Attachment 9

Doses from Iodine Re-evolution
XC-Q1111-98014, Revision 1

DESIGN ENGINEERING CALCULATION
GRAND GULF NUCLEAR STATION
UNIT ONE

CALC NO.: XC-Q1111-98014
REVISION: 1
PAGE i **of** iii

TITLE: Doses from Iodine Re-evolution

REVISION STATUS
☐ Pending
☒ Final
☐ Canceled

SUPERSEDED BY:
☒ N/A
Calc.
Rev.:

SUPERSEDES:
☒ N/A
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Rev.:

☒ Safety Related
☐ Non Safety Related
☐ Appendix B

ORG CODE: NPE-Safety Analysis

CALC TYPE NUCSAFE

KEYWORD(S):
ACCIDENT
DOSE

AFFECTED COMPONENT(S): (add sheets as needed)
N/A

SYSTEM(s): N/A

COMMENT(s): N/A

SOFTWARE USED FOR CALCULATION: ☐ Yes ☒ No

Software Manufacturer:

Software Name/ Program No:

Version/ Release No:

REVIEW AND APPROVAL

PREPARED BY: G.E. Broadbent / G.E. Broadbent **DATE:** 6/14/99
Signature / Name

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Supervisor Signature / Name

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Responsible Manager Signature / Name

REVISION STATUS SHEET

ENGINEERING CALCULATION REVISION SUMMARY

REVISION	DATE	DESCRIPTION
0	4/2/99	Issue for use
1	6/16/99	Revised to include control room model

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SHEET REVISION STATUS

SHEET NO.	REVISION	SHEET NO.	REVISION	SHEET NO.	REVISION
i	1	5	0	12	1
ii	1	6	1	13	1
iii	1	7	1	14	1
1	1	8	1	15	1
2	1	9	1	16	1
3	1	10	1		
4	1	11	1		

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APPENDIX/ATTACHMENT REVISION STATUS

APPENDIX NO.	REVISION	ATTACHMENT NO.	REVISION
		1	1
		2	1
		3	1
		4	1

TABLE OF CONTENTS

1.0 PURPOSE

The GGNS suppression pool pH analysis [1] concludes that the pool pH does not drop below a value of 7 in the event of a design basis LOCA. This evaluation, however, is sensitive to a number of assumptions which, if changed to become more restrictive, could result in a late pH transient. This calculation evaluates the offsite radiological impact of the resulting iodine re-evolution using the methodology reported in Engineering Report GGNS-98-0039 [3]. Revision 1 of this calculation adds a control room model and updates the containment leakage rate. △1

2.0 BACKGROUND

BWR suppression pools are credited in minimizing containment pressurization by condensing steam resulting from a loss of coolant accident (LOCA). At GGNS, the suppression pool is also credited for the long-term retention of iodine, which is washed into the pool by containment spray or by the scrubbing of airborne source term flows through the pool. Section 5.2 of NUREG-1465 [2] reports that there is a potential for suppression pools to scrub substantial amounts of iodine in the early phases of an accident only to re-evolve it later as elemental iodine.

Since the NRC has not formally endorsed a methodology for evaluating suppression pool pH transients and all analyses submitted to date have been proprietary, a generic methodology was developed in Reference 3. This methodology assumes that all of the released cesium that is not in the chemical form of cesium iodide is released as cesium hydroxide and is immediately dissolved in the suppression pool, serving to moderate the pH transient by neutralizing the acids that enter the pool during the accident. Although a transport calculation was not prepared to support this cesium assumption, it was felt that this assumption was conservative when taken in conjunction with the assumption that all hydrochloric acid generated by cable radiolysis is immediately transported to the suppression pool without consideration of any loss due to reaction with the metal surfaces in the containment and drywell.

This calculation evaluates the potential radiological consequences of iodine re-evolution at GGNS if this assumption on cesium hydroxide is modified. For the resulting pH transient, the iodine re-evolution from the pool and the offsite dose are evaluated using the methodology in Reference 3. △1

3.0 GIVEN

3.1 Suppression Pool pH Transient

The GGNS pH profile is reported in Reference 1 (and illustrated below) based on a cesium hydroxide inventory being 100% of the released cesium that is not in the form of cesium iodide. This calculation will consider cesium hydroxide fractions as low as 60% of the released cesium that is not in the form of cesium iodide. △1

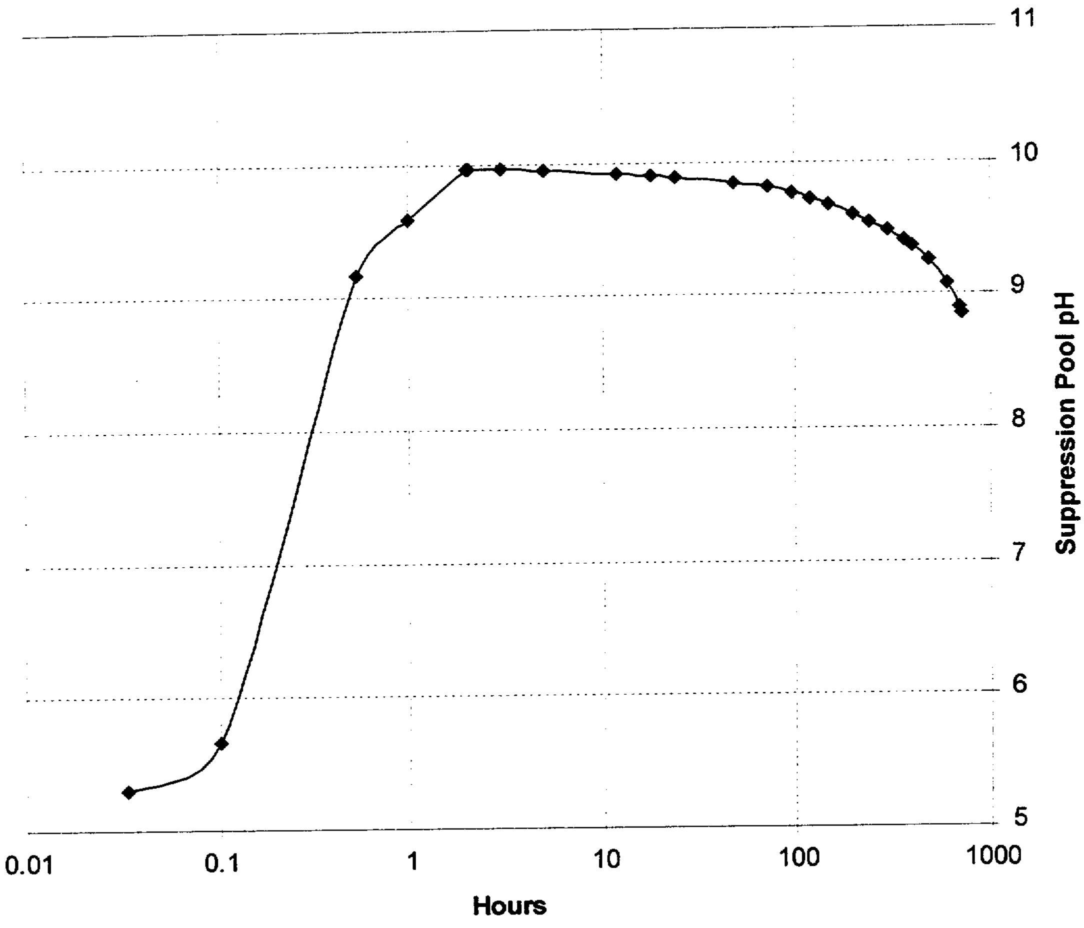

Figure 3-1 GGNS Pool pH Transient

3.2 Analytical Methodology

This calculation will utilize the iodine re-evolution methodology outlined in Engineering Report GGNS-98-0039 [3].

3.3 Breathing Rate

The breathing rate applied in the calculation of the inhalation dose at the LPZ is 2.32E-4 m^3/s per Section 2.c of Regulatory Guide 1.3 [4] for times after 24 hours. The breathing rate in the control room is 3.47E-4 m^3/s [11]. △1

3.4 SGTS Model

A SGTS flow of 4000 cfm is applied with 1 cfm bypassing the charcoal filter train. The charcoal bed is tested to a 99% removal efficiency for both elemental and organic iodine. With these inputs, the effective SGTS efficiency can be calculated to be 98.975%.

$$eff = 1.0 - \frac{(4000\,\text{cfm})\cdot(1-0.99)+(1\,\text{cfm})\cdot(1-0.00)}{4001\,\text{cfm}} = 0.98975$$

3.5 Pool Iodine Inventory

The initial pool iodine inventory is based on the bounding iodine source terms calculated in Table 5-3 of Reference 6 and decay constants applied in the RADTRAD code, documented in NUREG/CR-6604 [5]. The half-life of I-129 is taken to be 1.6E7 years. Consistent with the gap and in-vessel release phases, 30% of the core iodine is assumed to be dissolved in the suppression pool. This iodine distribution is listed below. As discussed in Section 4.4, the suppression pool pH is assumed to remain above 7 for the first 96 hours. The pool iodine inventory is therefore calculated below at 96 hours.

Table 3-1 Applied Isotopic Distribution

Isotope	Decay Constant (hr^{-1})	Core Inventory @ t=0 (g-atoms)	Core Inventory @ 96 hrs (g-atoms)	Pool Inventory @ 96 hrs(g-atoms)
I-127	0.0000E+00	7.175E+01	7.175E+01	21.525
I-129	4.9420E-12	2.295E+02	2.295E+02	68.850
I-131	3.5922E-03	6.630E+00	4.696E+00	1.409
I-132	3.0137E-01	0.000E+00	0.000E+00	0.000
I-133	3.3324E-02	1.420E+00	5.793E-02	0.017
I-134	7.9066E-01	0.000E+00	0.000E+00	0.000
I-135	1.0486E-01	4.300E-01	1.826E-05	0.000
				91.784

The inventories of I-132, I-133, I-134, and I-135 are neglected considering their insignificant pool inventories after 96 hours of decay.

3.6 Dose Conversion Factors

The effective dose conversion factors for the TEDE calculation are taken from FGR 11 [8] and 12 [9] as reported below.

Isotope	Inhalation DCF (Rem/Ci) [8]	Submersion DCF (Rem-m^3/s-Ci) [9]
I-127	0	0
I-129	1.7353E5	1.406E-3
I-131	3.2893E4	6.734E-2

3.7 Dispersion Coefficient

The GGNS LPZ χ/Q after 96 hours is 1.60E-5 s/m^3 [10]. The χ/Q from the SGTS vent to the control room intakes after 96 hours is 1.04E-4 s/m^3 [12].

3.8 Control Room Parameters

The control room occupancy factor is 0.4 after 96 hours [11]. The control room inleakage is modeled as the normal HVAC intake rate of 2000 cfm [13] into a control room volume of 2.53E5 ft^3 [14]. From this volume, the Murphy-Campe geometry factor can be calculated as 17.5to convert the dose from an infinite cloud to a dose from a finite cloud based on the formula in Section V.C of Reference 11.

4.0 ASSUMPTIONS

4.1 Isotopic Distribution

As developed in Section 5 of Engineering Report GGNS-98-0039, the aqueous I_2 concentration is a complex function of the pool pH and pool iodine concentration as described by the following equation.

$$[I_2]_{aq} = \frac{[I]_{aq}}{2} + \frac{d + e10^{-pH}}{8 * 10^{-2pH}} - \frac{1}{8 * 10^{-pH}}\sqrt{\frac{(d + e10^{-pH})^2}{10^{-2pH}} + 8[I]_{aq} * (d + e10^{pH})} \qquad (4\text{-}1)$$

Consistent with the discussion in Section 5 of Engineering Report GGNS-98-0039, this formula is applied with the total aqueous iodine inventory. The airborne iodine concentration is calculated from the aqueous concentration via the partition coefficient reported below.

$$PC = \frac{[I_2]_{aq}}{[I_2]_{gas}} = 10^{6.29-0.01497T} \qquad (4\text{-}2)$$

The airborne I_2 isotopic distribution is considered identical to the total pool iodine isotopic distribution.

4.2 Pool Temperature

The pool temperature transient after 96 hours is developed from the containment analysis in ABD-4 [7]. As shown in Figure 17 of ABD-4 [7], the suppression pool temperature is ~130°F after ~96 hours with minimum ECCS decreasing with the decay heat load to ~115°F at 30 days. The impact of the initial 2-hour core uncovery on this temperature profile is considered negligible since at this late period the suppression pool temperature is serving to remove the core decay heat. Adding 5 °F to the values read from this figure to consider uncertainties in reading these values from the plot and in fitting these values to a curve, the following expression can be developed. Table 4-1 illustrates the good fit achieved by this correlation.

$$T_{pool} = 225.2828 - 7.1240 \cdot \ln(t)$$

where:

t = time into accident (s).

Table 4-1 Suppression Pool Temperature Curve Fit

Time	Pool Temp from ABD-4 (°F)	Assumed Pool Temp (°F)	Calculated Pool Temp (°F)
3.1623E5	130	135	135.06
1.0E6	122	127	126.86
2.592E6	115	120	120.08

4.3 Plateout

Although the elemental iodine is expected to plateout in the containment, Auxiliary Building, and Enclosure Building, this effect is conservatively neglected.

4.4 Transient Timing

The transient pH profile will be calculated based on the assumed cesium hydroxide release fraction; however, it is assumed that the pH will remain above 7 for the first 96 hours. As such, the LPZ breathing rate in Section 3.3 is applicable as well as the LPZ χ/Q in Section 3.7. The sliding 2-hour EAB window is assumed to occur within the first few hours of the accident and, consequently, the EAB dose is not calculated in this analysis. A statement in the computer code will print a warning if the pH drops below 7 before 96 hours.

4.5 Pool Volume

Consistent with the suppression pool pH analysis [1], this calculation considers the additional pool inventory from the suppression pool makeup system and applies a total water volume of 170,954 ft^3 (4.841E6 liters). The impact of ESF leakage is insignificant compared to the large suppression pool volume and is consequently neglected.

4.6 Leak Rates

This calculation will assume a total MSIV leak rate of 250 scfh and a containment leak rate of 0.385% per day. Consistent with the recent draft regulatory guidance (distributed in a public NRC meeting on April 20, 1999 and included in Reference 15), the containment leak rate can be assumed to be reduced by a factor of 2 after 24 hours. The containment leak rate after 24 hours is calculated below to be equal to 112.3 ft^3 per hour.

$$1.4E6\ ft^3 \cdot \frac{0.385\%}{day} \cdot \frac{day}{24\ hours} \cdot 0.5 = 112.3\frac{ft^3}{hr}$$

The drywell atmosphere will not be at standard conditions after the reactor blowdown. Since this analysis will apply a flow rate from one volume to another without regard to thermal-hydraulic conditions, this leakage rate must be converted to a flow at the drywell conditions. After 4 days from the onset of the accident, the steamlines are expected to have cooled significantly from their original operating temperature such that the bulk drywell temperature can be applied to this leakage. Based on the drywell responses in the GGNS containment analysis in ABD-4 [7], a maximum drywell temperature of 150 °F is applicable for the large-break LOCA analyses after 96 hours. As calculated below at the tested pressure of 11.5 psig, a 100-scfh MSIV leakage rate would result in a nominal flow of 65.8 ft^3/hr at the drywell temperature.

$$100\frac{ft^3}{hr} \cdot \frac{459.67\ ^\circ R + 150\ ^\circ F}{459.67\ ^\circ R + 60\ ^\circ F} \cdot \frac{14.696\ psi}{14.696 + 11.5\ psi} = 65.8\frac{ft^3}{hr}$$

Consistent with the recent draft regulatory guidance, the MSIV leak rate can be assumed to be reduced by a factor of 2 after 24 hours. Considering the 250 scfh leakage rate, the total drywell leak rate after 24 hours to the Auxiliary Building can then be calculated as 82.3 ft^3 per hour.

After 96 hours, the source term concentrations in the containment and drywell volumes are assumed to be identical. As such, a total leak rate of 194.6 ft^3 per hour is assumed from the combined drywell/containment to the Auxiliary Building. △1

4.7 Iodine Chemical Species
The iodine re-evolved from the suppression pool is in the elemental species and is assumed to remain in this chemical form for the entire analysis period. If 3% of this iodine were to convert to the organic species consistent with Section 3.5 of NUREG-1465, the results would be unchanged since the transport paths applied in this analysis do not differentiate between the elemental and organic iodine species (*i.e.,* no pool scrubbing or containment spray is assumed). Also, the SGTS charcoal beds have the same removal efficiency for iodine in the elemental and organic species.

4.8 Early Re-evolution
As illustrated in Figure 3-1, the pool pH rapidly rises from the initial value of 5.3 to ~10 due to the addition of cesium hydroxide to the pool at the onset of the event. However, in addition to cesium hydroxide, iodine is also being added to the pool during this early period. Any potential pH-driven iodine evolution during this early period is ignored due to the very low iodine concentrations in the suppression pool at this time. Also, after approximately 6 minutes, the pool pH reaches a value of 6.0 at which the iodine evolution is negligible at these low iodine concentrations per Equation 4-1 and Figure 5-1 of Engineering Report GGNS-98-0039.

4.9 Mixing Efficiency
The airborne iodine source terms in the containment air are assumed to be homogeneously mixed with the entire containment atmosphere. Although the aqueous iodine in the suppression pool will approach equilibrium with the atmosphere just above the suppression pool, it is conservatively assumed that the containment is well mixed such that this equilibrium is established with the entire containment atmosphere. The volume of this atmosphere is 1.67E6 ft^3 per Table 1 of ABD-4 [7]. This assumption maximizes the airborne iodine inventory available for leakage. △1

A mixing efficiency of 50% is applied in the enclosure building through the application of half the actual building volume of 600,000 ft^3 consistent with the LOCA dose analysis [16]. No credit is taken for mixing or holdup in the Auxiliary Building. △1

5.0 CALCULATIONS

A computer program was written to evaluate the LPZ radiological impact of iodine re-evolution from the suppression pool. This program was then benchmarked against the solution of a simplified model. This section described this computer program and the associated benchmarks. This computer program is considered a single-use code fully documented in this calculation such that the requirements in Design Engineering Administrative Procedure 600 do not apply.

5.1 Computer Model

A computer program was written in Visual C++ to evaluate the LPZ dose resulting from iodine re-evolution from the suppression pool after 96 hours. This computer program is listed in Attachment 1 and considers:

- a transient suppression pool pH,
- homogeneous mixing in all nodes,
- radioactive decay, and
- iodine inventory depletion due to leakage.

A simplified flow diagram is illustrated below. This program evaluates the containment iodine inventory every second starting at 96 hours into the accident and calculates a containment airborne inventory based on the suppression pool temperature and pH such that the iodine concentration in the containment atmosphere is always in equilibrium with the suppression pool water. The pH results from Reference 1 are coded into a function called CalcpH. The iodine concentration in the enclosure building is updated each second through the event. The results of this program are reported in Attachment 2.

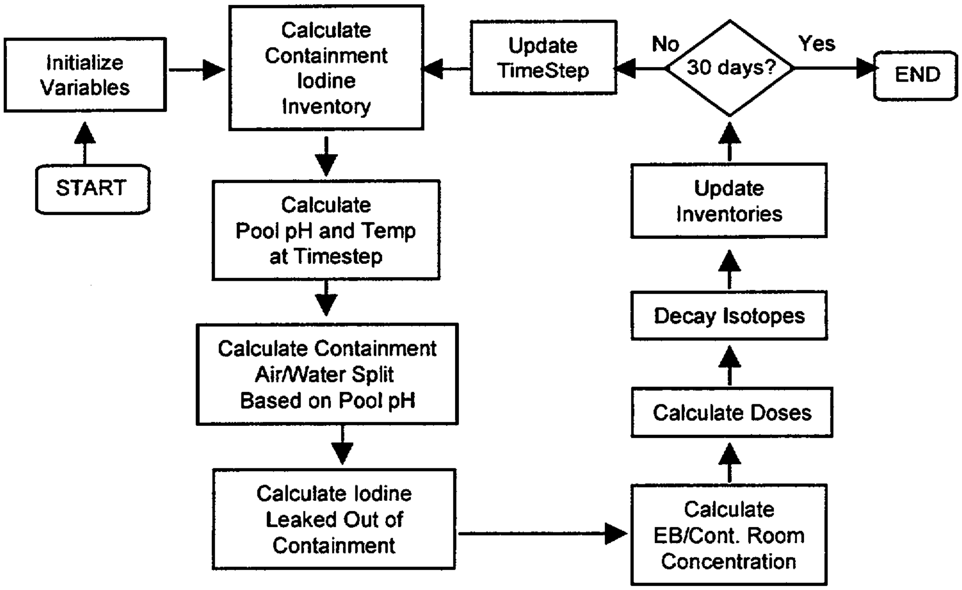

Figure 5-1 Computer Program Flow Diagram

5.2 Program Benchmark

This program can be benchmarked with a simplified analytical model in which the suppression pool temperature and pH are assumed to remain constant throughout the analysis period and the impact of leakage on the containment airborne inventory is conservatively neglected.

5.2.1 Governing Equations

If only radioactive decay is considered to reduce the containment/drywell airborne elemental iodine inventory (*i.e.*, leakage is neglected) and the pool pH and temperature are held constant, the elemental iodine concentration in the containment/drywell, C_A, may be established at the onset of the calculation. Otherwise, if leakage were considered (as it is in the computer program), this iodine equilibrium would have to be re-established at each timestep based on the depletion of iodine from the airborne inventory. This simplified model is illustrated in Figure 5-2.

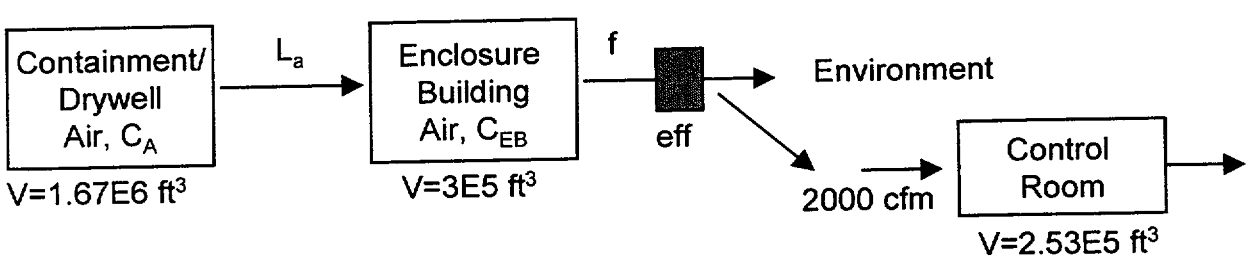

Figure 5-2 Simplified Airborne Model

With a leak rate of L_a, (194.6 ft^3/hr), this concentration leaks into the Enclosure Building since the impact of the Auxiliary Building is ignored. Since only 50% mixing is assumed in the Enclosure Building, a volume of 300,000 ft^3 is applied. The SGTS system then draws 4001 cfm (2.4E5 ft^3/hr) of the elemental iodine concentration in the Enclosure Building through the SGTS charcoal beds, which remove 98.975% of the iodine.

With an initial containment airborne concentration, C_{A0}, for each isotope, the containment airborne concentration is simply $C_{A0}e^{-\lambda t}$, where λ is the isotope's decay constant. The enclosure building concentration can then be described with the following differential equation.

$$\frac{d}{dt}C_{EB} = \frac{L_a}{V_{EB}}C_A(t) - \frac{f}{V_{EB}}C_{EB}(t) - \lambda C_{EB}(t)$$

$$\frac{d}{dt}C_{EB} + \left(\frac{f}{V_{EB}} + \lambda\right)C_{EB}(t) = \frac{L_a}{V_{EB}}C_A(t)$$

$$\frac{d}{dt}C_{EB} + \left(\frac{f}{V_{EB}} + \lambda\right)C_{EB}(t) = \frac{L_a}{V_{EB}}C_{A0}e^{-\lambda t}$$

With the initial condition that enclosure building iodine concentration (due to iodine re-evolution) is zero, $C_{EB}(t=0) = 0$, this equation can be solved for $C_{EB}(t)$.

$$C_{EB}(t) = \frac{L_a C_{A0}}{f}\left(e^{-\lambda t} - e^{-\left(\frac{f}{V_{EB}}+\lambda\right)t}\right)$$

Considering that the release rate to the environment is f*(1-eff)*C$_{EB}$(t), the LPZ dose can then be calculated with the following equation.

$$Integrated\ TEDE\ Dose(t) = f\cdot(1-eff)\cdot\frac{\chi}{Q}\cdot(DCF^{WB} + BR\cdot DCF^{inh})\cdot\int_0^t C_{EB}(t)dt$$

where:
f = SGTS flowrate (2.4E5 ft^3/hr)
eff = SGTS removal efficiency (0.98975 from Section 3.4)
χ/Q = LPZ dispersion coefficient (1.6E-5 s/m^3 for Section 3.7)
DCF^{WB} = immersion dose conversion factor (Rem-m^3/Ci-s from Section 3.6)
DCF^{inh} = inhalation dose conversion factor (Rem/Ci from Section 3.6)
BR = LPZ breathing rate (2.32E-4 m^3/s from Section 3.3)

The LPZ dose can then be calculated for each isotope with the following final equation.

$$Dose(t) = f\cdot(1-eff)\cdot\frac{\chi}{Q}\cdot\frac{L_a}{f}\cdot(DCF_i^{WB} + BR\cdot DCF_i^{inh})\cdot C_{A0,i}\cdot\left[\frac{e^{-\left(\frac{f}{V_{EB}}+\lambda_i\right)t} - 1}{\frac{f}{V_{EB}}+\lambda_i} + \frac{1-e^{-\lambda_i t}}{\lambda_i}\right]$$

The total dose is then the summation of the doses for both of the modeled radioactive isotopes.

$$Dose(t) = f\cdot(1-eff)\cdot\frac{\chi}{Q}\cdot\frac{L_a}{f}\cdot\sum_i(DCF_i^{WB} + BR\cdot DCF_i^{inh})\cdot C_{A0,i}\cdot\left[\frac{e^{-\left(\frac{f}{V_{EB}}+\lambda_i\right)t} - 1}{\frac{f}{V_{EB}}+\lambda_i} + \frac{1-e^{-\lambda_i t}}{\lambda_i}\right] \qquad (5\text{-}1)$$

In the control room, an activity balance can be written considering inleakage, outleakage, and decay similar to the enclosure building balance above.

$$\frac{d}{dt}C_{CR} = \frac{f}{V_{CR}}C_{out}(t) - \frac{f}{V_{CR}}C_{CR}(t) - \lambda C_{CR}(t)$$

$$\frac{d}{dt}C_{CR} + \left(\frac{f}{V_{CR}} + \lambda\right)C_{CR}(t) = \frac{f}{V_{CR}}C_{out}(t)$$

$\triangle 1$

where:
C$_{out}$ = activity concentration outside control room (Ci/ft^3),
f = control room inleakage/outleakage (2000 cfm per Section 3.8),

ENTERGY

CALCULATION SHEET

Sheet 11 Cont on 12
Rev. 1
Calculation No. XC-Q1111-98014
Prepared By J.E.B. Date 6/14/99 Checked By SCS Date 6/14/99

V_{CR} = control room volume (2.53E5 ft^3 per Section 3.8), and
λ = decay constant (min^{-1}).

Since the activity concentration outside the control room, C_{out}, can be calculated as f_{SGTS}*(1-eff)*$C_{EB}(t)$* χ/Q and that $C_{EB}(t)$ has been calculated explicitly above, the transient control room activity concentration can be calculated from the following differential equation.

$$\frac{d}{dt}C_{CR}+\left(\frac{f}{V_{CR}}+\lambda\right)C_{CR}(t)=\frac{f}{V_{CR}}C_{out}(t)$$

$$\frac{d}{dt}C_{CR}+\left(\frac{f}{V_{CR}}+\lambda\right)C_{CR}(t)=\frac{f}{V_{CR}}*f_{SGTS}*(1-eff)*\frac{\chi}{Q}*C_{EB}(t)$$

$$\frac{d}{dt}C_{CR}+\left(\frac{f}{V_{CR}}+\lambda\right)C_{CR}(t)=\frac{f}{V_{CR}}*f_{SGTS}*(1-eff)*\frac{\chi}{Q}*\frac{L_aC_{A0}}{f_{SGTS}}\left(e^{-\lambda t}-e^{-\left(\frac{f_{SGTS}}{V_{EB}}+\lambda\right)\cdot t}\right)$$

This differential equation can be solved for the following formula for $C_{CR}(t)$.

$$C_{CR}(t)=\frac{f}{V_{CR}}*(1-eff)*\frac{\chi}{Q}*L_aC_{A0}\left\{\frac{V_{CR}}{f}e^{-\lambda t}-\frac{e^{-\left(\frac{f_{SGTS}}{V_{EB}}+\lambda\right)\cdot t}}{\left(\frac{f}{V_{CR}}-\frac{f_{SGTS}}{V_{EB}}\right)}+\left[\frac{1}{\left(\frac{f}{V_{CR}}-\frac{f_{SGTS}}{V_{EB}}\right)}-\frac{V_{CR}}{f}\right]e^{-\left(\frac{f}{V_{CR}}+\lambda\right)\cdot t}\right\}$$

The TEDE dose contribution from each isotope can be calculated with the integral of the control room activity concentration as follows where MCGF is the Murphy-Campe Geometry Factor (17.5 from Section 3.8): △1

$$Integrated\ TEDE\ Dose(t)=\left(\frac{DCF^{WB}}{MCGF}+BR\cdot DCF^{inh}\right)\cdot\int_0^t C_{CR}(t)dt$$

$$Dose(t)=\left(\frac{DCF^{WB}}{MCGF}+BR\cdot DCF^{inh}\right)\cdot\frac{f}{V_{CR}}\cdot(1-eff)\cdot\frac{\chi}{Q}\cdot L_aC_{A0}\left\{\begin{array}{l}\frac{V_{CR}}{f}\frac{1-e^{-\lambda t}}{\lambda}+\frac{e^{-\left(\frac{f_{SGTS}}{V_{EB}}+\lambda\right)\cdot t}-1}{\left(\frac{f_{SGTS}}{V_{EB}}+\lambda\right)\left(\frac{f}{V_{CR}}-\frac{f_{SGTS}}{V_{EB}}\right)}\\+\left[\frac{\frac{V_{CR}}{f}-\frac{1}{\left(\frac{f}{V_{CR}}-\frac{f_{SGTS}}{V_{EB}}\right)}}{\left(\frac{f}{V_{CR}}+\lambda\right)}\right]\left(e^{-\left(\frac{f}{V_{CR}}+\lambda\right)\cdot t}-1\right)\end{array}\right\}$$

Similar to Equation 5-1, the above formula can be summed for each isotope to give the total TEDE dose in the control room at any time.

5.2.2 Initial Air/Water Split

For this benchmark case, the suppression pool pH will be assumed constant at a value of 4.5 for the duration of the analysis while the pool temperature remains at 150 °F. At a pool temperature of 150 °F, the iodine partition coefficient can be calculated to be 17.51 fromEq. 4-2.

As reported in Section 4.4, thirty percent of the core iodine is assumed to be initially dissolved in the 4.841E6 liters (per Section 4.5) of suppression pool water. Considering the 91.784 g-atoms of iodine in the pool water after 96 hours, an initial pool iodine concentration of 1.8960E-5 g-atoms/L can be calculated. From Eq. 4-1, the aqueous I_2 concentration can be calculated as 2.3152E-06 g-mols/L based on a pool pH of 4.5. With a partition coefficient of 17.51, the containment airborne I_2 concentration is 1.3222E-07 g-mols/L. Considering the containment/drywell combined airborne volume of 1.67E6 ft^3 (4.73E7 liters), a total quantity of 6.254 g-mols of I_2 (12.508 g-atoms of iodine) has evolved. This evolution reduces the aqueous iodine inventory to 79.276 g-atoms (91.784 – 12.508) or a concentration of 1.6376E-5 g-atoms/L, which is significantly different than the original value of 1.8960E-5 g-atoms/L. As such, the equilibrium airborne and aqueous concentration must be determined iteratively via a mass balance. This balance is reported in Attachment 3 and concludes that the equilibrium containment airborne I_2 concentration is 1.0902E-07 g-mols/L, representing 11.24% of the iodine inventory in the gaseous phase.

5.2.3 Benchmark Results

The application of Eq. 5-1 for the benchmark case leads to the results in Table 5-1. The computer code was revised to apply a constant pool pH of 4.5 and temperature of 150 °F instead of the varying parameters. The output from this revised code is listed in Attachment 4 and summarized in Table 5-1.

Table 5-1 Benchmark Results

	LPZ (Rem TEDE)			Control Room (Rem TEDE)		
Time (Hours)	**Analytical Model**	**Computer Code**	**Difference (%)**	**Analytical Model**	**Computer Code**	**Difference (%)**
96	0.000000	0.000000	0.00%	0.000000	0.000000	0.00%
100	0.001051	0.001049	0.19%	0.001941	0.001939	0.10%
200	0.032354	0.032243	0.34%	0.121723	0.121308	0.34%
300	0.054225	0.053959	0.49%	0.206056	0.205056	0.49%
400	0.069495	0.069079	0.60%	0.264940	0.263361	0.60%
500	0.080157	0.079609	0.68%	0.306054	0.303969	0.69%
600	0.087602	0.086946	0.75%	0.334761	0.332262	0.75%
700	0.092800	0.092058	0.80%	0.354804	0.351977	0.80%
720	0.093633	0.092877	0.81%	0.358019	0.355136	0.81%

As expected, the analytical results are slightly greater than the computer code results since the simplified analytical model neglects the containment inventory depletion due to leakage of iodine out of the containment. Otherwise, the results from the two different methods agree, thereby verifying correct execution of the computer model for this case. The only computer module not tested by this sample case is that of the pH calculation which is confirmed to be operating properly by running the existing GGNS case in which the 100% of the released cesium not in the form of cesium iodide is assumed to be cesium hydroxide dissolved in the suppression pool.

6.0 RESULTS

The results for the computer program are illustrated in Figures 6-1 and 6-2. As shown in Figure 6-1, if only 60% of the released cesium not in the form of cesium iodide is dissolved in the pool as CsOH, the GGNS suppression pool pH is expected to drop below 7.0 after approximately 185 hours. The offsite dose associated with this transient is illustrated in Figure 6-2 and demonstrates that the additional radiological impact at the LPZ is approximately 20 millirem TEDE which is negligible compared to the NRC proposed offsite acceptance criteria of 25 rem. In the control room, this pH transient results in an additional dose of 75 millirem TEDE to the operators which is only 1.5% of the NRC proposed control room acceptance criteria of 5 rem. If elemental iodine plateout and the reduction in iodine concentration at locations away from the surface of the suppression pool were considered, the radiological consequences would be even less.

This computer program demonstrates that an insignificant impact on offsite dose results from relaxing the cesium assumptions in the GGNS pool pH analysis. This conclusion is due to the late initiation of this pH transient. After 96 hours, (i) the EAB has been evacuated and the control room occupancy factor is reduced, (ii) the LPZ and control room χ/Q values are reduced, (iii) the suppression pool temperature has decreased from its peak, and (iv) a significant amount of the containment iodine inventory has decayed.

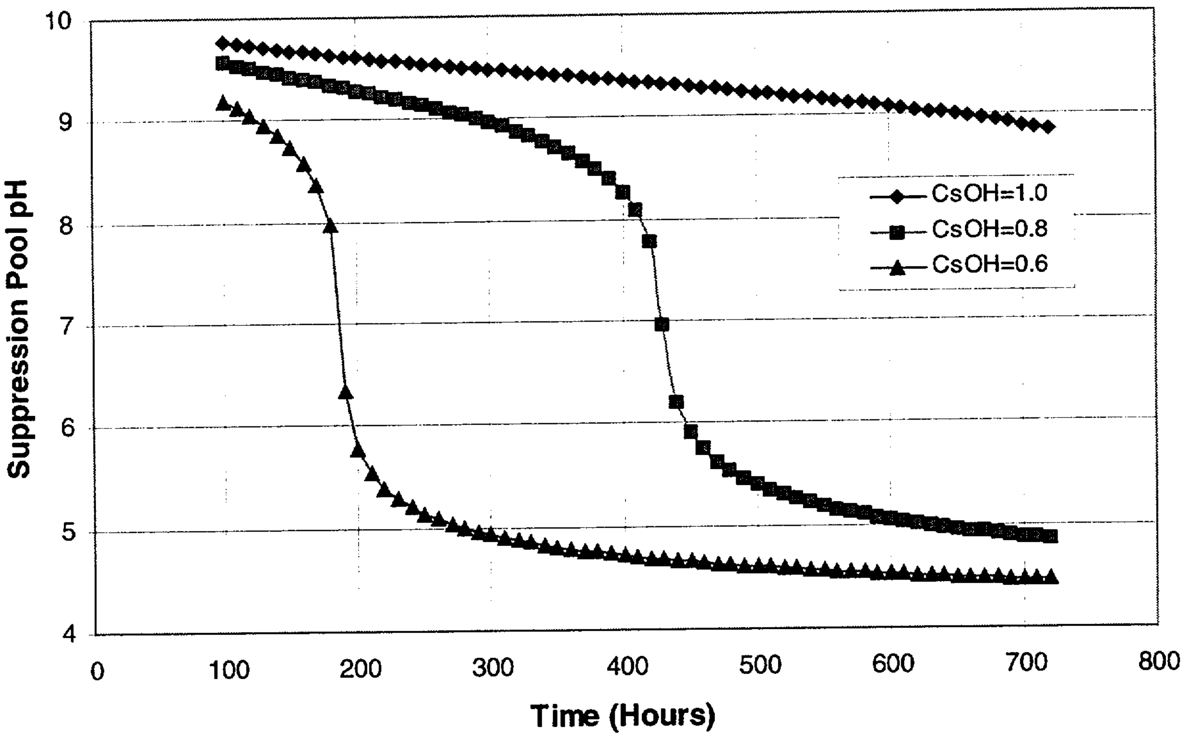

Figure 6-1 Suppression Pool pH Transients

ENTERGY

CALCULATION SHEET

Sheet 15 Cont on 16

Rev. 1

Calculation No. XC-Q1111-98014

Prepared By 9.E.B. Date 6/14/99 Checked By SCS Date 6/14/99

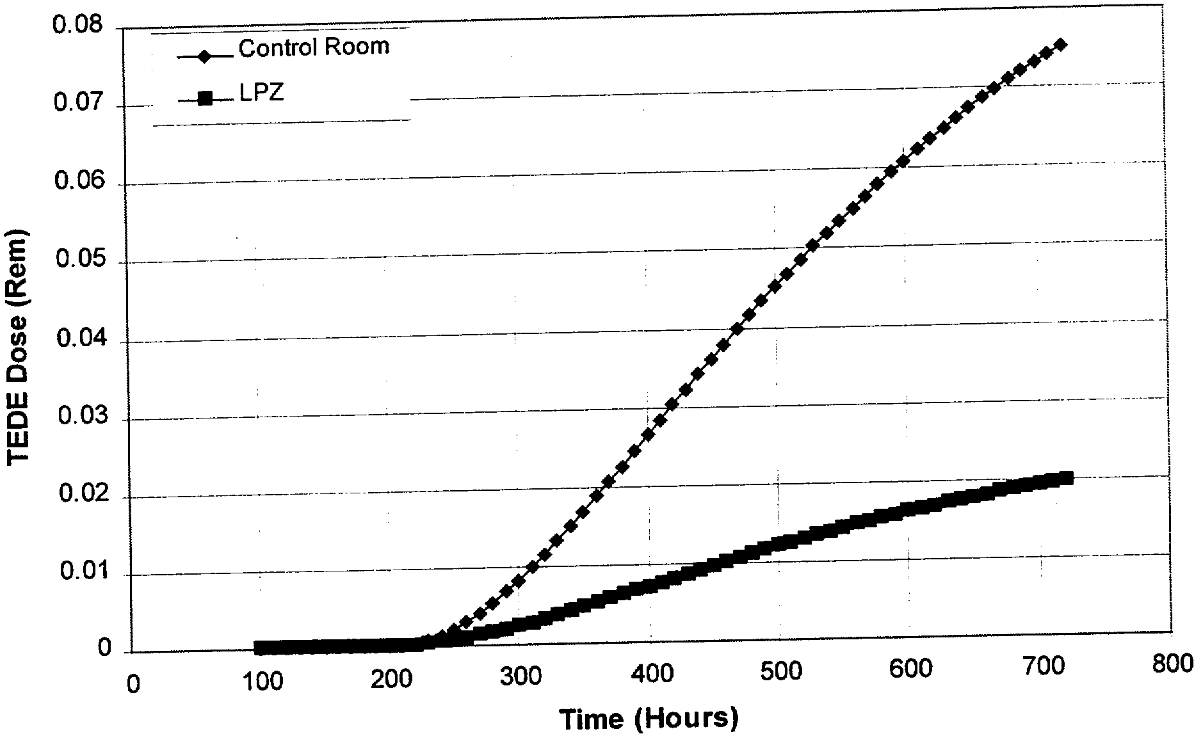

Figure 6-2 Doses Due to Iodine Re-evolution for 60% CsOH Case

△1

7.0 REFERENCES

1. Calculation XC-Q1111-98013, Rev. 0, Suppression Pool pH Analysis.
2. NUREG-1465, Accident Source Terms for Light-Water Nuclear Power Plants, dated February 1995.
3. Engineering Report GGNS-98-0039, Rev. 0, Suppression Pool pH and Iodine Re-evolution Methodology.
4. Regulatory Guide 1.3, Rev. 2, Assumptions Used for Evaluating The Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors, dated June 1974.
5. NUREG/CR-6604, RADTRAD: A Simplified Model for **RAD**ionuclide **T**ransport And Removal **A**nd **D**ose Estimation, dated April 1998.
6. Calculation XC-Q1J11-98010, Rev. 0, Cesium and Iodine Core Inventories for Pool pH Calculation.
7. Analysis Basis Document (ABD) 4, Rev. 0, Analytical Bases for Containment Performance.
8. Federal Guidance Report 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Second Printing 1989.
9. Federal Guidance Report 12, External Exposure to Radionuclides in Air, Water, and Soil, 1993.
10. Calculation XC-Q1C84-92009, Rev. 1, Short-term (Accident) Diffusion χ/Q.
11. K.G. Murphy and K.M. Campe, "Nuclear Power Plant Control Room Ventilation System Design for Meeting General Criteria 19", 13th AEC Air Cleaning Conference.
12. Calculation XC-Q1111-98011, Rev. 0, Control Room χ/Q Analysis.
13. Simplified Flow Diagram 0049, Rev. 7, Control Room HVAC System.
14. Calculation MC-QSZ51-91152, Rev. 0, Control Room Airtight Boundary Free Volume.
15. GIN 1999-01416, M.D. Withrow to Central File, "BWROG Memoto Revised Source Term Committee", dated June 14, 1999.

```
#include <stdio.h>
#include <stdlib.h>
#include <math.h>

double CalcPoolTemp (long int);
double CalcpH(long int, double);
long double CalcContI2Conc(long double, double, double, double, double);

main()
{
        // INITIALIZE CONSTANTS
        const int  NumIsos = 3;

        const double        PoolVolume = 4.841E6,                              // liters
                                    ContVolume = 1.67E6*28.317,                // liters
                                    EBVolume = 3.0E5*28.317,                   // liters
                                    CRVolume = 2.53E5*0.028317,                // m**3
                                    ContLeakRate = 194.6*28.317/3600.0,        // liters/sec
                                    SGTSFlow = 4001.0*28.317/60.0,             // liters/sec
                                    CRInleak = 2000.0*0.028317/60.0,           // m**3/s
                                    SGTSEff = 0.98975,
                                    LPZXQ = 1.60E-5,                           // s/m**3
                                    CRXQ = 1.04E-4,                            // s/m**3
                                    CROccFactor = 0.4,
                                    MCGeomFactor = 17.5,
                                    LPZBreathRate = 2.32E-4,                   // m**3/s
                                    CRBreathRate = 3.47E-4;                    // m**3/s

        const long int      StartTime = 96*3600;

        struct IsotopeData
        {
        long double StartGramAtoms,
                                    ContInv[2],
                                    CRAct[2],
                                    EBI2[2];

        double              DecayConst,
                                    ContFract,
                                    DCFInhal,
                                    DCFSubmers;
        } Isotope[3];

        FILE *OutFile;

        long int   Seconds;

        int        i;

        double     ContI2Conc,
                   ActReleased,
                   MolesI2ToEB,
                   MolesI2OutEB,
                   PartitionCoeff,
                   pH,
                   PoolTemp,
                   TotalContI,
                   PoolIConc,
                   CsOHFract,
                   CRDose,
                   LPZDose;

        // INITIALIZE ISOTOPE VARIABLES
        Isotope[0].StartGramAtoms = 21.525;           // I-127
        Isotope[0].DecayConst = 0.0;
        Isotope[0].DCFInhal = 0.0;
        Isotope[0].DCFSubmers = 0.0;
        Isotope[1].StartGramAtoms = 68.850;           // I-129
        Isotope[1].DecayConst = 1.294000E-15;
```

```
        Isotope[1].DCFInhal = 1.7353E5;
        Isotope[1].DCFSubmers = 1.406E-3;
        Isotope[2].StartGramAtoms = 1.409;              // I-131
        Isotope[2].DecayConst = 9.963996E-07;
        Isotope[2].DCFInhal = 3.2893E4;
        Isotope[2].DCFSubmers = 6.734E-2;

        Seconds = StartTime;
        LPZDose = CRDose = TotalContI = ContI2Conc = 0.0;

        CsOHFract = 1.0;

        for (i=0;i<NumIsos;i++)
        {
                Isotope[i].EBI2[0] = Isotope[i].CRAct[0] = 0.0;
                Isotope[i].ContInv[0] = Isotope[i].StartGramAtoms;
        }

        OutFile = fopen ("output.txt", "w");
        fprintf(OutFile,"Iodine Re-evolution Case with CsOH Fraction = %4.2f\n", CsOHFract);
        fprintf(OutFile,"Hours\tpH\tPoolTemp\tContI2Conc\tTotalContI\tLPZDose\tCRDose\n");

        if (CalcpH(Seconds,CsOHFract) < 7.0)
                fprintf(OutFile,"WARNING: Pool pH less than 7.0 at %d Hours\n",(int) (Seconds/3600));

        while (Seconds<=2592000)
        {
                TotalContI = 0.0;
                for (i=0;i<NumIsos;i++)
                        TotalContI += Isotope[i].ContInv[0];

                for (i=0;i<NumIsos;i++)
                        Isotope[i].ContFract = Isotope[i].ContInv[0]/TotalContI;

                // Calculate Pool pH at this timestep
                pH = CalcpH(Seconds,CsOHFract);
//              pH=4.5;

                // Calculate the Partition Coefficient based on the Pool temperature
                PoolTemp=CalcPoolTemp(Seconds);
//              PoolTemp=150.0;
                PartitionCoeff = pow(10.0,6.29-0.0149*(273.15+5.0/9.0*(PoolTemp-32.0)));

                // Calculate Containment I2 Concentration
                if (pH < 8.0)
                        ContI2Conc = CalcContI2Conc(TotalContI, pH, PoolVolume, ContVolume, PartitionCoeff);
                else
                        ContI2Conc = 0.0;

                PoolIConc = (TotalContI-2.0*ContI2Conc*ContVolume)/PoolVolume;
                if (PoolIConc <1E-6)
                {
                        fprintf(OutFile,"Pool Iodine Concentration = %10.6g\nBelow Correlation Bounds!\n",PoolIConc);
                        return (-1);
                }

                // Calculate Mass Transferred from Containment
                MolesI2ToEB=ContI2Conc*ContLeakRate;
                TotalContI -= 2*MolesI2ToEB;

                for (i=0;i<NumIsos;i++)
                {
                        // Calculate Mass Balance for Enclosure Building
                        MolesI2OutEB = Isotope[i].EBI2[0]/EBVolume*SGTSFlow;
                        Isotope[i].EBI2[1] = Isotope[i].EBI2[0] + Isotope[i].ContFract*MolesI2ToEB - MolesI2OutEB;
                        ActReleased = MolesI2OutEB*(1.0-SGTSEff)*2.0*6.022E23*Isotope[i].DecayConst/3.7E10;

                        // CALCULATE CONTROL ROOM ACTIVITY
```

```
                        Isotope[i].CRAct[1] = Isotope[i].CRAct[0] + ActReleased*CRXQ*CRInleak -
Isotope[i].CRAct[0]/CRVolume*CRInleak;

                        // CALCULATE DOSES
                        LPZDose+= ActReleased*LPZXQ*(LPZBreathRate*Isotope[i].DCFInhal+Isotope[i].DCFSubmers);
                        CRDose+=
Isotope[i].CRAct[1]/CRVolume*(CRBreathRate*Isotope[i].DCFInhal+Isotope[i].DCFSubmers/MCGeomFactor)*CROccFactor;

                        // DECAY IN ALL VOLUMES
                        Isotope[i].ContInv[1]=TotalContI*Isotope[i].ContFract*exp(-Isotope[i].DecayConst);
                        Isotope[i].EBI2[1]*=exp(-Isotope[i].DecayConst);
                        Isotope[i].CRAct[1]*=exp(-Isotope[i].DecayConst);

                        // UPDATE INVENTORIES
                        Isotope[i].ContInv[0]=Isotope[i].ContInv[1];
                        Isotope[i].EBI2[0]=Isotope[i].EBI2[1];
                        Isotope[i].CRAct[0]=Isotope[i].CRAct[1];
                }

                if ((Seconds%36000)==0)
                {
                        fprintf(OutFile,"%d\t%f\t%f\t%10.6g\t%10.6g\t%f\t%f\n",(int) (Seconds/3600),pH,PoolTemp,
                                ContI2Conc,TotalContI,LPZDose,CRDose);
                        printf("%d\t%f\t%10.6g\t%f\t%f\n",(int) (Seconds/3600),pH,ContI2Conc,LPZDose,CRDose);
                }

                Seconds++;
        }

        fclose(OutFile);

        return(0);

}
double CalcPoolTemp(long int Secs)
{
        // CALCULATES THE POOL TEMPERATURE BASED ON TIME INTO ACCIDENT

        return (225.2828-7.1240*log((double) Secs));

}

double CalcpH(long int Secs, double CsOHFract)
{
        // CALCULATES THE POOL PH BASED ON TIME INTO ACCIDENT

        double a,b,c,Root,Hours,PoolDose,DWBeta,DWGamma,ContBeta,ContGamma,
                DWHCl,ContHCl,HNO3,HConc,FinalHConc,OHConc,InitialpH,PoolpH,HI,
                TotalCsOH,CsOH;

        InitialpH = 5.3;
        HI = 1.0070E-6;
        TotalCsOH = 1.0481E-4;

        Hours = (double) Secs/3600.0;
        CsOH = CsOHFract*TotalCsOH;

        // Calculate Integrated Doses
        PoolDose = 1.05*(0.131*pow(0.1874,1.0/Hours)*pow(Hours,0.5697));
        DWBeta = 1.05*(1284-90786/Hours+2692641/pow(Hours,2.0));
        DWGamma = 1.05*(8.22*pow(0.9999,Hours)*pow(Hours,0.1267));
        ContBeta = 1.05*(248.2-16676.57/Hours+426559.0/pow(Hours,2.0));
        if (Hours <= 480)
                ContGamma = 1.05*(1.95*pow(0.5738,(1.0/Hours))*pow(Hours,0.2779));
        else
                ContGamma = 1.05*(1.95*pow(0.5738,(1.0/480.0))*pow(480.0,0.2779));

        HNO3 = 7.3E-6*PoolDose;
```

```
        DWHCl = 1.212E-11*(873.65/2.0+873.65)*DWBeta + 2.424E-11*(873.65+873.65)*DWGamma;
        ContHCl = 1.212E-11*(14049.27/2.0+1561.03)*ContBeta + 2.424E-11*(14049.27+1561.03)*ContGamma;

        HConc = pow(10.0,-InitialpH)+HI+HNO3+DWHCl+ContHCl;
        OHConc = 1.0e-14/pow(10.0,-InitialpH)+CsOH;

        a = 1.0;
        b = -(HConc+OHConc);
        c = HConc*OHConc-1.0E-14;
        Root = (-b-sqrt(b*b-4*a*c))/(2*a);

        FinalHConc = HConc-Root;

        PoolpH = -log10(FinalHConc);

        return (PoolpH);
}
long double CalcContI2Conc(long double IodineInv, double pH, double PoolVol, double ContVol, double PC)
{
        // CALCULATE CONTAINMENT POOL/AIR SPLIT
        double delta, d, e;
        long double PoolI2Conc, ContI2Conc, PoolIConc, NewPoolIConc;

        d = 4.22E-14;
        e = 1.47E-9;

        // Initially assume all iodine in pool
        PoolIConc = IodineInv/PoolVol;
        ContI2Conc = 0.0;

        delta=10.0;
        while (fabs(delta) > 1.0e-6)
        {
                PoolI2Conc = PoolIConc/2.0 + (d+e*pow(10,-pH))/(8*pow(10,-2*pH))
                        -1.0/(8.0*pow(10,-pH))*sqrt(pow((d+e*pow(10,-pH)),2.0)/pow(10,-2*pH)+
                        8*PoolIConc*(d+e*pow(10,-pH)));

                if (PoolI2Conc < 0.0)
                        PoolI2Conc = 0.0;

                ContI2Conc = PoolI2Conc/PC;
                NewPoolIConc = (IodineInv-2.0*ContI2Conc*ContVol)/PoolVol;
                delta = (NewPoolIConc-PoolIConc)/PoolIConc;
                PoolIConc=(PoolIConc+NewPoolIConc)/2.0;
        }

        return (ContI2Conc);
}
```

Iodine Re-evolution Case with CsOH Fraction = 1.00

Hours	pH	PoolTemp	Contl2Conc	TotalContl	LPZDose	CRDose
100	9.759220	134.139346	0	91.7639	0.000000	0.000000
110	9.741401	133.460357	0	91.715	0.000000	0.000000
120	9.724146	132.840488	0	91.6678	0.000000	0.000000
130	9.707480	132.270263	0	91.6222	0.000000	0.000000
140	9.691383	131.742318	0	91.5783	0.000000	0.000000
150	9.675818	131.250813	0	91.5359	0.000000	0.000000
160	9.660739	130.791040	0	91.495	0.000000	0.000000
170	9.646097	130.359151	0	91.4555	0.000000	0.000000
180	9.631848	129.951954	0	91.4174	0.000000	0.000000
190	9.617949	129.566779	0	91.3807	0.000000	0.000000
200	9.604359	129.201366	0	91.3453	0.000000	0.000000
210	9.591043	128.853785	0	91.3111	0.000000	0.000000
220	9.577967	128.522376	0	91.2781	0.000000	0.000000
230	9.565102	128.205702	0	91.2463	0.000000	0.000000
240	9.552420	127.902507	0	91.2156	0.000000	0.000000
250	9.539896	127.611691	0	91.186	0.000000	0.000000
260	9.527506	127.332283	0	91.1574	0.000000	0.000000
270	9.515230	127.063421	0	91.1298	0.000000	0.000000
280	9.503048	126.804338	0	91.1032	0.000000	0.000000
290	9.490942	126.554347	0	91.0776	0.000000	0.000000
300	9.478894	126.312832	0	91.0528	0.000000	0.000000
310	9.466889	126.079238	0	91.0289	0.000000	0.000000
320	9.454911	125.853060	0	91.0059	0.000000	0.000000
330	9.442945	125.633843	0	90.9837	0.000000	0.000000
340	9.430979	125.421170	0	90.9622	0.000000	0.000000
350	9.418998	125.214663	0	90.9415	0.000000	0.000000
360	9.406989	125.013974	0	90.9216	0.000000	0.000000
370	9.394941	124.818783	0	90.9023	0.000000	0.000000
380	9.382839	124.628799	0	90.8837	0.000000	0.000000
390	9.370674	124.443749	0	90.8658	0.000000	0.000000
400	9.358431	124.263385	0	90.8485	0.000000	0.000000
410	9.346098	124.087475	0	90.8318	0.000000	0.000000
420	9.333664	123.915804	0	90.8157	0.000000	0.000000
430	9.321117	123.748173	0	90.8002	0.000000	0.000000
440	9.308442	123.584396	0	90.7852	0.000000	0.000000
450	9.295628	123.424299	0	90.7708	0.000000	0.000000
460	9.282660	123.267721	0	90.7568	0.000000	0.000000
470	9.269526	123.114511	0	90.7434	0.000000	0.000000
480	9.256210	122.964526	0	90.7304	0.000000	0.000000
490	9.243314	122.817635	0	90.7179	0.000000	0.000000
500	9.230235	122.673711	0	90.7058	0.000000	0.000000
510	9.216959	122.532637	0	90.6941	0.000000	0.000000
520	9.203471	122.394302	0	90.6829	0.000000	0.000000
530	9.189754	122.258603	0	90.672	0.000000	0.000000
540	9.175792	122.125440	0	90.6616	0.000000	0.000000
550	9.161566	121.994721	0	90.6515	0.000000	0.000000
560	9.147057	121.866357	0	90.6417	0.000000	0.000000
570	9.132245	121.740265	0	90.6323	0.000000	0.000000
580	9.117107	121.616366	0	90.6233	0.000000	0.000000
590	9.101620	121.494586	0	90.6145	0.000000	0.000000
600	9.085756	121.374852	0	90.6061	0.000000	0.000000
610	9.069489	121.257097	0	90.5979	0.000000	0.000000
620	9.052786	121.141257	0	90.5901	0.000000	0.000000
630	9.035613	121.027271	0	90.5825	0.000000	0.000000
640	9.017934	120.915079	0	90.5752	0.000000	0.000000
650	8.999707	120.804628	0	90.5681	0.000000	0.000000
660	8.980885	120.695862	0	90.5613	0.000000	0.000000
670	8.961417	120.588732	0	90.5548	0.000000	0.000000
680	8.941245	120.483190	0	90.5484	0.000000	0.000000
690	8.920303	120.379188	0	90.5423	0.000000	0.000000
700	8.898518	120.276682	0	90.5364	0.000000	0.000000
710	8.875806	120.175631	0	90.5307	0.000000	0.000000
720	8.852068	120.075993	0	90.5253	0.000000	0.000000

Iodine Re-evolution Case with CsOH Fraction = 0.80

Hours	pH	PoolTemp	Contl2Conc	TotalContl	LPZDose	CRDose
100	9.562041	134.139346	0	91.7639	0.000000	0.000000
110	9.533643	133.460357	0	91.715	0.000000	0.000000
120	9.505452	132.840488	0	91.6678	0.000000	0.000000
130	9.477519	132.270263	0	91.6222	0.000000	0.000000
140	9.449822	131.742318	0	91.5783	0.000000	0.000000
150	9.422303	131.250813	0	91.5359	0.000000	0.000000
160	9.394886	130.791040	0	91.495	0.000000	0.000000
170	9.367485	130.359151	0	91.4555	0.000000	0.000000
180	9.340009	129.951954	0	91.4174	0.000000	0.000000
190	9.312362	129.566779	0	91.3807	0.000000	0.000000
200	9.284444	129.201366	0	91.3453	0.000000	0.000000
210	9.256148	128.853785	0	91.3111	0.000000	0.000000
220	9.227366	128.522376	0	91.2781	0.000000	0.000000
230	9.197976	128.205702	0	91.2463	0.000000	0.000000
240	9.167849	127.902507	0	91.2156	0.000000	0.000000
250	9.136841	127.611691	0	91.186	0.000000	0.000000
260	9.104791	127.332283	0	91.1574	0.000000	0.000000
270	9.071513	127.063421	0	91.1298	0.000000	0.000000
280	9.036794	126.804338	0	91.1032	0.000000	0.000000
290	9.000379	126.554347	0	91.0776	0.000000	0.000000
300	8.961966	126.312832	0	91.0528	0.000000	0.000000
310	8.921181	126.079238	0	91.0289	0.000000	0.000000
320	8.877561	125.853060	0	91.0059	0.000000	0.000000
330	8.830513	125.633843	0	90.9837	0.000000	0.000000
340	8.779262	125.421170	0	90.9622	0.000000	0.000000
350	8.722762	125.214663	0	90.9415	0.000000	0.000000
360	8.659553	125.013974	0	90.9216	0.000000	0.000000
370	8.587500	124.818783	0	90.9023	0.000000	0.000000
380	8.503301	124.628799	0	90.8837	0.000000	0.000000
390	8.401437	124.443749	0	90.8658	0.000000	0.000000
400	8.271597	124.263385	0	90.8485	0.000000	0.000000
410	8.090838	124.087475	0	90.8318	0.000000	0.000000
420	7.788581	123.915804	7.66382e-014	90.8157	0.000000	0.000000
430	6.965871	123.748173	3.36519e-012	90.8002	0.000000	0.000000
440	6.197909	123.584396	1.13029e-010	90.7852	0.000000	0.000001
450	5.914365	123.424299	4.06626e-010	90.7707	0.000002	0.000007
460	5.745595	123.267721	8.61672e-010	90.7567	0.000008	0.000025
470	5.625946	123.114511	1.45559e-009	90.7431	0.000018	0.000059
480	5.533567	122.964526	2.16795e-009	90.73	0.000033	0.000114
490	5.461636	122.817635	2.94129e-009	90.7172	0.000055	0.000191
500	5.400831	122.673711	3.79074e-009	90.7047	0.000082	0.000290
510	5.348262	122.532637	4.70347e-009	90.6926	0.000115	0.000413
520	5.302028	122.394302	5.66819e-009	90.6808	0.000155	0.000559
530	5.260818	122.258603	6.67497e-009	90.6692	0.000200	0.000728
540	5.223685	122.125440	7.71511e-009	90.658	0.000251	0.000920
550	5.189927	121.994721	8.78105e-009	90.647	0.000308	0.001133
560	5.159005	121.866357	9.86619e-009	90.6362	0.000370	0.001366
570	5.130502	121.740265	1.09648e-008	90.6257	0.000437	0.001619
580	5.104081	121.616366	1.20721e-008	90.6153	0.000509	0.001889
590	5.079475	121.494586	1.31836e-008	90.6052	0.000585	0.002176
600	5.056461	121.374852	1.4296e-008	90.5952	0.000664	0.002478
610	5.034855	121.257097	1.5406e-008	90.5855	0.000748	0.002794
620	5.014505	121.141257	1.6511e-008	90.5758	0.000834	0.003122
630	4.995278	121.027271	1.76088e-008	90.5664	0.000923	0.003460
640	4.977064	120.915079	1.86975e-008	90.5571	0.001014	0.003808
650	4.959767	120.804628	1.97757e-008	90.5479	0.001108	0.004165
660	4.943304	120.695862	2.08419e-008	90.5389	0.001203	0.004529
670	4.927602	120.588732	2.18952e-008	90.5299	0.001300	0.004898
680	4.912597	120.483190	2.29346e-008	90.5211	0.001398	0.005272
690	4.898234	120.379188	2.39595e-008	90.5125	0.001497	0.005651
700	4.884463	120.276682	2.49694e-008	90.5039	0.001597	0.006032
710	4.871239	120.175631	2.59639e-008	90.4954	0.001697	0.006415
720	4.858523	120.075993	2.69426e-008	90.487	0.001797	0.006799

Iodine Re-evolution Case with CsOH Fraction = 0.60

Hours	pH	PoolTemp	Contl2Conc	TotalContl	LPZDose	CRDose
100	9.190815	134.139346	0	91.7639	0.000000	0.000000
110	9.120846	133.460357	0	91.715	0.000000	0.000000
120	9.043789	132.840488	0	91.6678	0.000000	0.000000
130	8.957428	132.270263	0	91.6222	0.000000	0.000000
140	8.858013	131.742318	0	91.5783	0.000000	0.000000
150	8.738935	131.250813	0	91.5359	0.000000	0.000000
160	8.587148	130.791040	0	91.495	0.000000	0.000000
170	8.370841	130.359151	0	91.4555	0.000000	0.000000
180	7.966813	129.951954	3.79376e-014	91.4174	0.000000	0.000000
190	6.341327	129.566779	6.67399e-011	91.3807	0.000000	0.000000
200	5.765034	129.201366	8.96334e-010	91.3452	0.000008	0.000019
210	5.533187	128.853785	2.45907e-009	91.3109	0.000042	0.000124
220	5.388775	128.522376	4.50814e-009	91.2775	0.000114	0.000369
230	5.284889	128.205702	6.86029e-009	91.2451	0.000232	0.000783
240	5.204379	127.902507	9.38328e-009	91.2135	0.000397	0.001376
250	5.139045	127.611691	1.19839e-008	91.1827	0.000608	0.002149
260	5.084331	127.332283	1.45978e-008	91.1526	0.000864	0.003092
270	5.037443	127.063421	1.71817e-008	91.1233	0.001160	0.004193
280	4.996549	126.804338	1.97071e-008	91.0947	0.001493	0.005439
290	4.960381	126.554347	2.21561e-008	91.0667	0.001858	0.006812
300	4.928028	126.312832	2.45183e-008	91.0394	0.002252	0.008298
310	4.898813	126.079238	2.67882e-008	91.0127	0.002671	0.009881
320	4.872222	125.853060	2.89641e-008	90.9866	0.003110	0.011548
330	4.847854	125.633843	3.10462e-008	90.9611	0.003568	0.013284
340	4.825389	125.421170	3.30368e-008	90.9361	0.004039	0.015078
350	4.804572	125.214663	3.49387e-008	90.9116	0.004522	0.016917
360	4.785193	125.013974	3.67556e-008	90.8877	0.005014	0.018793
370	4.767079	124.818783	3.84914e-008	90.8643	0.005512	0.020696
380	4.750085	124.628799	4.01501e-008	90.8414	0.006015	0.022618
390	4.734091	124.443749	4.17358e-008	90.819	0.006521	0.024551
400	4.718991	124.263385	4.32525e-008	90.797	0.007027	0.026490
410	4.704697	124.087475	4.4704e-008	90.7755	0.007533	0.028427
420	4.691133	123.915804	4.60941e-008	90.7544	0.008038	0.030358
430	4.678232	123.748173	4.74262e-008	90.7338	0.008539	0.032279
440	4.665935	123.584396	4.87037e-008	90.7135	0.009036	0.034186
450	4.654191	123.424299	4.99296e-008	90.6936	0.009529	0.036074
460	4.642956	123.267721	5.11069e-008	90.6741	0.010015	0.037942
470	4.632189	123.114511	5.22383e-008	90.655	0.010496	0.039786
480	4.621855	122.964526	5.33265e-008	90.6362	0.010970	0.041605
490	4.612364	122.817635	5.43202e-008	90.6178	0.011436	0.043396
500	4.603220	122.673711	5.52778e-008	90.5996	0.011894	0.045155
510	4.594399	122.532637	5.62012e-008	90.5819	0.012344	0.046883
520	4.585881	122.394302	5.70924e-008	90.5644	0.012785	0.048578
530	4.577646	122.258603	5.79529e-008	90.5472	0.013217	0.050239
540	4.569677	122.125440	5.87844e-008	90.5303	0.013640	0.051865
550	4.561957	121.994721	5.95884e-008	90.5137	0.014054	0.053457
560	4.554472	121.866357	6.03661e-008	90.4974	0.014459	0.055013
570	4.547209	121.740265	6.11191e-008	90.4813	0.014854	0.056535
580	4.540154	121.616366	6.18483e-008	90.4655	0.015241	0.058021
590	4.533298	121.494586	6.2555e-008	90.4499	0.015618	0.059472
600	4.526628	121.374852	6.32403e-008	90.4345	0.015986	0.060888
610	4.520136	121.257097	6.39051e-008	90.4194	0.016345	0.062269
620	4.513813	121.141257	6.45504e-008	90.4045	0.016695	0.063615
630	4.507650	121.027271	6.5177e-008	90.3898	0.017036	0.064927
640	4.501639	120.915079	6.57859e-008	90.3753	0.017368	0.066205
650	4.495773	120.804628	6.63776e-008	90.3609	0.017691	0.067450
660	4.490046	120.695862	6.69531e-008	90.3468	0.018006	0.068661
670	4.484451	120.588732	6.7513e-008	90.3328	0.018312	0.069840
680	4.478982	120.483190	6.80579e-008	90.3191	0.018610	0.070987
690	4.473634	120.379188	6.85885e-008	90.3054	0.018900	0.072103
700	4.468402	120.276682	6.91053e-008	90.292	0.019182	0.073188
710	4.463281	120.175631	6.96089e-008	90.2786	0.019456	0.074242
720	4.458266	120.075993	7.00999e-008	90.2655	0.019722	0.075267

d=	4.22E-14		**Starting**			**Revised**	
e=	1.47E-09		**Aq I**	**Aq I2 Conc**	**Cont I2 Conc**	**Aq I**	**Airborne**
pH=	4.5		**g-atoms/L**	**g-mols/L**	**g-mols/L**	**g-atoms/L**	**Fract**
Pool Vol=	4.841E+06	Liters	1.8960E-05	2.3152E-06	1.32223E-07	1.6376E-05	1.363E-01
Cont Vol=	4.730E+07	Liters	1.6376E-05	1.8257E-06	1.04266E-07	1.6922E-05	1.075E-01
PC=	17.5100434		1.6922E-05	1.9262E-06	1.10003E-07	1.6810E-05	1.134E-01
Total I=	91.784	g-atoms	1.681E-05	1.9054E-06	1.08818E-07	1.6833E-05	1.122E-01
			1.6833E-05	1.9097E-06	1.09062E-07	1.6828E-05	1.124E-01
			1.6828E-05	1.9088E-06	1.09012E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.09022E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.9089E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.09021E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01
			1.6829E-05	1.909E-06	1.0902E-07	1.6829E-05	1.124E-01

Iodine Re-evolution Case with CsOH Fraction = 1.00

Hours	pH	PoolTemp	ContI2Conc	TotalContI	LPZDose	CRDose
100	4.500000	150.000000	1.0898e-007	91.7591	0.001049	0.001939
110	4.500000	150.000000	1.0887e-007	91.6982	0.004686	0.015045
120	4.500000	150.000000	1.08763e-007	91.639	0.008211	0.028631
130	4.500000	150.000000	1.08659e-007	91.5815	0.011610	0.041740
140	4.500000	150.000000	1.08558e-007	91.5256	0.014888	0.054381
150	4.500000	150.000000	1.0846e-007	91.4713	0.018049	0.066572
160	4.500000	150.000000	1.08364e-007	91.4184	0.021098	0.078328
170	4.500000	150.000000	1.08272e-007	91.3671	0.024037	0.089665
180	4.500000	150.000000	1.08181e-007	91.3171	0.026872	0.100598
190	4.500000	150.000000	1.08094e-007	91.2685	0.029606	0.111141
200	4.500000	150.000000	1.08008e-007	91.2212	0.032243	0.121308
210	4.500000	150.000000	1.07925e-007	91.1752	0.034785	0.131114
220	4.500000	150.000000	1.07844e-007	91.1303	0.037237	0.140570
230	4.500000	150.000000	1.07766e-007	91.0867	0.039602	0.149689
240	4.500000	150.000000	1.07689e-007	91.0442	0.041883	0.158484
250	4.500000	150.000000	1.07614e-007	91.0028	0.044082	0.166966
260	4.500000	150.000000	1.07542e-007	90.9624	0.046203	0.175146
270	4.500000	150.000000	1.07471e-007	90.923	0.048249	0.183034
280	4.500000	150.000000	1.07402e-007	90.8847	0.050222	0.190642
290	4.500000	150.000000	1.07334e-007	90.8472	0.052124	0.197980
300	4.500000	150.000000	1.07268e-007	90.8107	0.053959	0.205056
310	4.500000	150.000000	1.07204e-007	90.7751	0.055729	0.211881
320	4.500000	150.000000	1.07142e-007	90.7403	0.057436	0.218463
330	4.500000	150.000000	1.07081e-007	90.7063	0.059082	0.224812
340	4.500000	150.000000	1.07021e-007	90.6731	0.060670	0.230934
350	4.500000	150.000000	1.06963e-007	90.6407	0.062201	0.236839
360	4.500000	150.000000	1.06906e-007	90.6091	0.063678	0.242534
370	4.500000	150.000000	1.0685e-007	90.5781	0.065102	0.248026
380	4.500000	150.000000	1.06795e-007	90.5478	0.066476	0.253324
390	4.500000	150.000000	1.06742e-007	90.5182	0.067801	0.258433
400	4.500000	150.000000	1.0669e-007	90.4892	0.069079	0.263361
410	4.500000	150.000000	1.06639e-007	90.4608	0.070311	0.268114
420	4.500000	150.000000	1.06589e-007	90.433	0.071500	0.272697
430	4.500000	150.000000	1.0654e-007	90.4058	0.072646	0.277118
440	4.500000	150.000000	1.06492e-007	90.3792	0.073752	0.281383
450	4.500000	150.000000	1.06445e-007	90.353	0.074818	0.285495
460	4.500000	150.000000	1.06399e-007	90.3274	0.075847	0.289462
470	4.500000	150.000000	1.06354e-007	90.3023	0.076839	0.293288
480	4.500000	150.000000	1.0631e-007	90.2777	0.077796	0.296978
490	4.500000	150.000000	1.06266e-007	90.2535	0.078719	0.300537
500	4.500000	150.000000	1.06224e-007	90.2298	0.079609	0.303969
510	4.500000	150.000000	1.06182e-007	90.2065	0.080468	0.307280
520	4.500000	150.000000	1.06141e-007	90.1836	0.081296	0.310474
530	4.500000	150.000000	1.061e-007	90.1611	0.082094	0.313554
540	4.500000	150.000000	1.06061e-007	90.139	0.082865	0.316524
550	4.500000	150.000000	1.06022e-007	90.1173	0.083608	0.319390
560	4.500000	150.000000	1.05983e-007	90.0959	0.084324	0.322153
570	4.500000	150.000000	1.05946e-007	90.0749	0.085016	0.324819
580	4.500000	150.000000	1.05909e-007	90.0542	0.085682	0.327390
590	4.500000	150.000000	1.05872e-007	90.0339	0.086325	0.329870
600	4.500000	150.000000	1.05836e-007	90.0138	0.086946	0.332262
610	4.500000	150.000000	1.05801e-007	89.9941	0.087544	0.334569
620	4.500000	150.000000	1.05766e-007	89.9746	0.088121	0.336794
630	4.500000	150.000000	1.05731e-007	89.9554	0.088677	0.338940
640	4.500000	150.000000	1.05697e-007	89.9365	0.089214	0.341010
650	4.500000	150.000000	1.05664e-007	89.9179	0.089732	0.343007
660	4.500000	150.000000	1.05631e-007	89.8995	0.090232	0.344933
670	4.500000	150.000000	1.05598e-007	89.8813	0.090713	0.346790
680	4.500000	150.000000	1.05566e-007	89.8634	0.091178	0.348582
690	4.500000	150.000000	1.05534e-007	89.8457	0.091626	0.350310
700	4.500000	150.000000	1.05503e-007	89.8282	0.092058	0.351977
710	4.500000	150.000000	1.05472e-007	89.8109	0.092475	0.353585
720	4.500000	150.000000	1.05442e-007	89.7939	0.092877	0.355136

Attachment 10 to:
GNRO 2000/20005

BEFORE THE

UNITED STATES NUCLEAR REGULATORY COMMISSION

LICENSE NO. NPF-29

DOCKET NO. 50-416

IN THE MATTER OF

ENTERGY MISSISSIPPI, INC.

and

SYSTEM ENERGY RESOURCES, INC.

and

SOUTH MISSISSIPPI ELECTRIC POWER ASSOCIATION

and

ENTERGY OPERATIONS, INC.

AFFIRMATION

I, W. A. Eaton, being duly sworn, state that I am Vice President, Operations GGNS of Entergy Operations, Inc.; that on behalf of Entergy Operations, Inc., System Energy Resources, Inc., and South Mississippi Electric Power Association I am authorized by Entergy Operations, Inc. to sign and file with the Nuclear Regulatory Commission, this application; that I signed this application as Vice President, Operations GGNS of Entergy Operations, Inc.; and that the statements made and the matters set forth therein are true and correct to the best of my knowledge, information and belief.

William A Eaton
W. A. Eaton

STATE OF MISSISSIPPI
COUNTY OF CLAIBORNE

SUBSCRIBED AND SWORN TO before me, a Notary Public, in and for the County and State above named, this 21st day of January, 2000.

(SEAL)

Notary Public

My commission expires:
NOTARY PUBLIC STATE OF MISSISSIPPI AT LARGE
MY COMMISSION EXPIRES: Jan 27, 2004
BONDED THRU NOTARY PUBLIC UNDERWRITERS