# Decontamination Efficacy of Tritium: Lessons Learned Outside Nuclear Power Operations

**Edward J. Waller[+], David Cole and Terry Jamieson**
Science Applications International Corporation (SAIC Canada)
60 Queen Street, Suite 1516
Ottawa, Ontario, K1P 5Y7
(phone) 613-563-7242 (fax) 613-563-3399

+ Current address: University of Ontario Institute of Technology
School of Energy Systems and Nuclear Science
2000 Simcoe Street North
Oshawa, Ontario

**ABSTRACT**

Various pieces of equipment in use by the Canadian Department of National Defence (DND) contain radiation emitting components. One such piece is the sight knobs used on light artillery. At the request of the DND's Director General Nuclear Safety (DGNS – DND's internal nuclear regulatory agency), SAIC Canada was contracted to perform the removal of a luminous tritium-impregnated paint strip from over 300 sight knobs. In this paper we discuss:

- the physical description of the sight knobs
- the protocol developed for decontaminating the sight knobs
- the rational for the release limits used; and
- experience in gained in using and modifying the decontamination protocol

## THE SIGHT KNOBS

The Carl Gustaf sight knob includes a strip of tritium-based radioluminescent paint bound with a nitrocellulose lacquer. Photographs depicting the front and side view of this sight are seen in Figure 1.

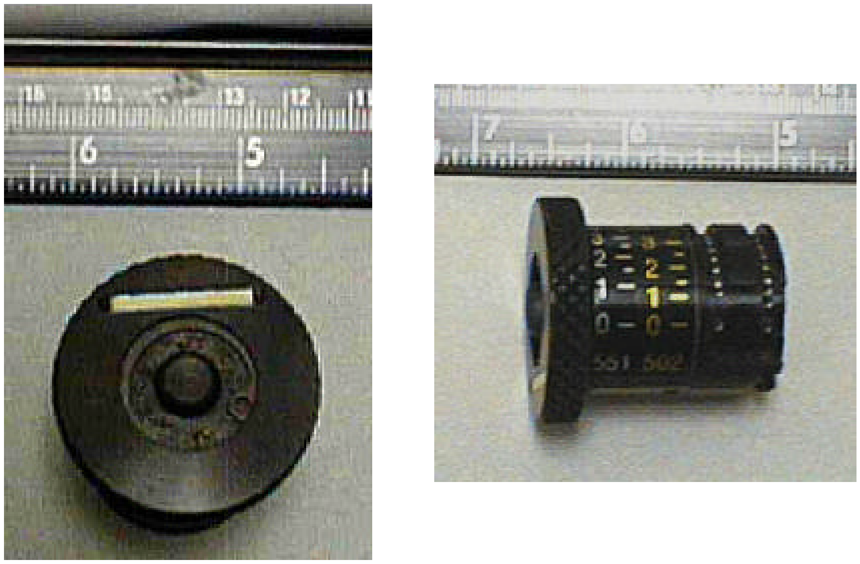


**Figure 1 - Front (L) and side (R) view of the Carl Gustaf sight with tritium strip**

The paint strip is nominally 0.3 mm thick, and 2.15 mm wide by 19 mm long. A conversion value of 0.05 gram of pigment per 100 $mm^2$ area coverage is used, and 1 gram of pigment contains 160 mCi (5.92 GBq) of tritium[1]. The estimated amount of tritium per sight, assuming the thickness is minimal, is therefore 121 MBq.

## THE DECONTAMINATION PROTOCOL

A multi-step chemical and physical decontamination process was developed.

The initial steps followed were:

- Removal of tritium strip (use of chemical remover)
- Tepid water rinse
- Acetone rinse
- Ultrasonic bath
- Swipe

[1] Swedish Ordnance – Saab Bofors Dynamics AB, Lysremsa Luminous Strip FFV 557 data sheet, 19 November, 1990.

Upon receipt of the preliminary swipes, the sights were decontaminated again using:

- Tepid water rinse
- Swipe

**THE RELEASE LIMITS**

In trial runs, it was demonstrated that the SAIC Canada paint strip removal process and associated decontamination/cleaning processes can achieve residual tritium non-fixed contamination immediately after cleaning.

A technical assessment (see Annex A) was performed to establish the appropriate clearance (release) limits for each sight knob. This assessment indicated that a limit of 200 Bq would be sufficient to ensure that future exposures of any individual due to the decontaminated Carl Gustaf telescopic sights are deemed de minimus. There are no likely scenarios where such sights could lead to a failure from exemption criteria for regulatory concern.

In practice, a limit of 140 Bq per knob was used.

**DECONTAMINATION EFFICIENCY**

A batch of 314 Carl Gustaf sights was processed as per the SAIC Canada protocol. In summary, the following was found:

- Out of 314 sights, a total of 273 had residual contamination levels of 150 Bq or less;
- Out of 314 sights, a total of 15 had residual contamination levels between 150 and 200 Bq; and
- Out of 314 sights, a total of 26 had residual contamination levels between 200 and 558 Bq. The highest residual swipe reading was 558 Bq.

The average value (over 314 sights) of the residual tritium is 75 Bq (assuming 100% swipe efficiency). The results of the first and second pass cleanings are shown in Figures 2 and 3. After second pass cleaning, approximately 87% of the sights were at or below the target 140 Bq. Any sight not meeting the 140 Bq release limit was subsequently re-processed.

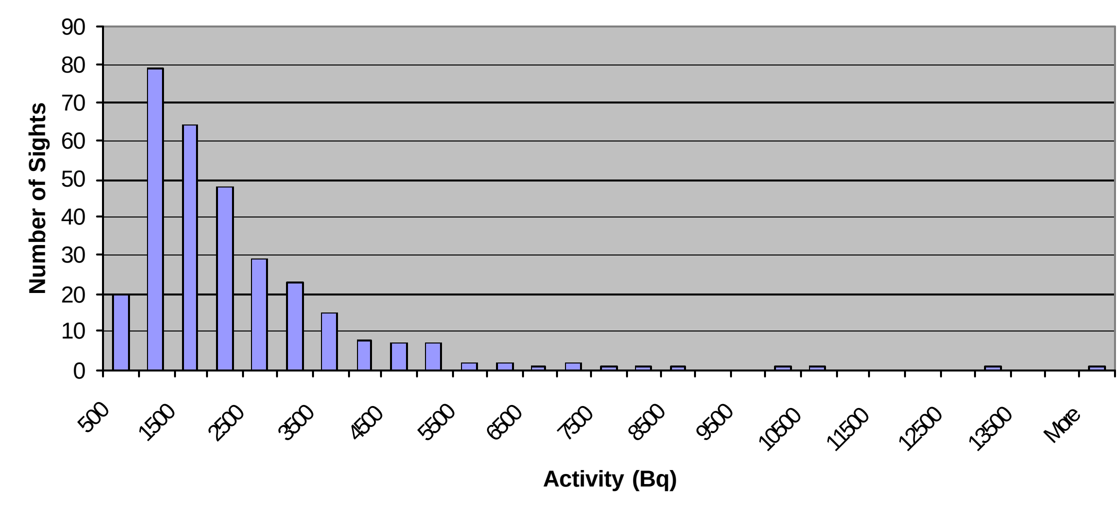


**Figure 2: Results After First Pass**

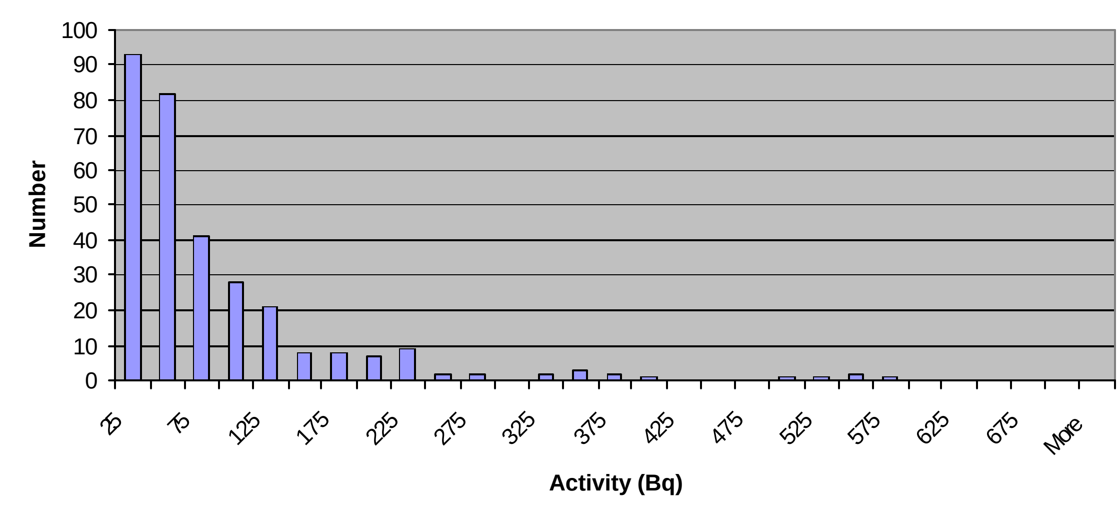
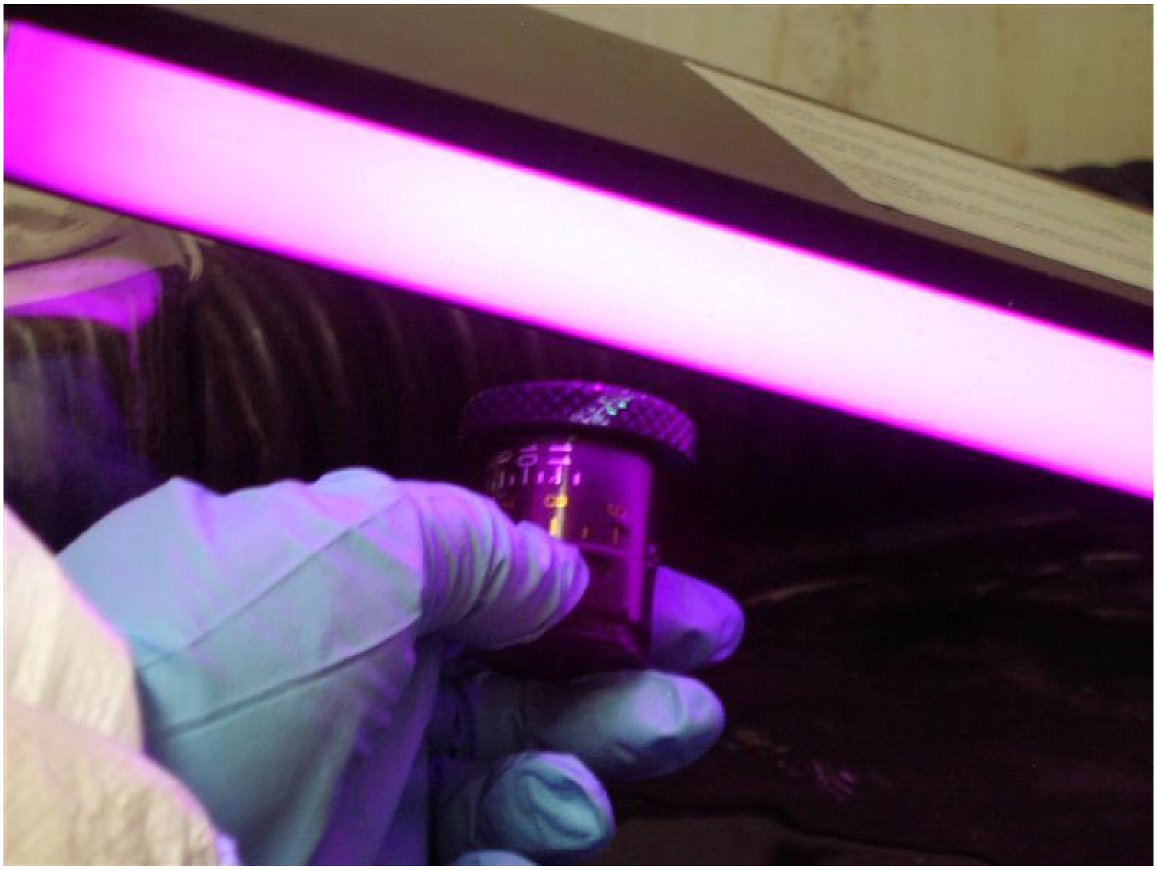


**Figure 3: Results After Second Pass**

Figure 4 depicts the examination of a sight knob under a black light. Note the indication of contamination on the knurled portion of the knob.

**Figure 4: Sight Knob Inspection Using a Black Light**



## LESSONS LEARNED

1. Tritium-contaminated material can be economically decontaminated to meet or exceed regulatory limits. This allows high-value items to be returned to service at less than replacement cost.

2. Tritium-contaminated material can be safely decontaminated. No measurable radiation doses were observed for any of the individuals participating in the decontamination. The tritium that was removed was packaged and disposed in accordance with current regulations.

3. In this work, a decontamination factor of approximately $10^6$ was achieved. Subsequently, two additional batches were processed. Improvements in the original protocol resulted in more efficient cleaning, both in terms of processing time and in initial decontamination results.

4. The multi-step process was generally very efficient in attaining the required decontamination factor. Only limited polishing work was required.

## REFERENCES

CNSC (1989a) “Basic Principles of Radiation Protection in Canada”, AECB INFO-0340.

CNSC (1989b) “Radiation Protection Requisites for the Exemption of Certain Radioactive Materials from Further Licensing upon Transferal for Disposal”, AECB Regulatory Document R-85.

CNSC (1990) “Recommended De Minimis Radiation Dose Rates for Canada”, AECB INFO-0355.

DGNS (2000) “Nuclear Safety Orders and Directives (NSODs)”, Department of National Defence.

IAEA (1996a) “International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources”, IAEA Safety Series No. 115.

IAEA (1996b) “Clearance Levels for Radionuclides in Solid Materials”, IAEA-TECDOC-855.

**Annex A: Release Limits for the Removal of Tritium Strip from SRAAW 84 mm Carl Gustaf Sight Knob**

## A.1 Background

DGNS Regulations (DGNS, 2000) specify a non-fixed contamination limit of 0.5 Bq/$cm^2$ for beta or gamma radiation.

It is believed that the beta emitting radioisotope limit of 0.5 Bq/$cm^2$ should not apply to the release of this material as non-radioactive. Current trends in exemption principles are moving towards isotope-specific exemption limits (for example, see Table 3, Nuclear Safety Orders and Directives), and since tritium is of the lowest relative toxicity of beta emitting isotopes, it has a correspondingly larger exemption limit. Also, the beta release limit of 0.5 Bq/$cm^2$ strictly applies to a surface area of 100 $cm^2$. The sight knob has an approximate outer surface area of 28.5 $cm^2$.

Tritium can readily ingress into metals and grease, and after careful observation of the sight fabrication, it is now believed that this level of removal of tritium is not achievable. Assuming that the area to be cleaned is 28.5 $cm^2$, the maximum activity (to achieve the goal of 0.5 Bq/$cm^2$) that can be on any one sight knob is approximately 14 Bq. Assuming that each knob, on average, starts with 120 MBq, the removal and decontamination efficiency must be greater than 99.999988%.

**Based on the above two considerations, a proposal for the unconditional release of the Carl Gustaf sight knobs is presented below.**

## A.2 Proposal for Release Limits

The current trend in radiation protection is to move away from a fixed a/ß limit approach for contamination and towards a risk model. With this in mind, protocols for the unconditional release of material as non-radioactive are being based upon isotope-specific release activities
and the concept of *de minimis* dose.

### A.2.1 De Minimis Dose

The concept of *de minimis* dose is explored in the Canadian Nuclear Safety Commission document INFO-0355 (CNSC, 1990). The recommended individual *de minimis* dose is given as 10 µSv/year, which is regarded as being negligible in comparison with other risks and far greater than radiation dose due to natural background. The view is also related in a number of CNSC documents (CNSC, 1989a,b) as well as being held internationally (for example, IAEA, 1996b).

The most significant document related to exemption criteria for unconditional release is the IAEA Basic Safety Series No. 115 (IAEA, 1996a). Within this document, criteria for exemption are clearly delineated, and are repeated here:

> *I-1. Practices and sources within practices may be exempted from the requirements of the Standards, including those for notification, registration or licensing, if the Regulatory Authority is satisfied that the sources meet the exemption criteria or the exemption levels specified in this Schedule or other exemption levels specified by the Regulatory Authority on the basis of these exemption criteria. Exemption should not be granted to permit practices that would otherwise not be justified.*
>
> *I-2. The general principles for exemption are that:*
>
> *(a) the radiation risks to individuals caused by the exempted practice or source be sufficiently low as to be of no regulatory concern;*
> *(b) the collective radiological impact of the exempted practice or source be sufficiently low as not to warrant regulatory control under the prevailing circumstances; and*
> *(c) the exempted practices and sources be inherently safe, with no appreciable likelihood of scenarios that could lead to a failure to meet the criteria in (a) and (b).*
>
> *I-3. A practice or a source within a practice may be exempted without further consideration provided that the following criteria are met in all feasible situations:*
>
> *(a) the effective dose expected to be incurred by any member of the public due to the exempted practice or source is of the order of 10 ?Sv or less in a year, and*
> *(b) either the collective effective dose committed by one year of performance of the practice is no more than about 1 man.Sv or an assessment for the optimization of protection shows that exemption is the optimum option.*

It may be seen that the intent of the exemption criteria is that due diligence be demonstrated by the Applicant for exemption and the Regulatory Authority granting the exemption. The minimum individual dose criteria of no greater than 10 µSv/year, or a collective dose of 1 man-Sv/year, should not be exceeded.

### A.2.2 Other Guidance Documents

As was previously discussed, the international trend is moving away from bulk limits and towards isotope specific limits.

Table A-1 presents some tritium specific guidance by various agencies involved with the clearance of materials. The values in the table are generally applied to disposal scenarios, however they are indicative of the limit agencies consider beyond regulatory concern. Since all values are based on 100 $cm^2$ swipe areas, the activity limit for each agency is 100 times more than reported in the table.

**Table A-1 - Tritium specific clearance limits by various agencies**

| Agency | Limit | Unit | Reference |
|---|---|---|---|
| DOE | 17 | $Bq/cm^2$ | |
| IAEA | 3000 | Bq/g | **IAEA-TECDOC-855** |
| ICRP | 3000 | $Bq/cm^2$ | **ICRP-57** |
| NRPB | 300 | $Bq/cm^2$ | **NRPB-DL2** |
| AECL | 37 | $Bq/cm^2$ | **IAEA Report 120 (tools)** |

The average value (over 314 sights) of the residual tritium is 75 Bq (assuming 100% swipe efficiency). The assumption of swipe efficiency is subjective. If a nominal 10% swipe efficiency is assumed, then the average residual contamination would be 750 Bq. In general, however, sight-to-mouth transfer for ingestion is assumed to have a nominal 1% efficiency, which lowers the intake amount by a factor of 100. Due to the fact that the sights were slightly damp when arriving at the swipe station, a swipe efficiency greater than 10% would be expected. However, to be conservative a nominal 10% swipe efficiency is assumed.

### A.2.3 Exposure Analysis

The estimation of exposure to personnel handling the sight knob is based on a set of assumptions, listed below:

(a) Total activity is 10x reported swipe activity (conservative)
(b) Dominant exposure pathway is via ingestion (reasonable based upon the use of the sight and the low activity levels available to become airborne)
(c) Transfer fraction is 10% of sight activity to the hands (reasonable)
(d) Transfer fraction is 10% of the hand activity to the mouth (reasonable)
(e) HTO is the dominant form (reasonable given the environment the sights will be in)

In addition, an ingestion dose conversion factor of $1.8x10^{-11}$ Sv/Bq is used. This value is taken from IAEA Safety Series No. 115 (IAEA, 1996), Schedule II, Table II-IV for members of the general public.

Based upon the above assumptions, swipe activity, and dose conversion factors, the committed dose for a single contact with each knob was calculated. Additionally, the number of contacts (or transfers, assuming each transfer carries away 1% of the activity) per year required to reach the *de minimis* dose level of 10 μSv was calculated.

The results indicate that, for the worst-case swipe result, it would take a total of over 10,000 successful transfers from knob to mouth to reach the *de minimis* dose level. On average, it would take over **200,000** successful transfers to reach this limit. On average, this suggests approximately 550 successful ingestion transfers of tritium each and every day for a complete year by a single individual.

### A.2.4 Proposed Limit

Based upon the above conservative analysis, it may be seen that even the outlying knobs require a very high number (~ 10,000 per year) of successful ingestion transfers to reach the *de minimis* dose level of 10 μSv.

Referring to the guidance provided by Safety Series No. 115, and applying the tests of Items I-2 and I-3 to exemption practice, it may be seen that I-2 (a), (b) and (c) are satisfied, and that I-3 (a) and (b) are also satisfied. In addition, it may be seen that the residual contamination levels on the swipes are well below any of the limits proposed by various international agencies.

Although, by examination of the *de minimis* dose and other international guidance, the sights are already of no potential committed dose consequence, a practical level per sight must be proposed.

**Based upon the statistics of the 314 sight knobs already decontaminated, a practical release limit of maximum 200 Bq per knobs (via swipe analysis) is proposed.** This is a practically achievable limit, and also is well below *de minimis* dose and international guidance considerations. It is also suggested that once the knobs have been released as *below regulatory concern*, there are no applicable transportation of dangerous goods limits, since they are exempt as radioactive material, and require no further action.