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

White Paper
Rev. 2

National Institute for Occupational Safety and Health

July 1, 2015

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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 (this additional information was included in Rev. 1 to the initial tritium follow-up paper). NIOSH requested that ORAUT:

- analyze RFP occupational tritium exposures prior to 1973 (see Appendix 1).
- 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).
- 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).

In this most recent revision (additional information included in this Rev. 2 to the initial tritium follow-up paper), ORAUT was also asked to:

- revise the best approach for tritium dose assignments for 1973 and provide additional explanation on the reconstruction of organically-bound tritium (OBT) using urine bioassay in IMBA (see Appendix 1).

- comprehensively close out the issue of RFP tritium exposure after 1973 by evaluating the evidence of a robust workplace monitoring program (see Appendix 3).

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 for 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 are being evaluated for 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 below presents a summary of the Rocky Flats tritium bubbler information contained in the SRDB.

Table 1: Rocky Flats Tritium Bubbler Information in the SRDB
(This table spans three pages)

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 pCi/m^3, but results exceed 1,000 pCi/m^3 on several occasions in Bldg. 559 - Rm 102, and in Bldg. 881- Rm 283. Highest result appears to be 89,230 pCi/m^3 in Bldg. 771 for the period May 11-18, 1978 (PDF pp. 92, 93), although the measurement appears to be associated with a filter plenum or filter unit and not workplace air.*
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.

Table 1: Rocky Flats Tritium Bubbler Information in the SRDB
(This table spans three pages)

SRDB Ref ID	Year	File Description	Comments
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.
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

Table 1: Rocky Flats Tritium Bubbler Information in the SRDB (This table spans three pages)			
SRDB Ref ID	**Year**	**File Description**	**Comments**
122788	1978	Drawing – Tritium detector details (1)	Engineering drawing
122789	1978	Drawing – Tritium detector details (2)	Engineering drawing
122790	1978	Drawing – Tritium detector details (3)	Engineering drawing
122791	1978	Drawing - Tritium detector flow diagram	Engineering drawing

* The bubbler location associated with the elevated result of May 11-18, 1978 was entered in the sample analysis log as "771 Fu 2". Two incident reports found in the SRDB refer to the FU2B filter plenum or filter unit in Building 771 (SRDB 17817, PDF pp. 285-287, 344-347; SRDB 17819, PDF pp. 363-365).

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 below lists the follow-up actions performed in support of SEC-00192.

Table 3 further below lists the follow-up interviews performed in support of SEC-00192.

SECONDARY FOLLOW-UP: APPENDICES 1, 2 AND 3

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**.

NIOSH further asked ORAUT to comprehensively close out the issue of RFP tritium exposure after 1973 by evaluating the evidence of a robust workplace monitoring program. Such a program would support using the co-worker model discussed in Appendix 1, Part II. The evaluation of evidence for a workplace monitoring program is provided in **Appendix 3**.

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	*Reconstructing Rocky Flats Tritium Doses Pre- and Post-1973* (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)
05/13/2015	*Workplace Air Tritium Monitoring at Rocky Flats, 1977-1981* (see Appendix 3)	ORAUT (Cincinnati OH)

[a]DOE-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.

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 Tom LaBone, Nancy Chalmers, and 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, T_2), 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.

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.

[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, T_2) 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.

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 A1-1** below shows the reported values.

Table A1-1: Reported Tritium Air Concentrations (μCi/m^3) from the August 30, 1974 Release

Sampling Reference	Plenum 205, Bldg. 776/777[a]	Room 452, Bldg. 777
Normal Concentrations	$<1\times10^{-2}$	$<1\times10^{-2}$
August 29-30, 1974	0.148	37.7
September 3-4, 1974	2.51	1.1

Source: SRDB 8790, pdf pp. 93-96

[a]The 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 4.9×10^{-3} μCi/m^3 on August 29 and 37.7 μCi/m^3 on August 30. The applicable Radioactive Concentration Guideline at the time was 5 μCi/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 3.43×10^{2} 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 A1-2** below (SRDB: 8790, pdf pp. 87-89).

Table A1-2: Tritium Activity Concentrations in Room Air: Rm. 452 - Special Assembly-Bldg. 777

Analysis Date (1974)	[^{3}H] (pCi/m^3)		Analysis Date (1974)	[^{3}H] (pCi/m^3)		Analysis Date (1974)	[^{3}H] (pCi/m^3)
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/m^3. The result on August 30 is 37,676,609 pCi/m^3, and the sample taken on September 3 indicated a tritium concentration in the room air of 1,098,901 pCi/m^3. 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 health physics technician who performed the monitoring. The technician's 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 A1-3** below shows individual results (SRDB 8790, pdf p. 90).

Table A1-3: Tritium Urinalysis Results - Exposed Workers and Others, August 30, 1974

Worker ID	Area	Urinary Tritium (pCi/L)	Uncertainty (pCi/L)
A	777	32320	± 6170
B	777	25610	± 6100
C	779	24000	---
D	777	22370	± 5800
E	777	21600	± 5800
F	707	17000	---
G	777	15740	± 6100
H	777	15730	± 5640
I	779	14000	---
J	707	13700	± 5370
K	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 [redacted] employee who did not work in radioactive material-handling areas were sampled with results < 0.01 µCi/L (<10,000 pCi/L). The Denver resident is identified in **Table A1-3**, and Worker ID K is believed, by implication, to be the [redacted] 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 A1-4** below.

Table A1-4: Tritium Smear Surveys - Work Areas in Buildings 776-777
(This table spans two pages)

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
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

Table A1-4: Tritium Smear Surveys - Work Areas in Buildings 776-777 (This table spans two pages)			
Date	**Bldg/Room**	**Location**	**Maximum Smear (pCi)**
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.

<u>Assessment of the 1974 Incident</u>

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 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 (also referred to as H-3). A shipment of scrap plutonium from LLNL was discovered to have been contaminated with tritium. This material was processed in Building 779A from April 9-25, 1973. Because the scrap 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 re-check, 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 above-cited investigation report. One of these five individuals is in NOCTS.

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. Doses will be assessed on an individual basis using reported H-3 bioassay results and any additional information in the NOCTS file. For those who were not monitored for H-3, dose will be assigned based on claimant-favorable assumptions.

As previously discussed, the tritium release incident report (SRDB 24165) discusses the tritium sampling of two-hundred-fifty people as of 10/15/73. There are no results or specific sample dates given in the report for those individuals who did not exceed the H-3 bioassay action level of 10,000 pCi/L. Only five individuals were found to have results exceeding the action level so this current assessment assumes that they are the maximally-exposed workers in the incident and that those who were not monitored would not have been exposed at those same levels. Therefore, for the purpose of this current tritium assessment, 10,000 pCi/L is used as the maximum H-3 bioassay result for those who were not monitored.

Based on this information, the following assumptions were applied:

- H-3 was in the form of tritiated water (HTO)
- IMBA was used to model intakes for inorganic H-3, as described in *Guidance on Use of IMBA Software for DOE Safety Applications* (DOE, 2006)
- Mode of intake was injection (for modeling with IMBA)
- Intake date = 4/9/1973 (first day the material was processed)
- Sample collected on 10/15/1973
- Result = 10,000 pCi/L (14,000 pCi/day)

Using the IMBA model, which is in agreement with values obtained from Rad Toolbox, the total dose is 49 mrem. Attachment A contains details and justification for the model used in IMBA.

Dose Assignment for 1974-1975 and Post-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 for the study.

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 tritium 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 a particular concern was identified. 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 95^{th} percentile was used because one-tenth of the population was sampled. The co-worker study for 1974 -1975 yielded doses of much less than 1 mrem for everyone. The file, *Tritium for 1974-1975 coworker.xlsx,* contains the assumptions employed in the study.

For the post-1975 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 personnel exposure trend. The dose from the 1974-1975 co-worker study (i.e., 0 mrem - see above) will apply to these years.
The ORAUT analysis of the post-1973 tritium exposures yielded information that suggests very low personnel doses and very little tritium exposure potential. Therefore, no additional unmonitored dose due to tritium, as it relates to the assessment performed in this analysis, will be assigned after 1973 at RFP.

Attachment A - Tritiated Water Models

Thomas LaBone, Nancy Chalmers, and E. M. Brackett, ORAUT

Introduction

IMBA[2] offers the ability to evaluate intakes of organically-bound tritium (OBT) using urine bioassay. The biokinetic model used for OBT in IMBA, which is the ICRP 56 OBT biokinetic model [ICRP(1990)] with the addition of a urinary bladder, is shown in **Figure A1-1** below (the diagram is from the technical documentation provided with IMBA).

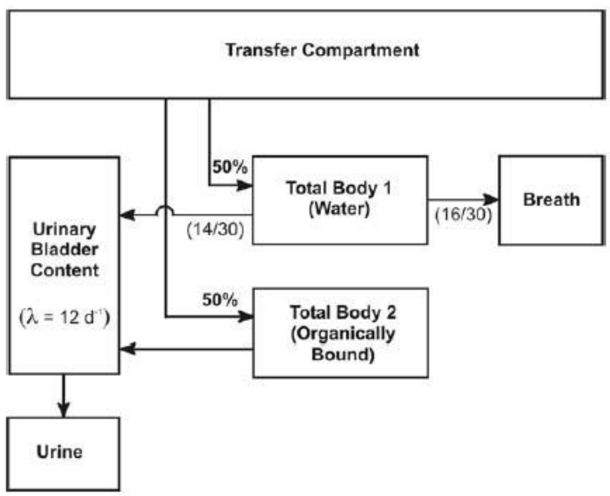

Figure A1-1: IMBA Biokinetic Model for OBT

IMBA does not natively offer the ability to evaluate intakes of tritiated water (referred to as inorganic tritium in IMBA) using urine bioassay. A workaround for this limitation is offered in DOE-HS-0002, *Guidance on Use of IMBA Software for DOE Safety Applications* (SRDB

[2] IMBA Professional Plus V4.1.18

33212). This workaround consists of changing the transfer rate constant going from the *Transfer Compartment* to *Total Body 1* from 0.5[ln(2)/0.25d] to 0.97[ln(2)/0.25d] and changing the transfer rate constant going from the *Transfer Compartment* to *Total Body 2* from 0.5[ln(2)/0.25d] to 0.03[ln(2)/0.25d], which effectively converts the OBT model to the tritiated water model. With this workaround, IMBA can provide the instantaneous urinary excretion rate $\dot{e}_u(t)$ and the 24-hour incremental urinary excretion $\Delta e_u(t)$ at time = t days after intake. The instantaneous concentration of tritium in the urine $C_u(t)$ is obtained by dividing the instantaneous urinary excretion rate by the daily urine output of 1.4 liters per day. The ICRP 88 biokinetic model for instantaneous urine concentration [ICRP(2001)] is given by dividing the content of the three systemic compartments[3] at time = t days after intake by the volume of free body water (42 liters). In the discussion below, we provide detailed calculations of the IMBA tritiated water biokinetic model and compare it to the ICRP 88 tritiated water biokinetic model. The calculations are performed in the statistics software *R* [The R Team(2013)] and are reproducible (i.e., the code can be copied from this document, pasted in R, and executed to give the same results given here).

Calculations

To calculate the IMBA and ICRP 88 urinary excretion functions we need to define and solve the system of differential equations based on the ICRP 56 biokinetic model shown above. Note that in R, log(x) is the natural logarithm of x. The biokinetic model is defined below.

```
#Rate matrix
k <- matrix(data=0,nrow=6,ncol=6)

#radioactive decay constant (in units of days)
lambda <- log(2) / (12.32 * 365.25)

#Name the compartments (makes life easier)
xfer <- 1
tbA <- 2
tbB <- 3
other <- 4
bladder <- 5
urine <- 6

#Define transfer and total removal rate constants (in units of 1/day)
k[xfer,tbA] <- 0.97 * log(2)/0.25
k[xfer,tbB] <- 0.03 * log(2)/0.25
k[tbA,bladder] <- log(2)/10 * 1.4/3
k[tbA,other] <- log(2)/10 * 1.6/3
```

[3] Transfer Compartment, Total Body 1, and Total Body 2.

```
k[tbB,bladder] <- log(2)/40
k[bladder,urine] <- 12
k[xfer,xfer] <- -(k[xfer,tbA]+k[xfer,tbB])
k[tbA,tbA] <- -(k[tbA,bladder]+k[tbA,other])
k[tbB,tbB] <- -(k[tbB,bladder])
k[bladder,bladder] <- -k[bladder,urine]
k[other,other] <-0
k[urine,urine] <-0

#Define the content of each compartment at t = 0
#Everything is in the transfer compartment
q0 <- numeric(6)
q0[1] <- 1
```

The function qq below implements the eigensystem method for solving systems of first order linear differential equations, as discussed by [Jacquez(1985)] and [Polig(2001)], to give the content of a given biokinetic compartment at time t. Because we are starting out with a unit intake (e.g., q0 =1 Bq), this is also the fraction of the intake present in the biokinetic compartment (i.e., the intake retention function [IRF]).

```
qq <- function(x,initial.burdens,rate.constants,comp) {
        K <- eigen(t(rate.constants))$values
        V <- eigen(t(rate.constants))$vectors
        M <- solve(V,initial.burdens)
        qq <- 0
        for (j in 1:nrow(rate.constants)) { qq <- qq + M[j]*V[comp,j]*exp(x*K[j]) }
        return(qq)
}
```

In the examples below,[4] the content of stable tritium in the cumulative urine compartment at t = 10 days after an acute unit intake of stable tritium, and the 24-hour incremental urinary excretion of stable tritium, are given.

```
t.bio <-10

#cumulative urine
qq(t.bio,q0,k,urine)
## [1] 0.22375899

#24-hour incremental urine
qq(t.bio,q0,k,urine) - qq(t.bio-1,q0,k,urine)
```

[4] A line starting with # is a comment and a line starting with ## is output from the R statement above it.

```
## [1] 0.01720243
```

The excretion functions for radioactive tritium are easily derived by adjusting the stable functions for radioactive decay. The reason why we differentiate between stable and radioactive tritium is that incremental urine samples and instantaneous urinary excretion rates are most easily calculated with stable excretion functions that are subsequently adjusted for radioactive decay.

```
#cumulative urine
exp(-lambda*t.bio) * qq(t.bio,q0,k,urine)
## [1] 0.22341458

#24-hour incremental urine
exp(-lambda*t.bio) * ( qq(t.bio,q0,k,urine) -qq(t.bio-1,q0,k,urine) )
## [1] 0.017175952
```

As a side note, the incremental urinary excretion functions for tritiated water given in *Radiological Toolbox V3.0.0* agree with those calculated above. For example, in Radiological Toolbox, $\Delta e_u(10) = 0.01718$ compared to $\Delta e_u(10) = 0.01718$ calculated above.

The function dq below implements the eigensystem method for solving systems of first order linear differential equations to give the instantaneous rate of change of the content of a given biokinetic compartment at time t. The instantaneous rate of change of the stable tritium in the urine compartment is the instantaneous urinary excretion rate of stable tritium. The instantaneous urinary excretion rate for radioactive tritium is obtained by adjusting the stable excretion rate for radioactive decay.

```
dq <- function(x,initial.burdens,rate.constants,comp) {
        K <- eigen(t(rate.constants))$values
        V <- eigen(t(rate.constants))$vectors
        M <- solve(V,initial.burdens)
        dq <- 0
        for (j in 1:nrow(rate.constants)) { dq <- dq + K[j]*M[j]*V[comp,j]*exp(x*K[j]) }
        return(dq)
}
```

The instantaneous urinary excretion rate $\dot{e}_u(10)$ of radioactive tritium is shown below, along with the instantaneous concentration $C_u(10)$ of tritium in urine.

```
#Instantaneous excretion (1/day)
exp(-lambda*t.bio) * dq(t.bio,q0,k,urine)
## [1] 0.016598922
```

```
#Instantaneous excretion (1/L)
exp(-lambda*t.bio) * dq(t.bio,q0,k,urine) / 1.4
## [1] 0.011856373
```

The instantaneous concentration of radioactive tritium in the urine at t = 10 days calculated with the ICRP 88 model is shown below. The excretion rates calculated here using the ICRP 88 approach agree with those given by [Potter(2004)]. For example, in Potter $C_u(10) = 0.0124$ compared to $C_u(10) = 0.01243$ calculated below.

```
exp(-lambda*t.bio) * ( qq(t.bio,q0,k,tbA) + qq(t.bio,q0,k,tbB) + qq(t.bio,q0,k,xfer) ) / 42
## [1] 0.01242897
```

The IMBA excretion rate (black line) is compared to the ICRP 88 excretion rate (blue line) in **Figure A1-2** below.

```
t.bio <- seq(0.1,200,by=0.1)
n <- length(t.bio)
Ins.IMBA <- numeric(n)
for(i in 1:n) {
        Ins.IMBA[i] <- exp(-lambda*t.bio[i]) * dq(t.bio[i],q0,k,urine) / 1.4
}
Ins.88 <-numeric(n)
for(i in 1:n) {
        Ins.88[i] <-exp(-lambda*t.bio[i]) * (qq(t.bio[i],q0,k,tbA) +
                qq(t.bio[i],q0,k,tbB) + qq(t.bio[i],q0,k,xfer)) / 42
}
```

```
plot(t.bio,Ins.IMBA,type="l",log="y", ylab="Instantaneous Urinary Excretion Rate",
        xlab="Days After Intake")
lines(t.bio,Ins.88,col="blue")
abline(v=30,col="red",lty=6)
```

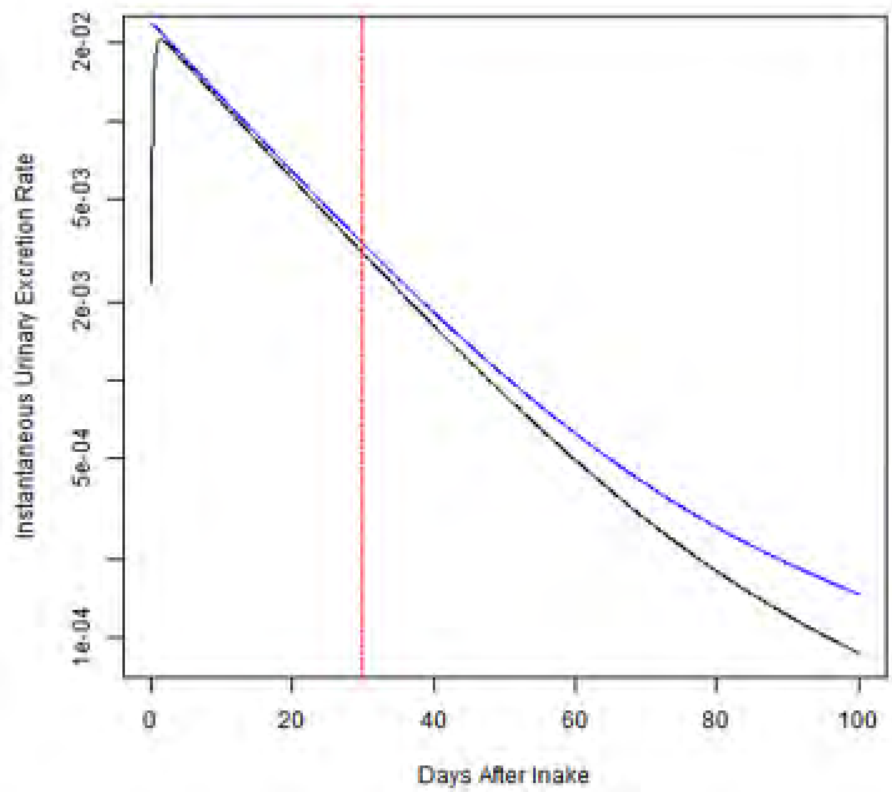

Figure A1-2: Comparison of IMBA Excretion Rate (black) and ICRP 88 Excretion Rate (blue)

The ICRP 88 model predicts a higher excretion rate than the IMBA model at all times after intake, which is a result of adding the contents of the OBT compartment into the free-body water pool in the ICRP 88 model. We consider this to be physiologically-inconsistent with the ICRP 56 biokinetic model[5]. Thus, the ICRP 88 model is an approximation of convenience that allows one to readily model the tritium urine concentration results, as was done in ICRP 54 [ICRP(1989)], which used a biokinetic model that consisted of a single free-body water compartment having a 10-day half-life. For reference, t = 30 days is indicated on the plot as the vertical red line. The significance of 30 days is that it is probably the greatest length of time between urine samples one would observe in a routine occupational monitoring program. The tritium concentrations predicted by the two models differ by ~ 9% at t = 30 days, which is an insignificant difference when modeling intakes of tritiated water in an operational radiation protection program. At t = 200 days post-intake, the excretion rates differ by ~ 90%. It is our opinion that the ICRP 88 approximation is not applicable at such extremely long times post-intake and that the ICRP 56 model, as implemented in IMBA, should be used.

[5] The ICRP never really explains how it is possible for the tritium in a compartment having a 40-day half-life to be evenly distributed in a free-body water compartment that has a half-life of 10 days.

```
#Ratio at 30 days post intake
t.bio[300]
## [1] 30
Ins.88[300] / Ins.IMBA[300]
## [1] 1.0886159

#Ratio at t = 200 days
t.bio[n]
## [1] 200
Ins.88[n] / Ins.IMBA[n]
## [1] 1.9191289
```

Intake and Dose Example

To illustrate the differences in the IMBA and ICRP 88 models, both are used to evaluate a spot urine sample having a concentration of 10,000 pCi/L collected 187 days after an acute uptake of tritiated water. The intake-to-dose conversion factor (DCF) in units of mrem/pCi is from Radiological Toolbox[6].

```
Result <-10000 #pCi/L
num.days <-187
DCF <-6.67E-8 #mrem/pCi
```

First, the intake (Result / irf) in pCi and 50-year committed equivalent dose (DCF * Result / irf) in mrem calculated with IMBA.

```
irf <-exp(-lambda*num.days) * dq(num.days,q0,k,urine) / 1.4

irf
## [1] 1.4285345e-05

Result / irf
## [1] 700018095

DCF * Result / irf
## [1] 46.691207
```

Then, the intake and dose is calculated with ICRP 88.

```
irf <- exp(-lambda*num.days) * (qq(num.days,q0,k,tbA) + qq(num.days,q0,k,tbB) +
        qq(num.days,q0,k,xfer)) / 42
```

[6] IMBA gives a slightly higher DCF of 6.76E-8 mrem/pCi

```
irf
## [1] 2.7392236e-05

Result / irf
## [1] 365066948

DCF * Result / irf
## [1] 24.349965
```

The dose calculated with the IMBA model is approximately a factor of 2 higher than the dose calculated with the ICRP 88 model.

References

[ICRP(1989)]
Individual Monitoring for Intakes of Radionuclides by Workers, ICRP Publication 54, Elsevier.

[ICRP(1990)]
Age-dependent Doses to Members of the Public from Intake of Radionuclides Part 1, ICRP Publication 56, Elsevier.

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Polig, E. (2001), *Modeling the Distribution and Dosimetry of Internal Emitters*, Health Physics 81(5):492–501.

[Potter(2004)]
Potter, C. A. (2004), *Application of the ICRP Clarification of the Tritium Metabolic Model*, Health Physics 87(4):375–381.

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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). The incident report indicates that 250 people who were determined to have exposure potential to this incident were sampled as of October 15, 1973. Two-hundred-forty-five of the 250 individuals were found to have results less than the action level of 10,000 pCi/L. This action level was employed to identify those individuals who needed follow-up sampling. It is assumed that those individuals who were not monitored would have also not exceeded the action level. Therefore, the action level will be used as the maximum bioassay result for those who were not monitored, given that no results or dates were provided for those individuals below that level. An analysis of the potential missed dose from a bioassay result at the action level resulted in a total dose of 49 mrem. This dose will be assigned to all unmonitored workers.

- 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	0.574	0. 574	3.73%
Prostate	0.000	0. 574	0. 574	1.36%
Skin BCC	0.000	0. 574	0. 574	3.25%
Skin SCC	0.000	0. 574	0. 574	0.44%

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 co-worker 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 A2-1 summarizes the cold trap sample data presented on pdf p. 79 in SRDB 111284.

Table A2-1: 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

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

- Building 774: (14.7 ± 4.7) pCi/m^3

- Building 779-A, Rm 154 NE and SW: The documentation offers no explanation for the high result of 400,750 pCi/m^3 on October 1, 1973.

  - Calculation including the high value: (46,810 ± 132,766) pCi/m^3
  - Calculation excluding the high value: (2568 ± 3466) pCi/m^3

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/m^3.

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 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 co-worker 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 co-worker model was based on the analysis of the NOCTS claimant data. The assessed dose from the co-worker 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 co-worker 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 D and P 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 A and D (and P) 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 one individual 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.

Appendix 3: Workplace Air Tritium Monitoring at Rocky Flats, 1977-1981

PURPOSE

NIOSH requested in May 2015 that ORAUT evaluate evidence of a robust workplace monitoring program in order to comprehensively close out the issue of RFP tritium exposure after 1973. This appendix establishes the locations and frequencies of workplace monitoring at the Rocky Flats Plant between 1977 and 1981. The existence of a robust workplace monitoring program at RFP would support the validity of bounding occupational exposures to tritium during and after 1973 using the analysis and co-worker model that ORAUT performed, as discussed in Appendix 1, Part II of this tritium follow-up paper.

METHOD

NIOSH has been unable to capture digitized records describing workplace tritium monitoring programs prior to the end of plutonium processing operations[7] (with which tritium releases and contamination incidents are closely linked). However, the SRDB contains three handwritten logs of analytical results for tritium collected by bubblers used for both environmental and workplace air sampling (SRDB 111095; 111157; 111189). One of these logs (SRDB 111095), spanning the period 4/1/1977 to 12/23/1981, was evaluated by noting the locations and results for bubbler samples of workplace air analyzed[8] during the first seven-day period of each year's records beginning in April 1977 and the last seven-day period of December 1981. Any location logged to indicate that sampling was taken from an effluent system, such as a plenum or exhaust duct, was excluded. Other sampling sites not otherwise clearly marked were excluded when documentation was found indicating that they sampled an effluent system (e.g., SRDB 24164, PDF p. 19) or a glovebox environment (SRDB 122692, PDF p. 9). Locations marked as a Room or as a support column coordinate within a room were assumed to be workplace air sampling locations.

RESULTS

Review of the selected log (SRDB 111095) identified 107 log entries for tritium bubbler sample results that are not associated with glovebox environments or effluents. The PDF page number, sampling location, date of analysis, and analytical result for each of these entries, grouped by

[7] Plutonium-processing operations ceased subsequent to the FBI raid in 1989 (SRDB 8016, PDF p. 12).
[8] Samples were typically analyzed within a week of collection, except over holidays.

location, is provided in an Excel spreadsheet (SRDB 144998). Results range[9] from 0 pCi/m^3 to a high of 7,920 pCi/m^3. The high value was associated with the Disassembly Area (SRDB 24164, PDF p. 10) at Glovebox 452 (SRDB 118366, PDF pp. 2, 5). The average value is 152.5 pCi/m^3 if 'less than' values are treated as zero.

There are 17 separate locations in the 107 entries where bubbler results for tritium were logged. An occurrence matrix showing the bubbler monitoring locations and the number of analyses reported for each of the periods for which results were noted is shown in **Table A3-1** below.

Table A3-1: Occurrence Matrix for Bubbler Tritium Air Samples, April 1977 – December 1981

Bldg.	Location	Number of Analyses*					
		Apr. 1977	Jan. 1978	Jan. 1979	Jan. 1980	Jan. 1981	Dec. 1981
374	First Floor	-	-	2	-	-	-
559	102	-	-	1	-	-	-
771	181	-	1	1	-	-	-
771	305	-	1	-	-	-	-
771	Rm 146	-	1	1	-	-	5
771	Rm 149	-	-	-	-	-	4
771	Rm 174	-	-	1	-	-	4
774	220	-	1	-	-	-	-
777	430, G-18	-	-	-	-	5	4
777	430, K-15	-	-	-	1	-	-
777	Rm 452, Downdraft	4	3	2	2	4	4
777	Rm 452, Col J-23	4	3	3	3	4	4
777	Rm 465	-	-	-	-	-	4
779A	Rm 154	-	4	2	4	7	2
881	225	-	-	-	-	-	1
881	283	-	2	-	1	3	-
881	Rm 15	-	-	-	-	-	2

*These are the numbers of work-area bubbler samples analyzed during the first seven days of records for 1977-1981, and for the last seven days of records for 1981.

[9] Values of zero do not appear in the record until after the first week of 1981; entries less than or equal to a value no greater than 170 pCi/m^3 (presumably the detection limit) are used instead of zero prior to this time.

Monitoring frequencies were consistent in three of these locations during the five-year period:

1. Building 777, Room 452 (Special Assembly) Downdraft, the location of tritium released from a contaminated shipping container on 8/30/1974 (SRDB 8790)

2. Building 777, Room 452, Col J-23

3. Building 779A, Room 154, the Hydriding Laboratory (SRDB 118367, PDF p. 3) and location of glovebox #1363, where elevated tritium levels were seen just prior to Dec 5, 1977 (SRDB 110903, PDF p. 2).

The above areas were known to have elevated potential for tritium release into the workplace because of the prior incidents. Samples were normally retrieved from these locations three times weekly (Monday, Wednesday, and Friday). This sampling frequency was specified on log sheets prior to January 1978 (SRDB 111095, PDF p. 22) and in later radiological operating instructions (SRDB 24307, PDF p. 3). The same (Monday, Wednesday, and Friday) frequency was applied wherever glovebox environment and effluent monitoring for tritium was performed.

Inspection of **Table A3-1** above shows that areas where tritium release to the workplace was known to have happened in the past were monitored frequently and consistently in the five-year period from 1977-1981 and that other areas were monitored occasionally. Tritium limits were established after the 1973 release for workplace surface smears (0.005 μCi/100 cm^2), effluent air (2 $\mu Ci/m^3$), and room air (0.05 $\mu Ci/m^3$) (SRDB 4632, PDF p. 165).

A brief review of two similar documents of handwritten tritium monitoring results for the years 1974-1982 and 1974-1975, respectively, indicated similar monitoring frequencies and locations as those discussed here during years not included in this analysis (SRDB 111157; 111189).

SUMMARY AND CONCLUSIONS

Workplace air monitoring for tritium using bubblers was performed frequently and consistently at the Rocky Flats Plant after 1973 in areas known to have a significant potential for personnel exposure. Other areas were also monitored, but less frequently, perhaps on the basis of production activity with a potential for tritium release. Analytical results indicate a detection limit almost three orders of magnitude below the 0.05 $\mu Ci/m^3$ limit for tritium in workplace air established by RFP management. The largest result noted for this analysis was 7,920 pCi/m^3, which is 16% of the limit.

Rocky Flats continued to monitor workplace tritium well beyond the release incident in 1973 with results indicating that tritium levels were normally quite low. NIOSH concludes that the use of a co-worker model for estimating and bounding tritium doses during normal operations at Rocky Flats is, therefore, appropriate.