**Attachment 14.2 of Calculation H-1-ZZ-MDC-1880, Revision 4, "Post-LOCA EAB, LPZ, and CR Doses" (GEH Non-Proprietary Information)**

**Note: Some pages in this attachment include a notation to "LRW-PSG-KT1-10-091" this refers to the GEH letter that provided the material to PSEG**

# ENCLOSURE 2

# LRW-PSG-KT1-10-091

## Attachment 14.2 of Calculation H-1-ZZ-MDC-1880, Revision 4

## Non-Proprietary Information

**Information Notice**

This is a non-proprietary version of LRW-PSG-KT1-10-091, Enclosure 1, from which the proprietary information has been removed. Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here [[ ]].

**Non-Proprietary Information**

**Attachment 14.2**

**Title: Evaluation to Determine the radiological impact of adding 12 Isotope Test Assemblies (ITAs) on the post-LOCA EAB, LPZ, and CR Doses.**

## 1.0 REASON FOR EVALUATION / SCOPE

The purpose of this evaluation is to determine radiological impact of adding twelve (12) Co-60 isotope test assemblies (ITAs) in the Hope Creek reactor core. The resulting post-LOCA dose consequences at the Exclusion Area Boundary (EAB), Low Population Zone (LPZ) and Control Room (CR) are analyzed. The doses are calculated using the Alternate Source Term (AST), guidance in Regulatory Guide (RG) 1.183, and Total Effective Dose Equivalent (TEDE) dose criteria.

## 2.0 METHODOLOGY

The design basis LOCA radiological consequence analysis documented in Reference 10.4 uses the average uprated core inventory with Co-60 inventory obtained from RADTRAD User's Manual, Table 1.4.3.2-3. The proposed insertion of the Co-60 ITAs will increase the Co-60 inventory in the core. The total Co-60 activity in the core including the Co-60 in the core plus Co-60 ITAs is calculated in Section 7.9. The Co-60 ITA activity is [[ ]] to account for uncertainty in release of Co-60 present in high concentrations in the cobalt isotope rods. The RADTRAD Nuclide Inventory File (NIF) is modify for the Co-60 inventory calculated in Section 7.9. The newly created RADTRAD NIF file (HEPULOCA2_DEF.txt) is used to calculate the dose consequences at EAB, LPZ, and CR. The following two (2) post-LOCA release paths are evaluated using the design input information in Reference 10.4 and additional Co-60 ITA related design input in Section 5.3:

1. Containment Leakage
2. MSIV Leakage

The ESF leakage dose only accounts for the iodine activity release from the core to the suppression pool water, with the remaining radioactive material assumed to remain in the pool water and retained in the liquid phase (Ref. 10.2, Appendix A, Section 5.3). Therefore, the Co-60 activity is assumed to remain in liquid phase and never becomes airborne and released to the environment.

### 2.1 Post-LOCA Containment Leakage:

The RADTRAD computer run HEPU300CL00.psf for the containment leakage is modified to use the newly developed Nuclide Inventory File HEPULOCA2_DEF along with other design inputs from Reference 10.4 to calculate the EAB, LPZ, and CR doses. The resulting doses are listed in Section 8.0 and added to the dose contributions from the other post-LOCA release paths, and the total doses are compared with the applicable dose limits.

### 2.2 Post-LOCA MSIV Leakage:

The RADTRAD computer run H1N300MS00.psf for the MSIV leakage is modified to use the newly developed Nuclide Inventory File HEPULOCA2_DEF along with other design inputs from Reference 10.4 to calculate the

EAB, LPZ, and CR doses. The resulting doses are listed in Section 8.0, and added to the dose contributions from the other post-LOCA release paths, and the total doses are compared with the applicable dose limits.

### 2.3 Post-LOCA CREF Filter Shine

The CREF charcoal and HEPA filter configuration with respect to the CR normally occupied area during a LOCA and modeling of the charcoal bed are described in Reference 10.4, Section 2.5.5.

The aerosol mass collected on the CR HEPA remains essentially the same as that previous collected due to the containment and MSIV leakage. Therefore, the CR filter shine calculated in Reference 10.4, Section 8.1, remains bounding. It is to be noted that the charcoal and HEPA filter iodine loading is not affected by the increased Co-60 activity.

## 3.0 ACCEPTANCE CRITERIA

The following NRC regulatory requirement and guidance documents are applicable to this HCGS Alternative Source Term LOCA Calculation:

- Regulatory Guide 1.183 (Ref. 10.2)
- 10CFR50.67 (Ref. 10.5)
- Standard Review Plan 15.0.1 (Ref. 10.7)

Dose Acceptance Criteria are:

**Regulatory Dose Limits**

| Dose Type | Control Room (rem) | EAB and LPZ (rem) |
|---|---|---|
| TEDE Dose | 5 | 25 |

## 4.0 ASSUMPTIONS

The assumptions used in evaluating the offsite and control room doses resulting from a Loss of Coolant Accident (LOCA) are the same as those in Reference 10.4, Section 4.0.

## 5.0 DESIGN INPUTS

### 5.1 General Considerations

#### 5.1.1 Applicability of Prior Licensing Basis

Same as that in Reference 10.4, Section 5.1.1

#### 5.1.2 Credit for Engineered Safety Features

Same as that in Reference 10.4, Section 5.1.2

#### 5.1.3 Assignment of Numeric Input Values

Same as that in Reference 10.4, Section 5.1.3.

#### 5.1.4 Meteorology Considerations

Atmospheric dispersion factors ($\chi$/Qs) for the onsite release points such as the FRVS vent for containment and ESF leakage release path and turbine building louvers for MSIV leakage release path are the same as those in Reference 10.4, Sections 5.1.4, 5.6.9 , 5.6.11, 5.7.1, and 5.7.3.

### 5.2 Accident-Specific Design Inputs/Assumptions

The design inputs/assumptions utilized in the EAB, LPZ, and CR habitability analyses are the same as those in Reference 10.4, Sections 5.3 through 5.7, except noted as follows:

| Design Input Parameter | Value Assigned | Reference |
|---|---|---|
| **5.3 CONTAINMENT AND MSIV LEAKAGE MODEL PARAMETERS** | | |
| **5.3.1 Source Term** | | |
| 5.3.1.1 Thermal Power Level | 3,917 MWt | 10.4, Section 7.9 |

5.3.1.2 Isotopic Average Core Inventory (Ci/MWt) (10.4, Section 5.3.1.3)

| Isotope | $Ci/MW_t$ | Isotope | $Ci/MW_t$ | Isotope | $Ci/MW_t$ |
|---|---|---|---|---|---|
| CO-58* | 1.529E+02 | RU103 | 7.700E+04 | CS136 | 1.860E+03 |
| CO-60** | [[ ]] | RU105 | 2.700E+04 | CS137 | 6.760E+03 |
| KR 85 | 3.330E+02 | RU106 | 2.940E+04 | BA139 | 4.950E+04 |
| KR 85M | 7.350E+03 | RH105 | 2.530E+04 | BA140 | 4.780E+04 |
| RB 86 | 1.420E+04 | SB127 | 2.800E+03 | LA140 | 5.080E+04 |
| KR 87 | 2.000E+04 | SB129 | 8.490E+03 | LA141 | 4.510E+04 |
| KR 88 | 6.350E+01 | TE127 | 2.780E+03 | LA142 | 4.370E+04 |
| SR 89 | 2.690E+04 | TE127M | 3.710E+02 | CE141 | 4.540E+04 |
| SR 90 | 2.640E+03 | TE129 | 8.350E+03 | CE143 | 4.220E+04 |
| SR 91 | 5.300E+04 | TE129M | 1.240E+03 | CE144 | 7.424E+04 |
| SR 92 | 3.610E+04 | TE131M | 2.764E+04 | PR143 | 4.080E+04 |
| Y 90 | 2.810E+03 | TE132 | 3.810E+04 | ND147 | 1.810E+04 |
| Y 91 | 3.440E+04 | I131 | 2.670E+04 | NP239 | 5.220E+05 |
| Y 92 | 3.620E+04 | I132 | 3.870E+04 | PU238 | 9.040E+01 |
| Y 93 | 4.160E+04 | I133 | 5.510E+04 | PU239 | 1.090E+01 |
| ZR 95 | 4.850E+04 | I134 | 6.060E+04 | PU240 | 1.410E+01 |
| ZR 97 | 1.468E+05 | I135 | 6.220E+04 | PU241 | 4.090E+03 |
| NB 95 | 4.870E+04 | XE133 | 5.300E+04 | AM241 | 4.600E+00 |
| MO 99 | 5.100E+04 | XE135 | 1.820E+04 | CM242 | 1.090E+03 |
| TC 99M | 4.460E+04 | CS134 | 5.350E+03 | CM244 | 5.240E+01 |

* CO-58 activity is obtained from RADTRAD User's Manual, Table 1.4.3.2-3 (Ref. 10.3)
** CO-60 activity is obtained from Section 7.9

Note: Additional daughter isotopes added to parent isotopes are shown in Reference 10.4, Table 1C

5.3.1.3 Radionuclide Composition

| Group | Elements | |
|---|---|---|
| Noble Gases | Xe, Kr | 10.2, RGP 3.4, Table 5 |
| Halogens | I, Br | |
| Alkali Metals | Cs, Rb | |
| Tellurium Group | Te, Sb, Se, Ba, Sr | |
| Noble Metals | Ru, Rh, Pd, Mo, Tc, Co | |
| Lanthanides | La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y, Cm, Am | |
| Cerium | Ce, Pu, Np | |

5.3.1.4 Timing of Release Phase (Ref. 10.2, Table 4)

| Phase | Onset | Duration | |
|---|---|---|---|
| Gap Release | 2 min | 0.5 hr | Gap release starts at 0.0 sec |
| Early In-Vessel Release | 0.5 hr | 1.5 hr | |

5.3.1.5 Iodine Chemical Form

| Iodine Chemical Form | % | |
|---|---|---|
| Aerosol (CsI) | 95.0% | 10.2, Section 3.5 |

**Non-Proprietary Information**

| Design Input Parameter | Value Assigned | Reference |
|---|---|---|
| Elemental | 4.85% | |
| Organic | 0.15% | |
| | | |
| 5.3.1.6 Release Fraction (Ref 10.2, Table 1) | | |
| **BWR Core Inventory Fraction Released Into Containment** | | |
| **Group** | **Gap Release Phase** | **Early In-Vessel Release Phase** |
| Noble Gases | 0.05 | 0.95 |
| Halogens | 0.05 | 0.25 |
| Alkali Metals | 0.05 | 0.20 |
| Tellurium Metals | 0.00 | 0.05 |
| Ba, Sr | 0.00 | 0.02 |
| Noble Metals | 0.00 | 0.0025 |
| Cerium Group | 0.00 | 0.0005 |
| Lanthanides | 0.00 | 0.0002 |
| 5.3.1.7 Co-60 Isotope Test Assembly Parameters<br><br>Number of ITAs<br>Number of Rod/ITA<br>Co-60 Activity/Rod<br>Total Activity<br>Uncertainty Multiplying Factor | <br><br><br>12<br>[[<br><br><br>]] | 10.1, RAI# 17, Section 4.3.4 |
| | | |
| | | |

## 6.0 COMPUTER CODES AND COMPLIANCE WITH REGULATORY REQUIREMENTS

### 6.1 Computer Codes

All computer codes used in this calculation have been approved for use with appropriate Verification and Validation (V&V) documentation. Computer codes used in this analysis include:

- **RADTRAD** 3.02 (Ref. 10.3): This is an NRC-sponsored code approved for use in determining control room and offsite doses from releases due to reactor accidents. This code was used by PSEG NUCLEAR in various AST license amendments, which are approved by the NRC. PSEG NUCLEAR performed in-house V&V of the code (Ref. 10.6). Therefore, the code is considered acceptable to be used for the HCGS AST analysis.

  RADTRAD 3.02 is used rather than the current RADTRAD 3.03 to maintain consistency with Calculation H-1-ZZ-MDC-1880, which is the basis for this Technical Evaluation, and the code version accepted by the NRC for the AST license amendment. Per the RADTRAD 3.03 V&V report, the following technical modifications, which have minimal impact on the RADTRAD 3.02 dose results, have been incorporated into RADTRAD 3.03:

  • Modifications to correct logic errors that existed in the previous version
    - Multiple release paths from a compartment to the environment caused a significant conservative error in the control room dose, it became proportional to the number of paths
    - Control room filter deposition used incorrect array (< 0.1% effect on calculated dose)
    - Invalid filter loading values for all cases (no effect on calculated dose)
    - Suppression pool decontamination used incorrect volume (NAI-11) (< 0.1% effect on calculated dose)
    - A coefficient for the Gormley & Kennedy turbulent deposition model was in error (no effect on calculated dose)
    - Natural deposition model for APWR had a coefficient error (NAI-12) (no effect on calculated dose)
    - Powers natural deposition model used a derived removal coefficient instead of the current value (< 0.1% effect on calculated dose)
    - Dose conversion filename length could cause the code to terminate (no effect on calculated dose)
    - RADTRAD control of time steps to improve dose accuracy (RADTRAD v3.02) (< 1% effect on calculated dose)
    - Suppression pool decontamination that removed noble gases was corrected to allow their passage through the pool. (RADTRAD v3.02) (potential significant non-conservative effect on calculated dose)

  • Modification to the definition of a control room
    - This modification was essentially a change to the definition of a control room. The control room was defined to be a compartment not included in the mass balance. This allows the offsite dose to be independent of the existence of a control room. Previously, the offsite dose would change (<1%) when a control room with a significant through flow was added. (NAI-7)
    - NRC Acceptance Test Case 16 (Table 8-1) originally called the auxiliary building a control room. As the mass balance excludes the control room, the input for this case was modified to allow a correct offsite and control room dose calculation. Doses can still be calculated in the auxiliary room by using an effective inlet $\chi/Q$ and an iodine protection factor formulation as was done in the rebaselining (Callan 1998) or by executing the model twice, first with the control room modeled as

the control room and second with the auxiliary building modeled as the control room. This is the same procedure one would use to evaluate dose on the Technical Support Center.

## 6.2 Compliance With Regulatory Requirements

As discussed in Reference 10.4, Section 4.0, Assumptions, the analysis in this calculation complies with line-by-line guidance in Regulatory Guide 1.183, Rev 0 (Ref. 10.2).

## 7.0 CALCULATIONS

### 7.1 HCGS Plant Specific Nuclide Inventory File (NIF) For RADTRAD3.02 Input

The RADTRAD nuclide inventory NIF HEPULOCA2_DEF.txt is used in this analysis.

### 7.2 Determination of MSIV Leak Rates

The post-LOCA MSIV leak rates are the same as those calculated in Reference 10.4, Section 7.2 and listed in Table 7.

### 7.3 Main Steam Line Volumes and Surface Area for Plate-out of Activity

The volumes and plate-out surface areas are same as those calculated in Reference 10.4, Section 7.3 and listed in Tables 2 through 5.

### 7.4 Plate-out of Activity in Main Steam Lines

The aerosol removal efficiencies are calculated in Reference 10.4, Section 7.4 and listed Table 6.

### 7.5 ESF Leak Rates

The ESF leak rate is calculated in Reference 10.4, Section 7.5.

### 7.6 FRVS Vent and Recirc, and CR Charcoal/HEPA Filters Efficiencies

The charcoal and HEPA filter efficiencies are calculated in Reference 10.4, Section 7.7 using the In-place penetration testing information, which are used in this analysis and listed as follows:

| Safety Grade Filter | Filter Efficiency Credited (%) | | |
|---|---|---|---|
| | Aerosol | Elemental | Organic |
| FRVS Vent | 99 | 90 | 90 |
| FRVS Recirc | 99 | 0 | 0 |
| Control Room | 99 | 99 | 99 |

### 7.7 Drywell Wetted Surface Area

The drywell surface area is calculated to be 33,200 $ft^2$ in Reference 10.4, Section 7.10.

### 7.8 Containment Elemental Iodine Removal Coefficient

The elemental iodine removal by wetted containment surface areas is calculated in Reference 10.4, Section 7.11 using the methodology outlined in NUREG-0800, Standard Review Plan 6.5.2.

**Non-Proprietary Information**

## 7.9 Co-60 Activity

Total number of Co-60 isotope test assemblies (ISAs) = 12 (Ref. 10.1, RAI#17, Section 4.3.4)
Number of cobalt isotope rods per ITA = [[ ]]
Total number of cobalt isotope rods = 12 x [[ ]] (Ref. 10.1, RAI#17, Section 4.3.4)

Assuming that each cobalt isotope rod contains [[ ]] of Co-60 (Ref. 10.1, RAI#17, Section 4.3.4)
Total activity = [[ ]] (Ref. 10.1, RAI#17, Section 4.3.4)

Multiplying factor = [[ ]] (Ref. 10.1, RAI#17, Section 4.3.4)
Gross activity in 12 ITAs = [[ ]]

Co-60 activity in core prior to addition of ITAs
= 1.830E+02 Ci/$MW_t$ (Ref. 10.4, Section 5.3.1.3) x 3,917 $MW_t$ = 716,811 Ci = 7.168E+05 Ci

Total Co-60 activity including 12 ITAs
= 7.168E+05 Ci (core activity) + [[ ]]

RADTRAD NIF Input = [[ ]] which is used in HEPULOCA2_DEF

**Non-Proprietary Information**

## 8.0 RESULTS SUMMARY

The post-LOCA EAB, LPZ, and CR doses due to combined core inventory including that from the 12 Co-60 ITAs are summarized in the following table:

| Post-LOCA Activity Release Path | Post-LOCA TEDE Dose (Rem) | | |
|---|---|---|---|
| | Receptor Location | | |
| | Control Room | EAB | LPZ |
| Containment Leakage | [[ | | |
| ESF Leakage | | | |
| MSIV Leakage | | | |
| Containment Purge | | | |
| Containment Shine | | | |
| External Cloud | | | |
| CR Filter Shine | | | |
| **Total** | | | ]] |
| **Allowable TEDE Limit** | **5.0 E+00** | **2.50E+01** | **2.50E+01** |
| | **RADTRAD Computer Run No.** | | |
| Containment Leakage | HCO60CL.o0 | HCO60CL.o0 | HCO60CL.o0 |
| ESF Leakage | HEPU300ES00.o0 | HEPU300ES00.o0 | HEPU300ES00.o0 |
| MSIV Leakage | HCO60MS.o0 | HCO60MS.o0 | HCO60MS.o0 |

## 9.0 CONCLUSIONS

This evaluation determines control room, EAB, and LPZ doses due to post LOCA radioactivity releases from containment via three release pathways, i.e., containment leakage, ESF leakage, and MSIV leakage using the combined core inventory including the inventory from 12 Co-60 Isotope Test Assemblies. The resulting dose consequences remained unchanged because [[

]]

The introduction of 12 ITAs (GE14i bundles) at HCGS presents no impact on the AST LOCA source term and resulting doses.

**Non-Proprietary Information**

## 10.0 REFERENCES

10.1 Hope Creek Letter LR-N10-0163, Response to Request for Additional Information – License Amendment Request (H09-01) Supporting the Use of Co-60 Isotope Test Assemblies (Isotope Generation Pilot Project), May 11, 2010.

10.2 U.S. NRC Regulatory Guide 1.183, Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors, July 2000.

10.3 S.L. Humphreys et al., "RADTRAD: A Simplified Model for Radionuclide Transport and Removal and Dose Estimation," NUREG/CR-6604, USNRC, April 1998.

10.4 Calculation No. H-1-ZZ-MDC-1880, Rev. 4, Post-LOCA EAB, LPZ, and CR Doses.

10.5 10 CFR 50.67, "Accident Source Term."

10.6 Critical Software Package Identification No. A-0-ZZ-MCS-0225, Rev 2, RADTRAD Computer Code

10.7 NUREG-0800, Standard Review Plan, "Radiological Consequence Analyses Using Alternative Source Terms," SRP 15.0.1, Rev. 0, July 2000

# 10 CFR 50.59 for Calculation H-1-ZZ-MDC-1880, Revision 4, "Post-LOCA EAB, LPZ, and CR Doses" (HC-10-125)