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ADVISORY BOARD ON
RADIATION AND WORKER HEALTH
National Institute for Occupational Safety and Health

SC&A RESPONSE TO REVISION 3 OF NIOSH'S "FOLLOW-UP EFFORTS ON SEC-00192, ROCKY FLATS PLANT TRITIUM ISSUES, WHITE PAPER," DECEMBER 28, 2015

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ABBREVIATIONS AND ACRONYMS

ABRWH or Advisory Board	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
Ci	curie
ER	evaluation report
H	hydrogen
H-3	tritium
HTO	tritiated water or tritium oxide
ICRP	International Commission on Radiation Protection
IMBA	Integrated Modules for Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
µCi	microcurie
µCi/m^3	microcurie per cubic meter
MDA	minimum detectable activity
mrem	millirem
mrem/d	millirem per day
mrem/yr	millirem per year
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH OCAS Claims Tracking System
pCi/day	picocurie per day
pCi/L	picocurie per liter
pCi/m^3	picocurie per cubic meter
RCG	Radio Concentration Guidelines
RFP	Rocky Flats Plant
RFPAO	Rocky Flats Area Office
SEC	Special Exposure Cohort
SRDB	Site Research Database
yr	year

1.0 INTRODUCTION

An exchange of white papers and Work Group discussions of issues related to the reconstruction of exposures of workers to tritium (also referred to as "H-3") at the Rocky Flats Plant (RFP) has been ongoing [see the timeline provided on page 34 of the National Institute for Occupational Safety and Health's (NIOSH's) December 28, 2015, white paper (NIOSH 2015a) cited and described below]. As part of these continuing investigations, in September 2014, SC&A issued *SC&A Response to NIOSH White Paper: "Follow-up Efforts on SEC-00192 Rocky Flats Plant Tritium Issues," dated May 30, 2014* (SC&A 2014). On December 28, 2015, partly in response to SC&A's September 2014 white paper, NIOSH issued *Follow-up Efforts on SEC-00192, Rocky Flats Plant Tritium Issues, White Paper*, Revision 3 (NIOSH 2015a). These white papers are part of a series of investigations performed in support of the Special Exposure Cohort (SEC) Petition SEC-00192 *Rocky Flats Plant Special Exposure Cohort Petition Evaluation Report* presented to the Advisory Board on Radiation and Worker Health ("Advisory Board") in September 2012 (NIOSH 2013).

The introduction of NIOSH's December 28, 2015, white paper (hereafter referred to as "NIOSH 2015a") states the following as the basis for the new material compiled by NIOSH since the last Work Group meeting that updates, supplements, and/or confirms its position with respect to these matters:

> *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.*

In this latest revision, NIOSH provided additional document data captures 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.

NIOSH 2015a presents NIOSH's approach to dose reconstruction to tritium exposures in Appendix 1, as follows:

- Part I, "Analysis of Rocky Flats Plant Tritium Exposures for 1959–1973," by J. S. Bogard, Oak Ridge Associated Universities Team (ORAUT)
- Part II, "Rocky Flats Tritium Dose Assignment for 1973 and Later," by E. M. Brackett, ORAUT; and Attachment A, "Tritiated Water Models," by Thomas LaBone, Nancy Chalmers, and E. M. Brackett, ORAUT
- Part III, "Example RFP Tritium Dose Reconstruction," by Mutty Sharfi, ORAUT

In NIOSH 2015a, NIOSH repeats most of the information presented in Revision 2 of the paper. (NIOSH 2015b; July 1, 2015). At the Work Group meeting on July 14, 2015, it was agreed that the method used by NIOSH to assign pre-1973 chronic tritium exposures to all workers was acceptable to the Work Group, as a bounding approach, and that issue was closed. The most relevant changes presented in Revision 3 of the white paper (NIOSH 2015a) are the revised approaches for tritium dose assignment for 1973 and later, presented in Part II of Appendix 1 and its application in Part III.

As the method used by NIOSH to assign pre-1973 doses was accepted during the July 2015 Work Group meeting, SC&A focused its reviews on NIOSH's approach for tritium dose assignments at RFP for 1973 and later.

SC&A has analyzed the RFP tritium dose assignment for 1973 in Part II of Appendix 1 of NIOSH 2015a, as well as Attachment A to Part II, where the model to calculate urinary excretion following an acute uptake of tritiated water (HTO) is described. SC&A has reviewed issues related to the reconstruction of exposures to tritium at RFP post-1973 (in Part II of Appendix 1). SC&A's review addresses the expanded NIOSH review in NIOSH 2015a in terms of the nine original issues raised by SC&A in its September 2014 white paper for the post-1973 time period.

In addition, SC&A has reviewed Part III of Appendix 1 to NIOSH 2015a, where the doses assigned for workers in the pre-1973, 1973, and post-1973 periods of exposure are used in an example for dose reconstruction.

2.0 COMMENTS ON REVISION OF PART II OF APPENDIX 1: ROCKY FLATS TRITIUM DOSE ASSIGNMENT FOR 1973 AND THE TRITIATED WATER MODEL AS SHOWN IN ATTACHMENT A

2.1 SUMMARY OF NIOSH ASSUMPTIONS

In NIOSH 2015a, NIOSH describes a 1973 incident that prompted the site to sample a number of workers for tritium exposure. The incident occurred due to the processing of tritium-contaminated material that was processed at the RFP from April 9 to April 25, 1973. 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. The five most exposed individuals were identified [urine levels higher than 10,000 picocuries per liter (pCi/L), the action level of the site].

Because the tritium contamination was associated with handling plutonium scrap material, NIOSH has taken the position that (1) tritium doses will be assigned to all individuals who were monitored for plutonium in 1973, (2) doses will be assessed on an individual basis using reported H-3 bioassay results and any additional information in the NIOSH OCAS Claims Tracking System (NOCTS) file, and (3) for those who were not monitored for H-3, dose will be assigned based on claimant-favorable assumptions.

The tritium release incident report [Site Research Database (SRDB) Ref. ID 24165] discusses the tritium sampling of 250 people as of October 15, 1973. There are no results or specific sample dates given in the report for those individuals who did not exceed the H-3 bioassay follow-up action level of 10,000 pCi/L. Only five individuals were found to have results exceeding the action level, so NIOSH's assessment is based on the assumption that these individuals were the maximally exposed workers due to the incident, and that those workers who were not monitored would not have been exposed at those same levels. After discussions about the tritium model at the RFP work group meeting, NIOSH decided to adopt the use of the tritium model described in "Review of the ICRP Tritium and C-14 Internal Dosimetry Models and Their Implementation in the GENMOD-PC Code," by R. B. Richardson and D. W. Dunford (2001), for this assessment.

Based on this information, the following assumptions were applied:

- H-3 was in the form of HTO.
- The model for inorganic H-3 is as described in "Review of the ICRP Tritium and C-14 Internal Dosimetry Models and Their Implementation in the GENMOD-PC Code," by R. B. Richardson and D. W. Dunford (2001).
- The mode of intake was injection [for modeling with Integrated Modules for Bioassay Analysis (IMBA)].
- The tritium date of intake was April 9, 1973 (first day the material was processed).
- Urine samples were collected on October 15, 1973.
- Sample result = 10,000 pCi/L (14,000 pCi/day urinary excretion rate), 187 days after the assumed intake date of April 9, 1973.

Using this information, NIOSH estimated a total dose of 103 millirem (mrem) due to the April 1973 incident

2.2 SC&A REVIEW OF NIOSH ASSUMPTIONS

SC&A reviewed the Richardson and Dunford (2001) model cited by NIOSH 2015a. The model is similar to the one used by the National Council on Radiation Protection and Measurements (NCRP) in its Report No. 161 (NCRP 2008; hereafter "NCRP 161"), but there are some differences. For example, though Richardson and Dunford (2001) suggested that the fraction excreted in urine is 0.47, the excretion fraction from body to urine in NCRP 161 is 0.55. This model is also similar to the International Commission on Radiation Protection (ICRP) retention and dosimetric model for tritiated water [ICRP Publication 78 (1997); hereafter "ICRP 78"], although neither the ICRP nor the NCRP models include the bladder compartment.

NIOSH modified the Richardson and Dunford (2001) model, introducing the bladder compartment. The ICRP and the NCRP did not consider the delay in excretion pathway due to the bladder. According to ICRP 78, urinary excretion should not result in a significant additional dose to the bladder wall, which is assumed to receive the same dose as other tissues. Richardson and Dunford (2001) state the following: "*We can find no evidence that any tritiated or C-14 compound model requires a urinary bladder compartment*" (page 293).

In spite of the introduction of the urinary bladder, SC&A finds that the delay caused by introducing the urinary bladder will not cause a relevant difference in the interpretation of the urinary excretion of tritium in terms of intake and dose.

The Richardson and Dunford model, published in 2001, was not experimentally tested for times as long as 187 days and thus, theoretically, should not be applied in this case. In addition, the same authors published a later paper (Richardson and Dunford 2003), that states: "*The ICRP HTO model has limited use in a bioassay intake estimation, as it does not possess components that represent the long-term retention of tritium in the body that has been measured in bone, adipose tissue and other tissues and organs*" (page 549). It proceeds to state that "*there are no definite data available to evaluate tritium biokinetics, especially at long times after intake*."

In previous discussions and white papers, SC&A suggested that NIOSH use a new draft ICRP (2012) model published on the ICRP website for public comment, which attempted to assign a long-term compartment to the tritium retention model. However, NIOSH indicated it could not use this model because it had not yet received formal ICRP endorsement. As an alternative, SC&A suggested the use of David Taylor's model, which has three compartments, the third with a half-life compatible with the long-term retention in the body (Taylor 2003). This paper is cited in Richardson and Dunford's 2003 paper, which, in many respects, is similar to the new draft ICRP model, suggested by SC&A.

In summary, NIOSH's proposed model assigns 103 mrem to unmonitored workers exposed or potentially exposed to tritium at RFP for 1973, based on a model that SC&A believes is appropriate for application to the long post-exposure time periods involved (i.e., 187 days).

If the new ICRP model would have been used, as described in the consulting document posted for public comment on the ICRP website (ICRP 2012), or the model published by David Taylor (2003), the dose would be a little higher, i.e., 40 mrem to 50 mrem higher, depending on which dosimetric model is applied. As this dose is just assigned to one year, 1973, for non-monitored workers, SC&A finds that the difference in dose estimated will not be substantive and will have negligible influence on the Interactive RadioEpidemiological Program (IREP) probability of causation calculations. In addition, NIOSH used a conservative urinary excretion result, H-3 bioassay follow-up action level of 10,000 pCi/L, instead of one-half the minimum detectable activity (MDA), and a maximum possible time interval between the intake and the sample collection date, which is claimant favorable.

However, SC&A recommends the use of the intake date of April 9, 1973, both for the workers who had monitoring data higher than 10,000 pCi/L, and for the workers who had monitoring data less than 10,000 pCi/L, and who were all working in the location where the accident occurred at the time of its occurrence. The dose assigned to a person, based on urine excretion results, depends on the time lag between exposure and sample collection. The longer the time lag, the higher the dose assigned to the exposed worker. SC&A had previously agreed that urinary excretion rates of 10,000 pCi/L may be applied for workers who were not monitored. The assignment of the conservative intake date of April 9, 1973, should be the same for unmonitored and monitored workers, if they were present at the location of the incident.

3.0 REVIEW OF ISSUES RELATED TO THE RECONSTRUCTION OF EXPOSURES TO TRITIUM AT ROCKY FLATS POST-1973

This section focuses on the nine issues raised by SC&A in its September 2014 white paper dealing with the reconstruction of exposures of Rocky Flats workers to tritium in 1974 and 1975 (SC&A 2014); i.e., following the April 1973 incident. We have structured this section by first restating each of the nine issues raised by SC&A (2014) on this subject (in italics) and then exploring the degree to which NIOSH has satisfactorily addressed each of these issues in NIOSH 2015a.

3.1 SC&A ISSUE 1

Based on the review of the above SRDB folders, SC&A concurs that there do not appear to be any incidents post-1973 where the doses to workers could have been greater than the doses that might have been associated with the April 1973 incident. In addition, there are considerable air sampling data, and a limited amount of bioassay data post-1973, that indicate that a plausible upper bound could be placed on the tritium exposures that workers might have experienced after the 1973 incident. However, one of our concerns is whether the locations of the bubblers are representative of the airborne tritium concentrations at the locations of the potentially exposed workers. Also, one of the conclusions on page 20 of the May 30, 2014, white paper states that, "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." This conclusion is not consistent with the material provided in SRDB 8790, where the potential doses involved in the August 1974 incident were certainly higher than1 mrem/yr, and it is unclear whether more than one of these incidents might have occurred. This observation also applies to the conclusion on page 22 of the NIOSH white paper that the bioassay data support a conclusion that the doses to workers from tritium for 1974 and 1975 were zero for everyone.[1] (SC&A 2014)

3.1.1 Material Provided by NIOSH that Addresses this Issue and SC&A's Position on this Issue

With respect to reconstructing tritium exposures in 1974 and 1975, NIOSH states the following on page 24 of NIOSH 2015a:

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 a particular concern was

[1] In preparing this report, we have determined that the doses associated with the August 1974 report were unlikely to have exceeded 1 mrem. Hence, this aspect of Issue 1 is retracted.

identified. Samples available in NOCTS for these two years indicate that analyses were performed throughout the year, with most individuals sampled only once.

This section of NIOSH 2015a reiterates that the 1-in-10 bioassay program initiated in 1974 found no workers with tritium concentrations in urine that could be associated with an annual dose in excess of 1 millirem per year (mrem/yr). For this reason, NIOSH believes that no tritium dose should be assigned to any workers post-1973, except for workers who were explicitly monitored for a known acute release of tritium that occurred post-1973.

Page 31 of NIOSH 2015a provides additional information pertinent to reconstructing post-1973 exposures to tritium. The white paper explains that the 1-in-10 program involved bioassay samples from 38 individuals in 1974 and 37 individuals in 1975. Such a program would appear to provide compelling evidence that, other than known exposures to specific incidents, these data indicate that it is unlikely that workers at RFP experienced acute or chronic exposures to tritium post-1973 that could have resulted in exposures exceeding 1 mrem/yr. Such a conclusion must be viewed cautiously, because these persons were only bioassayed about once per year and, since tritium has an effective half-life in a body water of about 10 days, it is reasonable to ask whether a substantial acute intake of tritium could have been missed.

With respect to this issue, it is possible that one or more undetected incidents occurred in 1974 and 1975 and acute intakes occurred, but none were detected in the 75 urine samples collected over the 1974 and 1975 time period when the 1-in-10 program was in effect. As best as can be determined, the 75 urine samples were collected from workers who had the potential for exposure to plutonium, and that these include workers who opened containers that might have been contaminated with tritium. On this basis, it appears to be unlikely that one or more acute intakes occurred but were undetected <u>by all 75 bioassay analyses</u>. We would agree with this conclusion if the bioassay data were collected randomly among individuals involved in plutonium handling, including opening shipping containers and “pressure cookers,” and if the samples were collected in a manner that was more or less uniformly distributed in time over the course of the 1-in-10 tritium bioassay program.

In order to ensure that NIOSH’s interpretation of the results of the 1-in-10 bioassay program is reasonable, SC&A posed two questions about the Rocky Flats tritium data sets, which we believe will help to confirm that NIOSH’s interpretation of the implication of the 1-in-10 program is reasonable. The two questions and associated discussions are as follows:

1. Were the 75 urine samples collected in 1974 and 1975 distributed randomly over the duration of the 1-in-10 program?

This question goes to concerns that, if the samples were clustered in time—e.g., if they were all collected at the same time—the samples could have missed one or more acute intakes. In order to address this issue, we searched over 900 Rocky Flats tritium records in the SRDB to identify the dates when each urine sample was collected. In Section 5.3.5.3 of ORAUT-TKBS-0011-5, *Rocky Flats Plant – Occupational Internal Dose,* Revision 03 (ORAUT 2014), NIOSH states that an analysis of NOCTS data from 1974 and 1975 revealed that 38 employees in 1974 and 37 employees in 1975 had tritium urinalysis testing as part of the 1-in-10 tritium testing protocol that was implemented following the April 1973 tritium release. This testing program appeared to have been in place from September 1974 (SRDB Ref. ID 111288) to September 1975 (SRDB

Ref. ID 24664). SC&A reviewed tritium bioassay-related documents for Rocky Flats on the SRDB, but the tritium bioassay data for 1974 and 1975 that were collected by NIOSH did not appear to be published in a single document. Even though the program managers did state that the testing was random, we could not confirm if the testing was distributed randomly during the 1-in-10 program. SC&A did not perform a search of NOCTS to find the employees who were tested during this program because of the magnitude of the effort.

As a fallback position, we tried to obtain information about the frequency that urine samples were collected for plutonium analyses. For example, if urine samples were collected monthly for plutonium analysis, and the 1-in-10 urine bioassay samples came from these samples, we can have some level of assurance that the urine samples collected and analyzed for tritium as part of the 1-in-10 program were, in fact, distributed more or less randomly over 1974 and 1975. If this is the case, we can have increased confidence that the 1-in-10 program did not miss an acute exposure. Unfortunately, again, we were unable to obtain information of the frequency of the routine plutonium bioassay program.

Observation 1: NIOSH should provide the results of each of the 75 bioassay measurements, including the dates the samples were collected and the results of the analyses.

2. Are there tritium emissions data that can be used to corroborate that no substantial releases of tritium occurred that might have been missed?

In order to help confirm that unusually high releases of tritium did not occur after 1973, we reviewed the Annual Environmental Monitoring Reports for a number of years and compared the reported releases to the atmosphere for a number of years (SRDB Ref. ID 8790) and also found a slide presentation (SRDB Ref. ID 110899) that fills in some gaps in the reported effluents, as shown in Tables 1 and 2.

Table 1. SRDB Documents that Provide Tritium Releases to the Atmosphere

Year	SRDB No. 8790 Reference ID	Tritium Release to the Atmosphere (Ci)
1974	966	10.38
1975	975	<1.5 Ci
1976	976	<1.159
1977	979	<0.528
1978	983	<0.941
1980	985	<0.842

Table 2. Additional Information Regarding Tritium Releases to the Atmosphere

Year	Tritium Release to Atmosphere (Ci) (from page 9 of SRDB 110899)
1973	500 to 2000
1974	—
1975	<1.539
1976	<1.159
1977	<0.528
1978	<0.941
1979	<0.844
1980	<0.842
1981	<0.447
1982	<0.232
1983	<0.165
1984	0.148
1985	<0.155
1986 (through October)	<0.197

The implications of these reported tritium releases are that the tritium release that occurred in August 1974—which was, in part, responsible for the relatively high atmospheric release that occurred in that year—does not appear to have been repeated in later years, where the tritium releases were quite small.

On the basis of the results of the 1-in-10 bioassay sampling program and the emissions monitoring program, it appears that it is unlikely that unmonitored workers in 1974 and subsequent years experienced tritium exposures in excess of 1 mrem/yr.

Further evidence that it is unlikely that one or more undetected large acute tritium intakes occurred in 1974 and 1975 and subsequent years, which could have resulted in exposures in excess of 1 mrem/yr, is provided by the result of the bubbler sampler data collected from 1974 through 1991. This subject is addressed in SC&A Issues 2 and 3, which follow.

3.2 SC&A ISSUE 2

> *In a related matter, Table A-2 of the NIOSH May 30, 2014, report and its supporting SRDB 8790 document, provide detailed air sampling data for Room 452 related to the August 1974 release. Our question is, were there other rooms where containers were opened, and if so, are there any air sampling data, swipe data, or effluent data that demonstrate that tritium releases did not occur at those locations? It appears that Item 2, under the section titled "Comment Reponses" beginning on page 36 of the NIOSH May 30, 2014, white paper provides information pertaining to this issue, but it is not clear that there is a high level of confidence that exposures to tritium associated with opening containers can be characterized and bounded.* (SC&A 2014)

3.2.1 Material Provided by NIOSH that Addresses this Issue and SC&A's Position on this Issue

Material addressing bubbler data in NIOSH 2015a begins on page 4, with a summary of the bubbler program provided in Table 1 of that report. The NIOSH white paper presents a description of the bubbler sampling system from 1974 through 1991. Table A1-2 of the white paper provides airborne tritium concentrations for 1974. In addition, Appendix 3 (page 42) addresses airborne tritium monitoring from 1977 through 1981. Appendix 3 provides useful information on the number and location of bubblers, explaining that the bubblers were located where elevated levels of tritium might be expected. However, the white paper does not provide tritium concentrations in the air for later years [except to note that the highest airborne tritium concentration was 7,920 picocuries per cubic meter (pCi/m^3)]. The paper would benefit by presenting information on the location and concentration of tritium as a function of time and whether the estimated airborne tritium concentrations take into consideration the efficiency of the bubblers. Such information would help to reassure us that there were no large undetected releases of tritium post-1974 that could have resulted in undetected exposures to workers in excess of 1 mrem per year.

NIOSH 2015a describes the data, reports, and interviews that were performed in order to determine if there were any substantial releases of tritium following the April 1973 incident and concludes that, collectively, there does not appear to be any evidence that there were tritium releases post-1973 that were comparable to the release that occurred in April 1973. However, the white paper does not review the data from the perspective that there might have been a multitude of relatively small tritium releases that could have resulted in post-1973 exposures in excess of 1 mrem per year (other than the data collected for the August 1974 incident).

In order to help validate NIOSH's conclusion regarding post-1973 exposures, SC&A reviewed the bubbler data provided in the SRBD as a function of time and location in order to determine if any of the bubbler data revealed the presence of any unusual spikes in the airborne concentrations of tritium at any of the bubbler locations. We believe that this type of data can help to supplement the data obtained from the 1-in-10 bioassay program and the tritium atmospheric release data provided above.

Appendix A presents a series of tables and excerpts that were compiled by SC&A from the SRDB in an attempt to determine if there were any unusually high concentrations of tritium at the bubbler locations from 1974 through 1981. As may be noted in Appendix A, the 1974 data collected from bubblers located in Room 457 of Building 777 reveal airborne tritium concentrations at the locations of the bubblers of about 1,000 to 5,000 pCi/m^3. As a point of reference, continuous exposure to 1 pCi/L of tritiated water is associated with an annual effective dose of 0.16 mrem/yr. Hence, continuous exposure to about 5,000 pCi/m^3 of tritiated water is associated with an effective dose of about 1 mrem/yr, assuming the reported airborne tritium concentrations take bubbler efficiency into consideration. If one considers that many of the bubblers were located near downdraft tables or in exhaust plenums, the reported concentrations may overestimate the tritium concentrations at the breathing zone of workers. Hence, it is not unreasonable to conclude that undetected exposures in excess of 1 mrem/yr were unlikely, based on the bubbler data.

Observation 2. NIOSH should discuss whether the airborne tritium concentrations reported in the white paper take bubbler efficiency into consideration.

The bubbler data in Appendix A also reveal a large spike in the airborne tritium concentration of tritium of over 37 million pCi/m^3 on August 30, 1974. The tritium concentration remained high for about 1 week, at which time the tritium concentrations appear to have returned to relatively normal levels for that time period (i.e., about 5,000 pCi/m^3). NIOSH 2015a indicates that follow-up bioassay data collected in response to this incident revealed doses of no greater than 0.15 mrem. This dose would appear to be low if it is assumed that a person experienced the observed high airborne tritium concentrations for one or more days. However, the results of the bioassay program indicate that the actual exposures were less than 1 mrem. We accept this result because bioassay results are a much more accurate method for estimating radionuclide intake than air sampling data. The implication is that the high concentrations of airborne tritium observed at the bubbler locations were unlikely to be the concentrations experienced by workers, at least not for prolonged periods of time.

Finally, the other bubbler data summarized in Appendix A for 1977 to 1981 reveal that the tritium concentrations did not likely exceed a level that could have been associated with exposures exceeding 1 mrem/yr.

The implications of SC&A's investigation described above for Issues 1 and 2 provide a weight of evidence that supports NIOSH's conclusion that no workers experienced undetected exposures to tritium following the April 1973 incident that could have resulted in doses in excess of 1 mrem/yr. However, we encourage NIOSH to address the observations noted in this report.

3.3 SC&A ISSUE 3

> *The NIOSH conclusion regarding doses post-1973 being less than 1 mrem/yr is likely based on the 1/10 bioassay program, but it is not apparent that the workers included in the bioassay program were bioassayed at a frequency that would have detected an incident. In addition, there are questions regarding the locations of the bubblers with respect to the degree to which those data are representative of the airborne tritium concentrations where workers might have been exposed to tritium. There are a substantial number of smear samples, but it is not apparent that the results of smear samples could be used to validate the conclusions that exposures to workers post-1973 were less than 1 mrem/yr.* (SC&A 2014)

3.3.1 Material Provided by NIOSH that Addresses this Issue and SC&A's Position on this Issue

This issue is discussed extensively as part of Issues 1 and 2 and need not be discussed here.

3.4 SC&A ISSUE 4

> *Another concern we have regarding the post-1973 air sampling data is we did not find any reports that used two bubblers in series to confirm the efficiency of the bubbler for collecting tritium. We note that the efficiency of bubblers can be affected by humidity, the flow rate of air through the bubbler, and how long the*

> *bubbler is on line before analysis. Some discussion of bubbler efficiency is required.* (SC&A 2014)

3.4.1 Material Provided by NIOSH that Addresses this Issue and SC&A's Position on this Issue

None of the NIOSH white papers address the efficiency of the bubblers. However, during the review of SRDB documents, SC&A found an efficiency concern identified in "Project Task 5 - Report - Estimating Historical Emissions from Rocky Flats 1952 – 1989" (ChemRisk 1994; SRDB Ref. ID 8017). According to that report, RFP has used an in-house-designed tritium sampler since 1973 for measurement of HTO in the exhaust ventilation. In 1978, a pilot test was performed where the in-house tritium sampler was modified to analyze for both HTO and elemental tritium. The modified sampler HTO results were significantly higher than the results from the in-house tritium sampler.

The report (ChemRisk 1994) concluded:

> *Tritium sampling efficiency is a source of uncertainty in the tritium emission estimates. Based on the limited special studies indicating a collection efficiency of 48 ±27 percent, actual tritium emissions to the air are estimated to have ranged from factors of 1.3 (i.e., $(0.48 + 0.27)^{-1}$) to 4.8 (i.e., $(0.48-0.27)^{-1}$) times the reported amounts.*

Observation 3. SC&A believes the collection efficiency concern identified in SRDB Ref. ID 8017 may apply to all the tritium exhaust samples prior to 1978. This concern should be investigated and resolved, and taken into consideration in the assessment of potential exposures of workers to tritium post-1973.

3.5 SC&A ISSUE 5

> *Drawings of the bubbler are provided in SRDB 122779 and 122791, and handwritten notes from an interview that discusses the location of the bubblers is provided in SRDB 122466. With respect to bubbler location, the notes in these SDBRs* [sic] *state that, "prior to 1980, bubbler contents from exhaust plenums went to 123. … In early 80's (81 or thereabouts) they put a bubbling unit where components were disassembled." The implications of these statements are that, prior to 1981, the bubblers may not have been placed in the optimum location for providing data useful for dose reconstruction. This matter requires further investigation and discussion.* (SC&A 2014)

3.5.1 Material Provided by NIOSH that Addresses this Issue and SC&A's Position on this Issue

This issue is discussed extensively as part of Issues 1, 2, and 4 and is not discussed further here.

3.6 SC&A ISSUE 6

> *We would also like to hear more about the handling of metal tritides at the facility and the exposures associated with incidents, such as the incident that occurred in 1977 in Room 154 where metal tritides might have been involved.* (SC&A 2014)

3.6.1 Material Provided by NIOSH that Addresses this Issue and SC&A's Position on this Issue

No NIOSH assessment is provided in NIOSH 2015a.

Observation 4. This issue is not addressed in the NIOSH white paper and requires some discussion during the next Work Group meeting.

3.7 SC&A ISSUE 7

> *Table 1 of the NIOSH white paper presents a thorough summary of the reports addressing bubblers, but not bubbler efficiency. However, Table 1 of the white paper does confirm that a substantial amount of airborne tritium concentration data was collected following the 1973 incident that might be useful in reconstructing potential tritium exposures to workers post-1973 if they were located where workers might have been exposed to tritium. We would like to reiterate the need to address bubbler location.* (SC&A 2014)

3.7.1 Material Provided by NIOSH that Addresses this Issue and SC&A's Position on this Issue

This issue is discussed extensively as part of Issues 1 and 2 and need not be discussed here.

3.8 SC&A ISSUE 8

> *Page 22 of the NIOSH white paper concludes that the doses after 1975 should be assigned as zero for the same reasons given for 1974. We are concerned with this conclusion for the same reason as given above regarding 1974 exposures.* (SC&A 2014)

3.8.1 Material Provided by NIOSH that Addresses this Issue and SC&A's Position on this Issue

This issue is discussed extensively as part of Issues 1 and 2 and need not be discussed here.

3.9 SC&A ISSUE 9

> *Page 40 of the NIOSH May 30, 2014, white paper explains why zero dose is being used as a coworker tritium dose for workers in 1974 (provided in response to a question posed by Dr. Ziemer). For the reasons discussed previously, we believe the basis for assigning zero doses to workers in 1974 and also 1975 is not well founded because of uncertainties with respect to where the bubblers were located*

relative to the breathing zone of the workers, and also the very limited amount of bioassay data collected under the 1/10 program. (SC&A 2014)

3.9.1 Material Provided by NIOSH that Addresses this Issue and SC&A's Position on this Issue

This issue is discussed extensively as part of Issues 1 and 2 and need not be discussed here.

4.0 REVISION OF PART III OF APPENDIX 1: EXAMPLE RFP TRITIUM DOSE RECONSTRUCTION

In this example of dose reconstruction, a male employee is diagnosed with lung cancer, prostate cancer, basal cell carcinoma (BCC), and squamous cell carcinoma (SCC) on December 31, 2000. He started working on January 1, 1959 and ended his employment on December 31, 1975.

The pre-1973 dose was assigned using the bounding estimate of 37.5 mrem/year (0.15 mrem/d during 250 days a year) of potential exposure prior to 1973. The worker was potentially exposed during 14 years to 37.5 mrem/yr or 525 mrem total dose until the end of 1972.

For 1973, NIOSH proposed that a dose of 103 mrem should be assigned to the unmonitored worker. This dose was obtained using an HTO model based on the one described in Richardson and Dunford (2001), an intake date at April 9, 1973, and a urine sample collected on October 15, 1973, measuring 10,000 pCi/L. This model is not appropriate for use at 187 days after exposure. The same authors, Richardson and Dunford, later published a paper in 2003, in which they state: "*The ICRP HTO model has limited use in a bioassay intake estimation, as it does not possess components that represent the long term retention of tritium in the body that has been measured in bone, adipose tissue and other tissues and organs*" (page 549).

If the new draft ICRP model had been used, as described in the consulting document posted on the ICRP website for public comment (ICRP 2012), or David Taylor's model (2003), which has a component that describes the longer retention of HTO in the body, the dose would be a little higher, 40 mrem to 50 mrem higher, depending on the dosimetric model applied. As this dose is just assigned to one year, 1973, for non-monitored workers, the difference in dose will not make a big difference in the probability of cancer.

For post-1973 exposures, NIOSH concluded that the 95th percentile of the coworker study for 1974–1975 yielded doses much less than 1 mrem for everyone. SC&A's supports NIOSH's conclusion that no workers experienced undetected exposures to tritium following the April 1973 incident that could have resulted in doses in excess of 1 mrem/yr. Using a worst case scenario, for 1974 the air sample results prior to August 30 had an average of 5,343 plus or minus 4,518 pCi/m^3 (page 19 of NIOSH 2015a). This gives a 95th percentile of about 15,000 pCi/m^3, assuming a normal distribution, about 2.4 mrem/yr. NIOSH assumed zero doses for 1974–1975 based on coworker urine samples and 95th percentile. SC&A concludes that the addition of a dose of 2.4 mrem for 1974 does not make a difference.

SC&A makes additional observations about the additional information and assessments provided in NIOSH's follow-on report but does not disagree with the conclusion that, for both 1973 and beyond, NIOSH can dose reconstruct tritium doses with sufficient accuracy.

5.0 OVERALL CONCLUSIONS

For 1973 tritium exposures, SC&A concludes that, if the new ICRP model had been used, as described in the consulting document posted for public comment on the ICRP website, or the model published by David Taylor (2003), the dose would be a little higher, i.e., 40 mrem to 50 mrem higher, depending on which dosimetric model is applied. As this dose is just assigned to one year, 1973, for non-monitored workers, the difference in dose estimated will not be substantive and will have negligible influence on the IREP probability of causation calculations.

For post-1973 tritium exposures, NIOSH concluded that the 95th percentile of the coworker study for 1974–1975 yielded doses much less than 1 mrem for everyone. SC&A supports NIOSH's conclusion that no workers experienced undetected exposures to tritium following the April 1973 incident that could have resulted in doses in excess of 1 mrem/yr. Using a worst case scenario, for 1974 the air sample results prior to August 30 had an average of 5,343 plus or minus 4,518 pCi/m^3 (page 19 of NIOSH 2015a). This gives a 95th percentile of about 15,000 pCi/m^3, assuming a normal distribution, or about 2.4 mrem/yr. Although NIOSH assumed zero doses for 1974–1975 based on coworker urine samples and application of a 95th percentile distribution, SC&A concludes that the conservative difference of a dose of 2.4 mrem for 1974 falls well within the range of uncertainty, and can be considered negligible under the circumstances.

SC&A makes additional observations about the additional information and assessments provided in NIOSH's follow-on report, but does not disagree with the conclusion that, for both 1973 and beyond, NIOSH can dose reconstruct tritium doses with sufficient accuracy.

6.0 REFERENCES

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APPENDIX A: COMPENDIUM OF AIRBORNE CONCENTRATION OF TRITIUM AT ROCKY FLATS BASED ON TRITIUM BUBBLER SAMPLES

Table A-1. 1974 Bubbler Tritium Sampling Data, Room Air Sampler – Room 452, Special Assembly Building 777, (Results >MDA) (SRDB Ref. ID 8790)

Analysis Date	Air Volume (m^3)	Sample Activity (pCi/sample)	Air Concentration (pCi/m^3)
3-Jun	5.94	56,000	9,427.6
5-Jun	5.94	72,000	12,121.2
4-Jun	5.94	121,000	20,370.3
7-Jun	5.94	35,000	5,892.2
6-Jun	5.94	96,000	16,498.3
14-Jun	5.94	32,000	5,387.2
13-Jun	6.15	28,000	4,552.8
12-Jun	6.15	16,000	12,357.7
11-Jun	6.37	89,000	13,971.7
11-Jun	6.15	67,000	10,894.3
21-Jun	5.52	24,000	4,347.8
20-Jun	6.15	28,000	4,552.8
19-Jun	6.57	29,000	4,414.0
18-Jun	4.67	21,000	5,781.5
11-Jun	6.15	42,000	6,829.2
26-Jun	5.09	23,000	4,518.6
2-Jul	6.37	22,000	3,453.6
1-Jul	2.76	12,000	4,347.8
27-Jun	6.15	33,000	5,365.6
27-Jun	6.15	28,000	4,552.8
8-Jul	5.94	23,000	3,872.0
5-Jul	5.94	18,000	3,030.3
3-Jul	5.37	25,000	4,655.5
10-Jul	6.15	16,000	2,601.6
9-Jul	6.37	16,000	2,511.7
11-Jul	6.15	28,000	4,552.8
17-Jul	5.09	107,000	21,021.6
16-Jul	6.15	31,000	5,040.6
15-Jul	5.34	36,000	6,741.5
19-Jul	6.15	31,000	5,040.6
18-Jul	5.94	25,000	4,208.7
24-Jul	5.94	6,000	1,010.1

Analysis Date	Air Volume (m^3)	Sample Activity (pCi/sample)	Air Concentration (pCi/m^3)
23-Jul	6.37	31,000	4,866.5
22-Jul	6.37	31,000	4,866.5
29-Jul	6.37	16,000	2,511.7
26-Jul	4.25	9,000	2,111.6
25-Jul	6.15	19,000	3,089.4
1-Aug	5.97	11,000	1,842.5
30-Jul	6.31	11,000	1,726.8
1-Aug	5.13	13,000	2,268.7
7-Aug	5.09	6,000	1,118.8
5-Aug	6.37	16,000	2,511.7
8-Aug	6.37	4,000	627.8
12-Aug	6.37	8,000	1,255.9
13-Aug	6.15	8,000	1,300.8
20-Aug	6.15	15,000	2,439.0
21-Aug	6.37	20,000	3,139.7
22-Aug	6.37	21,000	3,296.7
26-Aug	6.15	18,000	2,926.8
27-Aug	6.15	19,000	3,089.4
28-Aug	5.95	29,000	4,873.9
29-Aug	5.52	22,000	3,985.5
30-Aug	6.37	240,000,000	37,676,609.0
3-Sep	6.37	7.0E+06	1,098,901.1
4-Sep	6.37	54,000	8,477.2
5-Sep	5.09	26,000	5,108.0
9-Sep	5.94	18,000	3,030.3
10-Sep	6.37	20,000	3,139.7
11-Sep	5.52	16,000	2,898.5

From SRDB 8790, "Investigation of a Tritium Release Occurring in Building 777 on September 3–4, 1974."

SRDB 8790 states the following (PDF page 29):

> *Room Air Sampling*
>
> *Only one tritium room air sampler was installed In Building 777 at the time of the current tritium release problem. It is located in room 452 near the downdraft table entry to the Special Assembly Line.*
>
> *The applicable standard in plant Radio Concentration Guideline (RCG) Is 5 x 10 -6 µCi/ml. Examination of daily air sample records in room 457 shows results*

ranging from less than 1.0 x 10-3 µCi/m^3, except for samples dated August 30, (37.7 µCi/m^3) and September 3 (1.1 µCi/M3).

The record of room air samples from June 3 to present is included as Exhibit 13.

Room air samples are collected in a water bubbler sampler on the day shift only. Sampling time is from six to eight hours with sample flow rate at 2 liters/min. The 40 hour average for the week of August 26-30 was 7.4 µCi/m^3, or about 1.5 times the applicable RCG.

For the week of September 3-6 (Sept 2 Labor Day) the average tritium concentration was approx. 2.85 x 10^{-1} µCI/m^3 or about 6% of the RCG.

Investigation established that the September 3 sample was collected in the same flask that held the August 30 sample without the flask being washed between samples. Thus the second sample is considered suspect because it was contaminated. Further, during the week of September 9, tritium contamination surveys conducted throughout room 452 failed to show evidence of much tritium contamination (less than 1.0 x 10^{-3} µCi per smear).

Table A-2. 1977–1981 Bubbler Tritium Sampling Data (Excluding Exhaust and Glovebox Samplers) (SRDB Ref. ID 111095)

Building	Location (Room or ID)	Analysis Date	Analytical Result (pCi/m^3)
777	452 Downdraft	4/1/1977	≤ 60
777	Rm 452 Col J-23	4/1/1977	50
777	452 Downdraft	4/4/1977	—
777	Rm 452 Col J-23	4/4/1977	—
777	452 Downdraft	4/6/1977	60
777	Rm 452 Col J-23	4/6/1977	90
777	452 Downdraft	4/11/1977	10
777	Rm 452 Col J-23	4/11/1977	20
779A	Rm 154	1/3/1978	≤ 60
777	452 Downdraft	1/4/1978	20
777	Rm 452 Col J-23	1/4/1978	≤ 10
881	283	1/4/1978	≤ 10
779A	Rm 154	1/4/1978	≤ 90
771	181	1/5/1978	≤ 40
771	305	1/5/1978	≤ 20
771	Rm 146	1/5/1978	≤ 10
774	220	1/5/1978	≤ 20
777	452 Downdraft	1/6/1978	30
777	Rm 452 Col J-23	1/6/1978	40
881	283	1/6/1978	20
779A	Rm 154	1/6/1978	90
777	452 Downdraft	1/9/1978	≤ 40

Building	Location (Room or ID)	Analysis Date	Analytical Result (pCi/m^3)
777	Rm 452 Col J-23	1/9/1978	≤ 30
779A	Rm 154	1/9/1978	120
777	452 Downdraft	1/2/1979	60
777	Rm 452 Col J-23	1/2/1979	≤ 40
777	452 Downdraft	1/3/1979	80
771	181	1/4/1979	≤ 50
771	Rm 146	1/4/1979	≤ 50
771	Rm 174	1/4/1979	≤ 30
777	Rm 452 Col J-23	1/5/1979	60
779A	Rm 154	1/5/1979	170
374	First Floor	1/8/1979	≤ 80
559	102	1/8/1979	80
777	Rm 452 Col J-23	1/8/1979	≤ 40
779A	Rm 154	1/8/1979	≤ 120
374	First Floor	1/9/1979	≤ 50
779A	Rm 154	1/2/1980	≤ 70
779A	Rm 154	1/2/1980	100
777	Rm 452 Col J-23	1/4/1980	70
779A	Rm 154	1/4/1980	170
777	452 Downdraft	1/7/1980	≤ 50
777	Rm 452 Col J-23	1/7/1980	≤ 50
881	283	1/7/1980	≤ 50
779A	Rm 154	1/7/1980	≤ 120
777	430 K-15	1/9/1980	120
777	452 Downdraft	1/9/1980	150
777	Rm 452 Col J-23	1/9/1980	≤ 70
777	430 G-18	1/5/1981	80
777	452 Downdraft	1/5/1981	≤ 70
777	Rm 452 Col J-23	1/5/1981	≤ 80
881	283	1/5/1981	≤ 80
779A	Rm 154	1/5/1981	≤ 170
779A	Rm 154	1/5/1981	≤ 170
779A	Rm 154	1/5/1981	170
779A	Rm 154	1/5/1981	≤ 120
777	430 G-18	1/7/1981	1780
777	452 Downdraft	1/7/1981	440
777	Rm 452 Col J-23	1/7/1981	540
779A	Rm 154	1/7/1981	170
777	430 G-18	1/8/1981	7920
777	430 G-18	1/9/1981	1720
777	452 Downdraft	1/9/1981	510
777	Rm 452 Col J-23	1/9/1981	640
881	283	1/9/1981	≤ 80
779A	Rm 154	1/9/1981	90
777	430 G-18	1/12/1981	180

Building	Location (Room or ID)	Analysis Date	Analytical Result (pCi/m^3)
777	452 Downdraft	1/12/1981	≤ 40
777	Rm 452 Col J-23	1/12/1981	≤ 80
881	283	1/12/1981	≤ 60
779A	Rm 154	1/12/1981	≤ 120
771	Rm 146	12/16/1981	0
771	Rm 146	12/16/1981	0
771	Rm 149	12/16/1981	0
771	Rm 174	12/16/1981	0
777	430 G-18	12/16/1981	0
777	452 Downdraft	12/16/1981	90
777	Rm 452 Col J-23	12/16/1981	90
777	Rm 465	12/16/1981	-80
771	Rm 146	12/18/1981	0
771	Rm 149	12/18/1981	60
771	Rm 174	12/18/1981	-80
777	430 G-18	12/18/1981	0
777	452 Downdraft	12/18/1981	0
777	Rm 452 Col J-23	12/18/1981	-80
777	Rm 465	12/18/1981	80
881	225	12/18/1981	0
881	Rm 15	12/18/1981	0
771	Rm 146	12/22/1981	0
771	Rm 149	12/22/1981	0
771	Rm 174	12/22/1981	0
774	Rm 441	12/22/1981	0
777	430 G-18	12/22/1981	0
777	452 Downdraft	12/22/1981	0
777	Rm 452 Col J-23	12/22/1981	0
777	Rm 465	12/22/1981	0
779A	Rm 154	12/22/1981	60
771	Rm 146	12/23/1981	80
771	Rm 149	12/23/1981	0
771	Rm 174	12/23/1981	0
774	Rm 441	12/23/1981	80
777	430 G-18	12/23/1981	80
777	452 Downdraft	12/23/1981	0
777	Rm 452 Col J-23	12/23/1981	0
777	Rm 465	12/23/1981	0
881	Rm 15	12/23/1981	0
779A	Rm 154	12/23/1981	90

SRDB Ref. ID 118366 states the following:

> *On January 6 and 7, 1981, a release of tritium occurred in Building 777 to qlovebox exhaust Plenums 205 and 206, and subsequently to the environment. The release occurred from tritium contaminated materials that were returned to the glovebox system for part verification.*

SRDB 118366 also states:

> *From the room air H20 bubbler sample located at Glovebox 452, data indicated that one, or both, cans, when received at Glovebox 45l.on January 6, 1981, were leaking. This sample for the time period January 5 to January7 showed a concentration in the room air of 1720 pCi/m^3. This sample normally shows MDA (80 to 120 pCi/m^3).*

Table A-3. Building 777 Bubbler Tritium Sampling Data – January 5 to 12, 1981 (Excluding Exhaust and Glovebox Samplers)

Location (Room or ID)	Analysis Date	Analytical Result (pCi/m^3)
430 G-18	1/5/1981	80
452 Downdraft	1/5/1981	≤ 70
Rm 452 Col J-23	1/5/1981	≤ 80
430 G-18	1/7/1981	1780
452 Downdraft	1/7/1981	440
Rm 452 Col J-23	1/7/1981	540
430 G-18	1/8/1981	7920
430 G-18	1/9/1981	1720
452 Downdraft	1/9/1981	510
Rm 452 Col J-23	1/9/1981	640
430 G-18	1/12/1981	180
452 Downdraft	1/12/1981	≤ 40
Rm 452 Col J-23	1/12/1981	≤ 80

Source: SRDB Ref. ID 8790, Exhibit 13, pages 87–89: