previously performed and submitted by 21st Century Technologies on behalf of TRUGLO, Inc. for approval by the NRC specifically for TRUGLO, Inc.. 21st Century Technologies received approval from the NRC for this exact device. Please reference Amendment No. 2 dated May 15, 2002 Reference No. 30-23697-01E; Docket or Reference Number 030-34261 of License Number 42-23850-02E. Therefore, no further prototype testing has been conducted. (Please see Attachment "J" for the documents pertaining to 21st Century Technologies.)

ESTIMATED EXTERNAL RADIATION DOSES:

The following information was obtained from referencing the ICRP Publication 30 – Limits for Intakes of Radionuclides By Workers, International Commission on Radiological Protection, Publication 30, 1978.

The radiation dose estimates associated with the GTLS and a comparison to the limits in Section 32.23 are presented here. The basis for these calculations are presented. The requirement addresses radiation exposure from both external sources and dose commitments from the intake of radioactive material. There is not external radiation dose from a GTLS due to the sort range of the low-energy beta emitted by the radioactive decay of tritium. Dose commitments are possible through several pathways including:

Inhalation of the tritium gas
Absorption through skin
Inhalation or Ingestion of tritium oxide as water or water vapor

The ICRP in Publication 30 presented the basis for dose modeling from thse pathways and is the method endorsed by the NRC in setting their radiation standards. Using these techniques. limiting quantities of radioactive material allowed within a year and limiting concentrations in air through out the year were calculated.

Two separate models are used for elemental tritium and tritiated water. There is no established Annual Limit of Intake from exposure to elemental tritium. The ICRP explains that the exposure to tritium gas only needs to be modeled as exposure to a cloud of gas. The total dose equivalent received from such an exposure is from tritium contained within the lung. Using this approach they established a Derived Air Concentration (DAC) for elemental tritium as 2×10^{10} Bq/m^3.

A DAC is a derived limit chosedn such that exposure to 2000 hours of this concentration in the air would result in a 5000 mrem committed dose equivalent. Comparison of this DAC with that of tritiated water provides a relative hazard index.

The DAC of 2×10^{10} Bq/m^3 represents the complete contents of about 42 GTLS per cubic meter, assuming 15 mCi per device.

The DAC for tritiated water is 8×10^5 Bq/m^3. The relative hazard between elemental tritium and tritiated water is therefore:

$$\frac{2 \times 10^{10}}{8 \times 10^{5}} = 25{,}000$$

with elemental tritium being the least hazardous. This is the form of tritium in the GTLS.

More information is avaialable on the dosimetry of tritium oxide than for elemental tritium. For the oxide form an Annual Limit on Intake is given. This value represents the total quantity of material allowed to be taken in the body throughout the year which would result in a 5000 mrem committed effective dose equivalent. The ALI for tritium oxide is
3×10^9 Bq (the complete contents of four bow sights if the tritium was oxide.)

The internal dosimetry model for tritium oxide recommended by ICRP 30 assumes instantaneous mixing and distribution among all soft body tissues at any time following an intake, regardless of the route of entry. The retention of tritium in the body is described as a single exponential with a half-life of ten days.

For reference to man this model results in a committed dose equivalent of 1.8×10^{-11} Sv/Bq (IAEA91). This factor is similar to the exposure to dose conversion factor specified in Federal Guidance Report No. 11 (EPA88) which is 1.73×10^{-11} Sv/Bq. This factor is the same for inhalation and ingestion since tritium is assumed to be rapidly distributed within the body regardless of the route of entry.

The effects of exposure to a 13 mCi gaseous source may be made using the dose conversion factor for HTO and applying the relative hazard ratio of the gaseous form. Using the dose conversion factor of 1.73×10^{-11} Sv/Bq as defined by the EPA, the following estimate can be made:

$$13\text{mCi} \times \frac{3.7\times10^{7}\ \text{Bq}}{\text{mCi}} \times \frac{1.73\times10^{-11}\text{Sv}}{\text{Bq}} \times \frac{100\ \text{rem}}{\text{Sv}} = 0.832\ \text{rem}$$

The dose conversion factor used only applies to tritium oxide, but are the only values quoted. Applying the 25000:1 reduction for tritium gas would result in:

$$13\text{mCi} \times \frac{3.7\times10^{7}\ \text{Bq}}{\text{mCi}} \times \frac{1.73\times10^{-11}\text{Sv}}{\text{Bq}} \times \frac{100\ \text{rem}}{\text{Sv}} \times \frac{1000\text{mrem}}{\text{rem}} \frac{1}{25000} = 0.033\ \text{mrem}$$

from the total intake of 1 GTLS source at its maximum activity.

The ICRP also states that exposure to tritiated water vapor results in 3 x 10-2 Bq/min absorbed for each Bq/m3 in the air. Assuming a 13 mCi GTLS was broken and all converted to oxide in volume of 2 m3 and ten minutes exposure, the resultant intake would be:

$$3 \times 10^{-2} \times \frac{13\text{mCi}}{2\text{m}^{3}} \times \frac{3.7\times10^{7}\ \text{Bq}}{\text{mCi}} \times 10\ \text{minutes} = 7.2\times10^{7}\ \text{Bq}.$$

Applying the dose conversion factor for oxide, one obtains:

$$7.2\times10^{7}\ \text{Bq} \times \frac{1.73\times10^{-11}\ \text{Sv}}{\text{Bq}} = 1.25\times10^{-3}\ \text{Sv} = 0.125\ \text{rem} = 125\ \text{mrem}$$

These models are conservative because they do not account for the conversion of elemental tritium to oxide over time. Following a broken GTLS, the tritium gas would be readily dispersed and diluted. The actual dose would be much lower.

Little acutual data exists where exposure to a broken GTLS is estimated, but in one reported experiment Skibin (Skibin73) estimated the dose to an individual from crushing two 12 mCi sources (24 mCi total). Skibin estimates that if an individual was contained in a 12 m^3 plastic tent for over two hours following the crushing of these sources, he would receive about a 5 mrem exposure.

The dose limits established to demonstrate compliance with the licensing requirements are given in 10CFR Section 32.23. The normal use and disposal of a single unit can not result in more than 1 mrem/year to the whole body or 3 mrem per year to any organ (lung). During normal use there would be negligible dose since there is no external radiation hazard from tritium. The estimated dose for the intake of a single unit as calculated above was 0.03 mrem.

The dose limit allowed for the accumulation of a quantity of units is 10 mrem. At 0.03 mrem per device, this would allow for 3,333 units in one location to fail creating a cloud of elemental gas with no subsequent actions of individuals to reduce their dose.

A dose limit of 500 mrem is applied to hypothetical failure of a container and shielding. This limit would allow the simultaneous crushing of 16,666 units in one location with no action by an individual to reduce their dose.

(See Attachment "K")

REFERENCES

EPA88 Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion. Federal Guidance Report No. 11, EPA-520/1-88-020, September 1988.

Evans66 Evans, E.A., Tritium and Its Compounds, D. Van Nostrand Company, Inc. 1966 and 1974.

HEW1970 Radiological Health Handbook, U.S. Department of Health, Education and Welfare, 1970.

IAEA91 Safe Handling of Tritium, Review of Data and Experience, IAEA Technical Reports Series No. 324. International Atomic Energy Agency, Vienna, 1991.

ICRP78 Limits for Intakes of Radionuclides by Workers, International Commission on Radiological Protection, Publication 30,1978.

NCRP76 Tritium Measurement Techniques, National Council on Radiation Protection and Measurement, NCRP Report No. 47, 1976. Second printing 1988.

NCRP79 Tritium and Other Radionuclide labeled Organic Compounds Incorporated into Genetic Material, National Council on Radiation Protection and Measurements, Report No. 63, 1979.

NCRP87 Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources, National Council on Radiation Protection and Measurement, NCRP Report No. 95, 1987.

Skibin73 Skibin, D., Hazards from Rupture of a Tritium Activated Light Source, Health Physics, Vol. 25, No. 2, pp 184-186, 1973

UNSCEAR 77 Sources and Effects of Ionizing Radiation, United Nations Scientific Committee of Atomic Radiation 1977 report to the General Assembly, with annexes. 1977