International Radiation Safety Consulting, Inc.

Dose Calculations: Gaseous Tritium Light Sources for Gun Sights (Revision 4)

Doses to Various Critical Groups
Based on NUREG 1717 Methodology

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June 22, 2015

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A. Introduction

This document contains dose calculations to support an application for a sealed source and device registration for tritium-lighted gun sights. Calculations have been performed in this report for H-3 sources with this activity using the NUREG-1717 methodology. These are Gaseous Tritium Light Sources (GTLSs).

B. Radioactive Material Contained

Isotope: Hydrogen-3 (tritium), two 80 mCi sources or four 40 mCi sealed sources per device
Total Activity: 160 mCi total per device
Half-life: 12.28 years

Armson U.S.A. (Armson) is licensed for 200 Ci of ^{3}H. Therefore, the absolute maximum number of gun sights that might be in Armson's possession is

$$\frac{200\ \text{Ci}}{1} \times \frac{1000\ \text{mCi}}{\text{Ci}} \times \frac{\text{gun sight}}{160\ \text{mCi}} = 1250\ \text{gun sights.}$$

C. External Dose Potential

1. Particle Radiation

Tritium decays to stable Helium-3 (He-3) by emitting a negative beta particle. No direct photon (gamma) radiation occurs during this transformation. The E_{max} energy of this beta particle is 0.0186 MeV (18.6 keV) and the E_{av} energy is 0.005685 MeV (5.69 keV)[1]. The yield of this transformation is 1.0.

Inspection of the Beta Particle Range-Energy Curve from the Health Physics and Radiological Health Handbook[2] shows that a ^{3}H beta particle, even at the maximum particle energy (with a yield approaching zero) will not penetrate a density-thickness of 7 mg/cm^{2} (the nominal density-thickness of the upper layer of the epidermis (the *stratum corneum* or dead skin cell layer). Therefore, as an external hazard, there would be *no* shallow dose (SDE), *no* eye (lens) dose (LDE) and *no* deep dose (DDE) delivered to any person from the ^{3}H particle emissions.

[1] Kocher, David C. "Radioactive Decay Data Tables." U.S. Department of Energy, DOE/TIC-11026.
[2] After Schleien, Bernard "The Health Physics and Radiological Health Handbook," Revised Edition, copyright 1992, p. 184.

2. Photon Radiation

Bremsstrahlung photon emissions from an intact device will be negligible. This is confirmed in NUREG-1717[3] on page A.4-10, Table A.4.2 footnote b, which states that for ^{3}H the "Dose due to *bremsstrahlung* is assumed to be zero (0), because the energies of the *bremsstrahlung* photons are very low and pathways of internal exposure also are assumed to occur." Additional justification is provided in NUREG-1717 section 2.13.4.1.3.

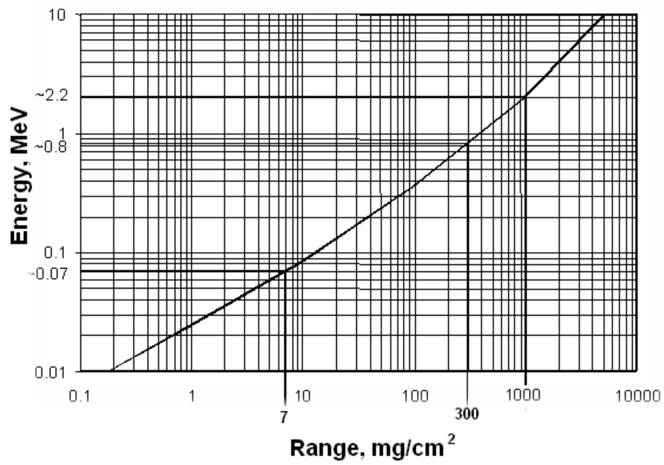

Figure 1. Beta particle range-energy curve showing threshold energies for shallow (7 mg/cm^2), lens or eye (300 mg/cm^2) and deep (1000 mg/cm^2) dose equivalents.

Conclusion

External radiation dose to all exposed individuals and groups is zero. Internal doses, at a leak rate of 10 ppb/h, should be negligible and certainly less than 1 mrem per year for an individual and less than 10 mrem per year to handlers and distributors of these devices. This fulfills the requirements of 10CFR 32.23 and 10 CFR 32.24.

Therefore, in normal handling and storage of the quantities of exempt units likely to accumulate in one location during marketing, distribution, installation, and servicing of the product, it is unlikely that the external radiation dose in any one year, or the dose commitment resulting from the intake of radioactive material in any one year, to a suitable sample of the group of individuals expected to be most highly exposed to radiation or radioactive material from the product will exceed the dose to the appropriate organ as specified in Column II of the table in § 32.24.

[3] U.S. Nuclear Regulatory Commission. "Systematic Radiological Assessment of Exemptions for Source and Byproduct Materials." NUREG-1717. Washington, D.C., June 2001.

Also, in normal use and disposal of a single exempt unit, it is unlikely that the external radiation dose in any one year, or the dose commitment resulting from the intake of radioactive material in any one year, to a suitable sample of the group of individuals expected to be most highly exposed to radiation or radioactive material from the product will exceed 1 mrem.

It follows, then, that there will be no dose greater than 15 mrem to the skin or extremities.

Finally, tritium has no specific target organ, so no single body organ will exceed a dose of 3 mrem.

D. Accident Scenarios Considered

Armson is licensed for 200 Ci of ^{3}H, which (at 160mCi per set of sights) converts to 1,250 sets $\left(\frac{200{,}000\ \text{mCi}}{160\ \text{mCi}}\right)$. It is presumed that all 200 Ci of tritium is present in the facility.

For purposes of these calculations, six scenarios are considered.

1. Dose to a warehouse worker and to a firefighter extinguishing a fire in a manufacturer's warehouse containing 1,200 sets. This scenario assumes that all the sets are destroyed in the fire, **2E+8 µCi = A**;
2. Dose to firefighters extinguishing a tractor trailer fire, with the trailer containing 200 devices. This scenario assumes that all of these sets are destroyed in the fire, **3.2E+7 µCi = A**;
3. Dose to firefighters extinguishing a fire in an end use facility, assumed to be a private residence and containing 3 gun sights (4.8 E+5 µCi). All three gun sights are assumed to be destroyed in the fire releasing **4.8E+5 µCi = A**.
4. Catastrophic release from crushing of a set of gun sights in a small repair shop, releasing **1.6E+5 µCi = A**.
5. An accident involving the crushing of a set of gun sights in a home, releasing **1.6E+5 µCi = A**.
6. A shipping accident in a storeroom or cargo-handling area involving the crushing of a shipment of 1000 gun sight sets, releasing $1000\ \text{sets} \times \frac{160\ \text{mCi}}{\text{set}} =$ 160 Ci or **1.6E+8 µCi = A**.

E. Internal Dose Potential

1. Instantaneous Airborne Concentration (C) in an Accidental Release[4]

$$C = \frac{Q}{V\,k\,t}\left(1 - e^{-kt}\right) \qquad \textbf{(1)}$$

And

$$Q = RF \times A \qquad \textbf{(2)}$$[5]

Where, from above:

Scenario	Enclosure	A (µCi)
1	Warehouse	2E+8
2	Tractor Trailer	3.2E+7
3	Residence	4.8E+5
4	Sm Repair Shop	1.6E+5
5	Residence	1.6E+5
6	Warehouse	1.6E+8

Table 1. Total amount of radioactive material involved in each scenario.

1.a. Calculate Quantity Released (Q)

$$Q = RF \times A \qquad \textbf{(3)}$$

Where:

Q = quantity (µCi) released

RF = fraction of radioactive material released as respirable size particles (100% for gaseous sources[6]) and

A = total amount of radioactive material involved in a fire.

Since the RF =1, the values for Q equal the values for A (above).

Scenario	Enclosure	# Sets	Q (µCi)
1	Warehouse	1,200	2E+8
2	Tractor Trailer	200	3.2E+7
3	Residence	3	4.8E+5
4	Sm Repair Shop	1	1.6E+5
5	Residence	1	1.6E+5
6	Warehouse	1,000	1.6E+8

Table 2. Total amount of radioactive material released in each scenario.

[4] NUREG-1717, page A.1-1, equation 1.
[5] NUREG-1717, page A.1-2, equation 3.
[6] Release fraction (RF) = 100% (NUREG-1717 Table A.1.1).

1.b. Calculate Instantaneous Airborne Concentration (C)

$$C = \frac{Q}{V\,k\,t}\,(1 - e^{-kt}) \qquad \textbf{(4)}$$

Where:

Q = released quantity (µCi)

V = volume (m^3) into which activity is released[7] (see table 1 below)

k = ventilation rate (see table 1 below)[7]

t = time over which C is averaged. A time of 1 hour is used for this calculation.

$(1 - e^{-(1)(1)}) = (1 - 0.37) = 0.63$

$$C_{WH-1} = \frac{2E+8}{(3000)(1)(1)}\,(1 - e^{-(1)(1)})$$
$$= 66{,}667\ (0.63) = 4.2E + 4\mu Ci/m^3$$

$$C_{TT} = \frac{3.2E+7}{(87)(1)(1)}\,(1 - e^{-(1)(1)})$$
$$= 367{,}816\ (0.63) = 2.3E + 5\mu Ci/m^3$$

$$C_{Res-1} = \frac{4.8E+5}{(450)(1)(1)}\,(1 - e^{-(1)(1)})$$
$$= 1067\ (0.63) = 672\ \mu Ci/m^3$$

$$C_{Shop} = \frac{1.6E+5}{(18)(1)(1)}\,(1 - e^{-(1)(1)})$$
$$= 8888\ (0.63) = 5.6E + 3\ \mu Ci/m^3$$

$$C_{Res-2} = \frac{1.6E+5}{(450)(1)(1)}\,(1 - e^{-(1)(1)})$$
$$= 356\ (0.63) = 224\ \mu Ci/m^3$$

$$C_{WH-2} = \frac{1.6E+8}{(3000)(4)(1)}\,(1 - e^{-(4)(1)})$$ see footnote[8]
$$= 13{,}333\ (0.98) = 1.3E + 4\ \mu Ci/m^3$$

[7] From NUREG-1717 Table A.1.2.

[8] Ventilation rate for a storeroom or cargo handling area (k) 14 4, in accordance with NUREG 1717 Table A.1.2.

Type of Enclosure	**Q** (µCi)	L x W x H (m)	Floor area (m^2)	Volume **(V)** (m^3)	Ventilation Rate **(k)** (volume/h)	**C** Instantaneous air conc (µCi/m^3)
Warehouse-1	2E+8	30.5 x 30.5 x 3.66	9.3E+2	3,000[9]	1	2.7E+4
Tractor trailer	3.2E+7	13.7 x 2.35 x 2.7	32	87	1	2.3E+5
Residence-1[10]	4.8E+5	186 m^2 x 2.44	186	450	1	672
Small Repair Shop	1.6E+5	2 x 3 x 3	6	18	1	5.6E+3
Residence-2	1.6E+5	186 m^2 x 2.44	186	450	1	224
Warehouse-2	1.6E+8	30.5 x 30.5 x 3.66	9.3E+2	3,000	4	1.3E+4

Table 3. Assumed attributes of relevant enclosure volumes; instantaneous airborne concentrations.

2. Inhalation Intake

During a fire, an individual's intake from inhalation of airborne radioactive material (µCi) is given by

$$\mathbf{I_{Inh} = C \times BR \times t}, \qquad \mathbf{(4)}$$

Where t = time of exposure (h),

BR = breathing rate (m^3/h) = 1.2 m^3/h[11]

C = average concentration of airborne radioactive material (µCi/m^3) over time, t.

Type of Enclosure	**Avg. Concentration (C) (µCi/m^3)**	**Breathing Rate (BR) (m^3/h)**	**Intake µCi t = 0.083 hour (5 min) Worker (or Resident)**	**Intake µCi t = 2 hour Firefighter[12] w/o SCBA (with SCBA)**	**Intake µCi t = 0.5 hour Firefighter[10] w/o SCBA (with SCBA)**	**Intake µCi t = 1 hour Firefighter[10] w/o SCBA (with SCBA)**
Warehouse-1	4.2E+4	1.2	4,183	100,800 (33,600)	--	--
Tractor trailer	2.3E+4	1.2	22,908	--	138,000 (46,000)	--
Residence-1	672	1.2	67	--	--	806 (269)
Small Repair Shop	5.6E+3	1.2	558		3360 (1120)	--
Residence-2	224	1.2	22			269 (90)
Warehouse-2	1.3E+4	1.2	1,295	31,200 (10,400)		

Table 4. Calculated intakes due to fires for the various enclosure types, for workers (residents) as well as firefighters. Firefighter intakes in parenthesis account for SCBA use.

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[9] NUREG 1717, Table A.1.2 Enclosure Values and Ventilation Rates, lists a warehouse volume of 3,000 m^3, but it also adds a footnote that states "See NUREG/CR–1775 and O'Donnell et al. (1981). Volume corresponds to a warehouse measuring approximately 30.5 m × 30.5 m × 3.66 m." These dimensions yield a volume of 3,405 m^3.

[10] Analogous to an end use facility.

[11] NUREG-1717, section A.1.5, last paragraph.

[12] Fire fighters are presumed to be wearing self-contained breathing apparatus (SCBA) that provides an assigned protection factor of 3 against tritium. Refer to 10 CFR 20 Appendix A footnote f.

3. Inhalation Dose (Workers/Residents)

Internal dose is calculated by comparing the calculated intake to the stochastic ALI for tritium in Appendix B to 10 CFR 20. This ALI is 8E+4 µCi. Using proportionalities:

$$\text{E.g., } x_{WH-1} = \frac{5000 \text{ mrem}}{8\text{E}+4 \ \mu\text{Ci}} = \frac{x \text{ mrem}}{4{,}183 \ \mu\text{Ci}}$$

$$x_{WH-1} \ \frac{(4{,}183 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E}+4 \ \mu\text{Ci}} = 261 \text{ mrem}$$

$$x_{TT} \ \frac{(22{,}908 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E}+4 \ \mu\text{Ci}} = 1{,}432 \text{ mrem}$$

$$x_{Res-1} \ \frac{(67 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E}+4 \ \mu\text{Ci}} = 4 \text{ mrem}$$

$$x_{Shop} \ \frac{(558 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E}+4 \ \mu\text{Ci}} = 35 \text{ mrem}$$

$$x_{Res-2} \ \frac{(22 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E}+4 \ \mu\text{Ci}} = 1 \text{ mrem}$$

$$x_{WH-2} \ \frac{(1{,}295 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E}+4 \ \mu\text{Ci}} = 81 \text{ mrem}$$

Type of Enclosure	**Intake (µCi) t = 0.083 hour Worker (Resident)**	**Worker (Resident) Dose mrem**
Warehouse-1	4,183	**261**
Tractor trailer	22,908	**1,432**
Residence-1	67	**4**
Small Repair Shop	558	**35**
Residence-2	22	**1**
Warehouse-2	1,295	**81**

Table 5. Calculated internal doses to workers (residents) due to inhalation.

4. Inhalation Dose (Firefighters)

Internal dose is calculated by comparing the calculated intake to the stochastic ALI for tritium in Appendix B to 10 CFR 20. This ALI is 8E+4 µCi. Using proportionalities:

$$\text{E.g., } x_{WH-1} = \frac{5000 \text{ mrem}}{8\text{E+4 } \mu\text{Ci}} = \frac{x \text{ mrem}}{33{,}600 \ \mu\text{Ci}}$$

$$x_{WH-1} \frac{(33{,}600 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E} + 4 \ \mu\text{Ci}} = 2{,}100 \text{ mrem}$$

$$x_{TT} \frac{(46{,}000 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E} + 4 \ \mu\text{Ci}} = 2{,}875 \text{ mrem}$$

$$x_{Res-1} \frac{(269 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E} + 4 \ \mu\text{Ci}} = 17 \text{ mrem}$$

$$x_{Shop} \frac{(1120 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E} + 4 \ \mu\text{Ci}} = 70 \text{ mrem}$$

$$x_{Res-2} \frac{(90 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E} + 4 \ \mu\text{Ci}} = 6 \text{ mrem}$$

$$x_{WH-2} \frac{(10{,}400 \ \mu\text{Ci})(5000 \text{ mrem})}{8\text{E} + 4 \ \mu\text{Ci}} = 650 \text{ mrem}$$

Type of Enclosure	Intake (µCi) t = 2 hours	Dose (mrem) t = 2 hours	Intake (µCi) t = 0.5 hour Firefighter	Dose (mrem) t = 0.5 hour	Intake (µCi) t = 1 hour Firefighter	Dose (mrem) t = 1 hours
Warehouse-1	(33,600)	**2,100**	--	--	--	--
Tractor trailer	--	--	(46,000)	**2,875**	--	--
Residence-1	--	**--**	--	--	(269)	**17**
Small Repair Shop			(1120)	**70**		
Residence-2					(90)	**6**
Warehouse-2	(10,400)	**650**				

Table 6. Summary of calculated internal doses to fire fighters for various exposure times due to inhalation. Intakes in parentheses indicate that the APF for SCBAs (3) has already been accounted for.

5. Ingestion Intakes

Released gaseous ^3H is quickly bound into airborne water vapor as T_2O (^3H_2O). A portion of this might be absorbed through the skin and is considered to be an ingestion. Ingestion intake[13] is calculated as follows:

$$I_{Ing.} = A \times 1E\text{-}4 \quad \textbf{(5)}$$

where A = total amount of available material at risk during the accident.

In these three scenarios, A = Q from the calculations above.

Scenario	Enclosure	A (µCi)	A x 1E-4 (µCi)
1	Warehouse	2E+8	20,000
2	Tractor Trailer	3.2E+7	3,200
3	Residence	4.8E+5	48
4	Sm Repair Shop	1.6E+5	16
5	Residence	1.6E+5	16
6	Warehouse	1.6E+8	1.6E+4

Table 7. Estimated ingested quantities (µCi).

[13] NUREG-1717, section A.1.6, 2nd paragraph, page A.1-3.

6. Ingestion Doses to Workers (Residents)

Activity on skin is absorbed and is considered another ingestion component, added to the inhalation quantity.

Internal dose is calculated by comparing the intake to the stochastic ALI for tritium in Appendix B to 10 CFR 20. This ALI is 8E+4 µCi. Using proportionalities,

$$\text{E.g., } x_{WH-1} = \frac{5000\text{ mrem}}{8\text{E+4 µCi}} = \frac{x\text{ mrem}}{20{,}000\text{ µCi}}$$

$$x_{WH-1} = \frac{(20{,}000)(5000\text{ mrem})}{8\text{E}+4\text{ µCi}} = 1{,}250\text{ mrem}$$

$$x_{TT} = \frac{(3{,}200)(5000\text{ mrem})}{8\text{E}+4\text{ µCi}} = 200\text{ mrem}$$

$$x_{Res-1} = \frac{(48)(5000\text{ mrem})}{8\text{E}+4\text{ µCi}} = 3\text{ mrem}$$

$$x_{Shop} = \frac{(16)(5000\text{ mrem})}{8\text{E}+4\text{ µCi}} = 1\text{ mrem}$$

$$x_{Res-2} = \frac{(16)(5000\text{ mrem})}{8\text{E}+4\text{ µCi}} = 1\text{ mrem}$$

$$x_{WH-2} = \frac{(1.6\text{E}+4)(5000\text{ mrem})}{8\text{E}+4\text{ µCi}} = 1{,}000\text{ mrem}$$

Scenario	Enclosure	Ingested (µCi)	Dose Worker (Resident) (mrem)
1	Warehouse	20,000	1,250
2	Tractor Trailer	3,200	200
3	Residence	48	3
4	Sm Repair Shop	16	1
5	Residence	16	1
6	Warehouse	1.6E+4	1,000

Table 8. Calculated internal doses to workers (residents) due to ingestion.

NOTE: NUREG-1717[14] gives an ingestion dose conversion factor for H-3 of 6.4E-5 rem/µCi. Use of this factor results in essentially the same doses as are calculated above using ALIs.

[14] NUREG-1717, Table 2.1.2 Dosimetry Data for Selected Byproduct Materials.

7. Ingestion Doses to Firefighters

Activity on skin is absorbed and is considered another ingestion component, added to the inhalation quantity. For a fire fighter in full turnout gear, assume a dose reduction of 33% (multiply by 0.67).

Internal dose is calculated by comparing the intake to the stochastic ALI for tritium in Appendix B to 10 CFR 20. This ALI is 8E+4 µCi. Using proportionalities,

E.g., $x_{WH-1} = \dfrac{5000\ \text{mrem}}{8\text{E+4}\ \mu\text{Ci}} = \dfrac{x\ \text{mrem}}{13{,}340\ \mu\text{Ci}}$

$$x_{WH-1} = \frac{(13{,}340)(5000\ \text{mrem})}{8\text{E} + 4\ \mu\text{Ci}} = 834\ \text{mrem}$$

$$x_{TT} = \frac{(2{,}144)(5000\ \text{mrem})}{8\text{E} + 4\ \mu\text{Ci}} = 134\ \text{mrem}$$

$$x_{Res-1} = \frac{(32)(5000\ \text{mrem})}{8\text{E} + 4\ \mu\text{Ci}} = 2\ \text{mrem}$$

$$x_{Shop} = \frac{(11)(5000\ \text{mrem})}{8\text{E} + 4\ \mu\text{Ci}} = 1\ \text{mrem}$$

$$x_{Res-2} = \frac{(11)(5000\ \text{mrem})}{8\text{E} + 4\ \mu\text{Ci}} = 1\ \text{mrem}$$

$$x_{WH-2} = \frac{(10{,}720)(5000\ \text{mrem})}{8\text{E} + 4\ \mu\text{Ci}} = 670\ \text{mrem}$$

Scenario	Enclosure	Ingested (µCi)	33% Reduction	Dose Firefighter (mrem)
1	Warehouse-1	20,000	13,340	834
2	Tractor Trailer	3,200	2,144	134
3	Residence-1	48	32	2
4	Sm Repair Shop	16	11	1
5	Residence-2	16	11	1
6	Warehouse-2	1.6E+4	10,720	670

Table 9. Calculated internal doses to fire fighters due to ingestion.

NOTE: NUREG-1717[15] gives an ingestion dose conversion factor for H-3 of 6.4E-5 rem/µCi. Use of this factor results in essentially the same doses as are calculated above using ALIs.

[15] NUREG-1717, Table 2.1.2 Dosimetry Data for Selected Byproduct Materials.

F. Total Effective Dose Equivalent (TEDE) Estimate

$$TEDE = \sum DDE + CEDE$$

In the case of tritium, deep dose equivalent (DDE) is zero as described above.

Committed effective dose equivalent (CEDE) has two components—inhalation and ingestion doses—that are additive. A summary table is provided below.

Type of Enclosure	Inhalation Dose (mrem) Worker (Resident)	Ingestion Dose (mrem) Worker (Resident)	TEDE Worker (Resident) (mrem)
Warehouse-1	261	1,250	**1,511**
Tractor trailer	1,432	200	**1,632**
Residence-1	4	3	**7**
Sm Repair Shop	35	1	**36**
Residence-2	1	1	**2**
Warehouse-2	81	1000	**1,081**

Table 10. Total effective dose equivalent (TEDE) to workers (residents) in the postulated accident scenarios.

Type of Enclosure	Inhalation Dose Fire Fighter (mrem)	Ingestion Dose Fire Fighter (mrem)	TEDE Fire Fighter (mrem)
Warehouse-1	2,100	834	**2,934**
Tractor trailer	2,875	134	**3,009**
Residence-1	17	2	**19**
Sm Repair Shop	70	1	**71**
Residence-2	6	1	**7**
Warehouse-2	650	670	**1,320**

Table 11. Total effective dose equivalent (TEDE) to fire fighters in the postulated accident scenarios.

G. Basis for "Low Probability" and "Negligible Probability" Decision

a. Footnote 1 to 10 CFR 32.23 admits that "The probabilities have been expressed in general terms to emphasize the approximate nature of the estimates which are to be made."

b. An exhaustive search of the internet for accidents or incidents involving gaseous tritium light sources in the form of gun sights failed to uncover any such accidents or incidents. Since these sights contain radioactive material it is reasonable to expect that any such incident anywhere in the world would receive extensive media coverage. There have been no such reports.

   The first patent application that could be located for tritium-illuminated gun sights is dated May 13, 1990[16]. Therefore it appears that the safety record of these devices over a period of nearly 25 years is exemplary. We believe that this excellent safety record justifies putting the probabilities of any of these incidents actually occurring into the "negligible probability" category.

H. Effectiveness of the Containment

10 CFR 32.23(c) requires that it be "unlikely that there will be a significant reduction in the effectiveness of the containment, shielding, or other safety features of the product from wear and abuse likely to occur in normal handling and use of the product during its useful life."

These devices are ruggedly constructed and are designed to be used by hunters, police and military. Based on the long and successful history of these sights cited in G above, Armson believes that a significant reduction in the effectiveness of the containment of these devices is extremely unlikely.

I. Conclusion

Based on the above analyses, Armson is therefore confident in stating, and believes that all available evidence supports the conclusions that:

a. in normal use and disposal of a **single exempt unit**, it is unlikely that the external radiation dose in any one year, or the dose commitment resulting from the intake of radioactive material in any one year, to a suitable sample of the group of individuals expected to be most highly exposed to radiation or radioactive material from the product will exceed the dose to the appropriate organ as specified in Column I of the table in § 32.24 of this part (i.e., 1 mrem);

b. In normal handling and storage of the **quantities of exempt units likely to accumulate** in one location during marketing, distribution, installation, and servicing of the product, it is unlikely that the external radiation dose in any one year, or the dose commitment

[16] Appl. No.: 07/527,271**;** Inventor: Bindon, Glyn A. J. (Farmington Hills, MI); Filed: May 23, 1990.

resulting from the intake of radioactive material in any one year, to a suitable sample of the group of individuals expected to be most highly exposed to radiation or radioactive material from the product will exceed the dose to the appropriate organ as specified in Column II of the table in § 32.24 (i.e., 10 mrem).

c. It is unlikely that there will be a **significant reduction in the effectiveness** of the containment, shielding, or other safety features of the product from wear and abuse likely to occur in normal handling and use of the product during its useful life.

d. In use and disposal of a **single exempt unit**, or in handling and storage of the **quantities of exempt units likely to accumulate** in one location during marketing, distribution, installation, and servicing of the product, the probability is low that the containment, shielding, or other safety features of the product would fail under such circumstances that a person would receive an external radiation dose or dose commitment in excess of the dose to the appropriate organ as specified in Column III of the table in § 32.24 (i.e., 500 mrem), and the probability is negligible that a person would receive an external radiation dose or dose commitment in excess of the dose to the appropriate organ as specified in Column IV of the table in § 32.24 (i.e., 15,000 mrem).

June 22, 2015

K. Paul Steinmeyer, RRPT