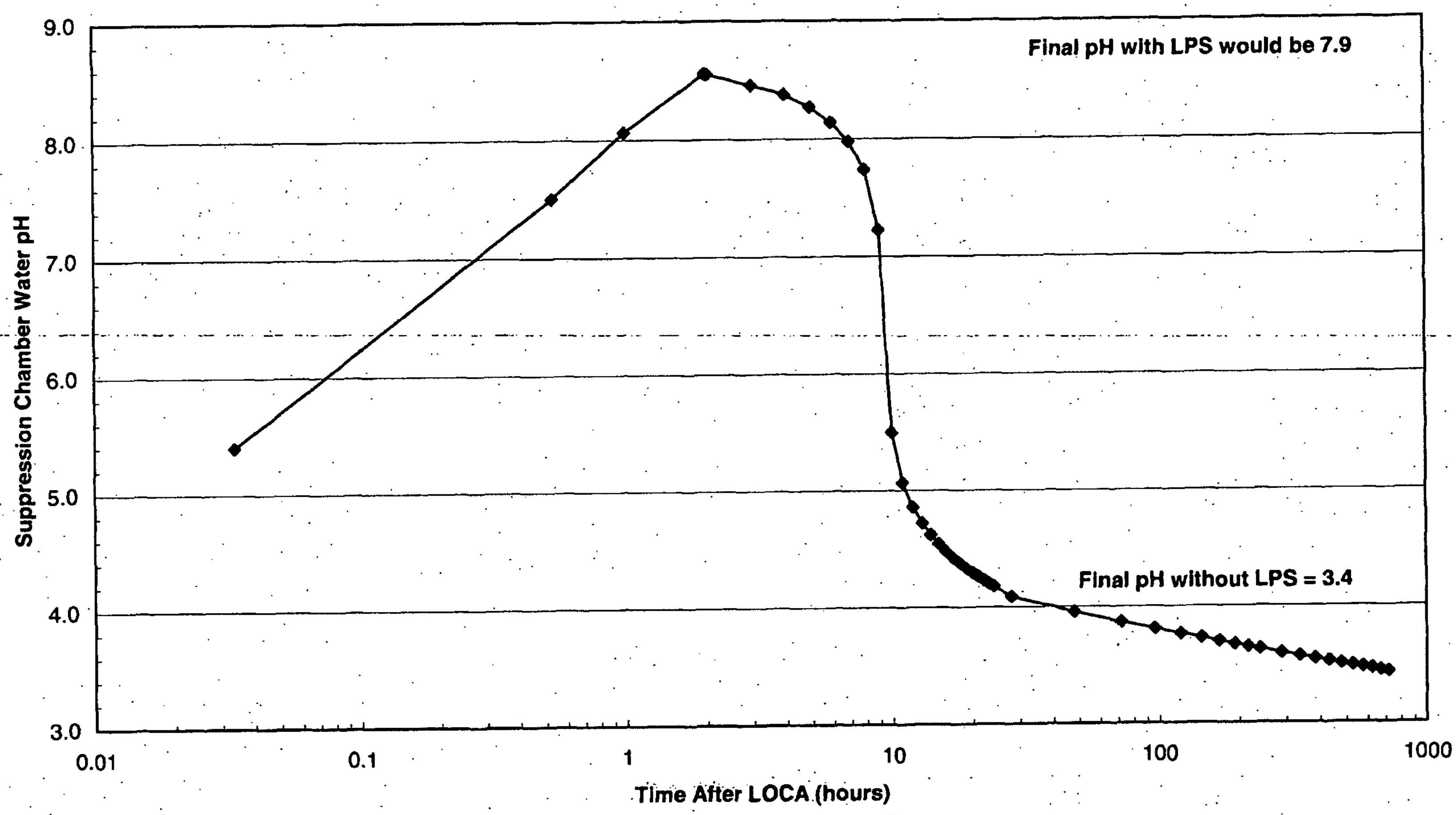
Minimum Suppression Chamber Water Volume Case

Table of Contents

Radiation dose profile figures are not provided in this attachment as they follow the same trends as those provided in Attachment 4. Similarly, the methodology used in the tables in this attachment is the same as that used in the tables in Attachment 4; therefore, equations are not provided for the tables in this attachment.

Note that each table in this attachment has been developed using Microsoft Excel. Some tables reference each other; for these references, see the "tab" name at the bottom of each sheet.

Figure 6-1: Nine Mile Point Unit 1
Post-LOCA Suppression Chamber Water pH Analysis
Minimum Suppression Chamber Water Volume Case
pH Response without LPS



Pool pH

Table 6-1: Post-LOCA pH Calculation without LPS

Initial conditions

SC water mass	*4,961,429 lbm*	*Table 4.9 (maximum values)*
RCS mass	0 lbm	Table 4.9 (maximum values)
Total post-LOCA SC mass	4,961,429 lbm	
suppression chamber water pH	5.5	Design Input 4.1 (minimum value)
reactor coolant pH	5.5	Design Input 4.2 (minimum value)
initial [H^+]	3.16E-06 g-mole/l	weighted average
initial [OH^-]	3.16E-09 g-mole/l	weighted average

Time (hr)	Pool Volume[1] (liter)	[HI][2] (g-moles/l)	[HNO_3][3] (g-moles/l)	[HCl][2] (g-moles/l)	[CsOH][2] (g-moles/l)	Total [H^+] (g-moles/l)	Total [OH^-] (g-moles/l)	Pool Temp (°F)	Water Density (lbm/ft^3)	K_w at Pool Temp (-)	x (g-moles/l)	[H^+] (g-moles/l)	Pool pH (-)
0	2,259,783					3.16E-06	3.16E-09	85.0	62.17	1.409E-14	-1.29E-09	3.16E-06	5.5
0.034	2,280,890		1.08E-07	7.286E-07		4.00E-06	3.16E-09	127.3	61.60	6.240E-14	-1.24E-08	4.01E-06	5.4
0.534	2,295,911	1.57E-07	1.70E-06	1.149E-05	2.04E-05	1.65E-05	2.04E-05	149.9	61.19	1.234E-13	1.65E-05	3.13E-08	7.5
1	2,299,888	4.00E-07	3.18E-06	2.15E-05	4.48E-05	2.82E-05	4.48E-05	155.3	61.09	1.438E-13	2.82E-05	8.67E-09	8.1
2	2,302,718	9.38E-07	5.26E-06	3.223E-05	9.88E-05	4.16E-05	9.88E-05	159.1	61.01	1.594E-13	4.16E-05	2.78E-09	8.6
2.034	2,302,814	9.38E-07	5.33E-06	3.254E-05	9.88E-05	4.20E-05	9.88E-05	159.2	61.01	1.599E-13	4.20E-05	2.81E-09	8.6
3	2,303,355	9.38E-07	7.07E-06	4.086E-05	9.88E-05	5.20E-05	9.88E-05	159.9	60.99	1.63E-13	5.20E-05	3.49E-09	8.5
4	2,302,537	9.39E-07	8.72E-06	4.838E-05	9.88E-05	6.12E-05	9.88E-05	158.9	61.02	1.583E-13	6.12E-05	4.21E-09	8.4
5	2,302,418	9.39E-07	1.03E-05	5.513E-05	9.88E-05	6.95E-05	9.88E-05	158.7	61.02	1.577E-13	6.95E-05	5.37E-09	8.3
6	2,302,418	9.39E-07	1.17E-05	6.135E-05	9.88E-05	7.72E-05	9.88E-05	158.7	61.02	1.577E-13	7.72E-05	7.28E-09	8.1
7	2,302,418	9.39E-07	1.26E-05	6.715E-05	9.88E-05	8.39E-05	9.88E-05	158.7	61.02	1.577E-13	8.39E-05	1.06E-08	8.0
8	2,302,418	9.39E-07	1.35E-05	7.261E-05	9.88E-05	9.02E-05	9.88E-05	158.7	61.02	1.577E-13	9.02E-05	1.83E-08	7.7
9	2,302,418	9.39E-07	1.43E-05	7.78E-05	9.88E-05	9.62E-05	9.88E-05	158.7	61.02	1.577E-13	9.62E-05	5.95E-08	7.2
10	2,302,418	9.39E-07	1.51E-05	8.275E-05	9.88E-05	1.02E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	3.19E-06	5.5
11	2,302,418	9.39E-07	1.59E-05	8.75E-05	9.88E-05	1.07E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	8.65E-06	5.1
12	2,302,418	9.39E-07	1.66E-05	9.207E-05	9.88E-05	1.13E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	1.39E-05	4.9
13	2,302,418	9.39E-07	1.72E-05	9.649E-05	9.88E-05	1.18E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	1.90E-05	4.7
14	2,302,418	9.39E-07	1.79E-05	0.0001008	9.88E-05	1.23E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.39E-05	4.6
15	2,302,418	9.39E-07	1.85E-05	0.0001049	9.88E-05	1.28E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.87E-05	4.5
16	2,302,418	9.39E-07	1.91E-05	0.000109	9.88E-05	1.32E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	3.34E-05	4.5
17	2,302,418	9.39E-07	1.97E-05	0.0001129	9.88E-05	1.37E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	3.79E-05	4.4
18	2,302,418	9.39E-07	2.03E-05	0.0001168	9.88E-05	1.41E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	4.23E-05	4.4
19	2,302,418	9.39E-07	2.08E-05	0.0001205	9.88E-05	1.45E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	4.66E-05	4.3
20	2,302,418	9.39E-07	2.14E-05	0.0001242	9.88E-05	1.50E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	5.08E-05	4.3
21	2,302,418	9.39E-07	2.19E-05	0.0001278	9.88E-05	1.54E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	5.50E-05	4.3

Table 6-1: Post-LOCA pH Calculation without LPS

Time (hr)	Pool Volume[1] (liter)	[HI][2] (g-moles/l)	$[HNO_3]$[3] (g-moles/l)	[HCl][2] (g-moles/l)	[CsOH][2] (g-moles/l)	Total $[H^+]$ (g-moles/l)	Total $[OH^-]$ (g-moles/l)	Pool Temp (°F)	Water Density (lbm/ft^3)	K_w at Pool Temp (-)	x (g-moles/l)	$[H^+]$ (g-moles/l)	Pool pH (-)
22	2,302,418	9.39E-07	2.24E-05	0.0001313	9.88E-05	1.58E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	5.90E-05	4.2
23	2,302,418	9.39E-07	2.29E-05	0.0001348	9.88E-05	1.62E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	6.30E-05	4.2
24	2,302,418	9.39E-07	2.34E-05	0.0001382	9.88E-05	1.66E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	6.69E-05	4.2
28	2,302,418	9.39E-07	2.53E-05	0.0001512	9.88E-05	1.81E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	8.19E-05	4.1
48	2,302,418	9.39E-07	3.34E-05	0.000172	9.88E-05	2.10E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	1.11E-04	4.0
72	2,302,418	9.39E-07	4.11E-05	0.0001895	9.88E-05	2.35E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	1.36E-04	3.9
96	2,302,418	9.39E-07	4.76E-05	0.0002029	9.88E-05	2.55E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	1.56E-04	3.8
120	2,302,418	9.39E-07	5.34E-05	0.000214	9.88E-05	2.72E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	1.73E-04	3.8
144	2,302,418	9.39E-07	5.87E-05	0.0002235	9.88E-05	2.86E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	1.87E-04	3.7
168	2,302,418	9.39E-07	6.35E-05	0.0002319	9.88E-05	2.99E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.01E-04	3.7
192	2,302,418	9.39E-07	6.80E-05	0.0002394	9.88E-05	3.11E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.13E-04	3.7
216	2,302,418	9.39E-07	7.22E-05	0.0002463	9.88E-05	3.23E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.24E-04	3.7
240	2,302,418	9.39E-07	7.62E-05	0.0002525	9.88E-05	3.33E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.34E-04	3.6
288	2,302,418	9.39E-07	8.37E-05	0.0002638	9.88E-05	3.52E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.53E-04	3.6
336	2,302,418	9.39E-07	9.05E-05	0.0002736	9.88E-05	3.68E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.69E-04	3.6
384	2,302,418	9.39E-07	9.69E-05	0.0002825	9.88E-05	3.84E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.85E-04	3.5
432	2,302,418	9.39E-07	1.03E-04	0.0002905	9.88E-05	3.98E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	2.99E-04	3.5
480	2,302,418	9.39E-07	1.09E-04	0.0002979	9.88E-05	4.11E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	3.12E-04	3.5
528	2,302,418	9.39E-07	1.14E-04	0.0003048	9.88E-05	4.23E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	3.24E-04	3.5
576	2,302,418	9.39E-07	1.19E-04	0.0003112	9.88E-05	4.35E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	3.36E-04	3.5
624	2,302,418	9.39E-07	1.24E-04	0.0003172	9.88E-05	4.46E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	3.47E-04	3.5
672	2,302,418	9.39E-07	1.29E-04	0.0003229	9.88E-05	4.56E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	3.57E-04	3.4
720	2,302,418	9.39E-07	1.34E-04	0.0003282	9.88E-05	4.66E-04	9.88E-05	158.7	61.02	1.577E-13	9.88E-05	3.67E-04	3.4

Notes

1) Pool volume is computed as follows: (m_{SP} / ρ_{SP})*28.31685 l/ft^3

2) The HI, HCl, and CsOH concentrations calculated in Tables 4-2, 4-4, and 4-5 are based on the SP volume from Table 4-9. To adjust for the SP volume as it changes throughout the LOCA, the concentration from Tables 4-2, 4-4, and 4-5 is multiplied by the following factor: V_{basis}/V_{SP} where V_{basis} is the volume in Table 4-9 and VSP is calculated in this sheet.

3) The HNO_3 concentration does not directly utilize the SP volume and therefore is not adjusted as described in Note 2. However, the HNO_3 generation is based on ρ_{H2O}=1000 g/l. To account for the density in the post-LOCA SP, the concentration from Table 4-3 is multiplied by ρ_{SP} / 1000 g/l * 453.6 g/lbm / 28.31685 l/ft^3

Table 6-2: Hydriodic Acid (HI) Production

9/10/05

<u>Core iodine inventory</u>			
Core iodine - gap release	7.20	g-mole	Attachment 1, Table 1-1
Core iodine - EIV release	36.02	g-mole	Attachment 1, Table 1-1
Fraction of release as HI	0.05	max	Reg Guide 1.183 (main body Ref. 7.10.2)
Gap release onset	2	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)

	Time (hr)	cumulative HI (g-mole)	suppression chamber water volume (liter)	cumulative HI (g-mole/l)
onset	0.033	0.00	2,259,685	0.00E+00
end of gap release	0.533	0.36	2,259,685	1.59E-07
	1.000	0.92	2,259,685	4.07E-07
end of EIV	2.033	2.16	2,259,685	9.56E-07

HNO_3 generation 7.3E-06 g-mole/l per MRad NUREG/CR-5950 (main body Ref. 7.13)

	Time (hr)	Suppression Chamber Water TID @ 1,850 MWt (rad)	cumulative HNO_3 (g-mole/l)
onset	0.034	1.50E+04	1.09E-07
end of gap release	0.534	2.38E+05	1.73E-06
	1	4.45E+05	3.25E-06
end of EIV	2	7.38E+05	5.38E-06
	2.034	7.47E+05	5.45E-06
	3	9.91E+05	7.23E-06
	4	1.22E+06	8.92E-06
	5	1.44E+06	1.05E-05
	6	1.64E+06	1.20E-05
	7	1.77E+06	1.29E-05
	8	1.89E+06	1.38E-05
	9	2.01E+06	1.47E-05
	10	2.12E+06	1.55E-05
	11	2.22E+06	1.62E-05
	12	2.32E+06	1.69E-05
	13	2.42E+06	1.76E-05
	14	2.51E+06	1.83E-05
	15	2.59E+06	1.89E-05
	16	2.68E+06	1.96E-05
	17	2.76E+06	2.02E-05
	18	2.84E+06	2.07E-05
	19	2.92E+06	2.13E-05
	20	3.00E+06	2.19E-05
	21	3.07E+06	2.24E-05
	22	3.14E+06	2.29E-05
	23	3.21E+06	2.35E-05
	24	3.28E+06	2.40E-05
	28	3.55E+06	2.59E-05
	48	4.68E+06	3.42E-05
	72	5.76E+06	4.21E-05
	96	6.68E+06	4.87E-05
	120	7.49E+06	5.47E-05
	144	8.22E+06	6.00E-05
	168	8.90E+06	6.49E-05
	192	9.53E+06	6.95E-05
	216	1.01E+07	7.39E-05
	240	1.07E+07	7.80E-05
	288	1.17E+07	8.56E-05
	336	1.27E+07	9.26E-05
	384	1.36E+07	9.92E-05
	432	1.44E+07	1.05E-04
	480	1.52E+07	1.11E-04
	528	1.60E+07	1.17E-04
	576	1.67E+07	1.22E-04
	624	1.74E+07	1.27E-04
	672	1.81E+07	1.32E-04
	720	1.88E+07	1.37E-04

Cables

PVC properties:

radiolysis yield, G	7.980E-06 g-mole HCl per MRad-g	main body §5.5
linear absorption coefficient	38.976 cm^{-1} for beta radiation	Attachment 3
linear absorption coefficient	0.0739 cm^{-1} for gamma radiation	Attachment 3

Cable jacket and insulation:

Typical Cable		
cable OD	0.22	in
jacket thickness	30	mil
jacket material	PVC	
insulation thickness	0	mil
insulation material	n/a	

chlorine-bearing material:

mass in free air	1,400.0	lbm
mass in tray	0.0	lbm
mass in free air	635,026.0	gram
mass in tray	0.0	gram

Irradiation:

	Typical Cable		
		beta	
	gamma	free air	tray
cable radius (cm)	0.2794	0.2794	0.2794
jacket thickness (cm)	0.0762	0.0762	0.0762
mass irradiated (g)	635,026.0	635,026.0	0.0
flux averaging factor	0.997337	0.341356	0.341356
absorption factor	0.005615	0.948695	0.948695

Table 6-4: Hydrochloric Acid (HCl) Production

Time (hr)	pool volume (liter)	gamma TID (rad)	beta TID (rad)	Drywell HCl gamma (g-mole)	Drywell HCl beta (g-mole)	HCl (g-mole/l)
0.034	2,259,685	3.48E+04	1.01E+06	9.87E-04	1.66E+00	7.35E-07
0.534	2,259,685	5.52E+05	1.61E+07	1.57E-02	2.64E+01	1.17E-05
1	2,259,685	1.04E+06	3.01E+07	2.94E-02	4.94E+01	2.19E-05
2	2,259,685	1.59E+06	4.52E+07	4.52E-02	7.42E+01	3.28E-05
2.034	2,259,685	1.61E+06	4.56E+07	4.57E-02	7.49E+01	3.32E-05
3	2,259,685	2.05E+06	5.73E+07	5.81E-02	9.41E+01	4.16E-05
4	2,259,685	2.45E+06	6.78E+07	6.95E-02	1.11E+02	4.93E-05
5	2,259,685	2.81E+06	7.73E+07	7.98E-02	1.27E+02	5.62E-05
6	2,259,685	3.15E+06	8.60E+07	8.94E-02	1.41E+02	6.25E-05
7	2,259,685	3.31E+06	9.41E+07	9.40E-02	1.55E+02	6.84E-05
8	2,259,685	3.46E+06	1.02E+08	9.82E-02	1.67E+02	7.4E-05
9	2,259,685	3.60E+06	1.09E+08	1.02E-01	1.79E+02	7.93E-05
10	2,259,685	3.72E+06	1.16E+08	1.06E-01	1.90E+02	8.43E-05
11	2,259,685	3.84E+06	1.23E+08	1.09E-01	2.01E+02	8.92E-05
12	2,259,685	3.95E+06	1.29E+08	1.12E-01	2.12E+02	9.38E-05
13	2,259,685	4.05E+06	1.35E+08	1.15E-01	2.22E+02	9.83E-05
14	2,259,685	4.15E+06	1.41E+08	1.18E-01	2.32E+02	0.000103
15	2,259,685	4.25E+06	1.47E+08	1.21E-01	2.41E+02	0.000107
16	2,259,685	4.34E+06	1.53E+08	1.23E-01	2.51E+02	0.000111
17	2,259,685	4.42E+06	1.58E+08	1.26E-01	2.60E+02	0.000115
18	2,259,685	4.51E+06	1.64E+08	1.28E-01	2.69E+02	0.000119
19	2,259,685	4.59E+06	1.69E+08	1.30E-01	2.77E+02	0.000123
20	2,259,685	4.66E+06	1.74E+08	1.32E-01	2.86E+02	0.000127
21	2,259,685	4.74E+06	1.79E+08	1.34E-01	2.94E+02	0.00013
22	2,259,685	4.81E+06	1.84E+08	1.37E-01	3.02E+02	0.000134
23	2,259,685	4.88E+06	1.89E+08	1.39E-01	3.10E+02	0.000137
24	2,259,685	4.95E+06	1.94E+08	1.40E-01	3.18E+02	0.000141
28	2,259,685	5.18E+06	2.12E+08	1.47E-01	3.48E+02	0.000154
48	2,259,685	6.07E+06	2.41E+08	1.72E-01	3.96E+02	0.000175
72	2,259,685	6.84E+06	2.66E+08	1.94E-01	4.36E+02	0.000193
96	2,259,685	7.45E+06	2.85E+08	2.11E-01	4.67E+02	0.000207
120	2,259,685	7.96E+06	3.00E+08	2.26E-01	4.93E+02	0.000218
144	2,259,685	8.40E+06	3.13E+08	2.38E-01	5.14E+02	0.000228
168	2,259,685	8.79E+06	3.25E+08	2.49E-01	5.34E+02	0.000236
192	2,259,685	9.14E+06	3.36E+08	2.59E-01	5.51E+02	0.000244
216	2,259,685	9.46E+06	3.45E+08	2.69E-01	5.67E+02	0.000251
240	2,259,685	9.76E+06	3.54E+08	2.77E-01	5.81E+02	0.000257
288	2,259,685	1.03E+07	3.70E+08	2.92E-01	6.07E+02	0.000269
336	2,259,685	1.08E+07	3.84E+08	3.06E-01	6.30E+02	0.000279
384	2,259,685	1.12E+07	3.96E+08	3.18E-01	6.50E+02	0.000288
432	2,259,685	1.16E+07	4.07E+08	3.30E-01	6.69E+02	0.000296
480	2,259,685	1.20E+07	4.18E+08	3.40E-01	6.86E+02	0.000304
528	2,259,685	1.23E+07	4.27E+08	3.50E-01	7.01E+02	0.000311
576	2,259,685	1.26E+07	4.36E+08	3.59E-01	7.16E+02	0.000317
624	2,259,685	1.29E+07	4.45E+08	3.67E-01	7.30E+02	0.000323
672	2,259,685	1.32E+07	4.53E+08	3.75E-01	7.43E+02	0.000329
720	2,259,685	1.35E+07	4.60E+08	3.83E-01	7.55E+02	0.000334

Table 6-5: Cesium Hydroxide (CsOH) Production

Core cesium - gap release	53.72	g-mole	Attachment 1, Table 1-2
Core cesium - EIV release	214.87	g-mole	Attachment 1, Table 1-2
CsI - gap release	6.84	g-mole	fraction iodine release in form of CsI
CsI - EIV release	34.22	g-mole	fraction iodine release in form of CsI
CsOH - gap release	46.88	g-mole	
CsOH - EIV release	180.65	g-mole	
Gap release onset	2	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
Gap release duration	30	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)
EIV duration	90	minutes	Reg Guide 1.183 (main body Ref. 7.10.2)

	Time (Hr)	cumulative CsOH (g-mole)	suppression pool volume (liter)	cumulative CsOH (g-mole/l)
onset	0.033	0.00	2,259,685	0.00E+00
end of gap release	0.533	46.88	2,259,685	2.07E-05
	1.000	103.08	2,259,685	4.56E-05
end of EIV	2.033	227.53	2,259,685	1.01E-04

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Buffering by Liquid Poison System

LPS:			
Nominal LPS pump flow rate	30	gpm	Design Input 4.12
Min LPS injection tank volume	1,325	gal	Design Input 4.12
Max LPS temp	105	°F	Design Input 4.12
Min LPS temp	70	°F	Design Input 4.12
LPS SPB concentration by weight	9.423%		Design Input 4.12
Specific gravity	1.0		Design Input 4.12
Water density at max LPS temperature	61.93		Ref. 7.18
LPS solution density at max temperature	61.93	lbm/ft^3	
Final suppression pool temp (bounding)	200	°F	
Boric acid K	1.30E-09	at	200 °F
MW sodium pentaborate ($Na_2B_{10}O_{16}*10H_2O$)	585.984		Design Input 4.12
Volume sodium pentaborate	177.1	ft^3	
Mass sodium pentaborate	1,033.6	lbm	
Mass sodium pentaborate	800.1	g-mole	
Unbuffered pH	3.44		
Unbuffered $[H^+]$	3.673E-04	g-mole/l	
Suppression chamber water volume	2,259,685	liter	
Equivalents unbuffered $[H^+]$	829.9	g-mole	
Final pH	7.91		
Time to inject boron	44.2	minutes	

Time [hr]	gamma dose: Torus Water TID @ 1850 MWt [rad]	gamma dose: Drywell & Wetwell TID @ 1850 MWt [rad]	beta dose: Drywell TID @ 1850 MWt [rad]	Source for γ Values [-]	Source for β Values [-]
0					
0.034	1.5E+04	3.5E+04	1.0E+06	linear interpolation	linear interpolation
0.534	2.4E+05	5.5E+05	1.6E+07	linear interpolation	linear interpolation
1	4.454E+05	1.035E+06	3.011E+07	Attachment 2, Table 2-2	Attachment 2, Table 2-1
2	7.4E+05	1.6E+06	4.5E+07	log-log interpolation	log-log interpolation
2.034	7.5E+05	1.6E+06	4.6E+07	log-log interpolation	log-log interpolation
3	9.9E+05	2.0E+06	5.7E+07	log-log interpolation	log-log interpolation
4	1.2E+06	2.4E+06	6.8E+07	log-log interpolation	log-log interpolation
5	1.4E+06	2.8E+06	7.7E+07	log-log interpolation	log-log interpolation
6	1.641E+06	3.150E+06	8.6E+07	Attachment 2, Table 2-2	log-log interpolation
7	1.8E+06	3.3E+06	9.4E+07	log-log interpolation	log-log interpolation
8	1.9E+06	3.5E+06	1.0E+08	log-log interpolation	log-log interpolation
9	2.0E+06	3.6E+06	1.1E+08	log-log interpolation	log-log interpolation
10	2.1E+06	3.7E+06	1.2E+08	log-log interpolation	log-log interpolation
11	2.2E+06	3.8E+06	1.2E+08	log-log interpolation	log-log interpolation
12	2.3E+06	3.9E+06	1.3E+08	log-log interpolation	log-log interpolation
13	2.4E+06	4.1E+06	1.4E+08	log-log interpolation	log-log interpolation
14	2.5E+06	4.2E+06	1.4E+08	log-log interpolation	log-log interpolation
15	2.6E+06	4.2E+06	1.5E+08	log-log interpolation	log-log interpolation
16	2.7E+06	4.3E+06	1.5E+08	log-log interpolation	log-log interpolation
17	2.8E+06	4.4E+06	1.6E+08	log-log interpolation	log-log interpolation
18	2.8E+06	4.5E+06	1.6E+08	log-log interpolation	log-log interpolation
19	2.9E+06	4.6E+06	1.7E+08	log-log interpolation	log-log interpolation
20	3.0E+06	4.7E+06	1.7E+08	log-log interpolation	log-log interpolation
21	3.1E+06	4.7E+06	1.8E+08	log-log interpolation	log-log interpolation
22	3.1E+06	4.8E+06	1.8E+08	log-log interpolation	log-log interpolation
23	3.2E+06	4.9E+06	1.9E+08	log-log interpolation	log-log interpolation
24	3.282E+06	4.950E+06	1.9E+08	Attachment 2, Table 2-2	log-log interpolation
28	3.6E+06	5.2E+06	2.121E+08	log-log interpolation	Attachment 2, Table 2-1
48	4.7E+06	6.1E+06	2.4E+08	log-log interpolation	log-log interpolation
72	5.8E+06	6.8E+06	2.7E+08	log-log interpolation	log-log interpolation
96	6.7E+06	7.5E+06	2.8E+08	log-log interpolation	log-log interpolation
120	7.5E+06	8.0E+06	3.0E+08	log-log interpolation	log-log interpolation
144	8.2E+06	8.4E+06	3.1E+08	log-log interpolation	log-log interpolation
168	8.9E+06	8.8E+06	3.3E+08	log-log interpolation	log-log interpolation
192	9.5E+06	9.1E+06	3.4E+08	log-log interpolation	log-log interpolation
216	1.0E+07	9.5E+06	3.5E+08	log-log interpolation	log-log interpolation
240	1.1E+07	9.8E+06	3.5E+08	log-log interpolation	log-log interpolation
288	1.2E+07	1.0E+07	3.7E+08	log-log interpolation	log-log interpolation
336	1.3E+07	1.1E+07	3.8E+08	log-log interpolation	log-log interpolation
384	1.4E+07	1.1E+07	4.0E+08	log-log interpolation	log-log interpolation
432	1.4E+07	1.2E+07	4.1E+08	log-log interpolation	log-log interpolation
480	1.5E+07	1.2E+07	4.2E+08	log-log interpolation	log-log interpolation
528	1.6E+07	1.2E+07	4.3E+08	log-log interpolation	log-log interpolation
576	1.7E+07	1.3E+07	4.4E+08	log-log interpolation	log-log interpolation
624	1.7E+07	1.3E+07	4.4E+08	log-log interpolation	log-log interpolation
672	1.8E+07	1.3E+07	4.5E+08	log-log interpolation	log-log interpolation
720	1.875E+07	1.350E+07	4.6E+08	Attachment 2, Table 2-2	log-log interpolation
2400	4.219E+07	2.115E+07	6.134E+08	Attachment 2, Table 2-2	Attachment 2, Table 2-1

Note: Shaded values taken from Attachment 2.

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Table 6-8: Post-LOCA Suppression Chamber Water Temperature Response

From Data (Ref. 7.6.5)

Time Post-LOCA (sec/days)*	(hr)	Temp (°F)
0	0	85
2.81	7.81E-04	89.1
5.83	1.62E-03	95.77
8.95	2.49E-03	102.7
12.08	3.36E-03	109.4
15.2	4.22E-03	114.7
30.83	8.56E-03	122.1
99.58	0.028	126.5
	0.034	127.3
296.2	0.082	133.7
910.58	0.253	143.5
	0.534	149.9
2,622.58	0.728	154.3
	1	155.3
	2	159.1
	2.034	159.2
8,349.58	2.319	160.3
9,574.08	2.659	160.3
	3	159.9
	4	158.9
14,925.33	4.146	158.7
	5	158.7
	6	158.7
	7	158.7
	8	158.7
	9	158.7
	10	158.7
	11	158.7
	12	158.7
	13	158.7
	14	158.7
	15	158.7
	16	158.7
	17	158.7
	18	158.7
	19	158.7
	20	158.7
	21	158.7
	22	158.7
	23	158.7
	24	158.7
	28	158.7
2	48	158.7
3	72	158.7
4	96	158.7
5	120	158.7
6	144	158.7
7	168	158.7
8	192	158.7
9	216	158.7
10	240	158.7
12	288	158.7
14	336	158.7
15	360	158.7
	384	158.7
	432	158.7
20	480	158.7
	528	158.7
	576	158.7
25	600	158.7
	624	158.7
	672	158.7
30	720	158.7

* Seconds are the units for t=0 to 24 hours; days are the units for t=48 to 720 hours.

Used for pH Analysis

Time (hr)	Temp (°F)
0	85.0
0.034	127.3
0.534	149.9
1	155.3
2	159.1
2.034	159.2
3	159.9
4	158.9
5	158.7
6	158.7
7	158.7
8	158.7
9	158.7
10	158.7
11	158.7
12	158.7
13	158.7
14	158.7
15	158.7
16	158.7
17	158.7
18	158.7
19	158.7
20	158.7
21	158.7
22	158.7
23	158.7
24	158.7
28	158.7
48	158.7
72	158.7
96	158.7
120	158.7
144	158.7
168	158.7
192	158.7
216	158.7
240	158.7
288	158.7
336	158.7
384	158.7
432	158.7
480	158.7
528	158.7
576	158.7
624	158.7
672	158.7
720	158.7

The shaded values are taken from Reference 7.6.5 (Design Input 4.15). Other other values are either interpolated or extrapolated. The long term temperature is maintained at 158.7°F.

Table 6-9: Post-LOCA Suppression Chamber Water Volumes

Parameter	Symbol	Unit	Minimum SC Mass	Maximum SC Mass	Reference
Suppression Chamber Water (SC)					
Suppression chamber water volume	V_{SC}	ft^3	79,800	86,000	Design Input 4.6
Suppression chamber water temperature	T_{SC}	°F	85	60	Design Input 4.7
Suppression chamber pressure	P_{SC}	psia	14.7	14.7	Design Input 4.8
Density of suppression chamber water	ρ_{SC}	lbm/ft^3	62.17	62.37	Ref. 7.18
Mass of water in suppression chamber	m_{SC}	lbm	4,961,429	5,364,128	$= V_{SC}{*}\rho_{SC}$
Reactor Coolant System (RCS)					
RCS mass	m_{RCS}	ft^3	501,500	501,500	Design Input 4.3
Post-LOCA (SC+RCS)					
RCS mass added to SC	$m_{RCS,tot}$	lbm	0	501,500	no RCS mass included in SC for min; all steam condenses in SC for max
Total water mass in SC	$m_{PL\_SC,tot}$	lbm	4,961,429	5,865,628	$= m_{SC} + m_{RCS}$
Total volume of water in SC	$V_{PL\_SC,tot}$	ft^3	79,800	94,040	$= m_{PL\_SC,tot} / \rho_{SC}$
Total volume of water in SC	$V_{PL\_SC,tot}$	liters	2,259,685	2,662,924	$= V_{PL\_SC,tot}$ [ft^3] * 28.31685 liter/ft^3

Attachment 7: DESIGN VERIFICATION REPORT

Document being design-verified: ☐ DCP ☑ Calc ☐ Spec ☐ NER ☐ DBD ☐ Other

Doc#, Rev and Title: H21C08~~2~~4 (aml 1/10/05) Revision 0, "Post-LOCA Suppression Chamber (Torus) Water pH Analysis"

Extent of Design Verification (Briefly describe):
A detailed review of the calculation was performed by the mechanical, radiological, and chemistry disciplines.

Method of Design Verification:

☑ Design Review ☐ Qualification Testing
☐ Alternate Calculations ☐ Applicability of Proven Design

Results of Design Verification:

☑ Fully acceptable with no issues identified
☐ Fully acceptable based on the following issues identified and resolved:

☐ Continuation Page Follows

Discipline Involvement and Approvals:

	Name	Signature	Date
Lead Design Verifier:	Matthew B. Cooper	Matthew B Cooper	12/27/04

Discipline Design Verifiers, if required:

Discipline	Name	Signature	Date
Chemistry	Jeri C. Penrose	Jeri C. Penrose	12-27-04
Radiological	W. Joseph Johnson	[signature]	12-28-04