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NUCLEAR FUELS & SYSTEMS ENGINEERING
ANALYSIS/CALCULATION COVER SHEET

Calc. No. SE-B-NA-078
Superseded by
SRMS File Code R2-1

TITLE: Conservative Calculation of Offsite and Control Room Doses for a 25 GPM Reactor Water Leak Taking No Credit for Secondary Containment (Quality)

SSES UNIT B

SSES CYCLE NA

Rev. No.	Total No. of Pages	Prepared By	Date	Reviewed By	Date	Approved By	Date
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REVISION DESCRIPTION INDEX

Rev. No.	Revised Pages	Affected Sections	Description/Purpose of Revision
1	Added pages 19 – 27	Added Appendix C	Extend calculation to evaluate a 50 GPM Reactor Water Leak for 48 hours.
2	11, 17, 24, 26	Section III, Appendix B, Appendix C	Correct Control Room Whole Body Doses by multiplying by .25, which is missing in the Control Room Whole Body Dose formulas on pages 17 and 24 and revise summary tables on pages 11 and 26 with correct control room whole body doses.

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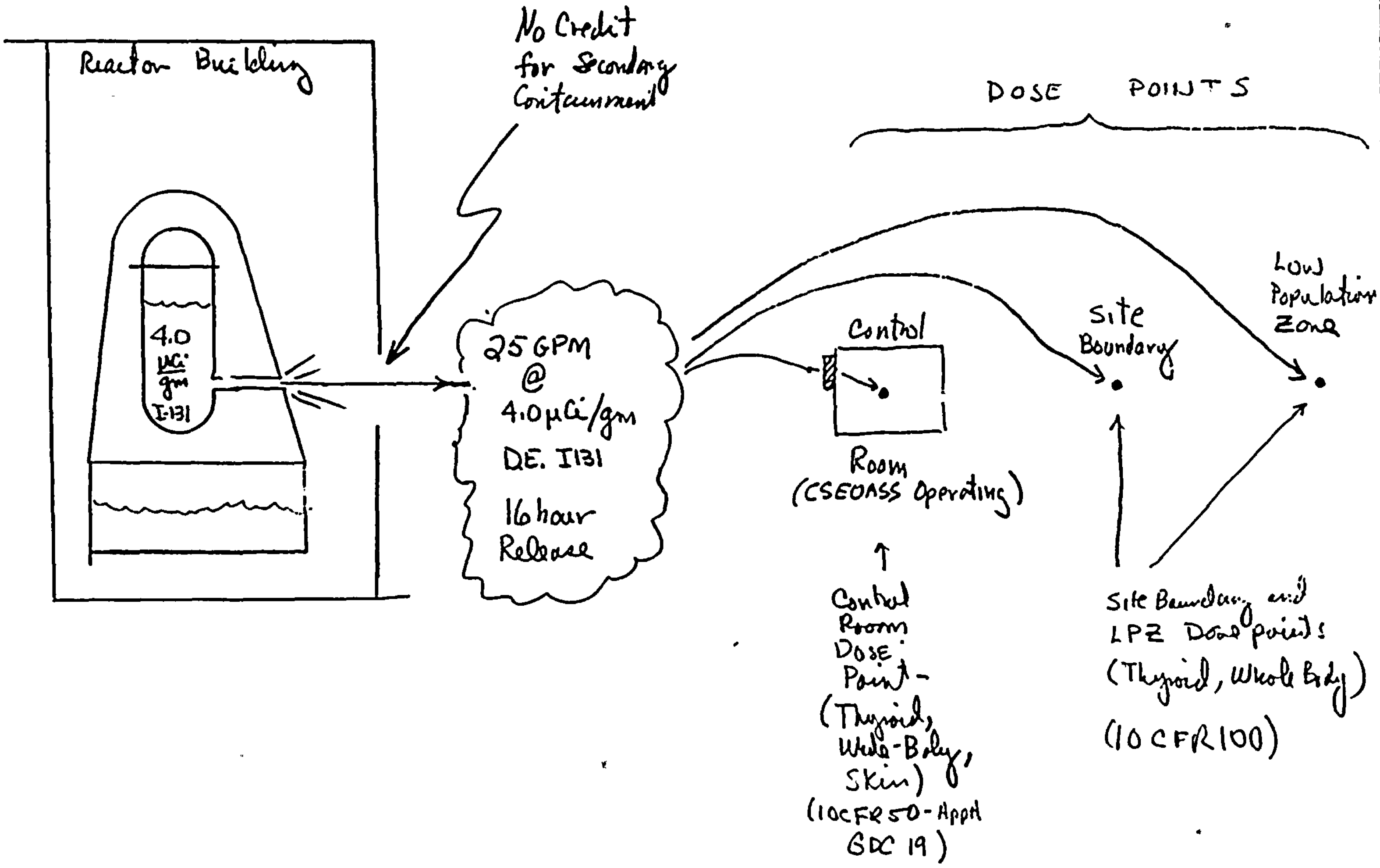
I. OBJECTIVE

The purpose of this calculation is to perform a conservative, worst case evaluation of the offsite and control room doses resulting from a steam (water) leak of reactor grade water of 25 gpm into secondary containment. No credit for removal, holdup or decay of 4.0 µCi/gm of Dose-Equivalent Iodine-131 is to be taken. As such, no credit for the secondary containment is taken for iodine removal. The conservative situation modeled in this analysis is shown in Figure 1. The period of the leak is assumed to be 16 hours, after which environmental leaking is terminated.

Figure 1:
Evaluation Scenario



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II. Methodology

Because a worst case scenario is to be employed, a bounding hand calculation employing methodology outlined in SSES-FSAR Chapter 15-Accident Analyses (Ref. 1) is used. A source term concentration of 4.0 $\mu Ci/gm$ of Dose Equivalent I-131 (Reference 2) is assumed. At this concentration, reactor operation must enter a LCO and be in hot shutdown in 12 hours as per SSES TS(U1/U2) 3/4.4.5 (Reference 3). A 25 gpm leak of this concentration is assumed to exist for 4 hours prior to entering the 12 hour LCO period. Thus a leak of 25 gpm

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of 4.0 $\mu Ci/gm$ of Dose Equivalent Iodine-131 is assumed to exist for a period of 16 hours. This leak is assumed to pass directly to the environment with no removal, holdup or decay. Thyroid, whole body and Control Room skin doses are determined for this source term. Noble Gases in coolant are assumed to be processed by the Offgas System, and do not carry over with reactor coolant. Additionally, all particulate activity is assumed to be retained in secondary containment and does not volatilize as does the iodine. No dose contribution from particulates or noble gases is calculated.

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The equations to calculate offsite doses are taken from the SSES-FSAR. For the Thyroid Dose, equation 15B-2 of Ref 1 is used:

$$D^{os}_{thyroid_i} = \chi/Q_i \times BR_i \times Q^i_I \times TDCF \qquad \text{(SSES-FSAR 15B-2)}$$

$D^{os}_{thyroid_i}$ = Offsite thyroid dose for time period i

χ/Q_i = Dispersion Factor for SB, LPZ for ith time period i

BR_i = Breathing Rate at SB, LPZ for time period i

Q^i_I = Total I-131 emitted in time period i

TDCF = Thyroid Dose Conversion Factor for Iodine 131,

This equation is evaluated for the periods of 0-8hrs and 8hrs to 16 hrs to account for the change in χ/Q at 8 hours. Numerical values of the parameters shown are found in Appendix A

Whole body doses are calculated using

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The gamma whole-body Equation 15B-I of Ref 1 (Equation developed in Reference 5):

$$D_{\gamma i}^{os} = .25 \times \chi/Q_i \times Q_I^i \times \overline{E}_I \qquad \text{(Equation 15B-1)}$$

where

$D_{\gamma i}^{os}$ = Offsite wholebody dose for timeperiod i

χ/Q_i = Dispersion Factor for SB, LPZ for timeperiod i

Q_I^i = total I-131 emitted in time period i

$\overline{E}_I$ = .374 MeV/Disint (Table 15B-2)

This equation is evaluated for the periods of 0-8hrs and 8hrs to 16 hrs to account for the change in X/Q at 8hours.

Doses to control room operators as per 10CFR50 Appendix A-GDC19 is also evaluated for this conservative scenario. Since the

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release of iodine will cause a high concentration of radioactivity in the reactor building air inlet, the control room is assumed to be operating in the emergency mode and the CSEOASS filter train operating with an iodine removal efficiency of .99. With this efficiency, the Iodine Protection Factor (IPF) (Reference 4) is 85.46. The control room thyroid dose is then formulated as

$$D^{CR}_{thyroid_i} = \chi^{CR}/Q_i \times BR_{CR} \times Q^i_I \times TDCF \times \frac{1}{IPF}$$

where

$D^{CR}_{thyroid_i}$ = Control Room Thyroid Dose for time period i

χ^{CR}/Q_i = Dispersion factor for Control Room for the ith time period

BR_{CR_i} = Control Room Breathing Rate for period i

Q_I^i = total iodine-131 emitted in time period i

TDCF = Thyroid Dose Conversion Factor

IPF = Iodine Protection Factor for Iodine (Ref 4)

The gamma (whole Body) dose is calculated for the ith period as

$$D_{\gamma_i}^{CR} = .25 \ \chi^{CR}/Q_i \times Q_I^i \times \bar{E}_I \times \frac{1}{IPF}$$

where

$D_{\gamma_i}^{CR}$ = Control Room Whole Body dose for period i

χ^{CR}/Q_i = Dispersion Factor for Control Room for the ith time period

Q_I^i = total iodine-131 emitted in time period i

$\bar{E}_I$ = $.374 \frac{MeV}{dis}$ (Table 15B-2)

IPF = Iodine Protection Factor from Ref. 4

Due to the low energy γ @ .374 MeV/dis, it is assumed the control room walls shield operators from external iodine gamma contribution to whole body dose

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The skin dose to control room operators can be evaluated using modified equations 15B-4 and 15B-10 from the SSES-FSAR. The skin dose (beta) for the ith time interval can be written:

$$D^{CR}_{\beta I_i} = Q^i_I \times \chi^{CR}/Q_i \times \beta DCF \times \frac{1}{IPF}$$

$D^{CR}_{\beta I_i}$ = Control Room skin dose (beta) in period i

Q^i_I = Total iodine-131 emitted in time period i

χ^{CR}/Q_i = Dispersion Factor for Control Room for the ith time period.

βDCF = Beta Dose Conversion Factor, Table 15B-4

$= 3.02 \times 10^{-2} \frac{Rem/sec}{Ci/m^3}$

IPF = Iodine Protection Factor from Reference 4

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III RESULTS / CONCLUSIONS

The offsite doses and control room doses associated with the above scenario all fall below 10CFR100 and 10CFR50 Appendix A GDC 19 dose limits for the extremely conservative assumptions used in the analysis. As such, it can be reasonably assumed that a 25 GPM leak of Reactor Water (or steam) occurring in the actual plant would have even less dose consequences. A summary Table of the calculated values is provided in Table 1.

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TABLE 1: COMPARISON OF CALCULATED DOSES TO 10CFR DOSE LIMITS.

DOSE CATEGORY	CALCULATED DOSE (REM)	DOSE LIMIT (REM)	REGULATION
2HR* SITE BOUNDARY THYROID	16.6	300 @2HR	10CFR100
2HR* SITE BOUNDARY WHOLE BODY	3.0×10^{-2}	25 @2HR	10CFR100
30 DAY** LOW POP. ZONE THYROID	1.7	300 @30DAYS	10CFR100
30 DAY** LOW POP ZONE WHOLE BODY	3.05×10^{-4}	25 @30DAYS	10CFR100
30 DAY** CONTROL ROOM THYROID	.426	30 @30DAYS	10CFR50 APP A-GDC19
30 DAY** CONTROL ROOM WHOLE BODY	8.0×10^{-5} ~~3.2×10^{-4}~~ Rev. 2	5 @30DAYS	10CFR50 APP. A-GDC19
30 DAY** CONTROL ROOM SKIN	2.53×10^{-5}	30 @30DAYS	10CFR50 APP. A-GDC19

NOTES:

* ACTUAL EXPOSURE WAS FOR 16 HOURS,
10CFR100 REQUIRES DOSE EVALUATION AT 2HRS ONLY, HOWEVER, EVEN 16 HOUR DOSE IS <u>BELOW</u> LIMITS.

** ACTUAL EXPOSURE WAS FOR 16 HOURS, NO FURTHER DOSE ACCRUED FOR 16 HOURS TO 30 DAYS
10CFR100 and 10CFR50 REQUIRE DOSE EVALUATION AT 30 DAYS

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IV. REFERENCES

1. SSES-FSAR, Chapter 15, Accident Analyses

2. SSES Chemistry Manual, Chapter 2.3.3.5

3. SSES Unit 1/Unit 2 Technical Specifications Section 3/4.4.5

4. TACT-III Evaluation of SOOR-1-88-042, System Engineering Calculation SE-1-NA-005 December, 1988.

5. Meteorology and Atomic Engergy - 1968, D.H. Slade, USAEC/Division of Technical Information, 1968.

6. ASME STEAM TABLES - 1983

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Appendix A
Parameter Values Extracted from SSES FSAR Chapter 15

Parameter		Value	Reference (FSAR)
X/Q, SB	0-16 HRS*	2.3×10^{-4} sec/m³	Table 15.0-3
X/Q, LPZ	0-8 HRS	2.13×10^{-5} sec/m³	Table 15.0-3
X/Q, LPZ	8-24 HRS	2.3×10^{-6} sec/m³	Table 15.0-3
X/Q, CR	0-8 HRS	3.32×10^{-4} sec/m³	Table 15B-1
X/Q, CR	8-24 HRS	1.96×10^{-4} sec/m³	Table 15B-1
Thyroid Dose Conv. Factor I-131		1.49×10^{6} Rem/Curie	Table 15B-2
β Dose Conversion Factor		3.02×10^{-2} (Rem/sec)/(Ci/m³)	Table 15B-4
BR, Breathing Rate, Conservatively used in ALL time periods.		3.47×10^{-4} m³/sec	Table 15B-3
IPF, Iodine Protection Factor		85.46	Reference 4
$\bar{E}_I$, Average Energy of I-131 per disintegration		.374 MeV/dis.	Table 15B-2

* This value assumed conservatively to extend to 16 hrs.

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Appendix B
Numerical Calculations

1) Determine Source Term in Ci/hr for 25 GPM Leak.

— Assume Reactor Water at 548°F and 1028 psia —

$\therefore \rho_{RW} = 46.08 \frac{lbm}{ft^3} = .74 \frac{gm}{ml}$ (Steam Tables - Ref 6)

— Assume 4.0 $\mu Ci/gm$ DE-I-131 Source Concentration

Ci/hr of I-131 = $\dot{Q}_I$

$$\dot{Q}_I = 25\,GPM \times 3785.3 \frac{ml}{gallon} \times .74 \frac{gm}{ml} \times 4.0 \frac{\mu Ci}{gm} \times \frac{1\,Ci}{10^6\,\mu Ci} \times \frac{60\,min}{hr}$$

$$\boxed{\dot{Q}_I = 16.8\ Ci/hr}$$

2) Calculate Thyroid Dose For Site Boundary

$$\dot{Q} \times \Delta t \times X/Q \times \beta \times TDCF$$

$$D^{SB}_{Th\,0-16} = 16.8\ \cancel{Ci}/\cancel{hr} \times 16\,\cancel{hr} \times 9.6\times10^{-4} \frac{sec}{m^3} \times 3.47\times10^{-4} \frac{m^3}{sec} \times 1.48\times10^{6} \frac{Rem}{\cancel{Ci}}$$

$$\boxed{\begin{aligned} D^{SB}_{Th\,0-16} &= 132.5\ Rem\ @\ 16\,hrs \\ \therefore D^{SB}_{Th\,0-2} &= 132.5 \times \frac{2\,hr}{16\,hr} = 16.6\ Rem\ @\ 2\,hrs \end{aligned}}$$

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3) Calculate Thyroid Dose for Low Population Zone

$$\dot{Q} \times \Delta t \times X/Q \times BR \times TDCF$$

$$D^{LPZ}_{TH\,0-8} = 16.8\,\tfrac{Ci}{hr} \times 8hr \times 2.18\times10^{-5}\,\tfrac{sec}{m^3} \times 3.47\times10^{-4}\,\tfrac{m^3}{sec} \times 1.43\times10^{6}\,\tfrac{Rem}{Ci}$$

$$= 1.5 \text{ Rem}$$

$$D^{LPZ}_{TH\,8-16} = 16.8\,\tfrac{Ci}{hr} \times 8hr \times 2.32\times10^{-5}\,\tfrac{sec}{m^3} \times 3.47\times10^{-4}\,\tfrac{m^3}{sec} \times 1.48\times10^{6}\,\tfrac{Rem}{Ci}$$

$$= .2 \text{ Rem}$$

$$\boxed{D^{LPZ}_{TH\,0-16} = D^{LPZ}_{TH\,0-8} + D^{LPZ}_{TH\,8-16} = 1.5 \text{ Rem} + .2 \text{ Rem} = 1.7 \text{ Rem}}$$

4) Calculate Whole Body Dose for Site Boundary

$$.25 \times \dot{Q} \times \Delta t \times X/Q \times \bar{E}_I$$

$$D^{SB}_{\gamma\,0-16} = .25 \times 16.8\,\tfrac{Ci}{hr} \times 16hr \times 9.6\times10^{-4}\,\tfrac{sec}{m^3}\ .374\,\tfrac{MeV}{dis}$$

$$D^{SB}_{\gamma\,0-16} = .024 \text{ Rem @ 16hrs}$$

$$\therefore D^{SB}_{\gamma\,0-2} = .024 \text{ Rem} \times \frac{2hr}{16hr} = .0030 \text{ Rem @ 2hrs}$$

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5) Calculate Whole Body Dose for Low Population Zone

$$.25 \times \dot{Q} \times \Delta t \times \chi/Q \times \bar{E}_{\gamma}$$

$$D^{LPZ}_{\gamma 0\text{-}8} = .25 \times 16.8\ Ci/hr \times 8hr \times 2.18 \times 10^{-5}\ \frac{sec}{m^3} \times .374\ \frac{mev}{dis}$$

$$= 2.7 \times 10^{-4}\ Rem$$

$$D^{LPZ}_{\gamma 8\text{-}16} = .25 \times 16.8\ Ci/hr \times 8hr \times 2.82 \times 10^{-6}\ \frac{sec}{hr} \times .374\ \frac{mev}{dis}$$

$$= 3.5 \times 10^{-5}\ Rem$$

$$D^{LPZ}_{\gamma 0\text{-}16} = D^{LPZ}_{\gamma 0\text{-}8} + D^{LPZ}_{\gamma 8\text{-}16} = 2.7 \times 10^{-4}\ Rem + 3.5 \times 10^{-5}\ Rem$$

$$\boxed{D^{LPZ}_{\gamma 0\text{-}16} = 3.05 \times 10^{-4}\ Rem}$$

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6) Calculate Thyroid Dose for Control Room

$$\dot{Q} \times \Delta t \times X/Q \times BR \times TC...$$

$$D^{CR}_{thyroid\,0-8} = 16.8\ Ci/hr \times 8hr \times 3.32\times10^{-4}\ \frac{sec}{m^3} \times 3.47\times10^{-4}\ \frac{m^3}{sec} \times 1.48\times10^{6}\ \frac{Rem}{Ci} \times \frac{1}{85.46}$$

$$D^{CR}_{thyroid\,0-8} = .268\ Rem$$

$$D^{CR}_{thyroid\,8-16} = 16.8\ Ci/hr \times 8hr \times 1.96\times10^{-4}\ \frac{sec}{m^3} \times 3.47\times10^{-4}\ \frac{m^3}{sec} \times 1.48\times10^{6} \times \frac{1}{85.46}$$

$$D^{CR}_{thyroid\,8-16} = .158\ Rem$$

$$D^{CR}_{thyroid\,0-16} = D^{CR}_{thyroid\,0-8} + D^{CR}_{thyroid\,8-16} = .268\ Rem + .158\ Rem =$$

$$\boxed{D^{CR}_{thyroid\,0-16} = .426\ Rem}$$

7) Calculate Whole Body Dose for Control Room

$$Q \times \Delta t \times X/Q \times E \times \frac{1}{TF}$$

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$$D^{CR}_{\gamma\,0-8} = 16.8\frac{Ci}{hr} \times 8hr \times 3.32\times10^{-4}\frac{sec}{m^3} \times .374\ \frac{MeV}{Dis} \times \frac{1}{85.46} \times .25 \times .25$$

$$D^{CR}_{\gamma\,0-8} = \cancel{2.0\times10^{-4}\ Rem}\ \ 5.0\times10^{-5}\ Rem$$ Rev. 2

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$$D^{CR}_{\gamma\,8-16hr} = 16.8\frac{Ci}{hr} \times 8hr \times 1.96\times10^{-4}\frac{sec}{m^3} \times .374\ \frac{MeV}{dis} \times \frac{1}{85.46} \times .25$$

$$D^{CR}_{\gamma\,8-16} = \cancel{1.2\times10^{-4}\ Rem}\ \ 3.0\times10^{-5}\ Rem$$ Rev. 2

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$$\boxed{D^{CR}_{\gamma 0\text{-}16} = D^{CR}_{\gamma 0\text{-}3} + D^{CR}_{\gamma 3\text{-}16} = \begin{matrix} 5.0\times10^{-5} + 3.0\times10^{-5} \\ \cancel{2.0\times10^{-4} + 1.2\times10^{-4}} \end{matrix} = \begin{matrix} 8.0\times10^{-5}\ \text{Rem} \\ \cancel{3.2\times10^{-1}\ \text{Rem}} \end{matrix}\ \text{Rem.}}$$

8) Calculate Skin Dose for Control Room

$$\dot{Q} \times \Delta t \times \chi/Q \times \text{DCF} \times \frac{1}{\text{IPF}}$$

$$D^{CR}_{\beta I\, 0\text{-}8} = 16.8\ \frac{\cancel{Ci}}{hr} \times 8\,hr \times 3.32\times10^{-4}\ \frac{\cancel{sec}}{\cancel{m^3}} \times 3.02\times10^{-2}\ \frac{Rem/\cancel{sec}}{\cancel{Ci/m^3}} \times \frac{1}{85.96}$$

$$D^{CR}_{\beta I\, 0\text{-}8} = 1.6\times10^{-5}\ \text{Rem}$$

$$D^{CR}_{\beta I\, 8\text{-}16} = 16.8\ \frac{Ci}{hr} \times 8\,hr \times 1.96\times10^{-4}\ \frac{sec}{m^3} \times 3.02\times10^{-2}\ \frac{Rem/sec}{Ci/m^3} \times \frac{1}{85.76}$$

$$D^{CR}_{\beta I\, 8\text{-}16} = 9.3\times10^{-6}\ \text{Rem}$$

$$\boxed{D^{CR}_{\beta I\, 0\text{-}16} = D^{CR}_{\beta I\, 0\text{-}8} + D^{CR}_{\beta I\, 8\text{-}16} = 1.6\times10^{-5}\ \text{Rem} + 9.3\times10^{-6}\ \text{Rem} = \underline{2.53\times10^{-5}\ \text{Rem}}}$$

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Appendix C

Extension of Calculation to a Leak of 50 gpm for a 48 hr. Period.

I. INTRODUCTION

The purpose of this Appendix is to extend the methodology of the dose calculation to an increased leakage flow and leak duration. The leakage is increased to 50 gpm of reactor grade water for a duration of 48 hrs. This situation is considered to provide a conservative bounds for future requirements for analyses of this type. The X/Qs for the low population zone and control room must be extended to the 48 hr leak period duration. The site boundary X/Q will remain the same because the required evaluation time is at 2 hrs.

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For the Low Population Zone (LPZ) X/Q, the value from Table 15.0-3 for the 24-96 hr time period is used. That is:

$$X/Q, LPZ \; (24\text{-}96\,hrs) = \boxed{1.43 \times 10^{-6} \; \frac{sec}{m^3}}$$

For the Control Room X/Q, the value from Table 15B-1 for the 1-4 day time period is used. That is

$$X/Q, CR \; \left(\begin{matrix}1\text{-}4\,day \\ 24\text{-}96\,hr\end{matrix}\right) = \boxed{7.64 \times 10^{-5} \; \frac{sec}{m^3}}$$

The above X/Q's are required to extend the calculation to the 48 hr leak period. Note that a conservative breathing rate of 3.47×10^{-4} m^3/sec is used for all time periods in this calculation for additional conservatism. All dose values are rounded up for conservatism

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II. Numerical Calculations

1) Determine Source Term: from Appendix B-1), substituting 50 GPM for 25 GPM gives

$$\dot{Q}_I = 50\,GPM \times 3785.3\,\frac{ml}{gallon} \times .74\,\frac{gm}{ml} \times 4.0\,\frac{\mu Ci}{gm} \times \frac{1\,Ci}{10^6\,\mu Ci} \times \frac{60\,min}{hr}$$

$$\boxed{\dot{Q}_I = 33.6\ \frac{Ci}{hr}}$$

2) Calculate 2 HR Site Boundary Thyroid Dose -

$$D^{SB}_{Th\,(0-2)} = \dot{Q}_I \times \Delta t \times X/Q \times \beta \times TDCF$$

$$= 33.6\,\frac{Ci}{hr} \times 2\,hr \times 9.6\times10^{-4}\,\frac{sec}{m^3} \times 3.47\times10^{-4}\,\frac{m^3}{sec} \times 1.48\times10^6\,\frac{Rem}{Ci}$$

$$\boxed{D^{SB}_{Th\,(0-2)} = 33.2\ Rem\ @\ 2hrs}$$

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3) Calculate Thyroid Dose for Low Population Zone

$$\dot{Q} \times \Delta t \times X/Q \times BR \times TDCF$$

$$D_{TH}^{LPZ}(0\text{-}8) = 33.6\,\frac{Ci}{hr} \times 8hr \times 2.18\times10^{-5}\,\frac{sec}{m^3} \times 3.47\times10^{-4}\,\frac{m^3}{sec} \times 1.48\times10^{6}\,\frac{Rem}{Ci}$$

$$= 3.1 \text{ Rem}$$

$$D_{TH}^{LPZ}(8\text{-}24) = 33.6\,\frac{Ci}{hr} \times 16hr \times 2.82\times10^{-6}\,\frac{sec}{m^3} \times 3.47\times10^{-4}\,\frac{m^3}{sec} \times 1.48\times10^{6}\,\frac{Rem}{Ci}$$

$$= .8 \text{ Rem}$$

$$D_{TH}^{LPZ}(24\text{-}48) = 33.6\,\frac{Ci}{hr} \times 24hr \times 1.43\times10^{-6}\,\frac{sec}{m^3} \times 3.47\times10^{-4}\,\frac{m^3}{sec} \times 1.48\times10^{6}\,\frac{Rem}{Ci}$$

$$= .6 \text{ Rem}$$

$$\boxed{D_{TH}^{LPZ}(0\text{-}48) = D_{TH}^{LPZ}(0\text{-}8) + D_{TH}^{LPZ}(8\text{-}24) + D_{TH}^{LPZ}(24\text{-}48) = 3.1\text{ Rem} + .8\text{ Rem} + .6\text{ Rem} = 4.5\text{ Rem}}$$

4) Calculate Whole Body Dose for Site Boundary

$$.25 \times \dot{Q} \times \Delta t \times X/Q \times \bar{E}_{I}$$

$$D_{\gamma}^{SB}(0\text{-}2) = .25 \times 33.6\,\frac{Ci}{hr} \times 2hr \times 9.6\times10^{-4}\,\frac{sec}{m^3} \times .374\,\frac{MeV}{dis}$$

$$\boxed{D_{\gamma}^{SB}(0\text{-}2) = 6.1\times10^{-3}\text{ Rem @ 2hrs}}$$

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5) Calculate Whole Body Dose for Low Population Zone

$$.25 \times \dot{Q} \times \Delta t \times X/Q \times \bar{E}_{\gamma}$$

$$D_{\gamma}^{LPZ}(0\text{-}8) = .25 \times 33.6 \tfrac{Ci}{hr} \times 8hr \times 2.18\times10^{-5} \tfrac{sec}{m^3} \times .374 \tfrac{MeV}{dis}$$

$$= 5.5\times10^{-4} \text{ Rem}$$

$$D_{\gamma}^{LPZ}(8\text{-}24) = .25 \times 33.6 \tfrac{Ci}{hr} \times 16hr \times 2.82\times10^{-6} \tfrac{sec}{m^3} \times .374 \tfrac{MeV}{dis}$$

$$= 1.5\times10^{-4} \text{ Rem}$$

$$D_{\gamma}^{LPZ}(24\text{-}48) = .25 \times 33.6 \tfrac{Ci}{hr} \times 24hr \times 1.43\times10^{-6} \tfrac{sec}{m^3} \times .374 \tfrac{MeV}{dis}$$

$$= 1.1\times10^{-4} \text{ Rem}$$

$$D_{\gamma}^{LPZ}(0\text{-}48) = D_{\gamma}^{LPZ}(0\text{-}8) + D_{\gamma}^{LPZ}(8\text{-}24) + D_{\gamma}^{LPZ}(24\text{-}48) = 5.5\times10^{-4}\text{ Rem} + 1.5\times10^{-4}\text{ Rem} + 1.1\times10^{-4}\text{ Rem}$$

$$\boxed{D_{\gamma}^{LPZ}(0\text{-}48) = 8.1\times10^{-4} \text{ Rem}}$$

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6) Calculate Thyroid Dose for Control Room

$$Q \times \Delta t \times X/Q \times BR \times TDCF \times \frac{1}{IPF}$$

$$D_{TH}^{CR}(0\text{-}8) = 33.6\ \frac{Ci}{hr} \times 8hr \times 3.32\times10^{-4}\ \frac{sec}{m^3} \times 3.47\times10^{-4}\ \frac{m^3}{sec} \times 1.43\times10^{6}\ \frac{Rem}{Ci} \times \frac{1}{85.46}$$

$$= .54\ Rem$$

$$D_{TH}^{CR}(8\text{-}24) = 33.6\ \frac{Ci}{hr} \times 16hr \times 1.96\times10^{-4}\ \frac{sec}{m^3} \times 3.47\times10^{-4}\ \frac{m^3}{sec} \times 1.48\times10^{6}\ \frac{Rem}{Ci} \times \frac{1}{85.46}$$

$$= .64\ Rem$$

$$D_{TH}^{CR}(24\text{-}48) = 33.6\ \frac{Ci}{hr} \times 24hr \times 7.64\times10^{-5}\ \frac{sec}{m^3} \times 3.47\times10^{-4}\ \frac{m^3}{sec} \times 1.48\times10^{6}\ \frac{Rem}{Ci} \times \frac{1}{85.46}$$

$$= .38\ Rem$$

$$D_{TH}^{CR}(0\text{-}48) = D_{TH}^{CR}(0\text{-}8) + D_{TH}^{CR}(8\text{-}24) + D_{TH}^{CR}(24\text{-}48) = .54\ Rem + .64\ Rem + .38\ Rem$$

$$\boxed{D_{TH}^{CR}(0\text{-}48) = 1.6\ Rem}$$

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7) Calculate Whole Body Dose for Control Room

$$Q \times \Delta t \times X/Q \times \bar{E} \times \frac{1}{IPF} \times .25$$

$$D_{\gamma}^{CR}(0\text{-}8) = 33.6\ \frac{Ci}{hr} \times 8hr \times 3.32\times10^{-4}\ \frac{sec}{m^3} \times .374\ \frac{MeV}{dis} \times \frac{1}{85.46} \times .25$$

$$= \cancel{4.0\times10^{-4}\ Rem}\quad 1.0\times10^{-4}\ Rem$$ Rev. 2

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$$D_{\gamma}^{CR}(8\text{-}24) = 33.6\ \frac{Ci}{hr} \times 16hr \times 1.96\times10^{-4}\ \frac{sec}{m^3} \times .374\ \frac{MeV}{dis} \times \frac{1}{85.46} \times .25$$

$$= \cancel{4.7\times10^{-4}\ Rem}\quad 1.175\times10^{-4}\ Rem$$ Rev. 2

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$$D_{\gamma}^{CR}(24-48) = 33.6\ \frac{Ci}{hr} \times 24hr \times 7.64\times10^{-5}\ \frac{sec}{m^3} \times .374\ \frac{MeV}{dis} \times \frac{1}{85.46} \times .25$$

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$$= \cancel{2.7\times10^{-4}\ Rem}\ \ 6.75\times10^{-5}\ Rem$$

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$$D_{\gamma}^{CR}(0-48) = D_{\gamma}^{CR}(0-8)+D_{\gamma}^{CR}(8-24)+D_{\gamma}^{CR}(24-48) = \cancel{4.0\times10^{-4}\ Rem + 4.7\times10^{-4}\ Rem + 2.7\times10^{-4}\ Rem}$$

$$1.0\times10^{-4} + 1.175\times10^{-4} + 6.75\times10^{-5}$$

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$$\boxed{D_{\gamma}^{CR}(0-48) = \cancel{1.2\times10^{-3}\ Rem}\ \ 2.850\times10^{-4}\ Rem}$$

8) Calculate Skin Dose for Control Room

$$Q \times \Delta t \times \chi/Q \times \beta DCF \times \frac{1}{IPF}$$

$$D_{\beta I}^{CR}(0-8) = 336\ \frac{Ci}{hr} \times 8hr \times 3.32\times10^{-4}\ \frac{sec}{m^3} \times 3.02\times10^{-2}\ \frac{Rem/sec}{Ci/m^3} \times \frac{1}{85.46}$$

$$= 3.2\times10^{-5}\ Rem$$

$$D_{\beta I}^{CR}(8-24) = 33.6\ \frac{Ci}{hr} \times 16hr \times 1.96\times10^{-4}\ \frac{sec}{m^3} \times 3.02\times10^{-2}\ \frac{Rem/sec}{Ci/m^3} \times \frac{1}{85.46}$$

$$= 3.8\times10^{-5}\ Rem$$

$$D_{\beta I}^{CR}(24-48) = 33.6\ \frac{Ci}{hr} \times 24hr \times 7.64\times10^{-5}\ \frac{sec}{m^3} \times 3.02\times10^{-2}\ \frac{Rem/sec}{Ci/m^3} \times \frac{1}{85.46}$$

$$= 2.2\times10^{-5}\ Rem$$

$$D_{\beta I}^{CR}(0-48) = D_{\beta I}^{CR}(0-8) + D_{\beta I}^{CR}(8-24) + D_{\beta I}^{CR}(24-48) = 3.2\times10^{-5}\ Rem + 3.8\times10^{-5}\ Rem + 2.2\times10^{-5}\ Rem$$

$$\boxed{D_{\beta I}^{CR}(0-48) = 9.2\times10^{-5}\ Rem}$$

TABLE C1 – COMPARISON OF CALCULATED DOSES FOR 50 GPM LEAK FOR 48 HR TIME PERIOD TO 10CFR DOSE LIMITS

DOSE CATEGORY	CALCULATED DOSE (REM)	DOSE LIMIT (REM)	REGULATION
2 HR* SITE BOUNDARY THYROID	33.2	300 @ 2HR	10 CFR 100
2 HR* SITE BOUNDARY WHOLE BODY	6.1×10^{-3}	25 @ 2HR	10 CFR 100
30 DAY** LOW POPULATION ZONE THYROID	4.5	300 @ 30 DAYS	10 CFR 100
30 DAY** LOW POPULATION ZONE WHOLE BODY	8.1×10^{-4}	25 @ 30 DAYS	10 CFR 100
30 DAY** CONTROL ROOM THYROID	1.6	30 @ 30 DAYS	10 CFR 50 APP. A - GDC 19
30 DAY** CONTROL ROOM WHOLE BODY	2.850×10^{-4} ~~1.2×10^{-3}~~ Rev. 2	5 @ 30 DAYS	10 CFR 50 APP A - GDC 19
30 DAY** CONTROL ROOM SKIN	9.2×10^{-5}	75*** @ 30 DAYS	10 CFR 50 APP. A - GDC 19

* ALTHOUGH ACTUAL EXPOSURE PERIOD IS 48 HRS, REG. REQUIRES DOSE CALC @ 2HR FOR SITE BNDRY.

** ACTUAL EXPOSURE ENDED AFTER 48 HRS, WITH NO FURTHER DOSE ACCUMULATED OUT TO 30 DAYS

*** SKIN DOSE LIMIT IS INCREASED TO 75 REM BECAUSE PP&L HAS COMMITTED TO PROTECTIVE CLOTHING RQMT IN EP-IP-033.

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III RESULTS.

The results of the calculations are displayed in TABLE C1.

IV CONCLUSIONS

The results show that even for a leak rate of 50 GPM for a duration of 48 hrs, NO 10 CFR 100 or 10 CFR 50 dose limits are exceeded even with the extreme conservatisms considered in this analysis.