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Development of Tritide Dose Assumptions for Tritium Processing and Extraction Facilities MACCS2 Consolidated Hazard Analysis and Documented Safety Analysis Revision

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Revision History

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1. Introduction

The purpose of this report is to identify the Tritide Dose Assumptions applicable to the Tritium Facilities. These dose assumptions support the MELCOR Accident Consequence Code System 2 (MACCS2) revision of the Consolidated Hazards Analysis (CHA) and Documented Safety Analysis (DSA) for the Tritium Facilities, including the Tritium Extraction Facility.

This report consolidates the analyses of the dose conversion factors (DCF's), Airborne Release Fractions/Respirable Fractions (ARF*RF's), and tritium oxide dose estimates from several sources [Ref. 1, 2, and 3], including the derivation of the applicable ARF*RF's from DOE-HDBK-3010 [Ref. 5], to provide concise tritide dose assumptions for the hazards and accident analyses of the tritium facilities. These assumptions address the mechanisms of release and the type of container or vessel involved in the event (i.e. tritium hydride containers, and installed process hydride vessels), but do not address preventive or mitigative features/factors (e.g. installed frits or the size of a fire). This report also provides examples (refer to Attachments 1 and 2) of the application of the tritide dose assumptions to estimate doses to the collocated worker and the maximally exposed offsite individual (MOI).

2. Background

In accordance with DOE-STD-3009-94 or DOE-STD-3009-14, the hazards analysis (HA) and accident analysis (AA) evaluates potential accidents that could expose the MOI, collocated worker, facility worker, and the environment to hazardous materials. This evaluation requires the analyst to estimate the consequences due to the hazardous material, or material at risk (MAR), involved in the event. The MAR involved in the accident event is the MAR that is available to be acted on by the event and/or during the progression of the event. The hazard analysis includes an examination of the complete spectrum of potential accidents.

The key radioactive MAR at the Tritium Facilities is tritium, which is present in the form of elemental tritium, tritium oxide (tritiated water or HTO), and tritides. Tritides are Special Tritium Compounds (STCs) whereby the tritium is captured or bound in a solid matrix which differs from the other forms of tritium. Therefore, separate analyses of how the different accident events act on and release these radioactive tritides is needed. Specific analysis of tritide release events was performed in references 1 and 2. This report consolidates these analyses and concludes with a set of assumptions for estimating the tritide dose relative to tritium oxide.

3. Discussion of Development and Justification for Tritide Dose Assumptions

Summary of Tritium Hydride Containers and Vessels

Various containers and vessels that are used or expected to be used in the Tritium Facilities contain hydrides which interact with tritium to form STCs (i.e. stable metal tritides). The general categories of these containers/vessels evaluated in this report are summarized below:

- Single fill hydride containers (e.g. reservoirs, Hydride Storage Vessels (HSVs)) produce limited fines (small particles including tritides) because the number of hydrogen absorption/desorption cycles is limited, thus very little hydride decrepitation occurs. Calculation M-CLC-H-02863 [Ref. 2] empirically determined the particulates produced in this type of vessel.
- Multiple fill hydride containers/vessels support activities and processes which require many absorption/desorption cycles, leading to the production of a significant amount of fines (including tritide particles) as documented in Calculation M-CLC-H-02863 [Ref. 2]. These multiple fill vessels include:
  - Hydride Transport Vessels (HTVs): HTVs are designed to store tritium on a hydride bed (as a stable metal tritide) for transport. After loading with tritium, the pressure within the HTV is slightly below atmospheric pressure.
  - Process hydride vessels: These vessels are installed in the tritium process to support gas separation and purification processes. These hydride vessels are operated over a range of pressures (from full vacuum to ~500 psig). For example, the flowthrough beds, TCAP feed, TCAP product, and TCAP raffinate storage beds may operate from a full vacuum up to pressures on the order of ~500 psig. The TCAP columns (Palladium/Kieselghur (Pd/K) beds) may operate from a full vacuum to ~ 200 psig.
- Based on the operational pressures, these multiple fill vessels can be categorized per DOE-HDBK-3010 [Ref. 5] as listed below.
  - Multiple fill hydride containers (e.g. HTVs) with an internal pressure of ~25 psig or less as documented in Calculation S-CLC-H-01288 [Ref. 1]. Although this calculation refers to these containers as "robust containers," the ARF*RF derived in the calculation (provided later) is applicable to any multiple fill hydride vessel or container (e.g. "non-robust" containers) at ~25 psig or less internal pressure based on DOE-HDBK-3010 [Ref. 5].
  - Multiple fill, installed/pressurized hydride vessels (e.g. installed process vessels, typically containing—Lanthanum, Nickel, and Aluminum (LANA) or Pd/K bed) may be operated at elevated pressures, and therefore treated as significantly pressurized based on DOE-HDBK-3010, i.e. pressurized well above 25 psig [Ref. 5].

Summary of ARF*RF Determinations and Comparison of Inhalation DCFs for Tritides to Tritium Oxide

Calculations S-CLC-H-01288 and M-CLC-H-02863 [Ref. 1 and 2] analyzed the ARF*RF for a release of MAR in the form of tritides from hydride vessels. There are three cases to consider for a loss of confinement (with no fire or thermal energy involved).

The three cases and the applicable ARF*RF's are listed below:

- A release from single fill hydride containers (e.g. reservoirs, HSVs); an ARF*RF of 1E-4 is based on empirical HSV data for limited fines, independent of internal pressure.
- A release from multiple fill non-pressurized or slightly pressurized hydride containers (e.g. HTVs); an ARF*RF of 2E-3 is based on a release of powder from a vessel or container pressurized to 25 psig or less.

- A release from multiple fill, installed/pressurized hydride vessels (e.g. installed process LANA and Pd/K beds); an ARF*RF of 7E-2 is based on a release of powder from a vessel or container pressurized to greater than 25 psig.

Calculations S-CLC-H-01288 and M-CLC-H-02863 [Ref. 1 and 2] also compared the inhalation dose for MAR released in the form of tritides to that of MAR released in the form of tritium oxide. The ARF*RF for tritium oxide is 1.0. A conservative inhalation DCF for tritides (9.6E-1 mrem/uCi or 2.6E-10 Sv/Bq) for an unknown host material (hydride) was selected as recommended by DOE-STD-1129-2015 [Ref. 4] to bound all types of hydride materials. The inhalation DCF for tritium oxide is 6.7E-2 mrem/uCi, or 1.8E-11 Sv/Bq (no skin absorption). Therefore, the selected tritide inhalation DCF is a multiple of 14.3 times larger than the oxide inhalation DCF, i.e. the DCF_{ratio} = 14.3. Considering both the differences in the ARF*RF's and the DCF_{ratio} for tritides vs tritium oxide, the calculated Equivalent Inhalation Oxide Fractions for a tritide loss of confinement event are as follows:

- Tritide release from single fill, hydride vessels/containers;
  Equivalent Inhalation Oxide Fraction = 0.143%
- Tritide release from multiple fill, hydride vessels/containers (internal pressure of ≤25 psig);
  Equivalent Inhalation Oxide Fraction = 2.86%
- Tritide release from multiple fill, installed/pressurized hydride vessels (internal pressure >25 psig);
  Equivalent Inhalation Oxide Fraction = 100%

Development of Assumptions for Estimating Tritide Dose

In order to conveniently estimate the tritide dose directly from the tritium oxide dose provided by Calculation S-CLC-H-01286 [Ref. 3] the skin absorption dose factor (SKF =1.5) for tritium oxide is applied to the above results. The DCF for exposure to tritium oxide is 1.5 x 6.7E-2 mrem/uCi [DOE-STD-1129-2015, App A, pg A-3; and Calculation S-CLC-G-00372, Ref. 4 and 6]. In Calculation S-CLC-H-01286 [Ref. 3], or similar tritium oxide total dose determinations, the inhalation and skin absorption dose contributions are included in the total tritium oxide dose. An Effective Oxide Dose Fraction for accurately estimating tritide doses must account for the SKF (refer to Equation 3 in Appendix A); therefore, the Effective Oxide Dose Fraction is calculated as follows:

Effective Oxide Dose Fraction = (Equivalent Inhalation Oxide Fraction) / SKF

Therefore, for a tritide loss of confinement event, the three Effective Oxide Dose Fractions are listed below:

- Tritide release from single fill, hydride vessels/containers, independent of internal pressure (e.g. reservoirs, HSVs);
  Effective Oxide Dose Fraction = 0.095%, rounded to 0.1%
- Tritide release from multiple fill, hydride vessels/containers, internal pressure ≤25 psig (e.g. HTVs);
  Effective Oxide Dose Fraction = 1.91%, rounded to 2.0%

- Tritide release from multiple fill, installed/pressurized hydride vessels, internal pressure >25 psig (e.g. LANA, Pd/K);
  Effective Oxide Dose Fraction = 67%, which can be rounded to 70% with adequate conservatism

Note, the Effective Oxide Dose Fraction of 2.0% for multiple fill hydride vessels (internal pressure ≤25 psig) bounds the Effective Oxide Dose Fraction of 0.1% for single fill hydride vessels and may be used to estimate the dose for a loss of confinement involving both single and multiple fill containers.

Therefore, due to loss of confinement events, the tritide dose will be estimated based on the following:

- For MAR released from *only single fill* hydride vessels/containers (e.g. reservoirs, HSVs), the tritide dose to the individual (facility worker/collocated worker/MOI) may be estimated as 0.1% of the total oxide dose received from the total amount of MAR (tritium) available. (This value can be applied when the event involves <u>only single fill</u> vessels/containers and <u>no other vessel types</u>.)
- For MAR released from *multiple fill* vessels/containers (≤ 25 psig) (e.g. HTVs), or a combination of multiple and single fill hydride vessels/containers, the tritide dose to the individual (facility worker/collocated worker/MOI) is estimated as 2.0% of the total oxide dose received from the total amount of MAR (tritium) available.
- For MAR released from *installed/pressurized* process hydride vessels (typically *pressurized >25 psig*, multiple fill hydride vessels), the estimated tritide dose to the individual is 70% of the total oxide dose received from the total amount of MAR (tritium) available.

In addition, Calculation M-CLC-H-02863 [Ref. 2] previously concluded that fire and explosion events would act on the tritide form of MAR such that the dose could be estimated as 100% tritium oxide. The conclusions from that calculation are summarized below:

- For fires involving tritide MAR, the DCF for tritium oxide can be used (with an ARF*RF of 1 for the released tritium oxide vapor) to bound the dose. A large fire of sufficient energy and duration would drive all the tritium off the hydride bed and then oxidize all the tritium. Therefore, the estimated maximum dose to the individual can be bounded by the tritium dose due to a 100% tritium oxide release.

  Note: *This ESR does not evaluate the size or duration of potential fires for the tritium facilities. Additional research on the effect of fires on the release of tritides from hydride vessels can be found in References 7 and 8.*

- For explosions involving tritide MAR, the DCF for tritium oxide can be used to bound the dose. The bounding ARF*RF for an explosion of 7E-2 combined with the conservative tritide-to-oxide inhalation DCF_{ratio} of 14.3 result in a tritide dose equal to the oxide inhalation dose.

  Note: *This ESR does not evaluate whether an explosion event involving hydride vessels (or acting on hydride material) is or is not credible. For additional information on the likelihood of explosions in hydride vessels, refer to Reference 9.*

4. *Conservatisms*

The development of the tritide dose estimating assumptions utilizes numerous conservative inputs and analyses which include the following.

- In the development of the tritide dose estimating assumptions, the effective oxide dose fractions are rounded up for convenience of math estimates and thus provide conservative tritide dose estimates.
- The estimates for the tritide dose to the MOI are conservative because the MACCS dispersion model assumes a deposition velocity of zero for tritium oxide to calculate the dispersion factor for the MOI. Tritides are particulates, and therefore should be subject to a deposition rate in the dispersion model, which would result in an MOI dose smaller than that estimated by the Effective Oxide Dose Fraction.
- Estimating the dose resulting from a loss of confinement for a combination of single fill and multiple fill hydride vessels is bounded by the 2% Effective Oxide Dose Fraction for multiple fill hydride vessels (internal pressure of 25 psig or less). This approach over estimates the dose from the loss of confinement event for the single-fill vessels by an order of magnitude.
- Multiple fill hydride containers (e.g. HTVs) are assumed to be pressurized to ~25 psig. The HTVs, for example, are expected to be at sub-atmospheric pressure (well below 25 psig) when filled. In addition, the multiple fill vessel tritide contents for these vessels are treated as 100% powder for determination of the ARF*RF from DOE-HDBK-3010 in Calculation S-CLC-H-01288 [Ref.1]. These assumptions combined support conservative tritide dose estimates.
- Multiple fill installed process vessels are assumed conservatively to be significantly pressurized and the hydride contents are assumed to be 100% powder for loss of confinement events. Calculation M-CLC-H-02863 [Ref. 2] selected the most severe ARF*RF from DOE-HDBK-3010 for pressurized releases.
- A conservative inhalation DCF for tritides (9.6E-1 mrem/uCi or 2.6E-10 Sv/Bq) for an unknown host material (hydride) was selected as recommended by DOE-STD-1129-2015 [Ref. 4] to bound all types of hydride beds that may be used or introduced into the Tritium Facilities. Testing performed in 2011 showed that for LANA material, DCFs can be more than an order of magnitude below this value (the empirically determined LANA DCF may be considered to be approximately half that of tritium oxide) [Ref. 10]. Therefore, application of the Effective Oxide Dose Fraction for installed/process hydride beds to loss of confinement events strictly for LANA beds is conservative by at least one order of magnitude.
- For large fires and all hydride beds, the fires were assumed to be hot enough to drive off all the tritium from the tritide MAR and to oxidize 100% of the tritium to tritium oxide. All fires are not sustained fires capable of desorbing all of the tritium from the hydride vessel and oxidizing the tritium to tritium oxide.
- Explosion dose estimates will be based on the total (inhalation and skin) tritium oxide dose (from Calculation S-CLC-H-01286 [Ref. 3] or similar total dose calculation) instead of the oxide inhalation dose alone, which conservatively increases the estimated tritide dose by approximately 33%.

5. Conclusion—Assumptions for Estimating Dose from Tritides

For accident events involving tritium (MAR) in the form of tritides, assumptions were developed for estimating the dose to the individual (facility worker, collocated worker, or MOI). These assumptions address loss of confinement, fire, and explosion events. As discussed in Section 2, *Background*, the MAR involved in the accident event is the tritium MAR that is *available* to be acted on by the event and/or during the progression of the event. For a loss of confinement (LOC) event, the assumptions identify the specific type of container(s) to which the assumption is applied. These assumptions are applicable to events involving one or more of the identified hydride containers/vessels. For estimating the maximum dose due to fires and explosions, the confinement barrier is assumed to be breached (i.e. the damage ratio is 100%).

The Tritide Dose Assumptions

The Effective Oxide Dose Fractions for estimating the tritide dose from the tritium oxide dose calculated in Table 7 of Calculation S-CLC-H-01286 [Ref. 3] (or similar total oxide dose calculations) are provided below.

- A 0.1% Effective Oxide Dose Fraction may be applied for a LOC event that releases MAR in the form of tritides from *only single fill* hydride vessels/containers (independent of pressure, e.g. HSVs and reservoirs). The estimated tritide dose to the individual (facility worker/collocated worker/MOI) is 0.1% of the total oxide dose received from the total amount of MAR (tritium) available.
  The lower dose from the tritide form of MAR is due to an ARF*RF of 1E-4 for the single fill hydride material that is based on empirical data described in Calculation M-CLC-H-02863 [Ref. 2].

- A 2% Effective Oxide Dose Fraction is applied for a LOC event that releases MAR in the form of tritides from multiple fill hydride vessels/containers (≤ 25 psig) (e.g. HTVs), or a combination of multiple and single fill hydride vessels/containers. The estimated tritide dose to the individual (facility worker/collocated worker/MOI) is 2.0% of the total oxide dose received from the total amount of MAR (tritium) available.
  The lower dose from the tritide form of material is due to the bounding ARF*RF of 2.0E-3 for a particulate release from a multiple fill container (internal pressure ≤25 psig) as documented in Calculation S-CLC-H-01288 [Ref. 1].

- A 70% Effective Oxide Dose Fraction is applied for a loss of confinement event that releases MAR in the form of tritides from installed/pressurized process hydride vessels (typically pressurized >25 psig, multiple fill hydride vessels). The estimated tritide dose to the individual (facility worker/collocated worker/MOI) is 70% of the total oxide dose received from the total amount of MAR (tritium) available.
  The dose from the tritide form of material is due to the bounding ARF*RF of 7.0E-2 for a particulate release from a pressurized process vessel as documented in Calculation M-CLC-H-02863. [Ref. 2]

- For fire events, the estimated tritide dose can be bounded by the oxide dose for the total amount of MAR (tritium) available, based on Calculation M-CLC-H-02863 [Ref. 2].
  The bounding ARF*RF for tritium oxide vapor is 1.

> ***Note**: This first order estimate of the tritide dose assumes the size and the duration of the fire are sufficient to drive all the tritium off the hydride bed and oxidize the tritium. All potential fires in the tritium facilities are not sustained fires capable of this complete conversion; therefore, the typical dose due to tritides would be less. Refer to References 7 and 8 for additional research on the effect of fire on hydride beds.*

- For explosion events, the bounding tritide dose can be estimated as the oxide dose for the total amount of MAR (tritium) available.
  The tritide dose is based on the bounding ARF*RF of 7E-2 for particulate release due to an explosion as described in Calculation M-CLC-H-02863 [Ref. 2].

> ***Note**: This ESR does not evaluate whether an explosion event involving hydride vessels (or acting on hydride material) at the tritium facilities is or is not credible. For additional information refer to Reference 9.*

6. References

1. S-CLC-H-01288, *ARF/RF for Robust Containers*, Revision 0
2. M-CLC-H-02863, *ARF/RF for use in FY08 DSA Update*, Revision 1
3. S-CLC-H-01286, *Total Effective Dose Factors for use in Tritium Facilities Safety Basis Documents*, Revision 0
4. DOE-STD-1129-2015, *Tritium Handling and Safe Storage*, U.S. DOE
5. DOE-HDBK-3010-94, Reaffirmed 2013, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, U.S. DOE
6. S-CLC-G-00372, *Unit Total Effective Dose Factors for Onsite and Offsite Receptors at SRS (U)*, Revision 3
7. S-CLC-H-00326, *Tritium Release from a Hydride Storage Vessel (HSV) in a Fire Accident (U)*, Revision 0
8. S-CLC-H-00327, *Tritium Release from a Hydride Transport Vessel (HTV) in a Fire Accident (U)*, Revision 0
9. Heung, L. K., *Savannah River Laboratory Quarterly Report, Tritium Packaging and Related Technology*; "(U) Safety of a Palladium-Coated on Kieselguhr (Pd/K) Bed." DPWD-84-20-1, E.I. du Pont de Nemours & Co., Savannah River Laboratory, January – March 1984 (S/RD)
10. SRNL-STI-2011-00587, *Determination of In-Vitro Lung Solubility and Intake-To-Dose Conversion Factor for Tritiated Lanthanum Nickel Aluminum Alloy*, November 2011
11. DOE-STD-1189-2008, *Integration of Safety into the Design Process*, U.S. DOE
12. WSRC-TR-95-0491, Revision 0, *Hydride Storage Vessel Technical Data Summary (U)*, December 29, 1995.
13. WSRC-RP-92-1161, Revision 7, *(U) SRS H1616 Hydride Transport Vessel Qualification Report*

ATTACHMENT 1
Determination of Source Term and Dose

Equations for Source Term and Dose Determinations

ST = MAR * DR * ARF * RF * LPF [Ref. 5, Section 1.2] [Equation (Eqn) 1]

Where, for purposes of evaluating an accident event, e.g. a 100% loss of confinement:

- ST = Source Term
- MAR = Material at Risk
- DR = Damage Ratio = 1 (unitless) for the purposes of the attachments
- ARF = Airborne Release Fraction (unitless)
- RF = Respirable Fraction (unitless)
- LPF = Leak Path Factor = 1 (unitless)
- Value of ARF * RF as specified in tritide assumptions

Dose = ST * SpA * f_{HTO} * $UTED_{HTO}$ [Ref.3, Section 6.3] [Eqn 2]

Where:

- For a range of STs in units of grams of tritium, using this equation the tritium oxide dose for the CW and the MOI is calculated and presented in Table 7 of Calculation S-CLC-H-01286 [Ref. 3]
- SpA = Specific Activity of Tritium 9.69E+3 Ci/g [Ref. 6]
- f_{HTO} = fraction of tritium in oxide form (unitless, ranging from 0 to 1)
  Note: f_{HTO} =1 for the examples in Appendix 2. Also, f_{HTO} =1 for dose values given in Table 7 of Calculation S-CLC-H-01286 [Ref. 3]
- $UTED_{HTO}$ = Unit TED = Unit Total Effective Dose = (χ/Q * BR * DCF) for tritium oxide (HTO) for the MOI or CW (The value of UTED is provided in Table 4 of Calculation S-CLC-H-01286 [Ref. 3])
- χ/Q_{CW} = Dispersion Coefficient for Collocated Worker (CW)
- χ/Q_{MOI} = Dispersion Coefficient for MOI
- BR = Breathing Rate = 3.33E-4 m^3/sec
- DCF = Dose Conversion Factor (e.g. mrem/uCi, or Sv/Bq)

Expanding Equation 2 for estimating sSTC dose to the MOI or the CW results in:

$$\textbf{Dose}_{sSTC} = ST * SpA * f_{HTO} * UTED_{HTO} * (1/SKF) * DCF_{ratio} \qquad \text{[Eqn 3]}$$

Where:

- SKF = Skin absorption factor for tritium oxide dose = 1.5 (unitless) [Section 6.3, Ref. 6]
- DCF_{Ratio} = Ratio of $IDCF_{sSTC}$ to $IDCF_{HTO}$ = 14.3 (unitless)
- Note, stable tritides or stable STCs (sSTC) do not have a dose contribution due to skin absorption

Substituting for UTED in Equation 2, [Ref. 6, Section 6.3] the sSTC dose to the CW can be estimated directly per DOE-STD-1189 as follows:

$$\textbf{Dose}_{CW\,sSTC} = ST * SpA * f_{HTO} * \chi/Q_{CW} * BR * IDCF_{HTO} * DCF_{Ratio} \qquad \text{[Eqn 4]}$$

or

From Reference 6, Section 6.3, the sSTC dose to the CW can be estimated directly per DOE-STD-1189 as follows:

$$\textbf{Dose}_{CW\,sSTC} = ST * SpA * \chi/Q_{CW} * BR * IDCF_{sSTC} \qquad \text{[Eqn 5]}$$

Where:

- χ/Q_{CW} = 3.50E-3 sec/m^3 from S-CLC-G-00372 and DOE-STD-1189 [Ref. 6, Section 6.3; Ref. 11, Appendix A]
- $IDCF_{sSTC}$ = 9.6E-1 mrem/uCi or 2.6E-10 Sv/Bq for an unknown hydride material
- $IDCF_{HTO}$ = Inhalation Dose Conversion Factor for tritium oxide 6.7E-2 mrem/uCi, or 1.8E-11 Sv/Bq (no skin absorption)

ATTACHMENT 2
Examples of Tritide Dose Estimates

<u>Example 1</u>, Estimate CW Oxide (HTO) Dose; EstimateTritide (sSTC) Dose using the Effective Oxide Dose Fraction; Compare tritide estimated tritide dose to the CW tritide dose calculated using the DOE-STD-1189 dispersion coefficient:

Event: MAR = 20 grams tritium, Loss of Confinement (LOC) from HTV, with duration of 20 minutes

From Table 7 of the Tritium Total Effective Dose Factor (TEDF) Calculation S-CLC-H-01286 [Ref. 3] for a 20g tritium oxide release (note, the CW dose is not dependent upon the duration of 20 minutes):

$\text{Dose}_{CW\ HTO}$ = 2.25 E+1 Rem

<u>Applying the 2% Effective Oxide Dose Fraction for an HTV LOC event</u>:

$\text{Dose}_{CW\ sSTC}$ = $\text{Dose}_{CW\ HTO}$ * 0.02 = 2.25 E+1 rem * 2E-2 = 0.45 Rem

<u>Calculation of CW Dose based on S-CLC-H-01288, DOE-STD-1129, and DOE-STD-1189</u> [Ref. 1, 4,11] for 20g tritide LOC event from HTV (i.e. 20g of tritium MAR in form of tritide)

ST_{sSTC} = MAR * DR * ARF*RF * LPF [From Eqn.1]

Where DR =1 and LPF =1. ARF*RF = 2E-3 from Section 3, pg 6, of this report

= (2E+1 g tritide) * (2E-3) = 4E-2g tritide

$\text{Dose}_{CW\text{-}sSTC}$ = ST * SpA * χ/Q * BR * DCF_{sSTC} [From Eqn.4]

= 4E-2 g * (9.69E+9 uCi/g) * (3.5E-3 sec/m^3) * (3.33E-4 m^3/sec) * 9.6E-1 mrem/uCi

= 4.34 E+2 mrem = 0.434 Rem

(The slightly smaller dose than obtained using the stable metal tritide inhalation dose factor demonstrates the conservatism of the Effective Oxide Dose Fraction.)

<u>Example 2</u>, Estimate the MOI Tritide Dose for the LOC Event in Example 1:

From Example 1, *MAR = 20 grams tritium, LOC from HTV,* with duration of 20 minutes

From Table 7 of the Tritium TEDF Calculation S-CLC-H-01286 [Ref. 3] for a 20g tritium oxide release with a duration of 20 minutes:

$Dose_{MOI\ HTO}$ = 2.33E-2 rem or 23 mrem

Applying Effective Oxide Dose Fraction for an HTV LOC:

$Dose_{MOI\ sSTC}$ = $Dose_{MOI\ HTO}$ * 0.02 = (2.33E-2 rem) * 2E-2

= 4.66 E-4 rem or 0.5 mrem

***<u>Example 3</u>*, For a LOC event involving multiple reservoirs and HSVs/HTVs with a 20 minute release duration:**

- **Estimate the MOI tritide dose for 1kg MAR**
- **Determine amount of tritide MAR available that is necessary to result in nearly 25 rem to MOI**
- **Estimate tritide dose for a total facility MAR of approximately 20 kg**

<u>Estimate Dose for 1 kg MAR, LOC, 20 minute release duration:</u>

A conservative MOI tritide dose can be calculated using the 2% Effective Oxide Dose Fraction; however, it should be recognized that the TEDF for tritium oxide [Ref. 6] is based on a dispersion factor that assumes a zero deposition rate for HTO vapor. (The ARF*RF for HTO vapor is 1.)

For MOI, ST = (1 kg) * 1 = 1E+3 grams [From Eqn.1]

From Table 7, Tritium TEDF Calculation [Ref. 3], for 1 kg tritium (100% conversion to HTO form):

$Dose_{MOI\ HTO}$ = 1.16 Rem (for a 20 min duration)

Applying 2% Effective Oxide Dose Fraction to this 1000 g (1kg) tritide LOC release, the estimated dose is:

$Dose_{MOI\ sSTC}$ = $Dose_{MOI\ HTO}$ * 0.02 = 1.16 rem * 2E-2 = 2.32E-2rem or 23 mrem

<u>Determine amount of tritide MAR in reservoirs and HSVs/HTVs that is necessary to result in nearly 25 rem to MOI for a LOC event:</u>

Since 1000g results in an MOI tritide dose of 23 mrem, a release on the order of 1000 times that magnitude, or ~1000 kg of tritide MAR results in 23 rem, or nearly 25 rem to MOI.

<u>Estimate tritide dose for a LOC (from multiple reservoirs and HSVs/HTVs) for a total facility MAR of ~20 kg in the form of tritides:</u>

Applying Effective Oxide Dose Fraction:

From Table 7 TEDF Calculation for 20 kg tritium converted to 100% oxide, for a 20 minute duration, total oxide dose is 2.33E+1 rem; therefore, applying the 2% Effective Oxide Dose Fraction:

Dose $_{MOI\ sSTC}$ = 2.33E+1 rem oxide * 2E-2 = 4.66E-1 rem or (466 mrem due to tritides)

***<u>Example 4</u>*, Estimate Tritide Dose to the CW and MOI for a LOC event from a Pd/K process vessel containing 200g tritium in tritide form and operating at approximately 250 psig. For a significantly damaged vessel, a rapid depressurization is assumed.**

From Table 7 of the Tritium Total Effective Dose Factor (TEDF) Calculation S-CLC-H-01286 [Ref. 3], a release of 200g tritium in oxide form results in a Dose $_{CW\ HTO}$ = 2.25 E+2 rem (note, the CW dose in Table 7 is not dependent upon the release duration). Then, the Effective Oxide Dose Fraction for process vessels is applied for the tritide dose determination.

Applying the 70% Effective Oxide Dose Fraction results in the following:

Dose $_{CW\ sSTC}$ = 2.25 E+2 * 0.70 = 1.58 E+2 rem, or with rounding 160 rem

For the MOI from Table 7 of the Tritium TEDF Calculation [Ref. 3], select the desired duration of the release (3 minutes is reasonable for a rapid depressurization) and determine that a 200g tritium release in oxide form results in a MOI dose of 3.29E-1 rem; therefore, the estimated tritide MOI dose from application of the 70% Effective Oxide Dose Fraction r:

Dose $_{MOI\ sSTC}$ = 3.29E-1 rem * 0.70 = 2.30E-1 rem, or with rounding 230 mrem

<u>For comparison, the CW tritide dose may be calculated per DOE-STD-1189 using Equation 5:</u>

Dose $_{CW\ sSTC}$ = ST * SpA * χ/Q_{CW} * BR * IDCF $_{sSTC}$

Where:

IDCF $_{sSTC}$ = 9.6E-1 mrem/uCi

ST (from Equation 1) = MAR * DR * (ARF * RF) * LPF

ARF * RF = 7E-2 (summarized in the *Conclusions*)

Thus, ST = 200g * 1 * (7E-2) * 1 = 14g of tritium in the form of tritide

Dose $_{CW\ sSTC}$ =1.4 E+1g * 9.69E+3 Ci/g * (1E+6 uCi/Ci) * 3.50E-3 sec/m^3 * 3.33E-4 m^3/sec * 9.6E-1mrem/uCi

=1.52 E+5 mrem or 152 rem

For comparison, dose to CW may also be calculated using the CW UTED factor 1.16 E-4 rem/Ci for tritium oxide [Table 4, Ref. 3] in Equation 3 as shown below:

Dose $_{CW\ sSTC}$ = ST * SpA * f_{HTO} * $UTED_{HTO\ CW}$ * (1/SKF) * DCF $_{ratio}$

Where:

f_{HTO} = 1

SKF = 1.5

DCF $_{ratio}$ = 14.3

Dose $_{CW\ sSTC}$ = 1.4E+1g * 9.69E+3 Ci/g * 1 *1.16E-4 rem/Ci * (1/1.5) * 1.43E+1

= 1.50 E+2 rem or 150 rem

(The CW dose comparison results demonstrate that the 70% estimate of 160 rem is conservative for the CW tritide dose. Also refer to Section 4 for discussion of additional conservatisms.)

For comparison, the Dose to MOI may be calculated based on the MOI UTED factor of 1.70E-7 rem/Ci for tritium oxide for a 3 minute duration [Table 4, Ref. 3] and the dose equation from the Tritium TEDF Calculation [Section 6.3, Ref. 3], given below:

Dose $_{MOI\ HTO}$ = ST * SpA * f_{HTO} * UTED $_{MOI\ HTO}$

Dose $_{MOI\ sSTC}$ = ST * SpA * f_{HTO} * UTED $_{MOI\ HTO}$ * (1/SKF) * DCF $_{ratio}$

Dose $_{MOI\ sSTC}$ = 1.4E+1g * 9.69E+3 Ci/g * 1 * (1.70E-7 rem/Ci) * (1/1.5) * 1.43E+1

= 2.20 E-1 rem = 220 mrem

(This MOI comparison confirms that the 70% estimate of 230 mrem is conservative for the MOI tritide dose. Also refer to Section 4 for discussion of additional conservatisms.)