

Follow-up Efforts on SEC-00192 Rocky Flats Plant Tritium Issues

**White Paper
Rev. 1**

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INTRODUCTION

This is a summary of the initial and secondary tritium follow-up efforts performed by the National Institute for Occupational Safety and Health (NIOSH) Division of Compensation Analysis and Support (DCAS) and Oak Ridge Associated Universities Team (ORAUT) in support of the SEC-00192 Rocky Flats Plant (RFP) Special Exposure Cohort (SEC) Evaluation Report (ER) presented to the Advisory Board on Radiation and Worker Health (Advisory Board) in September 2012.

As part of the initial follow-up, additional document data captures and personnel interviews were performed (classified and unclassified) to: (1) clarify the existence of tritium on site and associated personnel exposures; (2) expand the investigation on tritium bubbler sampling; (3) confirm the existence of shipping container tritium surveys; and (4) confirm the type and amount of sampling analysis performed in Building 123. These initial follow-up efforts were performed to validate the tritium bounding method for the SEC-00192 RFP ER (which uses information from the 1973 tritium incident as the maximum exposure scenario), and to provide more precise estimates of doses due to tritium.

NIOSH requested that ORAUT conduct a secondary follow-up effort and evaluate all available documentation/data in light of the additional information captured during the initial effort in order to:

- analyze RFP occupational tritium exposures prior to 1973 (see Appendix 1 on 11)
- determine the best approach for tritium dose assignments for 1973 and later (see Appendix 1)
- provide an example tritium dose reconstruction using this approach (see Appendix 1)

ORAUT was also asked to prepare responses to comments from the Advisory Board Work Group and Sanford Cohen & Associates (SC&A) on the RFP Tritium White Paper (see **Appendix 2 on page 35**).

INITIAL FOLLOW-UP

A review of all RFP-related Site Research Database (SRDB) documents was performed to determine if any documents existed in that dataset that could expand on any of the issues raised regarding tritium. The documents relating to tritium monitoring at RFP were identified, including some tritium bubbler results, and some indication of tritium contamination surveys.

There are multiple documents regarding four significant incident-related tritium releases that occurred in 1968, 1973, 1974, and 1977 (SRDB Ref ID: 8265, 8790, 24164, 24165, 24167, 110900, 110901, and 110903). There are also post-1977 documents that confirm continued monitoring of tritium releases and residual tritium as a result of these four earlier releases.

There is also an SRDB document that provides information on post-1977 stack releases occurring in 1981 and 1986; both releases were considered small with no impact to site personnel or the immediate surrounding area (SRDB Ref ID: 110900). While some of the documents corroborated the classified interview issues addressed in the following sections of this white paper (i.e., bubblers and tritium contamination surveys), it does not appear that any of the new information supports the notion that there were any tritium levels that exceeded the 1973 incident. Therefore, ORAUT finds no evidence disputing the use of the 1973 incident data as the bounding estimate for tritium at RFP, as presented in the SEC-00192 RFP ER.

As stated in the SEC-00192 ER, RFP operations that were related to, or had potential exposure impacts associated with tritium included neutron generator operations (i.e., the use of tritiated targets), and returned pit operations. Subsequent post-ER classified interviews identified shipping container handling as a potential exposure source.

The following was learned:

- The follow-up effort corroborated in at least one interview (SRDB 122907) and in two documents (SRDB 118369; 117274) the point made in the SEC-00192 ER that the stainless steel reservoir operation was a construction operation before the introduction of tritium, which occurred at other sites. RFP was responsible constructing the reservoirs and shipping them to other locations where they were filled/used.
- The follow-up effort corroborated that the neutron generator tritium target sources did not represent a source larger than the one represented in the 1973 tritium incident.
- The tritium-contaminated pits and shipping containers are considered directly related because the shipping container tritium was a result of tritium from the pits loaded in the containers. Because of potential classification issues, the assessment of this issue will be addressed later in this document under the more general term Shipping Containers rather than the term Pits.
- A follow-up effort was directed to determine if there are any other scenarios with the potential to exceed the SEC-00192 RFP ER bounding approach. These scenarios are being assessed as part of the pre-1973 tritium shipping container exposure evaluation (discussed later).

The indications found in the available documentation and provided by the majority of interviewees, was that RFP did not work with tritium as a normal or usual process, and therefore, did not expect it on site. The RFP radiological program did very little monitoring for tritium prior to the 1973 incident because they felt they had limited tritium exposure potential. Changes to the program related to tritium monitoring were implemented as a result of the 1973 incident. It has been corroborated that tritium bubbler monitoring did exist on site as part of the usual RFP

air monitoring program before and after the 1973 tritium incident (SRDB 122907); however, the current information does not indicate how long before the 1973 incident bubblers existed on site.

The available bubbler monitoring data is being evaluated for its applicability in dose reconstructions.

As indicated in the SEC-00192 ER, the site implemented a routine tritium bioassay program after the 1973 tritium incident, but discontinued the routine program in 1975 due to lack of positive bioassay results. The program was subsequently implemented on an as-needed or as-identified basis. This situation was corroborated in at least one personnel interview performed during this follow-up effort (SRDB 122907).

INITIAL FOLLOW-UP: TRITIUM BUBBLERS

Significant information on the bubbler monitors was discovered during the additional follow-up data capture efforts. There is some documentation in the SRDB that discusses the use of tritium bubblers. Based on the available data, including the most recent information (schematics and pictures of the tritium air sampling and monitoring equipment and processes [SRDB 122779 through 122791]), there was a program that included the use of tritium bubblers to monitor enclosed and exhaust systems for tritium (SRDB 122466). As previously discussed, the exact start date for the use of bubblers has not been confirmed, but they did exist on site before the 1973 incident (SRDB 122907). Most individuals interviewed were not well-informed on bubbler use or operation.

The SRDB contains some tritium bubbler results (SRDB 111095 and 122712) as well as detailed schematics and pictures of the units (SRDB Ref ID's: 122691, 122692, 122693, 122787, 122788, 122789, and 122790). Based on these results, information discovered during the follow-up research, and the interviews there is nothing to support the occurrence of a release event more significant than the 1973 incident.

Table 1 beginning on the next page presents a summary of the Rocky Flats tritium bubbler information contained in the SRDB.

(continued)

Table 1: Rocky Flats Tritium Bubbler Information in the SRDB (on pages 5-7)			
SRDB Ref ID	Year	File Description	Comments
Category: Tritium Monitoring Results, Procedures, and Occurrences			
17824	1990-1991	Occurrence reports	Contains two occurrence reports involving inoperable bubblers, and one report of a Triton tritium air monitor that was shut off. None of the occurrences involved tritium releases.
24164	1976-1983	Tritium inventories and effluents	Contains: an evaluation of tritium-release potential from a proposed neutron crate counter (1983); elevated tritium effluents from Bldg 776/777 (January 1981); estimated inventory of tritium as surface contamination in glove boxes, ducts, and exhaust plenums in Bldg 776/777 (1980); evaluation of ethylene glycol in place of water in tritium bubblers (1978); special study of tritium in ambient air (1976); a report, "Estimates of Maximum Tritium Releases to the Atmosphere from Operations at the Rocky Flats Plant" (1976); and a Call Report indicating that 0.058 μCi of tritium would probably be vented to the atmosphere for an experiment on May 20, 1974.
24307	1986	Procedure for effluent and room air tritium sampling	Operating procedure
111095	1977-1981	Tritium bubbler sampling results	Log of analytical results for bubblers in operating areas, including room air and near downdraft tables. Most results are $<100 \text{ pCi/m}^3$, but results exceed $1,000 \text{ pCi/m}^3$ on several occasions in Bldg 559 - Rm 102, and in Bldg 881- Rm 283. Highest result appears to be $89,230 \text{ pCi/m}^3$ in Bldg 771 for the period May 11-18, 1978.
122466	2013	Documented interview with [Name redacted]	Includes a discussion of the different laboratories at Rocky Flats for analyzing tritium and other radionuclides in samples.
122712	1998	Lab report - tritium activity in bubblers	Detailed analytical report from Thermo NUtech, including sample activity, counting uncertainty, detection limit, and total propagated uncertainty.
122907; 24167	2013	Documented interview with [Name redacted]; 1973 incident report	Includes a discussion of the tritiated targets for laser fusion experiments and corroboration that bubblers were in use at several Rocky Flats locations prior to the 1973 tritium release incident.
Category: Tritium Sampler Photos and Design Documents			
122691	1973	Photos – tritium operations at Dow	Relevance of photos to tritium monitoring or tritium operations is not apparent, except for one photo of a Triton tritium monitor.
122692	1977	Photos - tritium monitoring	Good photos of sampling fixture for sealed cans and drums, Triton Model 955B tritium monitor, and bubblers mounted outside a glove box for sampling glove box air.

Table 1: Rocky Flats Tritium Bubbler Information in the SRDB (on pages 5-7)

SRDB Ref ID	Year	File Description	Comments
122693	1983	Photos – tritium air sampling station	Labeled tritium sampling assembly showing building number, air flow rates, and water volume.
122779	1974	Drawing 1 of 8 - Tritium and iodine sampler assembly	Engineering drawing
122780	1974	Drawing 2 of 8 - Tritium and iodine sampler assembly	Engineering drawing
122781	1974	Drawing - Environmental tritium and radioiodine sampler details	Engineering drawing
122782	1974	Drawing - Environmental tritium and radioiodine sampler wiring diagram	Engineering drawing
122783	1974	Drawing - Environmental tritium and radioiodine sampler mounting detail	Engineering drawing
122784	1974	Drawing - Environmental tritium and radioiodine sampler onsite electrical hookup	Engineering drawing
122785	1974	Drawing - Environmental tritium and radioiodine sampler offsite electrical hookup	Engineering drawing
122786	1974	Drawing - Environmental tritium and radioiodine sampler onsite and offsite electrical hookup	Engineering drawing
122787	1978	Drawing – Tritium detector assembly	Engineering drawing
122788	1978	Drawing – Tritium detector details (1)	Engineering drawing
122789	1978	Drawing – Tritium detector details (2)	Engineering drawing

Table 1: Rocky Flats Tritium Bubbler Information in the SRDB (on pages 5-7)			
SRDB Ref ID	Year	File Description	Comments
122790	1978	Drawing – Tritium detector details (3)	Engineering drawing
122791	1978	Drawing - Tritium detector flow diagram	Engineering drawing

INITIAL FOLLOW-UP: SHIPPING CONTAINER TRITIUM SURVEYS

As part of the follow-up, additional research was performed regarding the issue of tritium contamination in shipping containers. This issue arose from one of the classified interviews (SRDB 122516). Tritium contamination in shipping containers was corroborated in an SRDB document (SRDB Ref ID: 111301); however, no actual contamination surveys have been found. The follow-up survey requirements and processes were corroborated in a follow-up interview in which the interviewee discussed implementing the shipping container tritium survey program in response to the 1973 incident (SRDB 122907). During that interview, the interviewee said that no tritium contamination was ever found. Other classified interviewees indicated that they had heard about shipping-container contamination, but they had no direct experience of it. A worst-case situation analysis of potential shipping-container contamination levels has been performed for comparison with the SEC-00192 ER bounding analysis in order to validate the ER's bounding exposure scenario and to provide a more precise estimate for tritium dose prior to 1973. This analysis is provided in Appendix 1.

INITIAL FOLLOW-UP: SAMPLE ANALYSIS IN BUILDING 123

Analytical capability existed in both the production areas and in Building 123 (SRDB 122625), which housed the laboratories supporting worker health and safety (Industrial Hygiene and Health Physics) as well as the environmental programs (SRDB 122627). Samples collected in the production areas may have been analyzed either in the production laboratories or in Building 123, depending on the anticipated level of analytes and the potential for contamination with plutonium or uranium, for which strong contamination-control practices were in place. Tritium samples from stack exhausts, which were filtered several times before sampling and release to the environment, were typically analyzed in Building 123. Samples collected in the work areas were analyzed in a production area laboratory to eliminate the possibility of introducing plutonium contamination into the Building 123 lab (SRDB 122627). Samples with a high likelihood of elevated tritium content might also be analyzed in a production lab to prevent tritium contamination in the low-level Building 123 laboratories (SRDB 122624).

Some effort was made prior to 1973 to use commercially-available tritium monitoring equipment (e.g., the vibrating reed spectrometer and tritium sniffers) (SRDB 110885; 122623; 122670; 122671) or to develop an in-house capability (through development of specialized ion chambers or tritium concentration techniques, such as silica gel traps [SRDB 24648; 24680]). Liquid scintillation counting was reportedly used for quantitative analysis of a variety of radioactive materials in the production areas; it quickly became the technique of choice for tritium sample analysis after the 1973 environmental tritium release. Tritium sniffers continued to be used to indicate elevated tritium in the workplace, but they did not provide quantitative data of record. No results for tritium samples analyzed in the production areas have been captured, and only limited data are available from the Building 123 laboratories. ORAUT's understanding of the criteria for determining where tritium samples were analyzed comes solely from interviews with former Rocky Flats Plant employees.

INITIAL FOLLOW-UP: CONCLUSION

The additional documents and interviews obtained during the post-ER follow-up efforts provide additional evidence of the potential for tritium exposures. However, the information also supports the case that estimates of potential tritium exposure that could have occurred prior to 1973 are bounded by the exposure estimate for the 1973 event, and that more precise estimates are feasible.

Table 2 on the next page lists the follow-up actions performed in support of SEC-00192.

Table 3 on page 10 lists the follow-up interviews performed in support of SEC-00192.

SECONDARY FOLLOW-UP: APPENDICES 1 AND 2

In light of the additional information and data gathered during the follow-up effort, NIOSH requested that ORAUT evaluate the available documentation and data to: (1) analyze RFP tritium exposures for 1959-1973; (2) determine the best approach for dose assignment for 1973 and later; and then (3) produce an example tritium dose reconstruction employing the best approach determined in the analysis. The results of this assessment are provided in Appendix 1. NIOSH also asked ORAUT to prepare responses to comments from the Board Working Group and SC&A on the RFP Tritium White Paper. These responses are provided in Appendix 2.

(continued)

Table 2: Initial and Secondary Follow-up Actions Performed in Support of SEC-00192		
Date	Activity	Location^a
Initial Follow-Up Actions		
10/03/2012	Secure Discussions	NIOSH (Cincinnati OH)
10/28/2012	Data Capture	LANL (Los Alamos NM)
11/06/2012 through 11/07/2012	Eleven secure interviews with former RFP employees (see Table 3)	DOE-EMCBC (Denver CO)
01/15/2013 through 01/31/2013	Eight follow-up telephone interviews with former RFP employees (see Table 3)	Employee homes via telephone
02/03/2013	Data Capture	DOE-LM (Westminster CO) EMCBC (Denver CO)
02/22/2013	Data Capture	OSTI (Oak Ridge)
02/25/2013	Secure Discussions	NIOSH (Cincinnati OH)
Secondary Follow-Up Actions		
05/30/2013	<i>Reconstructing Rocky Flats Tritium Doses Pre- and Post- 1973</i> (see Appendix 1)	ORAUT (Cincinnati OH)
03/06/2014	Response to WG/SC&A Comments on the RFP Tritium White Paper (see Appendix 2)	NIOSH (Cincinnati OH); prepared by ORAUT (Cincinnati OH)

^aDOE-EMCBC (Denver), LANL (Los Alamos), and OSTI (Oak Ridge) are sites where reviews of classified material were performed. Secure interviews were conducted at DOE-EMCBC.

(continued)

Table 3: Follow-up Interviews Performed in Support of SEC-00192			
Site	Interview Topic	Interview Date	SRDB Ref ID
Rocky Flats, SEC-00192	Tritium (DFC)*	11/6/2012	122515
Rocky Flats, SEC-00192	Tritium (DFC)	11/6/2012	122553
Rocky Flats, SEC-00192	Tritium (DFC)	11/6/2012	122666
Rocky Flats, SEC-00192	Tritium (DFC)	11/6/2012	122667
Rocky Flats, SEC-00192	Tritium (DFC)	11/6/2012	122668
Rocky Flats, SEC-00192	Tritium (DFC)	11/6/2012	122551
Rocky Flats, SEC-00192	Tritium (DFC)	11/6/2012	122550
Rocky Flats, SEC-00192	Tritium (DFC)	11/7/2012	122517
Rocky Flats, SEC-00192	Tritium (DFC)	11/7/2012	122516
Rocky Flats, SEC-00192	Tritium (DFC)	11/7/2012	122669
Rocky Flats, SEC-00192	Tritium Building 123	1/15/2013	122627
Rocky Flats, SEC-00192	Tritium Building 123	1/15/2013	122628
Rocky Flats, SEC-00192	Tritium Building 123	1/16/2013	122624
Rocky Flats, SEC-00192	Tritium Building 123	1/18/2013	122625
Rocky Flats, SEC-00192	Tritium Building 123	1/22/2013	122629
Rocky Flats, SEC-00192	Tritium Building 123	1/22/2013	122623
Rocky Flats, SEC-00192	Tritium Building 123	1/23/2013	122626
Rocky Flats, SEC-00192	Tritium Building 123	1/31/2013	122670
Rocky Flats, SEC-00192	Tritium Building 123	1/31/2013	122671

* DFC = Denver Federal Center where secure interviews regarding tritium were conducted.

Appendix 1: Reconstructing Rocky Flats Tritium Doses Pre- and Post-1973

J. S. Bogard, E. M. Brackett, and Mutty Sharfi, ORAUT

Introduction

The potential for tritium exposure to Rocky Flats personnel was not considered significant until an unexpected release occurred in April 1973. Because tritium monitoring was not rigorous before this event, NIOSH requested that ORAUT perform a follow-up effort to validate the tritium bounding method for the SEC-00192 RFP ER, which uses information from the 1973 tritium incident as the maximum exposure scenario. ORAUT conducted additional document data captures and personnel interviews regarding the existence of tritium on site and associated personnel exposures as well as follow-up on tritium bubbler sampling, shipping container tritium surveys, and sampling analysis performed in Building 123.

In light of the additional information and data gathered during the follow-up effort, NIOSH requested that ORAUT evaluate the available documentation and data to: (1) analyze RFP tritium exposures for 1959-1973; (2) determine the best approach for dose assignment for 1973 and later; and then (3) produce an example tritium dose reconstruction employing the best approach determined in this analysis. This white paper presents the results of these three efforts:

- PART I: Analysis of Rocky Flats Tritium Exposures for 1959-1973 by J. S. Bogard
- PART II: Rocky Flats Tritium Dose Assignment for 1973 and Later by E. M. Brackett
 - Attachment A: Rocky Flats 1973 H-3 Dose Assignment by E. M. Brackett
- PART III: Example RFP Tritium Dose Reconstruction by Mutty Sharfi

PART I: Analysis of Rocky Flats Plant Tritium Exposures for 1959-1973

J. S. Bogard, ORAUT

Tritium Monitoring Data Prior to 1973

Although tritium was used as a boost gas in weapons and as target material in neutron generators, it was not processed or handled in any significant quantities at Rocky Flats. Tritium was monitored in the environment around the site for a time, but that monitoring ceased and was left to the State of Colorado for a brief period preceding an environmental release that occurred in April 1973. No analytical records have been captured by NIOSH that might help establish the Rocky Flats workplace tritium environment prior to that time.

The management of Rocky Flats woke abruptly to the potential for tritium workplace and environmental contamination with the release in April 1973 of 500 Ci - 2,000 Ci of tritium, primarily from Building 779A, and its eventual detection in waters draining into a reservoir serving as a municipal drinking water supply (SRDB Ref ID: 110941; 111269; 111284). The release also resulted in tritium exposure to a small number of Rocky Flats personnel. Subsequent workplace monitoring and personnel bioassay was implemented, in part to establish the baseline tritium environment against which future incidents could be evaluated. A smaller and less-impactful tritium release occurred in September 1974 from Building 777; the subsequent investigation report (SRDB Ref ID: 8790) includes release details along with summaries of tritium workplace monitoring results prior to the incident for comparison. These data provide the basis for a model for bounding chronic tritium exposures to workers and of smaller, less-notable tritium releases that might have occurred prior to 1973.

Several factors single out the 1973 tritium release as bounding for the entire history of Rocky Flats operations. These factors include the large quantity of tritium involved, the chemical form of the released tritium, and the meteorological conditions at the time of the release. Other documented releases involved smaller quantities of elemental tritium, having a much smaller dose conversion factor than the tritium oxide released in 1973. Bounds for personnel tritium exposures after the 1973 release can be developed based on measurement results, since personnel bioassay, air sampling, and workplace contamination monitoring for tritium became more common after that release. There are only very limited tritium measurement results prior to 1973 because tritium was not perceived as a radionuclide of occupational or environmental interest at Rocky Flats. Bounding tritium exposures for the pre-1973 period are more difficult to develop as a result of this lack of measurement data.

According to the ChemRisk report (SRDB 8017), there was no environmental monitoring for tritium prior to 1970, and little in the way of workplace monitoring until after the 1973 tritium release; therefore, evidence of tritium releases prior to 1973 is primarily anecdotal. A 600-Ci release of elemental tritium (from a different source than the 1973 release) occurred in 1968. The ChemRisk report said the following with regard to possible releases from tritiated Pu shipments (SRDB 8017, pdf p. 285):

The 1973 findings associated with the tritiated plutonium initiated an investigation of other possible similar shipments and processing of tritiated plutonium. The investigation discovered three other shipments with maximum estimated tritium releases of 57 Ci (April 1969), 40 Ci (March 1971), and 29 Ci (November 1971).

The reported investigation and the documented 1968 release of elemental tritium are the only sources of information about other possible releases. The 1968 release was elemental tritium with no significant environmental or personnel exposure. None of the three identified potential releases from tritiated Pu was near the magnitude of the 1973 release. There is no evidence of a tritium release comparable to the magnitude and impact of the 1973 release prior to that year.

Source of Data for the pre-1973 Period

Despite the lack of measurement data, it is possible to develop pre-1973 tritium exposure bounds based on measurement results provided in a Rocky Flats Area Office (RFAO) report issued subsequent to a tritium release in one of the Rocky Flats production buildings on August 30, 1974 (SRDB Ref ID: 8790). The information contained in this report includes measurement data (i.e., results from air samples, surface contamination surveys, and bioassay) from the production area where the release occurred as well as comparison data from other areas prior to, during, and after the release. Several factors support the use of these data as surrogates for bounding the tritium environment at Rocky Flats prior to 1973:

1. Background tritium levels immediately prior to the incident described in the RFAO report, although undoubtedly elevated since the more significant 1973 release, were well below dosimetrically-significant values and can be considered as fairly representative of typical background levels for this analysis. The background tritium levels monitored in the months prior to the 1974 incident are consistent with internal radiation doses from tritium of well under 1 mrem annually. They are dosimetrically insignificant in this sense.
2. The quantity of tritium released (1.5 Ci) was significantly less than that released in 1973, and is probably more typical of potential undocumented releases in work areas – particularly those resulting from opening contaminated shipping containers.
The 1974 1.5-Ci tritium release is the only documented release from a shipping container in the Rocky Flats workplace. It is taken to be typical since there are no other such documented

releases to use in forming the model. There is documented concern about tritium releases, as shown in the following quote from the ChemRisk report (SDRB 8017, pdf p. 38):

As early as 1962, Rocky Flats maintained instruments for detection of tritium gas in particular work areas of the plant because operations have sometimes resulted in the storage of tritium containers.

The instruments available to Rocky Flats at that time were only semi-quantitative for indicating the presence of tritium; NIOSH has captured no records of these results. Because NIOSH has only identified six documented releases from 1968-1974 (an average of 1 per year), the application of a daily release would be a significant/bounding overestimate of the number of RFP tritium releases.

3. Tritium was released to the workplace environment, and not in a glovebox.
4. The release involved elemental tritium (HT, T₂), and not tritium oxide (HTO)¹.
5. The tritium was released from a contaminated shipping container which was procured by Rocky Flats in 1970 and can be taken as representative of shipping containers in use prior to 1973.

As stated in the response to Item 2, the 1974 1.5-Ci tritium release is the only documented release from a shipping container in the Rocky Flats workplace. It is taken to be typical since there are no other such documented releases to use in forming the model. There is documented concern about such releases, as shown in the following quote from the ChemRisk report (SDRB 8017, pdf p. 38):

As early as 1962, Rocky Flats maintained instruments for detection of tritium gas in particular work areas of the plant because operations have sometimes resulted in the storage of tritium containers.

The instruments available to Rocky Flats at that time were only semi-quantitative for indicating the presence of tritium; NIOSH has captured no records of these results. Because NIOSH has only identified six documented releases from 1968-1974 (an average of 1 per year), the application of a daily release would be a significant/bounding overestimate of the number of RFP tritium releases.

¹ The impact of the 1973 tritium release was largely due both to the quantity (500 Ci – 2,000 Ci) and the chemical form (HTO) of the material. The presence of tritium oxide in the 1973 release resulted from peculiarities of the plutonium recovery operation from which it was generated. There is no indication that any other tritium release at Rocky Flats involved the oxide. Tritium in its elemental form (HT, T₂) is far more likely to have been a contaminant at Rocky Flats because of the nature of its possible source terms – tritiated accelerator targets (neutron generators), plutonium hydride in recovery operations, and boost gas in returned reservoirs or pits.

6. The incident occurred close enough in time to the 1973 tritium release that work practices and controls were likely more similar to those prior to 1973 than to those even a year or two later, as procedures and controls evolved with greater sensitivity to the potential for tritium contamination.

The RFAO report provides the best source of monitoring data for use in bounding both chronic and accidental tritium exposures to Rocky Flats personnel prior to the unique circumstances of the 1973 release. The RFAO report states that elevated tritium concentrations were detected in air samples from Room 452 (Special Assembly Area) in Building 777 and from the Building 205 exhaust plenum servicing Building 776/777 over the period of August 29 – September 4, 1974 (SRDB Ref ID: 8790, pdf p. 9). Subsequent sampling and investigation of the elevated sample results concluded that about 1.5 Ci of tritium was released from the exhaust system of Room 452, Building 777, when a shipping container (referred to as a “pressure cooker”) received in July 1974 from Battelle Pacific Northwest Laboratory (BNW) was opened on a downdraft table in Room 452 on August 30 (SRDB Ref ID: 8790, pdf pp. 36-39). No elevated environmental tritium levels were detected as a result of the incident, but workplace tritium levels seven times the applicable Radiological Control Guide were detected in air samples collected on August 30 in Room 452 adjacent to the downdraft table, with average concentrations for the work week about 1.5 times the guidelines. **Table A-1** below shows the reported values.

Table A-1: Reported Tritium Air Concentrations ($\mu\text{Ci}/\text{m}^3$) from the August 30, 1974 Release		
Sampling Reference	Plenum 205, Bldg. 776/777^a	Room 452, Bldg. 777
Normal Concentrations	$<1 \times 10^{-2}$	$<1 \times 10^{-2}$
August 29-30, 1974	0.148	37.7
September 3-4, 1974	2.51	1.1

Source: SRDB 8790, pdf pp. 93-96

^aThe Special Assembly Glovebox Line in Room 452, Building 777, was normally served by Plenum 206, but exhaust air from this area was vented through Plenum 205 from February 11 – August 7, 1974, while a new Plenum 206 was constructed. A tritium air sampler for Plenum 206 was installed on August 30, 1974, but showed no elevated results. However, both Plenums 205 and Plenum 206 showed elevated tritium removable contamination (SRDB 8790, pdf pp. 74-82).

An air sampler located near the downdraft table in Room 452 indicated a tritium air concentration of $4.9 \times 10^{-3} \mu\text{Ci}/\text{m}^3$ on August 29 and $37.7 \mu\text{Ci}/\text{m}^3$ on August 30. The applicable Radioactive Concentration Guideline at the time was $5 \mu\text{Ci}/\text{m}^3$. Two “pressure cookers” were opened at the downdraft table, coincident with the elevated tritium-in-air measurements, and were smear-sampled for removable tritium contamination. One cooker showed smear levels of

1.16×10⁻² μCi; the other showed 3.43×10² μCi and was presumed to be the source of the gaseous tritium release.

Air Sample Results

Results from air samples collected daily in Room 452, Building 777, are available from June 3 to September 11, 1974. The air sampler was located near the downdraft table entry to the Special Assembly Line where the tritium contaminated “pressure cooker” was opened and was the only tritium air sampler in Building 777 at the time. Room air samples were collected in a water bubbler during the day shift (approximately 6 or 8 hours sampling time) at an air flow rate of 2 L/min. Individual results are shown in **Table A-2 below** (SRDB: 8790, pdf pp. 87-89).

Table A-2: Tritium Activity Concentrations in Room Air: Rm. 452 - Special Assembly-Bldg. 777							
Analysis Date (1974)	[³H] (pCi/m³)		Analysis Date (1974)	[³H] (pCi/m³)		Analysis Date (1974)	[³H] (pCi/m³)
3-Jun	9,428		8-Jul	3,872		8-Aug	628
5-Jun	12,121		5-Jul	3,030		12-Aug	1,256
4-Jun	20,370		3-Jul	4,655		13-Aug	1,301
7-Jan	5,892		10-Jul	2,602		16-Aug	--
6-Jun	16,498		9-Jul	2,512		20-Aug	2,439
14-Jun	5,387		11-Jul	4,553		21-Aug	3,140
13-Jun	4,553		17-Jul	21,022		22-Aug	3,298
12-Jun	12,358		16-Jul	5,040		23-Aug	--
11-Jun	13,972		15-Jul	6,742		26-Aug	2,927
11-Jun	10,894		19-Jul	5,041		27-Aug	3,089
21-Jun	4,348		18-Jul	4,209		28-Aug	4,874
20-Jun	4,553		24-Jul	1,010		29-Aug	3,986
19-Jun	4,414		23-Jul	4,866		30-Aug	37,676,609
18-Jun	5,781		22-Jul	4,866		3-Sep	1,098,901
17-Jun	6,829		29-Jul	2,512		4-Sep	8,477
26-Jun	4,519		26-Jul	2,118		5-Sep	5,108
25-Jun	--		25-Jul	3,089		6-Sep	--
24-Jun	--		1-Aug	1,842		9-Sep	3,030
2-Jul	3,454		30-Jul	1,727		10-Sep	3,140
1-Jul	4,348		1-Aug	2,269		11-Sep	2,898
27-Jun	5,366		7-Aug	1,179			
27-Jun	4,553		5-Aug	2,512			

Source: SRDB: 8790, pdf pp. 87-89

The average and standard deviation of daily air sample results prior to August 30, the day of the tritium release from the contaminated shipping container, are (5343 ± 4518) pCi/m³. The result on August 30 is 37,676,609 pCi/m³, and the sample taken on September 3 indicated a tritium concentration in the room air of 1,098,901 pCi/m³. However, the September 3 result is suspect because the sample was collected in the same vessel that was used on August 30 and which had not been cleaned. Smear surveys of Room 452 on September 3 failed to show significant tritium contamination (SRDB: 8790, pdf pp. 37-38). Tritium levels in Building 777 were known to be somewhat elevated over normal background because of residual contamination present since the 1973 tritium release.

Bioassay Results

The practice of pulling a sample of air from within shipping containers through a tritium air monitor to check for contamination was implemented after the 1973 tritium release. This practice was discontinued after urinary tritium results in the range of 0.75 µCi/L – 1.3 µCi/L were detected in May 1974 for the [redacted for privacy] who performed the monitoring. The [redacted for privacy] urinary tritium dropped to less than 0.1 µCi/L beginning in early July 1974 (SRDB 8790, pdf pp. 18-19). All employees who worked in Room 452, Building 777, submitted urine samples after the August 30 tritium release, with a high result of 32,320 pCi/L. **Table A-3** below shows individual results (SRDB 8790, pdf p. 90).

Table A-3: Tritium Urinalysis Results - Exposed Workers and Others, August 30, 1974			
Worker ID	Area	Urinary Tritium (pCi/L)	Uncertainty (pCi/L)
[redacted]	777	32320	± 6170
[redacted]	777	25610	± 6100
[redacted]	779	24000	---
[redacted]	777	22370	± 5800
[redacted]	777	21600	± 5800
[redacted]	707	17000	---
[redacted]	777	15740	± 6100
[redacted]	777	15730	± 5640
[redacted]	779	14000	---
[redacted]	707	13700	± 5370
[redacted]	123	630	± 580
Non-Occupational (Denver)		470	---

Source: SRDB 8790, pdf p. 90; Three hyphens (---) = Value not provided.

The report indicates that both a Denver resident and a Dow employee who did not work in radioactive material-handling areas were sampled with results < 0.01 $\mu\text{Ci/L}$ (<10,000 pCi/L). The Denver resident is identified in Table 3, and Worker ID [redacted for privacy] is believed, by implication, to be the [redacted for privacy] non-radiological worker.

Work Area Smear Surveys

Over 200 smear results for tritium are tabulated in the RFAO report (SRDB 8790, pdf pp. 74-82). Most appear to be surveys inside glove boxes, but there are also workplace area results that can be used as indicators of likely sources of internal contamination of workers following an event such as the one in August 1974. The workplace smear results are shown in **Table A-4** below and continued on the next page.

Table A-4: Tritium Smear Surveys - Work Areas in Buildings 776-777 (pages 18-19)			
Date	Bldg/Room	Location	Maximum Smear (pCi)
9/6/74	776-205	205 Plenum - cold side	< 100
9/6/74	776-206	206 Plenum - cold side	< 100
9/6/74	777-452	206-532 - top of box	< 100
9/6/74	777-430	E.S. Welder	353,000
9/6/74	777-437	Penthouse	< 100
9/6/74	777-437	A-1	110,000
9/6/74	777-437	A-2	4,800
9/6/74	777-437	A-3	9,400
9/6/74	777-463	A-5	1,200
9/6/74	777-463	Conveyor Line	7,900
9/6/74	777-463	A-7	7,700
9/9/74	776-205	205 Plenum (hot side)	211,000
9/9/74	776-206	206 Plenum (hot side)	1,230,000
9/10/74	776 - Size Reduction	Floor	< 500
9/10/74	776-201	Floor	1,100
9/11/74	777-452	Floor at J-24	460
9/11/74	777-452	Floor at K-24	470
9/11/74	777-452	Floor at L-24	640
9/11/74	777-452	Floor at M-24	780
9/11/74	777-452	Floor at K-25	560

Table A-4: Tritium Smear Surveys - Work Areas in Buildings 776-777 (pages 18-19)			
Date	Bldg/Room	Location	Maximum Smear (pCi)
9/11/74	777-452	Floor at J-25	950
9/11/74	776-250	Plenum Floor	< 100
9/11/74	776-250	Plenum Fan	< 100
9/11/74	776-252	Plenum Floor	465
9/11/74	776-252	Plenum Filter	1,636
9/11/74	776-S-8	Plenum Filter	< 100
9/11/74	776-S-8	Plenum Deep Beds	< 100
9/11/74	776-S-7	Plenum Filter	< 100
9/11/74	776-S-7	Plenum Floor	< 100
9/11/74	776-S-4	Plenum Filter	< 100
9/11/74	776-251	Plenum Floor	3,625
9/11/74	776-251	Plenum Filter	3,603
9/11/74	776-440	Floor	1,000
9/11/74	776-432	Floor K-20	500
9/11/74	776-432	Floor H-19	1,460
9/11/74	776-432	Floor H-20	710
9/11/74	776-432	Floor K-19	520
9/11/74	776-201	#1 System Kathene	160,000
9/11/74	776-201	#4 System Kathene	400,000
9/11/74	776-201	#3/7 System Kathene	450,000
9/11/74	776-201	#8 System Kathene	140,000
9/11/74	776-201	GBDA System Kathene	400,000

Source: SRDB 8790, pdf pp. 74-82

The exhaust plenums and the Kathabar air driers (which use a lithium chloride solution called Kathene) appear to have collected the greatest amount of tritium after the release. Workers responsible for changing filters in the plenums or recharging the Kathabar systems would appear to be at greatest risk for tritium uptake after the initial release.

Assessment of the 1974 Incident

The 1.5-Ci tritium release from a contaminated shipping container occurred on August 30, 1974. The RFAO report provides air survey, bioassay, and smear survey results (SRDB 8790). Specific urine sample collection dates were not included in the report but data were matched to

two NOCTS claims, which reported a collection date of September 5, 1974. A dose assessment was performed using the Integrated Modules for Bioassay Analysis (IMBA) software. An intake date of August 30, 1974 was assumed, and the largest reported result collected after the incident, 36,320 pCi/L, was used. There was a slight discrepancy (one digit) between the result included in the RFAO report and that in the NOCTS case file; the NOCTS value is assumed to be correct because it is the handwritten urinalysis record and is also the larger of the two values. The resulting dose is < 1 mrem (0.15 mrem). The Excel file *RFP H-3 dose calculations – data.xlsx* contains the information above as well as the data used for the analysis.

Conclusion

The RFAO report (SRDB 8790) of a 1.5-Ci tritium release on August 30, 1974 from a contaminated shipping container (“pressure cooker”) provides air survey, bioassay, and smear survey results that can be used to model similar releases. Such a model can be scaled to account for the source term and applied to incidents prior to the 1973 environmental tritium release when such tritium monitoring data are not available for Rocky Flats. The baseline information from these data can also be used to model the pre-1973 background tritium environment at Rocky Flats because the 1974 release described in the RFAO report occurred close enough in time to the seminal 1973 tritium event that many or most of the procedures and workplace practices had only begun to transition to account for the new sensitivity to tritium and its potential impact on Rocky Flats operations.

The number and nature of reported tritium release events, both before and after 1973, provide the basis for assumptions of pre-1973 workplace release frequencies, quantities and chemical forms. The parameters of this model can then be used to estimate pre-1973 bounding doses to Rocky Flats workers from estimates of the tritium background environment and tritium release incidents, particularly those involving contaminated shipping containers.

Part III presents an example tritium dose reconstruction that provides dose estimates for the pre-1973, 1973, and post-1973 time periods as well as doses and probabilities of causation for four types of cancer. The results are summarized below.

- **Pre-1973:** Using the largest reported result collected after the August 30, 1974 incident, the resulting dose is < 1 mrem (0.15 mrem). Assuming one incident per day at 0.15 mrem for 250 days results in a dose of 37.5 mrem/year for the pre-1973 time period.
- **1973:** Using the bioassay samples collected after tritium incident associated with contaminated scrap in mid- to late-April 1973 resulted in a maximizing dose of 84 mrem and is applied as a bounding estimate of all unmonitored workers. This dose is more precise than the estimate in the evaluation report, but is still maximizing.
- **Post-1973:** A co-worker study using data from NOCTS for 1974 and 1975 resulted in an annual dose of less than 1 mrem; therefore, no dose will be assigned for unmonitored tritium after 1973.

PART II: Rocky Flats Tritium Dose Assignment for 1973 and Later

E. M. Brackett, ORAUT

Dose Assignment for 1973

The report, *Investigation of the Tritium Release Occurrence at the Rocky Flats Plant* (SRDB 24165, pdf p. 16), describes a 1973 incident that prompted the site to sample a number of workers for tritium exposure. A shipment of scrap plutonium from LLNL was discovered to have been contaminated with tritium. This material was processed at the Rocky Flats Plant from April 9 to 25, 1973 in Building 779A. Because it was not immediately identified as being contaminated, monitoring of potentially-exposed individuals did not begin until late September 1973.

Two hundred fifty people were sampled following the discovery; this included all employees who worked in areas in which the contaminated scrap was processed or who were involved in the processing of wastes from this scrap. Due to the large sample load, raw urine samples were first analyzed in many of the cases. It was noted that the counting efficiency was only about 3% for these analyses, and that the corrections made for spectral shift could lead to abnormally-high readings. Nineteen employees were initially identified as having elevated tritium levels in their urine. These samples were distilled and re-analyzed. Upon this recheck, fourteen of these employees were found to be below the 10,000 pCi/L action level established by the site. The five most-exposed individuals were identified and details of their potential exposures, including bioassay results, are included in the investigation report. One of these five individuals is in NOCTS. ORAUT reviewed the results of the five workers who exceeded the 10,000 pCi/L action level; this review is presented in Attachment A.

The best estimates for the five cases reviewed in Attachment A are summarized in **Table A-5 on the next page**. Tritium contamination was associated with plutonium scrap material; therefore, H-3 doses will be assigned to all individuals who were monitored for plutonium in 1973. Because monitoring began several months after the potential start of exposure, the largest assessed dose (84 mrem) will be assigned.

(continued)

Table A-5: Summary of Intake Assessments for the RFP 1973 Incident			
Case	Intake Date	Intake (μCi)	Dose (mrem)
A	9/19/73	38.7	2.6
B	7/1 thru 9/25/73	28.1	1.9
C	8/27/73	21.3	1.4
D	4/10 thru 4/25/73	1070	72
H	4/6/73	1240	84

Dose Assignment for 1974-1975

ORAUT performed a co-worker study using data from NOCTS for 1974 and 1975. There are 38 individuals with tritium data in 1974 and 37 in 1975. ORAUT-OTIB-0075, *Use of Claimant Datasets for Coworker Modeling*, provides justification and guidance.

When assessing tritium intakes for most sites, it is assumed that intake potential exists only while tritium bioassay monitoring is being performed because monitoring is cheap, easy, and requires only spot samples, thus presenting less of a burden than other forms of bioassay on both the employer and the employee. Because tritium was not of primary concern at RFP and was present only as a potential contaminant on equipment, a given individual was not placed on a routine sampling program. Instead, a program was established whereby one-tenth of the urine samples collected for plutonium analysis were also analyzed for tritium content (SRDB 111267, letter from RFP General Manager to RFAO AEC Manager) as well as the collection of samples when there was a particular concern. Samples available in NOCTS for these two years indicate that analyses were performed throughout the year, with most individuals sampled only once.

For the purpose of the co-worker study, it was assumed that each worker had the potential to be exposed at a constant level throughout the year in which the urine sample was collected. The 95th percentile was used because one-tenth of the population was sampled. The co-worker study for 1974 -1975 yielded doses of 0 mrem for everyone. The file *Tritium for 1974-1975 coworker.xlsx* contains the assumptions employed in the study.

Dose Assignment after 1975

For later years, there are 11 or fewer individuals in NOCTS with tritium data; this is insufficient for performing a co-worker study. Results for these years are consistent with those from the previous years and show a general decreasing trend. The intake rate from the 1974-1975 co-worker study (i.e., 0 mrem - see above) will apply to these years; therefore, no additional dose due to tritium, as it relates to the assessment performed in this analysis, will be assigned after 1973.

Example Dose Reconstruction

Part III on page 33 presents an example tritium dose reconstruction that provides dose estimates for the pre-1973, 1973, and post-1973 time periods as well as doses and probabilities of causation for four types of cancer.

Attachment A - Rocky Flats 1973 H-3 Dose Assignment

E. M. Brackett, ORAUT

As discussed in Part II of this white paper, ORAUT reviewed the results of the five workers who exceeded the 10,000 pCi/L action level for tritium following a 1973 incident. This attachment provides the results of ORAUT's review and proposes a method for the assignment of H-3 doses in 1973.

Background

Investigation of the Tritium Release Occurrence at the Rocky Flats Plant (SRDB 24165, pdf p. 16) describes an incident in 1973 that prompted the site to sample a number of workers for potential H-3 exposure. The initial location of the contaminated scrap was identified as Building 779A, Room 154, in mid- to late-April. The waste stream from the processing of this material was also contaminated, providing opportunities for intake of H-3 at later dates. The collection of samples from a tritium-contaminated water bubbler on September 19 and September 25, 1973 were also identified as possible opportunities for intakes.

The contamination problem was not immediately identified; therefore, urinalysis began several months after the potential start of intakes. Samples were collected from about 250 employees. All employees who worked in areas in which the contaminated scrap was processed, or who were involved in the processing of wastes from this scrap were included in the urinalysis program.

Exhibit 14 of the referenced report contains a section on Personnel Exposure Data. The following is an excerpt (SRDB 24165, pdf p. 122):

SAMPLING PROTOCOL

Dow began by sampling urines from all employees who were thought to have had the best chance of being exposed to tritium. As of October 15, 1973, about 250 employees have been tested. Dow is continuing to trace leads to other possible exposure and will sample them as

they are found. Dow intends to sample many employees who have had only a remote chance of coming in contact with tritium. Dow also tests the urine of any employee who requests this whether or not they are candidates for exposure.

ACTION LEVELS

An "action level" of 10,000 pCi/l was tentatively chosen for resampling. This level was chosen for several reasons such as:

- 1. An article by Fitzsimmons indicated that people wearing tritiated watches could excrete levels of 10,000 pCi/l.*
- 2. A calculation of worst possible circumstances indicate that an employee would have to exceed levels of 23,000 pCi/l before any permissible yearly levels of whole body radiation would be exceeded.*
- 3. The sample load was such that Dow could handle resampling only a limited number of employees on a frequent basis. It turned out that a relatively small number were over 10,000 pCi/l but a large fraction were in the 5,000 and 10,000 pCi/l range.*
- 4. Without predistilling the urine samples the counting efficiency drops to about 3% and the corrections made for spectral shift can lead to abnormally high reading.*
- 5. With a large sample load, counting time devoted to each sample must be restricted so that 10,000 pCi/l might be considered lowest detection limit available under the present circumstances.*

All samples above 10,000 pCi/l are redone by counting the distillate of the original sample.

Five workers with H-3 urinalysis results exceeding the action level of 10,000 pCi/L were identified. Results from these five workers are reviewed here. Fourteen other workers initially exceeded the 10,000 pCi/L level but fell below this upon recount (as noted above, the distillates of the original samples were counted).

Dose Assessment

Information about the five workers with the largest H-3 sample results (including H-3 urinalysis results and brief work histories) is included in the referenced SRDB document. This information was used to assess the doses to the affected workers and is displayed in italics in the sections below.

All five cases had initial samples that were not distilled, with one to five later distilled samples. In general, the two sets of results were not consistent, with the distilled samples yielding lower values. This is to be expected given the site discussion above (see Item 4). The pre-distilled results were used in the development of this white paper because there were more results available and they yielded claimant-favorable doses.

The following assumptions were employed in this assessment:

- Equal weight to all samples (measurement error the same for all samples)
- Only pre-distilled samples used for fits (these are shown as blue dots in the figures; distilled samples appear in red and are not used in the analysis)
- H-3 in the form of tritiated water (HTO)
- IMBA model for inorganic H-3, as described in *Guidance on Use of IMBA Software for DOE Safety Applications* (DOE, 2006)
- Injection intake (for modeling with IMBA)
- Intake dates based on worker information and examination of fit to urine sample results

The five workers identified as having the largest H-3 urinalysis results are assessed below. Text in italics indicates an excerpt from the incident report.

Case A

Case A worked in Room [redacted for privacy] from [redacted for privacy], until [redacted for privacy].

He was involved in the [redacted for privacy] of the parts in question from [redacted for privacy], along with Cases [redacted for privacy]. He was not involved in any of the following special projects:

- A. May 8, 1973, Window Change*
- B. June 16, 1973, TV Camera Installation*
- C. August 21, 1973, Rotary Blower Installation*

He was involved in taking samples from a [redacted for privacy] on [redacted for privacy] 1973. On [redacted for privacy], this was done without a rubber glove.

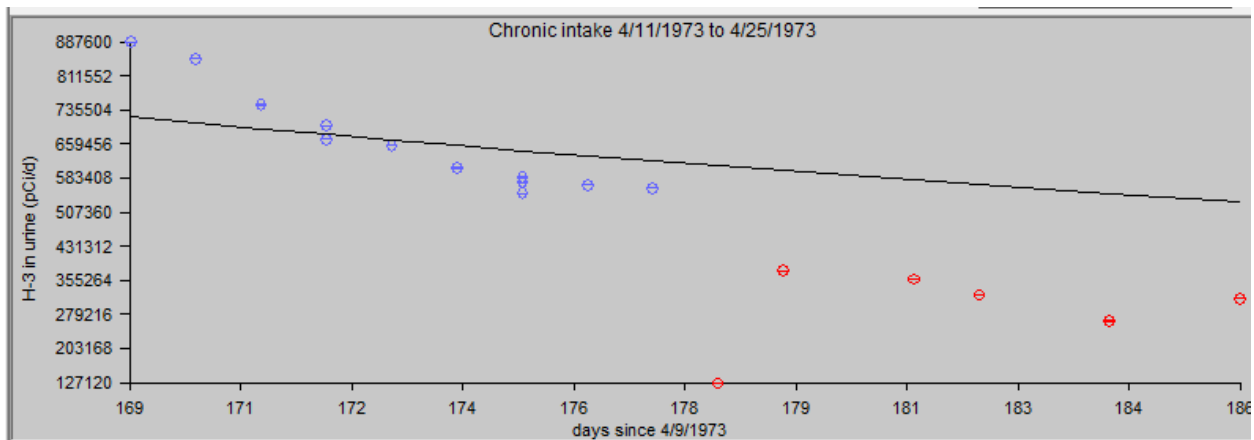
From this history, it would appear the most likely exposure occurred on [redacted for privacy]. If an exposure had occurred between [redacted for privacy], 1973, it is likely that both Cases [redacted for privacy] would have been exposed to the same source, and subsequently, excreted the same quantities of tritium.

The incident report also reads:

In Case A, a history of his work assignment and his urine results for the first two weeks indicate that he sustained a recent exposure. At the present time he is excreting tritium with an elimination half life of less than 10 days. According to Sanders and Snyder, this is the pattern of elimination from an exposure up to 90-days post exposure.

The statement that his intake appears to be recent agrees with current models for HTO intakes. If an intake is assumed from [redacted for privacy], a very poor fit to the data is obtained, as shown below in **Figure A-1**.

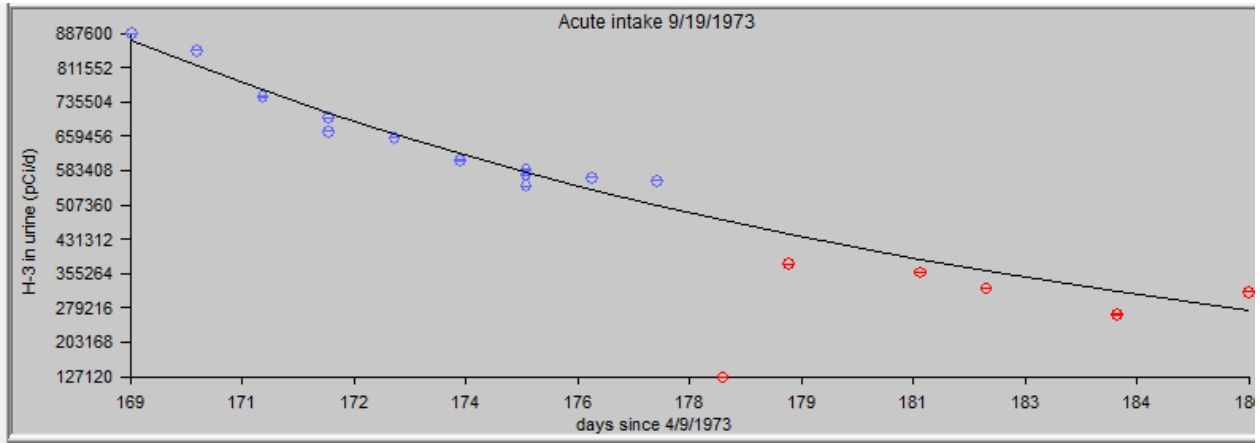
Figure A-1: Case A Chronic Intake of HTO from [redacted for privacy], 1973



Based on the worker's history and the bioassay result pattern, an acute intake was assumed to have occurred on [redacted for privacy], 1973. Using the results of samples collected from [redacted for privacy], and applying a uniform error to each of the samples, the intake is 38.7 μCi . The corresponding dose is 2.6 mrem. These samples are presumed to be pre-distilled because later samples from [redacted for privacy], are labeled as "distilled." This yields a very good fit to the pre-distilled results (see **Figure A-2 on the next page**).

(continued)

Figure A-2: Case A Acute Intake of HTO [redacted for privacy], 1973

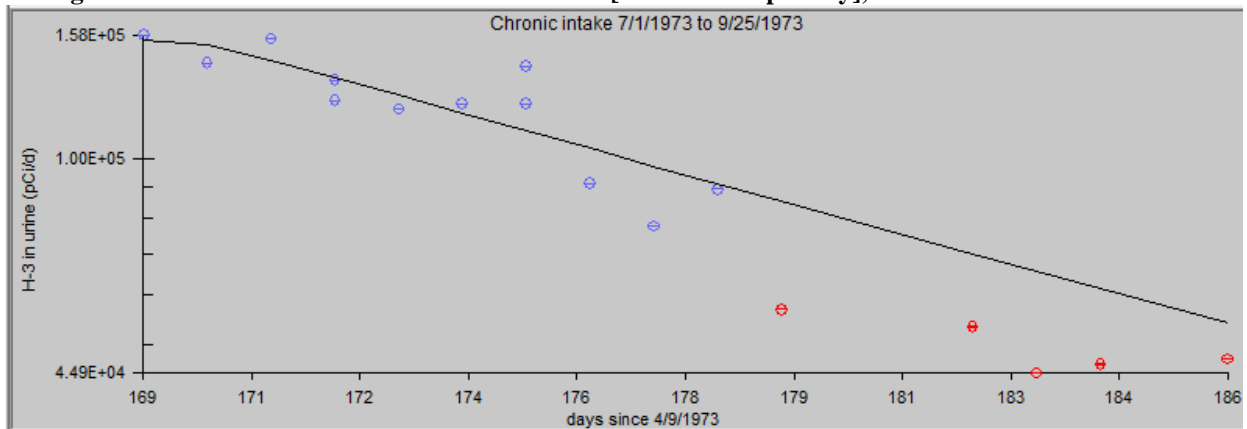


Case B

He has worked in [redacted for privacy], since [redacted for privacy]. He was in the room when [redacted for privacy], that contained tritium.

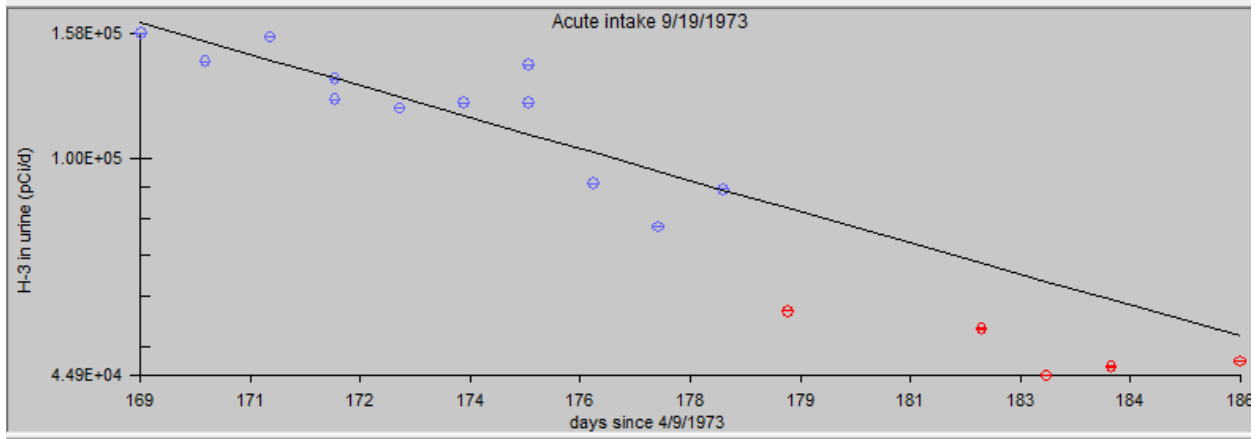
Assumption of a chronic intake from [redacted for privacy], (date of first urine sample) yields an intake rate of $0.33 \mu\text{Ci}/\text{d}$ (for a total intake of $28.1 \mu\text{Ci}$) and provides a reasonable fit to the results (see **Figure A-3 below**). The dose is 1.90 mrem.

Figure A-3: Case B Chronic Intake of HTO from [redacted for privacy], 1973



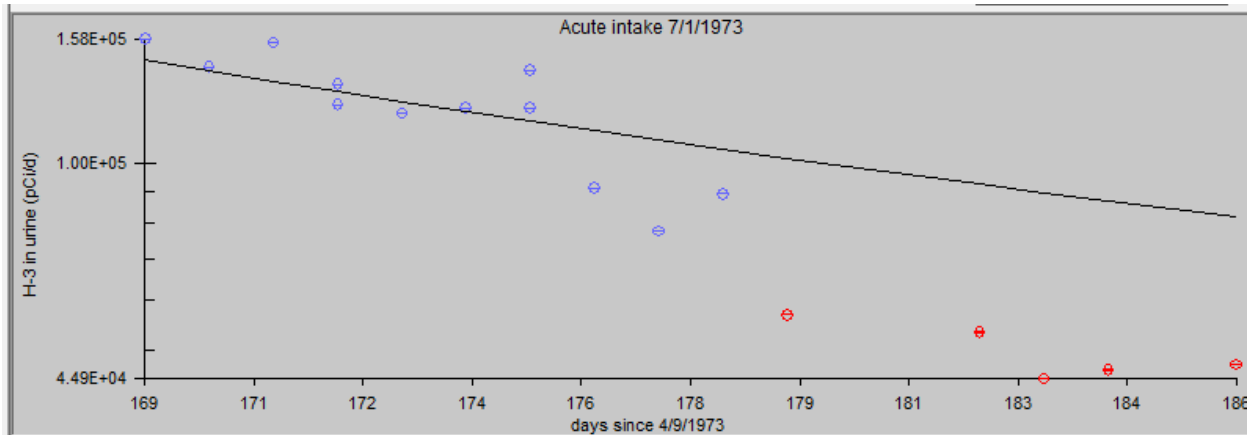
Assumption of an acute intake on [redacted for privacy], [redacted for privacy], yields an intake of $7.28 \mu\text{Ci}$. This fit (see **Figure A-4 below**) is almost identical to the first scenario.

Figure A-4: Case B Acute Intake of HTO on [redacted for privacy], 1973



A single acute intake on his [redacted for privacy] day in the area [redacted for privacy] yields an intake of 720 μCi and a dose of 49 mrem (see **Figure A-5 below**).

Figure A-5: Case B Acute Intake of HTO on [redacted for privacy], 1973



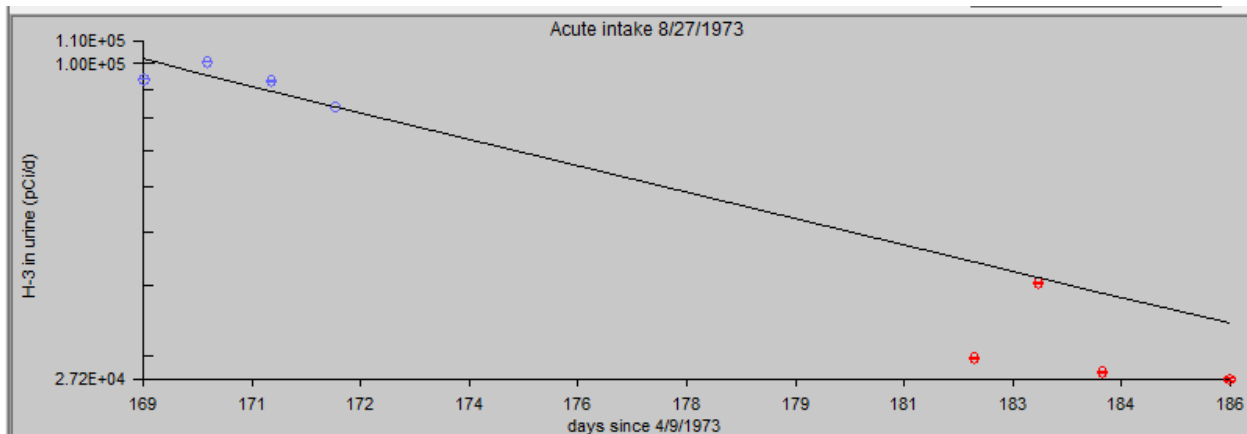
The single acute intake on [redacted for privacy] does not provide a good fit to the later pre-distilled results. The first two scenarios (chronic intake from [redacted for privacy], and acute intake on [redacted for privacy]) provide similar fits that reasonably follow the pattern of the pre-distilled samples. The chronic intake yields a larger intake so it is used for the best estimate.

Case C

He worked in [redacted for privacy] since [redacted for privacy]. He was not in the room when [redacted for privacy] containing tritium.

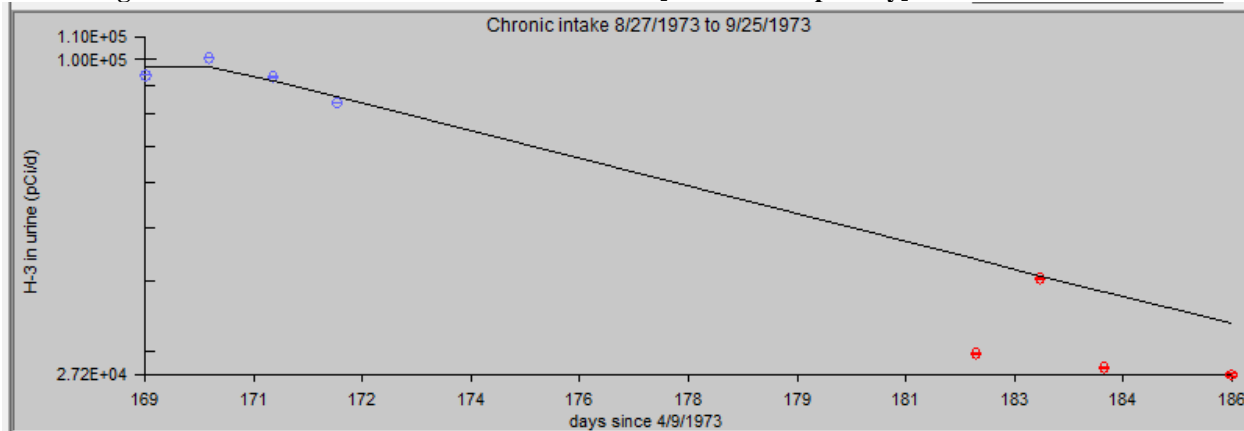
Given that the worker did not start in the area until [redacted for privacy], an acute intake was assumed on this date (see **Figure A-6 below**). Using only the pre-distilled sample results, his intake is 21.3 μCi with a dose of 1.4 mrem.

Figure A-6: Case C Acute Intake of HTO on [redacted for privacy] 1973



If a chronic intake is assumed to have started on his [redacted for privacy] day of potential exposure ([redacted for privacy]) and continued until the date of his [redacted for privacy] ([redacted for privacy]), the resulting intake is 0.24 $\mu\text{Ci}/\text{d}$ for a total intake of 7.08 μCi . This fit is shown in **Figure A-7 below**.

Figure A-7: Case C Chronic Intake of HTO from [redacted for privacy] 1973



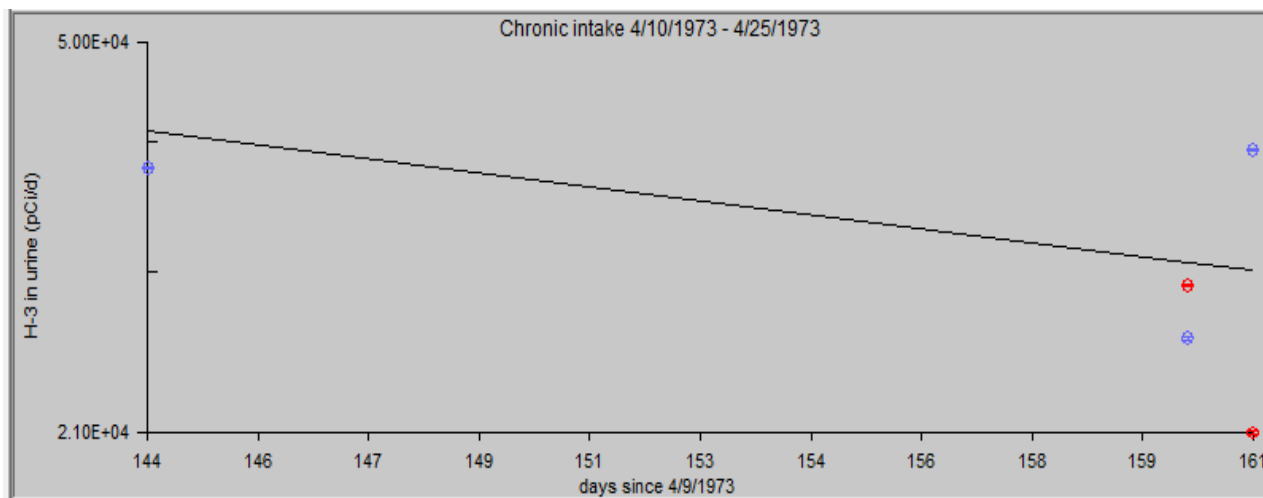
The two fits are very similar, so the acute intake is selected as the best fit as it results in a dose that is more favorable to the claimant.

Case D

He worked in [redacted for privacy], between [redacted for privacy], 1973. He has not been exposed to tritium since [redacted for privacy].

Case D submitted samples on only three days, although there are two results on two of those days. In one instance, one of the samples was distilled; on the other day, there is a note stating “repeated with sample channel ratio.” On the latter day, the results differ by a factor of almost two; the larger of these results is assumed to be the pre-distilled analysis and is used for the intake assessment. An assumed chronic intake from [redacted for privacy] (last date of incident) yields an intake of 71.2 $\mu\text{Ci}/\text{d}$ for a total intake of 1070 μCi (see **Figure A-8 below**). The resulting dose is 72 mrem.

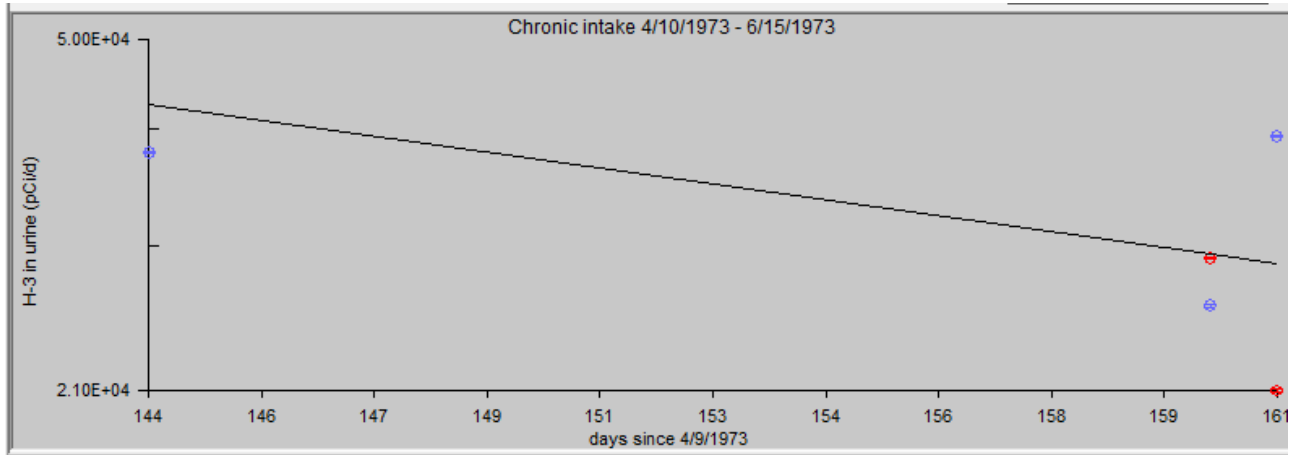
Figure A-8: Case D Chronic Intake of HTO from [redacted for privacy] 1973



A chronic intake from [redacted for privacy] yields an intake rate of 8.84 $\mu\text{Ci}/\text{d}$ for a total intake of 581 μCi (39 mrem), as shown in **Figure A-9 on the next page**.

(continued)

Figure A-9: Case D Chronic Intake of HTO from [redacted for privacy] 1973



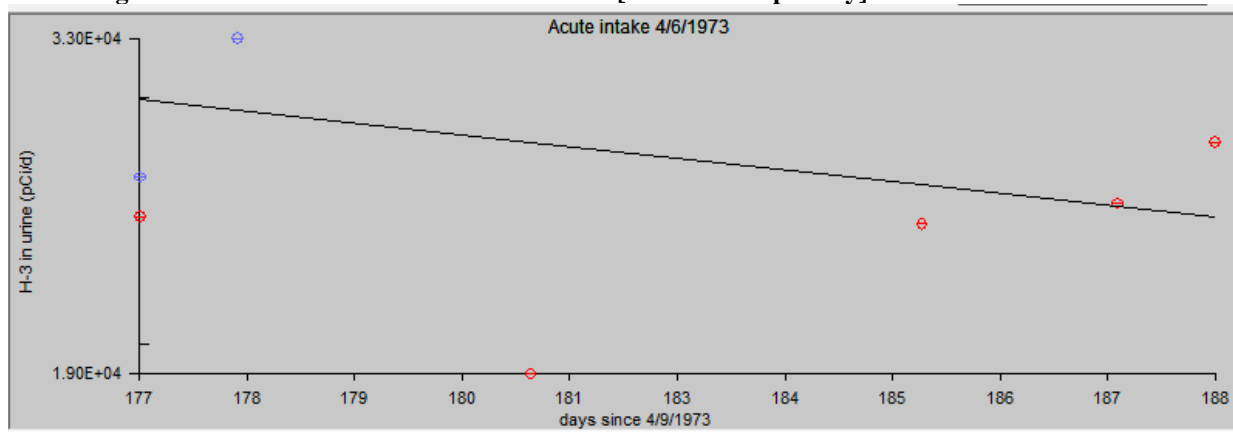
Because there are few samples and the results follow no specific pattern, there is little difference between the fits. Therefore, the acute intake is assigned because it yields the larger dose.

Case H

He came in contact with the possible source of tritium on [redacted for privacy] 1973.

No other information is included in the report. The conclusion in the report is: *(It is expected that, as a result of a review of his work history and urinalysis data, a dose assignment of less than 3 rem will be made.)* However, no follow-up information is available. Because the only available information indicates that an intake would have occurred on [redacted for privacy], an acute intake was modeled (see **Figure A-10 below**). The resulting intake is 1240 μCi with a dose of 84 mrem.

Figure A-10: Case H Acute Intake of HTO on [redacted for privacy] 1973



Recommendation

The best estimates for each case are summarized in **Table A-6** below. Tritium contamination was associated with plutonium scrap material; therefore, H-3 doses will be assigned to all individuals who were monitored for plutonium in 1973. Because monitoring began several months after the potential start of exposure, the largest assessed dose (84 mrem) will be assigned.

Case	Intake Date	Intake (μCi)	Dose (mrem)
A	9/19/73	38.7	2.6
B	7/1 thru 9/25/73	28.1	1.9
C	8/27/73	21.3	1.4
D	4/10 thru 4/25/73	1070	72
H	4/6/73	1240	84

Reference

DOE, 2006, *Guidance on Use of IMBA Software for DOE Safety Applications*, DOE-HS-0002, U.S. DOE, Washington D.C.; December 2006 (SRDB 33212)

PART III: Example RFP Tritium Dose Reconstruction

Mutty Sharfi, ORAUT

Employee Information

Cancer Description: Lung (ICD-9: 162); diagnosed 12/31/2000
Prostate (ICD-9: 185); diagnosed 12/31/2000
BCC (ICD-9: 173); diagnosed 12/31/2000
SCC (ICD-9: 173); diagnosed 12/31/2000

Year of birth: 1932
Gender: Male
Smoking: Never Smoked
Ethnicity: "White, non-Hispanic"

Employment Information

Start date: 01/01/1959
End date: 12/31/1975
Occupation: Unknown
Dosimetry Data: None

Organ Dose Assessed

Table A-7: Organ Dose Assessed		
Cancer	External Organ Used	Internal Organ Used
Lung	Lung	Lung
Prostate	Urinary Bladder	Heart Wall ¹
Skin	Skin	Skin

Source: ORAUT-OTIB-0005

¹ Non-metabolic organ with the highest dose

External Dose

Not applicable for tritium exposures.

Internal Dose

- Pre-1973: The 1.5-Ci tritium release from a contaminated shipping container occurred on August 30, 1974. The largest reported bioassay result (SRDB 8790) collected after the

incident was used to assess the potential exposure from this release. The resulting dose is was about 0.15 mrem. Assuming this event occurred every workday of the year (250 times a year), the resulting annual dose would be about 38 mrem/year.

- 1973: A tritium incident associated with contaminated scrap occurred in Building 779A, Room 154, in mid- to late-April 1973. Because of this incident, the site sampled a number of workers for potential H-3 exposure (SRDB 24165). An analysis of these bioassay samples resulted in a maximizing dose of 84 mrem and is applied as a bounding estimate of all unmonitored workers. The assessment of the bioassay data for the 1973 incident includes all potential exposures for the year. The assumption of an acute intake bounds any potential underlying chronic exposure.
- Post-1973: ORAUT performed a co-worker study using data from NOCTS for 1974 and 1975 in accordance with ORAUT-OTIB-0075, *Use of Claimant Datasets for Coworker Modeling*. The 95th percentile annual dose was less than 1 mrem. Therefore, no dose will be assigned for unmonitored tritium after 1973.

Uncertainty

All doses are applied as a constant distribution.

Summary

The assessment methods presented in this report define the methods by which a dose estimate can be determined for the evaluated worker class. These methods support NIOSH’s conclusion that the operationally-related internal dose for the evaluated worker class can be bounded. A summary of the doses and probability of causations are provided in **Table A-8** below.

Table A-8: Example RFP Tritium DR - Summary of Doses and Probabilities of Causation				
Cancer	External (rem)	Internal (rem)	Total (rem)	Probability of Causation
Lung	0.000	0.616	0.616	3.99%
Prostate	0.000	0.616	0.616	1.45%
Skin BCC	0.000	0.616	0.616	3.38%
Skin SCC	0.000	0.616	0.616	0.47%

Appendix 2: Response to Work Group/SC&A Comments on the Rocky Flats Plant Tritium White Paper

TIMELINE

7/2013 – Board Working Group Meeting – developed issues that were responded to in the response to comments document.

9/2013 – Board Working Group Meeting – the tritium white paper was reviewed and the three periods assessed in the white paper were discussed:

- 1973 – Liz B. to send the WG and SC&A her IMBA files so that they may perform a comparative review of the proposed pre-1973 method.
- Post-1973 (1974-1975) – WG/SC&A not in agreement at the meeting about the dose being less than 1 mrem.
- Pre-1973 – discussions about the applicability of the 1974 incident data for the pre-1973 period.

10/2013 – AB Meeting – although a SEC class is recommended that covers the time period in question related to the tritium exposure, additional confirmation/agreement to occur in regard to the partial DR method for tritium in the SEC period.

- Dr. Ziemer requested information on why the post-1973 coworker model came up with 0 dose when there was dose associated with the 1974 incident – ensure that the bioassay samples from the 1974 incident in a co-worker model.

1/2014 – The SC&A report titled: *SC&A Review of Part II, Rocky Flats Tritium Dose Assignment for 1973, Attachment A*, was provided as an additional review response to the NIOSH Tritium white paper based on Working Group tasking. Included in the email response associated with this SC&A review was an indication that this tritium dose assignment review only focused on the 1973 period, and that SC&A was awaiting a response for the pre and post-1973 methodologies presented in the NIOSH white paper.

COMMENT RESPONSES

1. If bubbler data exists and can be compared, compare pre-1973 data to 1974 data.

RESPONSE: Only environmental and stack effluent tritium results have been captured for Rocky Flats prior to 1973; no tritium bubbler data for RFP work areas have been found for the pre-1974 period. However, additional SRDB searches identified workplace tritium results obtained in September-October 1973 using cold traps – part of the effort by Rocky Flats to identify the source of the 1973 environmental tritium release. These data may be useful for comparison with the 1974 bubbler data, but they still represent results from work areas potentially affected by the April 1973 release. (See information in Item 2 below.)

2. Look at baseline survey data from 1973 (SRDB 68351) to see if comparisons can be made. NOTE: Recognize that bubbler data may be suspect based on a classified interview noting that the bubbler was only present during opening of the secondary container and not present when opening the primary container.

RESPONSE: In response to the working group discussion of the documents referenced in the white paper:

- SRDB 111095 is a collection of hand-written records of survey and air sample logs, including bubbler sample results (1121 pages). The document contains information for the years from 1977-1982.
- SRDB 122712 is a collection of 1997 bubbler results analyzed and reported by Thermo NUtech (33 pages). There is no information in this source about other years at RFP.
- SRDB 122550 is the official transcript of the NIOSH-ORAUT interview of a former RFP employee. The former employee indicates that RFP started using tritium bubblers when opening outer containers (not when opening inner containers containing the pits). This occurred in 1965 in the B771 downdraft room; however, no bubbler results for the period prior to 1973 have been found. The interviewee also indicated that the bubblers were positioned in front of the intake plenums of the exhaust systems to serve as alarming devices, and not to record routine airborne concentrations in the area.

Based on additional research into the tritium release evaluation at RFP, ORAUT confirmed that smears, radioactive gas monitors, and cold traps were used in tracing the source of the April 1973 release; however, the only workplace air monitoring results reported were from cold trap samples.

Radioactive gas monitor results were all from glove box atmospheres. SRDB 111284, pdf p. 75, states (bold added for emphasis):

“A general survey using smear technique and subsequent radiochemical analysis at Building 123 was initiated in all buildings or specific areas of those buildings where the possibility of tritium was suspected. Smears were also taken inside glovebox lines in several areas. Most of the analysis for the latter group of smears has not been completed. In addition, air was monitored using Johnson Model 1055 or 955 radioactive gas monitors and/or cold trap samplers in Buildings 774 and 779-A. A bubbler sampler was installed to sample the Building 779-A exhaust air effluent and analysis for tritium was performed on water traps normally used as part of the stack sampler system for the Building 774 evaporator stack.”

Table 1 summarizes the cold trap sample data presented on pdf p. 79 in SRDB 111284.

Table 1: RFP Cold Trap Samples – Air				
Building	Room	Date	H-3 (pCi/m ³)	Remarks
774	203	9-28-73	20.7	none
	220	9-28-73	9.2	none
	210	10-1-73	14	none
	320	10-1-73	15	none
779-A	154, NE	9-26-73	1,580	none
	154, NE	9-28-73	10,000	none
	154, NE	10-1-73	1,068	none
	154, NE	10-2-73	451	none
	154, NE	10-4-73	302	none
	154, SW	9-26-73	1,491	none
	154, SW	10-1-73	400,750	none
	154, SW	10-2-73	113	none
	154, SW	10-4-73	5,540	none
	001	10-4-73	3,700	Sampling from above liquid level in building process holding tanks
142	10-4-73	12,146	Boiler ventilation room. Filtered air passes through room and is recycled back to dryers and laboratories	

(continued)

NOTE: The average and standard deviation of the above results are:

- Building 774: (14.7 ± 4.7) pCi/m³
- Building 779-A, Rm 154 NE and SW: The documentation offers no explanation for the high result of 400,750 pCi/m³ on October 1, 1973.
 - Calculation including the high value: $(46,810 \pm 132,766)$ pCi/m³
 - Calculation excluding the high value: (2568 ± 3466) pCi/m³

Readings taken in Building 777, Rm 452 in the 3½ months prior to the 1974 tritium contamination incident had average and standard deviation of (5343 ± 4518) pCi/m³.

Building 779-A, Rm 154 housed the glove box hydriding reaction chamber where tritium-contaminated Pu from LLL was processed in April 1973, resulting in the highly-publicized environmental tritium release to public drinking water supply reservoirs. The resulting plutonium hydride was oxidized in other glove boxes in 779-A, Rm 154 before transfer to Bldg 771 for reduction to Pu metal. Bldg 771 process wastes were then transferred to Bldg 774 for further processing, or were sent either to the solar evaporation ponds or the sanitary sewer.

Glove boxes in Building 779-A, Rm 154 and in Buildings 771 and 774 were all found to be contaminated with tritium after the 1973 environmental release. It is interesting to note that, even though Bldg 774 glove boxes were tritium-contaminated, the Building 774 work area cold trap samples showed extremely low tritium results. It appears that the glove boxes provided good containment.

ORAUT also reviewed the available NOCTS claims that had tritium bioassay data to determine the existence of a pre-1973 bioassay sampling program and to assess the sufficiency of the monitoring program for identifying potential tritium exposures and/or incidents. Five pre-1973 tritium bioassay samples for five different individuals were identified out 312 total sample results for 125 individuals (data ranging from 1966-1996). The five pre-1973 tritium sample results are:

- Three urine samples, 1966: all background
- One urine sample, January 1973: 5542 ± 846 (units not specified - assumption: pCi/L)
- 1 urine sample, April 1973: background

There do not appear to be any specific tritium incidents related to the collection of any of the pre-1973 bioassay samples. However, the fact that the samples do exist indicates that there was a capability for tritium urinalysis and a will to use it going back to 1966. The result from January 1973 is about 17% of the highest urine specimen from the 1974 incident, which supports the use of the 1974 data to bound the pre-1973 tritium doses.

To date, no information has been identified to dispute the use of the 1974 data in the development of a pre-1973 bounding approach for tritium at RFP. NIOSH-ORAUT will continue to assess the data to confirm that this continues to be the case and will address issues with the bounding approach if and when they arise.

3. If the ChemRisk report is used for supporting dose reconstruction, look and see if the report was validated in any way.

RESPONSE: The ChemRisk report was referenced and used in the development of the RFP Environmental TBD; however, no additional validation of the report data has been performed by ORAUT. While this TBD may be used to support dose reconstructions, the associated exposure scenarios associated with the ChemRisk data are not considered to be representative of the most highly-exposed individuals (i.e., the data are more representative of radiological conditions outside of the work areas and plants). The available personnel monitoring/bioassay data contained in an individual's personnel monitoring records are considered the most representative and bounding from a personnel exposure perspective.

4. Determine whether Pantex changed their shipping controls/survey criteria/shipping survey and contamination limits (did they change?) after the 1973 tritium release at Rocky Flats. If so, when did any changes occur?

RESPONSE: Based on the available documentation, it appears that the earliest changes made by Pantex that were related to tritium-contaminated shipments were made in the early 1980s. Below is a summary of the documentation review:

Pantex:

- Based on the available documentation, it is not apparent that changes in the Pantex program in response to the 1973 or 1974 incidents (i.e., shipping controls/survey criteria/shipping survey and contamination limits) occurred until 1981 (SRDB 107801). Other Pantex documentation in the SRDB corroborates this conclusion (i.e., no available information is dated earlier than 1981) (SRDB 109244; 109245; 109246; 109255).

RFP:

- The 1974 incident occurred on September 3-4, 1974. Five RFP documents in the SRDB relate to the post-1974 incident follow-up:
 - SRDB 111267 (September 12, 1974)
 - SRDB 111288 (September 12-16, 1974)
 - SRDB 111301 (October 21, 1974)
 - SRDB 8789 (November 12, 1975)
 - SRDB 111106 (December 1974)

- All these documents are related to the RFP's post-incident responses, including: (1) implementation of RFP action levels; (2) RFP performance of tritium surveys of suspect shipments; and (3) RFP requests that sites shipping related packages to RFP perform their own surveys.

- A June 6, 1974 memorandum from Rocky Flats to the AEC indicates adoption of an upper limit of 10 mCi tritium per kilogram of plutonium shipped into Rocky Flats (SRDB 111268). Certification of an incoming material's history was required of shippers in response to AEC recommendations issued after the 1973 tritium release led to the realization that trace amounts of tritium could be found in almost all materials, thus pointing to the need for an acceptance limit. Incoming shipments that could result in excessive tritium levels at RFP continued to be monitored for verification.

- ORAUT coordinated a request for information from RFP related to communication with Pantex regarding the implementation of control limits for shipments. RFP responded that no information was available (August 8, 2013 email from Rod Hoffman); since the time limit for retention of those records has expired, RFP believes that the documents may have been destroyed per the document retention/destruction schedule.

ADDITIONAL COMMENT RESPONSE – DR. ZIEMER QUESTION

1. The question of why the coworker model came up with 0 dose when there was dose associated with the 1974 incident – was the bioassay samples from the 1974 incident included in the post-1973 RFP tritium co-worker model presented in the RFP tritium white paper.

RESPONSE: The coworker model was based on the analysis of the NOCTS claimant data. The assessed dose from the coworker was less than 1 mrem per year, which, in

terms of dose assignments for an individual DR under the EEOICPA program, results in a zero dose assignment for the purpose of calculating POC. All the NOCTS claimant data available for 1974 were used in the coworker study. While all the results from the 1974 site incident report were not added in because details regarding the individuals were incomplete, the data/results that can be matched with NOCTS claimants (for two individuals) were used – data from the claimant’s NOCTS files; no data were added from the incident report. The results matched with NOCTS claimants included those for one individual identified as having the largest intake from the incident. It is noteworthy that the largest dose from the 1974 incident was only 0.15 mrem so inclusion of all of the results still wouldn’t yield a dose greater than 1 mrem.

ADDITIONAL COMMENT RESPONSE – SC&A REVIEW OF TRITIUM WHITE PAPER

1. SC&A reviewed the NIOSH tritium White Paper and provided comments and feedback on the tritium dose reconstruction method presented for the 1973 period at RFP in their paper titled: *SC&A Review of Part II, Rocky Flats Tritium Dose Assignment for 1973, Attachment A*.

RESPONSE: The primary NIOSH response to the SC&A review is that the SC&A analysis uses a draft model that is clearly identified as not for use at this time, which is acknowledged in the SC&A response. The Rule governing this program explicitly requires the use of currently approved ICRP models for the purpose of assessments and use of such unapproved models is outside of the scope of the NIOSH methodology. As such, NIOSH has not performed a detailed analysis of the model as it relates to EEOICPA dose reconstruction or the results provided by SC&A in their assessment. The general observation is that it should have very little impact on situations outside of the RFP because it only affects cases where urine samples are collected more than 100 days after intake, which should be a rare occurrence for tritium. It is noted that the SC&A paper matched the NIOSH White Paper values when the bioassay was collected 50 or 60 days after the assumed intake. If the model is approved and issued by the ICRP, it will be reviewed for incorporation into the EEOICPA dose reconstruction program.

One of the focuses in the SC&A assessment of the NIOSH Tritium White Paper was the analysis of Case A (from the RFP evaluation of the five highest exposed individuals from the 1973 tritium release incident). It appears that the SC&A assessment results are approximately the same as the results presented in the NIOSH White Paper for Case A when the same intake assumptions are used. The similar results occur when assessing the exposures based on the ‘best fit’ of the data in the model – the best fit scenario is not disputed by SC&A; rather, the SC&A assessment offers other possible exposure situations that were not considered plausible based on NIOSH’s review. The earlier

intake date assumed by SC&A had been ruled out in the NIOSH analysis because Case A worked with Cases [redacted for privacy] in April and they did not exhibit similar excretion levels, and Case A's elimination pattern exhibited a less-than-10-day half time, which is indicative of a relatively recent intake. In its review, the SC&A assessment concurs with the NIOSH assessment of Case D. However, as it relates to Case A, SC&A does not address that workers [redacted for privacy] worked together in April 1973 on the same project. When considered, there is no support for the use of the SC&A assumptions for Case A that results in the significantly higher dose totals. Further explained, the likelihood of [fewer than 9] receiving an intake of 92 mCi when co-located workers received no intake, is not plausible. NIOSH concludes that the nature of the exposure scenario does not support large differences in personnel exposure; rather, it supports the use of the NIOSH best fit analysis.

The other details discussed by SC&A regarding the use of un-distilled versus distilled samples support the basis that the NIOSH assessment presents a claimant-favorable approach for tritium dose reconstruction in the SEC period. In addition to the above thoughts regarding the assessment of the tritium exposures for 1973, it is important to remember that the entire period being assessed for tritium falls in the currently recommended SEC period (through 1983). Therefore, NIOSH feels that the assessment for 1973, as well as the pre and post-1973 periods, represent NIOSH's best and final approaches for reconstructing tritium at RFP within the associated time periods.