SC&A S. Cohen & Associates
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May 18, 2007

Mr. David Staudt
Center for Disease Control and Prevention
Acquisition and Assistance Field Branch
Post Office Box 18070
626 Cochrans Mill Road – B-140
Pittsburgh, PA 15236-0295

Re: Contract No. 200-2004-03805, Task Order 5: Transmittal of a working draft, *Issues Connected to the Chapman Valve Exposure Matrix and the SEC Petition Evaluation Report*, SCA-SEC-TASK5-0054

Dear Mr. Staudt:

In accordance with direction provided by the Advisory Board at the full Board meeting held in Denver, Colorado, on May 2-4, 2007, SC&A's draft report (dated December 6, 2006) addressing the Chapman Valve SEC Petition and NIOSH's Evaluation Report has undergone Privacy Act (PA) review by CDC legal council and has been revised to remove any PA material. This is still a pre-decisional document, and has not been reviewed by the Board for factual accuracy or applicability within the requirements of 42 CFR 82.

Sincerely,

John Mauro, PhD, CHP
Project Manager

cc: P. Ziemer, PhD, Board Chairperson
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Project File (ANIOS/005/54)

Working Paper

Issues Connected to the Chapman Valve Exposure Matrix and the SEC Petition Evaluation Report

Contract No. 200-2004-03805
Task Order No. 5
SCA-SEC-TASK5-0054

Prepared by

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December 6, 2006

Disclaimer

This document is made available in accordance with the unanimous desire of the Advisory Board on Radiation and Worker Health (ABRWH) to maintain all possible openness in its deliberations. However, the ABRWH and its contractor, SC&A, caution the reader that at the time of its release, this report is pre-decisional and has not been reviewed by the Board for factual accuracy or applicability within the requirements of 42 CFR 82. This implies that once reviewed by the ABRWH, the Board's position may differ from the report's conclusions. Thus, the reader should be cautioned that this report is for information only and that premature interpretations regarding its conclusions are unwarranted.

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

During the meeting of the Advisory Board on Radiation and Worker Health (the Board) held in Las Vegas, Nevada, on September 19–21, 2006, S. Cohen & Associates (SC&A, Inc.) was directed by the Board to perform a review of the Chapman Valve Special Exposure Cohort (SEC) Petition (Chapman Valve 2005), which was qualified on November 9, 2005, and the NIOSH SEC Petition Evaluation Report (ORAUT 2006a), which was submitted to the Board on August 8, 2006. The purpose of this report is to provide the Board with an independent technical review of the issues raised by the petitioners and NIOSH's position regarding these issues as presented in the evaluation report.

The scope of the review includes each issue raised by the petitioners and the technical basis of NIOSH's position regarding each issue. Particular attention is given to the degree to which the available worker bioassay data are representative of the exposures experienced by the worker population, and the raw data and records that were used by NIOSH to determine that "the available monitoring records, process descriptions, and source term data are sufficient to either (1) estimate the maximum internal radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the internal radiation doses to members of the class more precisely than a maximum dose estimate."[1]

1.2 OBJECTIVE

The objective of this report is to provide the Board with complete and accurate technical information and evaluations regarding each of the issues raised in the Chapman Valve SEC Petition and NIOSH's evaluations of these issues. This report is designed to be used by the Board as part of the basis for determining whether radiation doses can be estimated with sufficient accuracy based on the following criteria:

> *Radiation doses can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class, or if NIOSH has established that it has access to sufficient information to estimate the radiation doses of members of the class more precisely than an estimate of the maximum radiation dose [42CFR83.13(c)(1)].*

1.3 TECHNICAL APPROACH

The approach used by SC&A to perform this review follows the procedures described in the draft report prepared by SC&A entitled *Board Procedures for Review of Special Exposure Cohort Petitions and Petition Evaluation Reports*, Revision 1 (SCA-TR-TASK5-0002, June 12,

[1] See Section 7.5 of the SEC Petition Evaluation Report (ORAUT 2006a).

2006) and the *Report to the Working Group on Special Exposure Cohort Petition Review* (Draft January 16, 2006). The latter is a set of draft guidelines prepared by a Board-designated working group for evaluation of SEC petitions performed by NIOSH and the Board. The former is a draft set of procedures prepared by SC&A for the Board and approved by the Board for use by SC&A on an interim basis (Advisory Board meeting transcript of June 16, 2006, p. 132). The procedures are designed to help ensure compliance with Title 42, Part 83, of the *Code of Federal Regulations* (42 CFR 83) and implement the guidelines provided in the report of the working group.

The key considerations identified in the report of the working group include the following:

(1) Timeliness

(2) Fairness

(3) Understandability

(4) Consistency

(5) Credibility and validity of the data set, including pedigree of the data, methods used to acquire the data, relationship to other sources of information, and internal consistency

(6) Representativeness and completeness of the exposure data with respect to the area of the facility, the time period of exposure, the types of workers and processes covered by the data

The working group guidelines also recommend that NIOSH include in their SEC evaluations a demonstration that it is feasible to reconstruct individual doses for the cohort, including sample dose reconstructions.

The specific steps that SC&A is implementing in performing its review include the following:

(1) Gathering and critically reviewing all documents and data sets cited by the petitioners and in the NIOSH evaluation report

(2) Meeting with former workers at Chapman Valve and petitioners to gain a richer understanding of the operations and incidents that took place during the time period covered by the petition, and to identify any additional records and data that may be pertinent to the review

(3) Preparing a draft position on each of the issues identified by the petitioners and the conclusions drawn by NIOSH in its evaluation report regarding each of these issues

(4) Identifying any new issues that emerged during review of the issues

(5) Discussing our draft position on each issue with the working group, the authors of the evaluation report, interested members of the public, and petitioners in order to ensure that our understanding of the issues and NIOSH's position regarding the issues is complete and correct

(6) Preparing and submitting our draft report to NIOSH and the Board, which includes an independent quality assurance evaluation of the issues

This document is a draft report for use in support of step 5 in the above-described process. It is our expectation that following discussion of this draft with the Working Group and NIOSH, parts of this report may be revised and resubmitted to NIOSH and the Board as our formal draft deliverable under this task order.

1.4 ORGANIZATION OF THE REPORT

Following this introduction, Section 2 of this report presents a review of the Chapman Valve site profile (ORAUT 2006b)[2] insofar as it is necessary to evaluate NIOSH's SEC Evaluation Report. The site profile presents the data and technical approach used by NIOSH for performing all dose reconstructions for Chapman Valve workers. An understanding of the strengths and limitations of the site profile (which is also referred to as the exposure matrix) will help in evaluating the issues raised by the petitioners and NIOSH's position regarding these issues as provided in the evaluation report.[3] Though Section 2 is not considered a formal site profile review as defined under Task Order 1 of SC&A's contract, it does contain a thorough review of the site profile as it relates to 42 CFR 83.

Section 3 of this report presents a summary of each issue raised by the petitioner and NIOSH's evaluation of each issue. This is followed by SC&A's evaluation of NIOSH's position regarding each issue. SC&A's evaluations of the issues draw heavily from Section 2.

Section 4 of this report discusses the degree to which the evaluation report meets the guidelines presented in the draft working group report. SC&A identifies a number of issues that we believe NIOSH should act upon in order to be more fully responsive to the issues raised by the petitioners.

The report includes several attachments, including an independent analysis of the issues prepared by Dr. Michael Thorne, a summary of worker interviews performed by SC&A on November 28, 2006, and an analysis matrix for internal exposures. This attachment presents a series of calculations that demonstrate how the uranium concentrations in urine change as a function of time following acute exposures to airborne uranium. Finally, two attachments are provided that address plausible upper-bound dust loadings.

The report does not conclude with a finding regarding whether or not NIOSH can reconstruct doses with sufficient accuracy. Instead, this report identifies a number of weaknesses in the exposure matrix and the evaluation report that we believe need to be addressed by NIOSH before such a determination can be made. We did not uncover any basic flaws in the exposure matrix or supporting data that clearly and unambiguously result in a determination that doses with sufficient accuracy cannot be reconstructed. In the main, we have identified gaps in the data and the exposure matrix.

[2] In this report, the terms 'site profile,' 'TBD,' and 'exposure matrix' are used interchangeably.

[3] SC&A's investigations of the Chapman Valve SEC petition and NIOSH's evaluation report began with a review of Revision 0 of the Chapman Valve exposure matrix. On October 17, 2006, SC&A received Revision 1 of the exposure matrix (dated October 16, 2006). This report includes a comprehensive review of Revision 1 of the exposure matrix and its supporting material.

2.0 REVIEW OF THE SITE PROFILE (EXPOSURE MATRIX)

On February 22, 2005, NIOSH published *Technical Basis Document: Basis for the Development of an Exposure Matrix for Chapman Valve Manufacturing, Indian Orchard, Massachusetts, Period of Operation: January 4, 1948 through April 30, 1949*. This document was used as the basis for reconstructing all doses for workers at Chapman Valve until it was replaced by Revision 1, dated October 16, 2006. It is important to note that Revision 0 of the site profile is referenced extensively in NIOSH's evaluation report. As such, a critical evaluation of this report and its revision is prerequisite to a review of the SEC petition and NIOSH's evaluation report.

The review of Revision 1 of the site profile is divided into sections corresponding to the major sections that comprise the site profile, including the following:

- Introductory and general background information pertaining to the facility (i.e., Sections 1 and 2 of the site profile)
- Estimation of Internal Dose (January 1, 1948, through December 31, 1949) (Section 3 of the site profile)
- External Exposures During Operations (January 1, 1948, through December 31, 1949) (Section 4 of the site profile)
- Residual Exposure (May 1, 1949, through December 31, 1993) (Section 5 of the site profile)

2.1 INTRODUCTORY AND GENERAL BACKGROUND INFORMATION PERTAINING TO THE FACILITY

Site Description

The site description provides information that is directly relevant to the petition. Specifically, the site profile states the following:

(1) AEC-contracted uranium work extended from January 1, 1948, through April 30, 1949.

(2) The post-operational residual contamination period extended from May 1, 1949, through December 31, 1993.

(3) The decontamination (remediation) period occurred in 1994 and 1995, but is not addressed in the site profile.

(4) Worker exposures during the documented period of AEC work appear to have been limited to natural uranium metal, metal oxides, and natural uranium's short-lived progeny. There was a dust sample taken during the decommissioning period that reportedly indicated 2.16% uranium enrichment. There was also a soil sample indicating slightly enriched uranium. These are discussed below.

(5) Uranium operations and attendant exposures were limited to a portion of Building 23 at the facility, which was partitioned off and measured approximately 200 feet long by 60 feet wide by 50 feet high.

Source Term and Process Description

The statements made in this section of the site profile that are especially relevant to the petition are as follows:

(1) During the AEC-contract period, Chapman Valve machined uranium metal from January to November 1948, and preparations for health and safety programs began in November 1947.

(2) Uranium rods were shipped to Chapman Valve on January 9, 1948. Actual production operations (machining of uranium rods) began in May 1948 and continued until November 1948.

(3) A "chip burner," also called a "chip incinerator" was operated in 1948. There was also a "cracking furnace." It is unclear whether this was a term used for the chip burner or whether there was a separate furnace by that designation. SC&A interviews indicate that the latter might be the case (see Attachment 2).

(4) All uranium materials and scrap were sent offsite by January 1, 1949.

(5) Pure natural uranium metal rods were shipped to Chapman Valve by rail. The rods were cut by mechanical saw, and then machined to the desired shape.

(6) There is some question whether Chapman Valve ever rolled uranium rods.

(7) Final shipment of all metal scrap, sweepings, oxides, etc., may not have been shipped offsite until April 1949.

(8) Access to AEC-contracted operations was controlled, workers were given specific job designations, and duration of work in controlled areas by each worker was recorded. In general, workers involved in these operations were assigned film badges; some were monitored under a bioassay program.

Incinerator Information

The statements made in this section of the site profile that are especially relevant to the petition are as follows:

(1) A furnace was used to oxidize uranium chips and turnings, and it was located in Building 23.

(2) Elevated levels of uranium residue were found near a window where the furnace exhaust had been located.

Safety

The statements made in this section of the site profile that are especially relevant to the petition are as follows:

(1) A radiation protection program was implemented at Chapman Valve for workers that entered the controlled area in Building 23. White coveralls were worn in controlled areas

and removed at the end of the day. Workers were required to shower at the end of each workday. Radiation surveys were performed using Geiger counters. Floors were swept every night. All workers were issued film badges worn on the chest. Also, self-reading pocket dosimeters were employed.

(2) Air-sampling data during operations at Chapman Valve are sparse; the data appear to be limited to air samples collected on May 4 and May 24, 1948.

(3) Wipe samples during operations are also sparse; they are limited to 3 samples collected on March 19, 1948. The results were 8 cpm for the cracking furnace and 300 cpm for the centerless grinder. These samples may have been taken prior to the startup of production operations, during the test phase.

Incidents

The statements made in this section of the site profile that are especially relevant to the petition are as follows:

(1) A fire involving uranium occurred some time prior to June 11, 1948, at which time urine samples were collected from workers who put out the fire and cleaned up following the fire. However, the exact date of the fire is not known; it appears that it occurred in early June.

(2) An explosion occurred, which killed a worker and destroyed a portion of the building. This explosion appears to have occurred before the start of AEC operations and did not involve any radioactive materials.

(3) It is conceivable that numerous small fires occurred, based on experience at other uranium machining facilities.

Physical Examinations/X-Rays

The site profile states that NIOSH was unable to locate any information regarding whether employees were required to have periodic physical examinations or x-rays. If, in fact, workers were required to receive pre-employment and annual x-rays or fluoroscopic examinations (which were often used at AEC contractor facilities at that time), SC&A believes that the external exposures could have been significant; on the order of 3 rem per fluoroscopic examination (see ORAUT-OTIB-0006 (ORAUT 2005b)). However, we do not believe this is an SEC issue, since a plausible upper bound on employment-related x-ray exposures could be assigned to workers at the facility.

Cleanup/Residual Contamination Period

The statements made in this section of the site profile that are especially relevant to the petition are as follows:

(1) A worker recalled being involved in a post-operational cleanup program that included removal of equipment, washing down areas, removing concrete and bricks, and adding new flooring.

(2) Chapman Valve continued non-radiological operations following the termination of the AEC contract and offsite shipment of residual uranium scrap in early 1949.

(3) All operations at the building that was formerly used for AEC operations ceased in August 1987, and it remained vacant. However, the building was not closed until December 31, 1993.

(4) Site decontamination took place in 1994 and 1995.

(5) Records that might be useful for characterizing residual uranium contamination in Building 23 following the termination of AEC operations were destroyed in the 1970s.

(6) Elevated levels of contamination were found in the early 1990s as part of Formerly Utilized Site Remedial Action Program (FUSRAP).

SC&A Confirmation of Selected Key Statements and Assumptions Listed Above

The statements summarized above were evaluated by a review of the references cited in the site profile and interviews with site experts. In general, we have found these statements and assumptions to be an accurate characterization of the available source documents. However, worker interviews indicate that there may have been gaps in the badging of workers involved in uranium operations (see below). The following presents a summary of some of the key source documents that SC&A reviewed to confirm these statements.

Mr. Charles D. Young, Project Engineer, Government Support Directorate, Architecture Planning and Technology Division of the Aerospace Corporation, sent a letter to Mr. Andrew Wallo III, Division of Facility and Site Decommissioning Projects of the Department of Energy (Young 1987). The letter recommends a site visit to the former Chapman Valve Company plant to meet with Mr. Paul R. Hundt of Crane Company. Attached to the letter is a memo to file that contains information pertinent to Chapman Valve based on a telephone conversation between Mr. Young's office and Mr. Hundt. Also attached to the letter is information assembled by Mr. Young to be used to facilitate preparation of a letter to the Crane Company requesting additional information regarding Chapman Valve. Inspection of that material confirms much of the information and assumptions adopted in the exposure matrix regarding types of activities that took place at Chapman Valve and the dates that those activities took place. Of particular relevance is the radiological history of the facility, which describes the facility's radiation protection program and information characterizing the fire that appears to have taken place in early June 1948.

Also of particular relevance to the assumptions used in the exposure matrix is a letter sent to Mr. James Fiore from Thomas J. Ungerland dated December 14, 1987 (Ungerland 1987). The letter was transmitted by Mr. Ungerland to Mr. Fiore in response to a DOE inquiry regarding Chapman Valve records pertinent to dose reconstruction. The letter indicates that records pertaining to Chapman Valve for the time periods of interest were destroyed, but pertinent information was available in an affidavit filed by a long service employee of Crane, which took ownership of Chapman Valve in 1959.

In summary, the employee worked at Chapman Valve from 1947–1948. Among other statements, the employee conformed that in 1947, Chapman Valve set aside a restricted area,

which was about one-third of Department 40, in order to machine uranium rods on behalf of Brookhaven National Laboratory (BNL). The affidavit states that the employee visited the facility daily when it initially was set aside, and thereafter visited several times a month to perform a variety of services. He stated that access to the restricted area was under the control of a guard. Upon access, workmen would remove their clothing, replace them with white coveralls, and then enter the manufacturing area.

He further stated that rods were brought in by a rail car on tracks that ran adjacent to the building. The rods were cut by a mechanical saw and machined to the shape requested by the customer. Every night the floors were carefully swept and the cuttings were placed in drums. The drums were disposed of by BNL periodically and at the end of the contract period, which he believed was the end of 1948.

He further states that workers wore radioactivity-sensitive badges on their uniforms, and periodically inspectors would pass through the site carrying Geiger counters. The affidavit cites one occasion when there was a fire that he believed was related to the highly volatile nature of the rods being machined.

The affidavit further states that, upon completion of each workday, the employees would return to the dressing room and remove their white coveralls, and were required to take a shower.

The affidavit states that when all work was completed at the end of 1948, the equipment and machinery used in the program were removed, along with wood block floors. It is worth noting that the employee's reference to wood block floors indicates that, like many other industrial facilities, wood blocks were used as flooring. These blocks are typically about 3 in by 6 in and 1.5 in thick (Kaswell 2006). Removal of the wood blocks and the machining equipment following AEC operations would have likely been effective in decontaminating the facility to a large extent. However, as is apparent from the radiological surveys performed in support of site characterization and cleanup as part of the FUSRAP and reported by Oak Ridge National Laboratory (ORNL 1992), large portions of the site contained low levels of residual radioactivity that required cleanup under the cleanup standards adopted by the FUSRAP.

Any uranium cuttings that were still onsite were set aside and later removed. After that, the premises were washed down and the wash water collected and placed in 55-gallon drums. After cleanup, an inspector surveyed the area with a Geiger counter. The inspector often required the area to be rewashed several additional times. The employee visited the site in 1987, while it was still standing. He stated that the walls were painted and the wood partition that was used to isolate the controlled area had been removed.

Other records that SC&A reviewed that are pertinent to the various assumptions and statements made by NIOSH in the exposure matrix include a monthly report by B.S. Wolf, MD, Medical Director, which indicates that on November 24, 1947, a meeting was held, that included Dr. Merrill Eisenbud, to help set up the radiation protection program for Chapman Valve. An activity report for the week of February 26 to March 3, 1948, reveals that a thorough study of the hazards of uranium machining operations at Chapman Valve was begun by Mr. Harris. This study is relevant because it might indicate that subsequent uranium machining operations at

Chapman Valve took advantage of Mr. Harris' experience in these matters. This experience, and the types of controls recommended by Mr. Harris for such operations, are described in Harris and Kingsley (1959). The literature reviewed by SC&A does not provide information regarding the types or extent of dust suppression techniques that were employed. However, based on conversations with former Chapman Valve workers, SC&A was able to determine that (1) the machining operations did not use localized ventilation systems to reduce the dispersal of uranium dust during operations, (2) lathe operators did not wear face shields or gloves, (3) the floors did not have grids that would have helped to reduce the buildup of uranium dust in the vicinity of the machining operations, (4) water-based coolant was used to cool the cutting edge of the lathe; however, large amounts of sparks were nevertheless generated during the lathing operations, and (5) a person was assigned to clean up the dust and turning at the end of every day, and he wore gloves.

Also, the BNL web site contains historical information regarding the Graphite Research Reactor (BNL 2006). A key statement made on that web site is as follows: "Originally, the BGRR was fueled with natural uranium, but, in 1958, a new kind of fuel was introduced that used uranium enriched in the normally rare U-235."

These statements are important primarily because they would tend to support the premise that there was a radiation protection program, operations were limited to machining uranium rods for BNL, the rods did not include enriched uranium, and there was only one fire that caught the attention of the employee that filed the affidavit.

We also reviewed a radiological survey report prepared in July 1992 titled *Results of the Radiological Survey at the Former Chapman Valve Manufacturing Company, in Indian Orchard, Massachusetts* (C1O001) by R.D. Foley and M.S. Uziel (ORNL 1992). The survey was performed as part of the FUSRAP. Some of the important findings in that report are that low levels of residual uranium contamination were found. However, there were no elevated levels of Ra-226 or Th-232 found, which conforms to the NIOSH position that uranium ores or concentrates were not handled at the site. One outdoor dust sample revealed what appeared to be uranium enriched in U-235 to 2.16% uranium. A soil sample taken in 1997 near this location indicated slightly enriched uranium (~1 %), though the TBD states that the sample is "consistent with unenriched uranium." While it is possible that possible interference of the 186-KeV radium-226 photon may interfere with the reliability of the U-235 measurement, the finding of enriched uranium in this sample is consistent with the 2.16% enriched dust sample. The implications of these findings are discussed later in this report.

To date, we have found the key statements and assumptions used in the exposure matrix, as summarized above, to be a generally accurate characterization of the information available in source documents. However, the following excerpt from ORNL 1992 is worth noting:

> *The Chapman Valve Manufacturing Company in Indian Orchard, Massachusetts, was one of many companies performing work associated with the development of nuclear energy for defense-related projects during the 1940s. This work, conducted under government contract to the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC), included the procurement, storage,*

and processing of uranium oxides, salts, and metals, and the subsequent machining of these products. As a result of these activities, equipment, buildings, and land at some of the sites became radiologically contaminated resulting in low levels of contamination on the properties. At contract termination, sites used by contractors were decontaminated in accordance with the standards and survey methods in use at that time. Since the original assessments, radiological criteria and guidelines for the release of such sites for unrestricted use have become more stringent. In some instances, records documenting decontamination efforts cannot be found, and the final radiological conditions of the site cannot be adequately determined. As a result, the Formerly Utilized Sites Remedial Action Program (FUSRAP) was established in 1974 to identify these formerly used sites and to reevaluate their radiological status.[1]

The radiological survey detailed in this report was performed under the FUSRAP program at the site of the former Chapman Valve Manufacturing Company. Chapman Valve was a principal supplier of regular and special valves and manifolds for the MED and the AEC. Records also indicate that Chapman Valve, under contract with Brookhaven Laboratory, machined uranium metal during the period January through November 1948. In a letter dated January 9, 1948, shipment of approximately 26 tons of extruded rods was directed to a Chapman Valve facility in Indian Orchard, Massachusetts. Machining operations may not have started until May 1948. One AEC memorandum indicates that Chapman Valve may also have conducted rolling operations on the uranium metal. The health and safety program for this work at the Chapman Valve facility was set up by the AEC.[2]

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[1] *U. S. Department of Energy, A Background Report for the Formerly Utilized Manhattan Engineer District/Atomic Energy Commission Sites Program, DOE/EV-0097, September 1980.*

[2] *Historical information on Crane Company (Former Chapman Valve Manufacturing Company), 203 Hampshire Street, Indian Orchard, Massachusetts, compiled by Roy E Weston, Inc., for Division of Off-Site Programs, Office of Eastern Area Programs, Office of Environmental Restoration, U.S. Department of Energy, Washington, DC, 2 pp. (no date).*

Neither of the documents cited appear to be on the Site Query database. The ORNL document also states that Chapman had "uranium oxides, salts, and metals," while the site profile considers only metals. This raises the question of whether materials were sent to Chapman during World War II.

These references might be significant because they provide evidence that Chapman was under contract to the Manhattan Engineer District during World War II to supply valves. Further, the official history of the Manhattan Project states that in early 1943 "the Chapman Valve Manufacturing Company accepted an order [from General Groves] for the hundreds of precision vacuum valves" needed for the electromagnetic enrichment plant (the Y-12 Plant) that was to be built in Oak Ridge, Tennessee (Hewlett and Anderson, 1990, p. 149). Finally, SC&A interviews with former workers indicated that Chapman Valve received large manifolds from Oak Ridge for maintenance and repair in the 1943-1945 period. While this repair was not done on the main Chapman Valve site where the enriched uranium samples were found, it was first shipped to the main site by rail. From there it was taken to the repair facility on Dean Street (see

Attachment 2). The dust sample and soil sample indicating enriched uranium may be especially significant in this context.

ORNL (1992) provides only U-238 measurements, but it is a pretty contemporaneous report. The TBD has made no effort to try to secure the underlying data. There must have been measurements of U-235 and possibly U-234 to conclude that one dust sample was enriched to 2.16%. The TBD is correct in stating that NIOSH has looked at the range of possible enrichments.

SC&A currently does not know whether the lower bound of enrichment for this dust sample was natural or something more or something less than that. However, a soil sample indicates the need for further consideration of this issue.

The TBD also cites a soil sample taken in 1996 just north of the chip burner. This sample had measurements for both U-238 (14 +/- 1 pCi/g) and U-235 (1 +/- 0.07 pCi/g). The TBD states that this is "consistent with unenriched uranium." However, the central value represents slightly enriched uranium (about 1.1%), and a lower confidence bound for the enrichment derived by using the 5 percentile value for U-235 and the 95 percentile value for U-238 also indicates enriched uranium (nearly 0.9% U-235). The estimate of enrichment would be slightly higher once natural background values for U-238 and U-235 are subtracted from the measurements. Further, while this enrichment is slight, it appears to be statistically significant, based on the data provided.[4] Finally, since it was taken decades after work with uranium was done at the site, the dilution of the original enrichment, for instance by deposition of fresh dust and soil, would mean that the originally deposited uranium was of higher enrichment. Of course, the problem for analysis of the overall situation is that only one dust sample and one soil sample indicate enriched uranium and the enrichment is slight. However, this may be consistent with the statement of a former employee that the manifolds were only trans-shipped from the main Chapman Valve plant site (on Pinevale Street) to the Dean Street site.

Given the evidence of the dust sample, the soil sample, and the contracts with MED during WWII, it is difficult to dismiss the enrichment issue without further investigation. In addition, some consideration must be given to the DOE document that states that salts and oxides were received at Chapman. Finally, the SC&A interviews indicate that the equipment that may have resulted in the contamination of the site with enriched uranium was brought there in the 1943 to early 1946 period. Sampling of the Dean Street facility is indicated, if it has not already been done.

All this indicates that it is appropriate to assume the use natural uranium for the period under consideration, since there is no evidence that anything other than natural uranium was processed then. Chapman Valve supplied uranium to BNL in this period, most likely for its graphite research reactor, which used natural uranium fuel until 1958.[5] But since the data in the TBD raise the enrichment question, we are obliged to discuss its implications, in that it raises the question of some other period of processing at Chapman that cannot be settled without further investigation. Due to the dilution of dust and soil over time, the issue cannot be satisfactorily

[4] In its calculations, SC&A assumed that the uncertainties cited were one-sigma.
[5] Brookhaven Graphite Research Reactor, on the web at http://www.bnl.gov/bnlweb/history/BGRR.asp.

settled by simply assuming a 2.16% enrichment of uranium during the 1948–1949 period under review here.[6] On the one hand, it would appear to give too large a dose to the 1948–1949 workers, for whom there is no evidence of work with enriched uranium. On the other hand, it may deprive other workers of due consideration if enriched uranium was handled during some other period. For the present, SC&A has treated further investigation of enriched uranium as beyond the scope of this review, because it may involve activities outside the periods under consideration.

2.2 ESTIMATION OF INTERNAL DOSE (JANUARY 1, 1948, THROUGH APRIL 30, 1949)

The methods currently being used by NIOSH to reconstruct the internal doses to all workers at Chapman Valve are described in Section 3 of Revision 1 of the exposure matrix. This section presents a critical review of that section of the exposure matrix.

The petition evaluation report covers three time periods; January 1, 1948, through April 30, 1949 (operation period), and the two periods for residual radioactivity exposure of May 1, 1949 to December 31, 1949, and January 1, 1991 through December 31, 1993. NIOSH has reserved the evaluation of the decommissioning period, 1994–1995, on the grounds that a preliminary evaluation indicated that the contractor (Bechtel National Inc.) carried out a full radiation protection program, so that data for dose reconstruction are likely to be available.

The data, assumptions, and methods used by NIOSH to reconstruct the internal doses to workers during the operational period and the residual radioactivity periods are markedly different. As a result, our review of data, methodologies, and assumptions employed by NIOSH for dose reconstruction is divided into these two separate time periods. This section addresses the earlier time period.

A fundamental premise upon which the exposure matrix is based for this time period is that the internal exposures experienced by Chapman Valve workers were limited to the inhalation and inadvertent ingestion of uranium and/or uranium oxide dust produced as a result of routine handling, sawing, and machining natural uranium rods, and that the rods did not contain any recycled uranium or enriched uranium. In addition, workers were exposed to uranium aerosols produced by uranium fires and the burning of uranium turnings, chips, and dust (produced during the rod processing operations) in a furnace located in Building 23.

Given these boundary conditions, which we generally verified as part of our investigations reported above in Section 2 (with the qualifications regarding possible AWE activities performed during World War II), the exposure matrix proceeds to describe the data, assumptions, and models used to estimate the internal exposures experienced by all workers. Data presented in the site profile that are relied upon most heavily as the basis for the exposure matrix are 40 urine bioassay samples that were collected from 37 of the approximate 100 workers. The urine

[6] SC&A has determined that, if one were to assume exposures were to 2.16% enriched uranium instead of 683 pCi U/mg, the conversion factor would be about 1,375 pCi/mg. The implications are that the uranium intakes and associated doses would approximately double.

samples were collected on 4 separate occasions during the time period covered by the petition. Table 2-1, reproduced directly from Table 1 of Revision 0 of the exposure matrix,[7] summarizes the bioassay data that serve as the cornerstone of the exposure matrix.

Table 2-1. Bioassay Results from Coworker Data
(Excerpted from Table 1 of Revision 0 of the exposure matrix, ORAUT 2005a)

Bioassay Date	Median Bioassay (pCi/day)	84th Bioassay (pCi/day)
6/11/1948[a]	16.7	54.6
7/27/1948[b]	7.43	11.3
9/8/1948[c]	9.56	9.56
10/7/1948[d]	9.56	9.56

a. The 7 results were log transformed and fit to a line, from which a geometric mean (GM) and geometric standard deviation (GSD) were calculated.
b. The 22 results were log transformed and fit to a line, from which a GM and GSD were calculated.
c. Five of the 6 results were reported as 0.01 mg/L and 1 was reported as <0.01 mg/L. The GM and the 84th percentile were assumed to be 0.01 mg/L.
d. Two of the 5 results were reported as 0.01 mg/L and 3 were reported as <0.01 mg/L. The GM and the 84th percentile were assumed to be 0.01 mg/L.

The first step in our review of the exposure matrix is to confirm that Table 2-1 is a realistic, if not conservative, interpretation of the raw data used to derive these results.

The controlled document list on the NIOSH server provides the original data sheets that were used to develop this table. These data sheets provide the dates when the urine samples were collected, the names of each person, and their job responsibilities. Table 2-2 presents a compilation of the original data, with the names of the individual removed (and replaced by a number) for Privacy Act reasons.

Table 2-2. Original Urine Bioassay Data

Number	Day Collected	As Reported mg U/l	LOD Adj. mg/l	pCi/day Excreted in Urine*
1	6/11/1948	0	0.01	9.56
2	6/11/1948	0	0.01	9.56
3	6/11/1948	0.01	0.01	9.56
4	6/11/1948	0.02	0.02	19.1
5	6/11/1948	0.02	0.02	19.1
6	6/11/1948	0.07	0.07	66.9
7	6/11/1948	0.08	0.08	76.5
8	7/26/1948	0	0.01	9.56
9	7/27/1948	0	0.01	9.56

[7] During the process of preparing this report, NIOSH issued Revision 1 of the exposure matrix. We found that some of the information provided in Revision 0 was useful in our investigations. Hence, this review makes use of some of the material provided in Revision 0, but the review focuses entirely on Revision 1 in so far as the dose reconstruction procedure suggested by NIOSH is concerned.

Table 2-2. Original Urine Bioassay Data

Number	Day Collected	As Reported mg U/l	LOD Adj. mg/l	pCi/day Excreted in Urine*
10	7/27/1948	0	0.01	9.56
11	7/27/1948	0	0.01	9.56
12	7/27/1948	0	0.01	9.56
13	7/27/1948	0	0.01	9.56
14	7/27/1948	0	0.01	9.56
15	7/27/1948	0	0.01	9.56
16	7/27/1948	0	0.01	9.56
17	7/27/1948	0	0.01	9.56
18	7/27/1948	0	0.01	9.56
19	7/27/1948	0	0.01	9.56
20	7/27/1948	0.01	0.01	9.56
21	7/27/1948	0.01	0.01	9.56
22	7/27/2948	0.01	0.01	9.56
23	7/27/1948	0.01	0.01	9.56
24	7/27/1948	0.01	0.01	9.56
25	7/27/1948	0.01	0.01	9.56
26	7/27/1948	0.01	0.01	9.56
27	7/27/1948	0.01	0.01	9.56
28	7/27/1948	0.01	0.01	9.56
29	7/27/1948	0.03	0.03	28.7
30	9/9/1948	0	0.01	9.56
31	9/8/1948	0.01	0.01	9.56
32	9/8/1948	0.01	0.01	9.56
33	9/8/1948	0.01	0.01	9.56
34	9/9/1948	0.01	0.01	9.56
35	9/9/1948	0.01	0.01	9.56
36	10/7/1948	0	0.01	9.56
37	10/7/1948	0	0.01	9.56
38	10/7/1948	0	0.01	9.56
39	10/7/1948	0.01	0.01	9.56
40	10/7/1948	0.01	0.01	9.56

* The values in this column are not in the records, but were derived by the author of this report by multiplying the values in column 4 by 682.96 pCi U/mg U and by 1.4 liters of urine excreted per day.

In order to convert the results of the urine analysis expressed in mg U/L to pCi/d, as reported in Table 2-1 above, NIOSH used a conversion factor (or specific activity) of 682.96 pCi U per mg U, and a urine excretion rate of 1.4 L/day. These conversion factors were checked and found to be correct. However, it is worth noting that the 84th percentile values for September 8, 1948, and October 7, 1948, are somewhat misleading. Since all the measurements made on these dates had values at or below the limit of detection (LOD) (0.01 mg/l), this table implies that the probability

that anyone could have had uranium excretion rates in urine on those days in excess of 9.56 pCi/day is zero. We will discuss this issue later.

As a check on the values listed in Table 2-1, we processed the data in the same manner used by NIOSH and obtained the following results:

Table 2-3. Independent Check on Table 2-1 (Uranium Urinary Excretion Rates)

Bioassay Date	Median (pCi/day)	84th Bioassay (pCi/day)	GSD	95th Percentile (pCi/day)
6/11/1948	16.53	54.08	3.37	116.2
7/27/1948	7.43	11.32	1.52	14.84
9/8/1948[a]	9.56	9.56	1	9.56
10/7/1948[a]	9.56	9.56	1	9.56
All Data	7.98	16.6	2.08	26.63

a. These values are not amenable to a statistical analysis since all reported values were the same.

Our analysis duplicates the values reported by NIOSH in the exposure matrix. Note that in Table 2-3, we included the 95th percentile values for each sampling period and for the roll-up of all the data. The roll-up of all the data may be considered pertinent if one assumes that the exposures at the facility were entirely stochastic. By "stochastic" we mean that any worker could have been exposed to elevated levels of airborne uranium, whether from machining/turning operations, chip fires, or chip burning. The implications of such an assumption would mean that the 40 urine samples could be considered random samples from the entire worker population.

If this "model" is judged to be representative of the operating conditions at the facility, then it could be argued that a claimant-favorable strategy for reconstructing the doses to the unmonitored workers should employ the upper 95th percentile value observed in the population of monitored workers. This strategy may be considered appropriate for all workers, including monitored workers, since, with only a few exceptions, only one urine sample was taken from each of the monitored workers in either June, July, September, or October. This means that we really do not know the exposures experienced by any of the monitored workers after their urine samples were collected. In light of this, using the upper 95th percentile for all workers might help to ameliorate this limitation in the bioassay data. Coincidentally, as discussed below, NIOSH elected to assume that all workers were chronically exposed to airborne uranium that is associated with 0.03 mg/L of urine. This translates to a chronic uranium excretion rate of 28.7 pCi/day (see Table 3-1 of Revision 1 of the exposure matrix). Hence, as can be seen in Table 2-3, NIOSH has effectively adopted the upper 95th percentile of all bioassay data as the default chronic exposure conditions, including the data associated with exposures to the fire. One caveat related to this observation is that the bioassay data presented in Table 2-2 do not appear to contain any samples from workers involved in loading and unloading the chip burner (although it is possible that some of the workers listed did, in fact, perform this function). As discussed later in this report, that activity has been found in other investigations to have a very high potential for internal exposure in at least some circumstances. Hence, we have some concerns that without bioassay data from these workers, the bioassay samples may not have captured some of the individuals with the highest potential for inhalation exposures. SC&A was not able to gather specific information on this issue during its interviews with workers (Attachment 2).

Continuing with this logic sequence, one could argue that one might expect that about 5% of the workers (i.e., 5 out of the approximate 100 workers) might have experienced urine excretion rates in excess of 0.03 mg/L at some time. However, it seems unlikely that any of workers could have experienced such levels of exposure all the time, given that only one worker was observed to have a uranium concentration in urine above 0.01 mg/L (not including the workers involved in the June fire). Based on these data alone, one could argue that it is highly unlikely that any worker could have experienced a time-integrated uranium intake over the duration of operations that is greater than that assumed in the exposure matrix. But, as discussed at length below, we cannot easily dismiss the possibility that some workers might have experienced short-term exposures to very high levels of uranium dust and fumes that were missed by the bioassay program. In theory, such exposures, if they occurred, could have resulted in uranium intakes that are larger than the intakes derived using the exposure matrix. **This is the central issue associated with the exposure matrix in the TBD and the evaluation report that needs to be further explored for the operational period**.

If we accept for the moment that Table 2-1 above is a reasonable representation of the exposures experienced by Chapman Valve workers, NIOSH makes a series of assumptions regarding the meaning of these data and, based on those assumptions, developed an exposure matrix for reconstructing the internal doses to all workers. The remainder of this section is devoted to describing and evaluating these assumptions with respect to the adequacy of the data used to support these assumptions.

Based on their review of records, NIOSH adopted the simplifying assumption that the observed concentrations of uranium in the 40 urine samples can serve as a reasonable surrogate for all workers that may have been exposed during AEC operations at the facility. NIOSH also assumed that the nature of the exposures to airborne uranium can be characterized as continuous, uniform exposures to airborne dust, but that 7 of the workers (i.e., the 7 workers whose urine samples were collected on June 11, 1948) also experienced acute exposures, due to fighting and recovering from a fire assumed to have occurred in early June.

For the purpose of creating an exposure matrix, NIOSH assumed that all workers were chronically exposed to airborne uranium that would result in a urine concentration of 0.03 mg U/L. This default value was selected because it is the largest concentration of uranium observed in urine for workers not involved in putting out the June fire and the associated cleanup operations. This "baseline" assumption is considered by NIOSH to be claimant favorable because the vast majority of the urine samples were at or below the LOD of 0.01 mg U/L (see Table 2-2).

Superimposed on this baseline, NIOSH assumes that the 7 workers involved in the June fire and its cleanup experienced an acute exposure that resulted in the observed peak uranium concentration in urine of 0.08 mg U/L. Again, this is considered by NIOSH to be a conservative assumption, because this is the highest of the uranium concentrations in urine observed among the 7 workers whose urine was collected on June 11, 1948 (see Table 2-2).

Using these assumptions, NIOSH converted the bioassay results, expressed in units of mg U/L to pCi/day excreted in urine on that day by assuming a specific activity of 682.96 pCi U_{nat} per mg

and a daily urine excretion rate of 1.4 L/day. Table 3-1 of Revision 1 of the exposure matrix presents the result, reproduced here as Table 2-4.

Table 2-4. Maximum Coworker Bioassay Data Used to Estimate Intakes
(Excerpted directly from Table 3-1 of Revision 1 of the site profile, ORAUT 2006b)

Bioassay Date	Fire Scenario (pCi/day excreted)	No Fire Scenario (pCi/day excreted)
6/11/1948	76.5	28.7
7/27/1948	28.7	28.7
9/8/1948	28.7	28.7
10/7/1948	28.7	28.7

This table simply states that if you observe 0.08 or 0.03 mg U/L of urine on a given day, the excretion rate of uranium on that day is 76.5 pCi or 28.7 pCi, respectively, where the excretion rate of 76.5 pCi/day on June 11, 1948, is a result of the combination of the chronic excretion from the chronic exposures that occurred up until that time, plus the excretion on that date due to the intake from the fire that occurred on June 10, 1948.

Using these assumptions, NIOSH derived the exposure matrix presented in Table 3-3 of Revision 1 of the site profile, reproduced here as Table 2-5. These values are used by NIOSH as deterministic, upper-bound intake rates as input to IMBA for the purpose of reconstructing annual organ dose equivalents to all workers, which, in turn, are used as input to IREP for the purpose of driving probability of causation.

Table 2-5. Inhalation Intake Summary for Operational Period
(Excerpted directly from Table 3-3 of Revision 1 of the site profile, OTAUT 2006b)

Scenarios[a]	Start	End	Intake Type	Absorption Type	Intake (pCi/day or pCi)
Fire plus workplace exposure	1/1/1948	4/30/1949[b]	Chronic	M	481
	6/10/1948		Acute	M	2170
Fire plus workplace exposure	1/4/1948	4/30/1949[b]	Chronic	S	14300
	6/10/1948		Acute	S	73900
Workplace exposures	1/4/1948	4/30/1949	Chronic	M	496
Workplace exposures	1/4/1948	4/30/1949	Chronic	S	14900

a. Only one of the four scenarios from the table is used to calculate an organ dose. The scenario choice depends on whether the worker could have been exposed to the fire between June 1 and June 11, 1948. The choice also depends on the organ of interest.
b. Not applicable.

Taking into consideration the type of cancer a given worker experienced, and whether the worker was involved in the June fire or not, NIOSH uses this table to select the appropriate input to IMBA for reconstructing the internal doses to all Chapman Valve workers. For example, if a given worker had a lung cancer and was involved in fighting or recovering from the June 1948 fire, the second set of entries would be used as input to IMBA; i.e., it is assumed that the worker had a continuous intake of 5 micron AMAD, Absorption Type S uranium (using U-234 as a

simplifying conservative assumption) from January 1, 1948, to April 30, 1949 of 14,300 pCi/day plus a single acute exposure of 73,900 pCi that occurred on June 10, 1948.

At this point in the review process, it is appropriate to raise certain questions regarding the bioassay data and NIOSH's use of the bioassay for constructing the exposure matrix, as follows:

(1) Out of the 40 urine samples collected, it appears that only Nos. 30, 34, and 35 belong to a job category that one would associate with machining and lathe operations (see Table 2-2). As may be noted in Table 2-2, the urine analyses of these workers gave results that were at or below the LOD for uranium in urine (i.e., 0.01 mg/L or 9.56 pCi/day excreted in urine). The data would have been more compelling as a surrogate for all workers if more of the monitored workers were more representative of machinists and lathe operators, since these individuals would seem to be among the workers with the greatest potential for chronic exposures to elevated levels of airborne uranium, especially if the facility did not have ventilation to remove dust from the machining areas. In addition, as will be discussed later in this report, workers who loaded and unloaded the furnace were also likely to have experienced high levels of exposure.[8] To a certain degree, this potential deficiency in the dataset may be offset by the use of the highest observed concentration of uranium in urine (i.e., 0.03 mg U/L) among the workers assumed not to have been involved in the fire. In addition, the exposure matrix is based on the assumption that the chronic exposures began on January 1, 1948, and continued until April 30, 1949. SC&A concurs with NIOSH that this is a conservative assumption also because actual machining operations appear to have been limited to a much shorter time period (i.e., May through October 1948).

(2) Most of the workers were not monitored. The implications are that at least a few of the unmonitored workers likely experienced uranium concentrations in urine that were higher than the highest concentrations observed in the monitored works, based solely on statistical considerations. If the monitored population was much greater than the unmonitored population, then there would be a high level of confidence that the high end concentration of uranium observed in the monitored population would, in fact, bound the high end concentrations in the unmonitored population. However, in this case, what assurances do we have that all of the workers that were not bioassayed had urine concentrations less than 0.03 mg U/L? In addition, what assurances do we have that even some of the monitored workers did not at one time have urine concentrations in excess of 0.03 mg U/L?

(3) Worker No. 7 in Table 2-2 was observed to have the highest uranium concentration in urine; i.e., 0.08 mg U/L or 76.5 pCi/day excreted in urine on that day. The exposure matrix assumes that this elevated level, and also those observed in some of the other workers that were sampled on June 11, 1948, were due to exposures they experienced

[8] A comprehensive description of the handling and machining of uranium, the associated exposures to uranium aerosols from different aspects of uranium-handling operations, and the various ventilation systems and operational practices that were found to be effective in controlling the production of dust and fumes is provided in *The Industrial Hygiene of Uranium Fabrication*, by William B. Harris and Irving Kingsley, A.M.A. Archives of Industrial Health, May 1959, Vol. 19, pp. 540-565, 1959 (Harris and Kingsley 1959).

during a chip fire and the subsequent cleanup operations. This may be a correct interpretation of the data and the historical events at the facility. However, is it possible that the elevated level of uranium in the urine of this worker, and perhaps other workers, was due to chronic exposures or due to an acute exposure to Type M or Type S material that occurred well before the urine sample was collected? If this were the case, what are the implications of such assumptions with respect to dose reconstruction for all workers? Attachment 3 to this report explores the implications of alternative assumptions regarding the uranium intake scenarios that are compatible with the observed uranium concentrations in urine.

(4) We understand that NIOSH has assumed that the fire took place on June 10, 1948. However, it could have taken place as early as June 1, 1948. The intake estimate is highly sensitive to the assumption of the date of the fire—the earlier the date assumed, the larger the acute intake estimate.

(5) Finally, we note that the last urine samples were collected on October 7, 1948, and included 5 workers, four of whom were inspectors. Is it possible that inspectors were not very representative of the exposures experienced by the workers with the greatest potential for exposure, even though the highest earlier routine sample was associated with an inspector (Sample 29)? In addition, is it possible that some workers experienced significant exposures after October 7, 1948?

We believe that these issues are fundamental to the credibility of the exposure matrix and are also pertinent to the SEC petition, because they bring into question whether plausible upper-bound exposures could be assigned to all workers. These and other questions/issues are addressed later in this report.

As a first step in verifying the validity of this matrix, SC&A ran IMBA to derive the uranium excretion rate in urine based on the default uranium intake assumptions. We then compared the results to the actual observed levels of uranium in urine, as presented in Table 2-2. Table 2-6 presents the results of the IMBA calculations.

Table 2-6. Results of SC&A's IMBA Calculations (Uranium Excretion Rate in Urine in Units of pCi/day)

Date	Type M			Type S		
	481 pCi/day Chronic Intake	2170 pCi Acute Intake on 6/10/1948	Total	14300 Ci/day Chronic Intake	73900 pCi Acute Intake on 6/10/1948	Total
1/1/1948	0	0	0	0	0	0
2/3/1948	18.2	0	18.2	16.3	0	16.3
2/14/1948	19.4	0	25.4	17.4	0	17.4
6/10/1948	26.1	0	30.1	24.4	0	25.8
6/11/1948	26.1	49.5	75.6	24.5	51.8	76.3
6/12/1948	26.2	2.0	28.2	24.6	2.31	26.9
6/14/1948	26.2	1.6	27.8	24.7	1.67	26.4
7/2/1948	26.8	0.70	27.5	25.6	0.69	26.3
8/8/1948	27.8	0.34	28.1	27.2	0.38	27.6
9/9/1948	28.5	0.27	28.8	28.6	0.31	28.9
10/8/1948	29.1	0.21	29.3	29.8	0.28	30.1

2.2.1 Discussion of Chronic Exposures

Assuming that the intake of uranium was limited to a chronic intake of 481 pCi/day Type M (5 micron AMAD), or alternatively, the chronic intake of uranium was 14,300 pCi/day Type S (5 micron AMAD), the predicted excretion rate of uranium in urine is about 27 pCi/day. This value is consistent with the observed urine concentration of 0.03 mg U/L for worker No. 29, as presented in column 4 of Table 2-2. In addition, if we ran IMBA using 1/3 the intake values, we would obtain urine excretion rates consistent with the lower limit of detection (LLD) of 0.01 mg U/L. **Hence, we concur that the chronic intake rates used in the exposure matrix are consistent with the high end concentration of uranium observed in the urine of workers who were chronically exposed, but did not experience any short-term acute intakes, such as those associated with the June 1948 fire**.

As a further verification of this finding, it is instructive to convert these chronic intake rates to airborne dust loadings, and then compare these values to the limited airborne uranium concentrations measured at Chapman Valve, and also with airborne uranium concentrations measured at other facilities involved in similar uranium machining operations.

2.2.1.1 Chapman Valve Airborne Uranium Concentrations

Assuming that the chronic intake was either 481 pCi/day Type M or 14,300 pCi/day Type S, the airborne dust loadings are calculated as follows:

Type M (5 micron AMAD): 481 pCi/day/(1.2 m^3/hr × 8 hr/day) = 50.1 pCi/m^3 = 0.07 mg/m^3 = 111 dpm/m^3 = 1.6 MAC

Type S (5 micron AMAD): 14,300 pCi/day/(1.2 m^3/hr × 8 hr/day) = 1490 pCi/m^3 = 2.2 mg/m^3 = 3,307 dpm/m^3 = 47 MAC

Section 3.1.2 of the exposure matrix cites one possible relevant air sample taken at a workbench on May 24, 1948. The result of that analysis is 29.1 dpm alpha/m^3, which corresponds to 13.1 pCi/m^3. The implications are that the assumptions employed in the exposure matrix are conservative as compared to the single air sample collected at a workbench on May 24, 1948. However, such a comparison is of limited value for obvious reasons.

2.2.1.2 Other AWE Facilities – The NYOO 1959 Report

It is also instructive to compare the derived default assumed chronic dust loadings to the dust-loading data for AWE facilities reported in 1949 in an AEC publication titled *Health Hazards in NYOO Facilities Producing and Processing Uranium: A Status Report, April 1, 1949* (AEC 1949). This report summarizes the uranium dust concentration surveys performed to that date at seven uranium processing plants. All of the studies present average daily exposures collected from the breathing zone and weighted for 8 hours of exposure per day. The data are presented as multiples of the preferred level (PL) of exposure of 70 alpha disintegrations per minute per cubic meter of air. The methodology is described in Appendix II of AEC 1949 as follows:

> *Dust samples are then collected from the workers breathing zone, and the general workroom air in such a way as to provide an estimate of the exposure for each job component. By properly weighting the samples with respect to time, we are then able to obtain the average daily concentrations to which the various employees are exposed.*

Mallinckrodt Chemical Works

Mallinckrodt operated two plants; #6, which was the refinery, and #4, which was the metal plant. Plant #6 produced brown oxide from pitchblend. Plant #4 converted the UF_4 to uranium metal. A dust survey was performed at these sites in 1948. The AEC 1949 report states that the results were published, but the available copy did not contain those figures. A summary of these results, along with the results of the other AWE facilities investigated by the NYOO, is reproduced here in Table 2-7.

Harshaw Chemical Company

Harshaw employed 90 people and operated a uranium conversion process plant, which converted brown oxide to green salt and green salt to UF_6. Dust concentration surveys were performed at this plant in September 1948. Of the seven plants included in this summary report, Harshaw had the largest number of workers exposed to high dust-concentration levels for long periods of time. Of the 88 employees, 33 were exposed to dust concentration levels ranging from 140 to 370 MAC (1 MAC = 31.5 pCi/m^3). Figure 11 of AEC 1949 indicates that 4 Brown Oxide Loaders were exposed to 140 MAC, another 4 Brown Oxide Loaders were exposed to 188 MAC, 1 Fume Recovery Room Operator was exposed to 216 MAC, and a total of 24 Hex Area Loaders were exposed to 374 MAC. In addition, these workers were exposed to these high dust-concentration

levels for extended periods of time. Table 2-7 is a reproduction of Table 5 of AEC 1949, which presents the exposure duration of the Harshaw employees as a function of dust-concentration level. Table 2-7 reveals that many workers were exposed to levels above 125 MAC (about 4000 pCi/m^3) for 1 or more years.

Table 2-7. Distribution of Employees by Length of Employment and Level of Dust Exposure at Harshaw Chemical Company

Multiple of Preferred Alpha Level*	Number of Months of Exposure						
	0–6	6–12	12–24	24–36	36–48	> 48	Total
0 – 1	1	2	2	0	1	1	7
1 – 5	1	1	0	0	2	0	4
5 – 25	0	5	5	12	10	11	43
25 – 125	0	0	0	0	0	0	0
> 125	0	17	10	3	4	0	34
Total Personnel	2	25	17	15	17	12	88

* A "preferred level" is also referred to as the Maximum Allowable Concentration (MAC), which corresponds to 70 dpm/m^3, which, in turn, corresponds to 31.5 pCi/m^3.

Linde Air Products

The Linde plant converted brown oxide from Mallinckrodt to UF_4 for shipment to Electro-Metallurgical Company. Dust was dispersed in the plant through the transfer of "brown oxide to the weighing drums, scooping of oxide onto trays, and transfer of the trays to and from the green salt reactor." Dust-concentration surveys were performed at this plant in October and November 1948. None of the 65 employees were exposed to dust concentration levels above 32 MAC (1009 pCi/m^3).

Electro Metallurgical Company, Division of Union Carbide & Carbon Co.

Electro Metallurgical Company converted green salt from Linde to uranium metal billets. Dust-concentration surveys were performed at this plant in November 1948. The majority of the plant's 50 employees were exposed to dust levels below 40 MAC (1,261 pCi/m^3). However, three Green Salt Room Operators involved in bomb concentration operations were exposed to dust levels of 557 MAC (17,562 pCi/m^3).

Simonds Saw & Steel

Uranium rolling processes at both Simonds Saw and Vulcan Crucible are described in AEC 1949 as the following:

> *Because of the pyrophoric character of uranium, this operation results in profuse atmospheric contamination. In addition to the fuming of the cherry-hot billets, continuous oxidation produces a scale, which consistently spills from the billets. This material after falling to the floor is ground to dust by heavy floor traffic incidental to the rolling operation.*

Several dust concentration surveys were performed between 1948 and 1949, which are summarized here in Table 2-8.

Table 2-8. Summary of Weighted Daily Exposures at Simonds Saw & Steel

No. of Employees	Multiples of Preferred Level for Continuous Exposure[1]		
	10/27/48*	12/1/48**	1/10/49***
2	25	13	5
8	17	13	4
8	155	28	13
6	25	10	28
4	8	4	1.4
2	9	10	1.6

* No dust control measures.
** Vacuum cleaner, and exhausts for rolls installed.
*** Exhaust for descaler installed.
[1] A "preferred level" is also referred to as the Maximum Allowable Concentration (MAC), which corresponds to 70 dpm/m^3, which, in turn, corresponds to 31.5 pCi/m^3.

Table 2-8 reveals that, prior to the use of dust control measures, eight employees at Simonds Saw were exposed to dust concentrations of 155 MAC (4,887 pCi/m^3).

Vulcan Crucible Steel Company

The uranium-rolling process at Vulcan was similar to those at Simonds Saw. Dust concentration surveys were performed at Vulcan in February 1949. The results indicate that four workers were exposed to over 5,000 MAC. All of the other employees had exposures below 40 MAC (1,261 pCi/m^3).

Vitro Manufacturing Company

The Vitro plant converted scrap materials to black oxide. The majority of the plant's 44 employees received dust-concentration exposures below 40 MAC (1,261 pCi/m^3).

Summary Comparison of Chapman Valve Data and Exposure Matrix with the Seven AWE Facilities

Table 2-9 and Figure 2-1 summarize the air-sampling data collected from the seven AWE facilities. As may be noted in Figure 2-1, the points on the graph closely fit a lognormal distribution. On this basis, the following are the summary statistics for the distribution:

Fitted lognormal distribution parameters

Parameter	Estimate
Geometric Mean	81.3 pCi/m^3
GSD	15.8
84th percentile	1,284 pCi/m^3
Mean	3,667 pCi/m^3
95th percentile	7,615pCi/m^3

The 84th percentile dust loading at these facilities appears to be consistent with the default chronic dust loading of 1,490 pCi/m^3 that is implied in the exposure matrix for Chapman Valve for Type S uranium. However, high-end dust loadings at these facilities appear to be about 6 times higher than the chronic exposure levels attributed to Chapman Valve operations. The question is, are comparisons between Chapman Valve and these other AWE facilities meaningful? A description of the operations at the seven AWE facilities reveals that there were substantial differences in the nature of the work at Chapman Valve. Most of the seven AWE facilities performed chemical processing activities, or were involved in uranium-rolling activities (i.e., Simonds Saw). Chapman Valve was involved in milling operations. It is difficult to judge which of these different types of facilities had the greater potential for elevated levels of airborne uranium. It could be argued that, if the operations at the 7 AWE facilities could be used to supplement the Chapman Valve data or used as a surrogate for Chapman Valve, the Chapman Valve values appear to be somewhat claimant favorable. Specifically, a little more than 84% of the workers would be expected to have had exposures less than the default values used in the exposure matrix, and a few of the Chapman Valve workers might have had chronic exposures in excess of 7,000 pCi/m^3 (1.56×10^4 dpm/m^3 or 222 MAC).

Table 2-9. Summary of Average Daily Exposures to Alpha Emitting Dust at Seven Uranium Plants

Uranium Plants	Multiples of PL*					
	0–1	**1–5**	**5–25**	**25–125**	**125**	**Total**
Mallinckrodt Chemical Works						
Plant #6	53 (31%)**	73 (43%)	24 (14%)	2 (1%)	18 (11%)	170
Plant #4	11 (14%)	7 (9%)	27 (35%)	30 (39%)	2 (3%)	77
Harshaw Chemical Company	9 (9%)	11 (11%)	45 (46%)	0	33 (34%)	98
Linde Air Products	119 (87%)	3 (2%)	0	15 (11%)	0	137
Electro-Metallurgical	19 (28%)	21 (31%)	21 (31%)	3 (5%)	3 (5%)	67
Simonds Saw & Steel (1/48)	0	16 (53%)	8 (27%)	6 (20%)	0	30
Vulcan Crucible Steel	0	4 (16%)	17 (68%)	0	4 (16%)	25
Vitro Manufacturing Company	23 (52%)	16 (36%)	4 (9%)	1 (3%)	0	44
Total	234 (36%)	151 (23%)	146 (23%)	57 (9%)	60 (9%)	648

* PL = Preferred Level for alpha emitting dust = 50 g of uranium/m^3 = 70 d/m/m^3 = 31.5 pCi/m3 on the average for an 8-hour workday.

** The first figure denotes the number of personnel. The second, in parentheses, expresses the first as a percentage of the total in the last column.

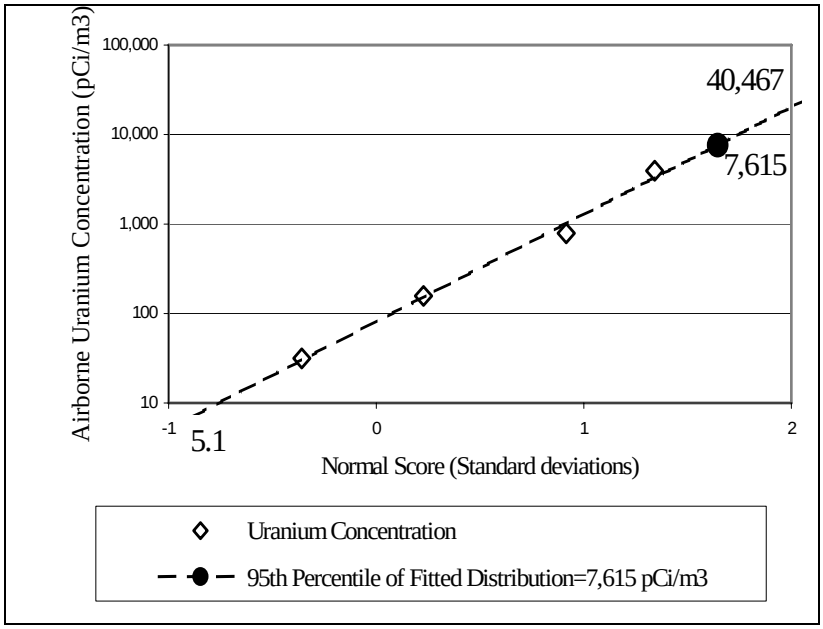

Figure 2-1. Lognormal Score Plot of the Air-Sampling Data for Seven AWE Facilities

In general, the data characterizing exposure to airborne uranium for Chapman Valve, and also the seven AWE facilities, appear to consist of a large number of samples (whether urine or air) where the exposures were relatively low, and a relatively small number of samples where the values were relatively high. This would mean that using the median value would not be claimant favorable for half the workers. On the other hand, using the 95th percentile value would grossly overestimate the exposures to the large majority of workers, but may underestimate the exposure of some workers.

One question that is appropriate to raise at this point is, should an SEC petition be granted if there is a real possibility that some workers may have experienced an exposure that is higher than the highest exposure associated with the exposure matrix, and it is not apparent that a plausible upper bound can be assigned to those exposures? There are paragraphs from page 22323 of Volume 67, No. 85, of the Federal Register (May 2, 2002, pp. 22314–22336) that apply:

> *Several commenters questioned at what point uncertainty associated with a dose reconstruction would be too great to be considered reasonable. EEOICPA requires reasonable estimates of radiation dose. 42 U.S.C. 7384n(d)(1). HHS interprets this term to mean estimates calculated using a substantial basis of fact and the application of science-based, logical assumptions to supplement or interpret the factual basis.* ***Claimants will in no case be harmed by any level of uncertainty involved in their claims since assumptions applied by NIOSH will consistently give the benefit of the doubt to claimants.*** *Hence, the level of uncertainty is not an issue whenever there is a sufficient factual basis to establish the radiation source type and quantity and a basic understanding of the process in which the employee worked. This information can provide the basis for a*

reasonable estimate. When this basic information is lacking, however, then NIOSH may not be able to establish reasonable estimates. [Emphasis added.]

This language from the rule and the Federal Register should be kept in mind as we discuss the Chapman Valve data, the exposure matrix, and the experience at other uranium-handling facilities.

2.2.1.3 Other Uranium-Handling Facilities

Attachment 1 to this report presents a more-detailed evaluation of air sampling and/or bioassay data collected at several uranium-handling facilities, including a more detailed evaluation of rolling operations at Simonds Saw during the early years (before January 1950), prior to the implementation of dust suppression techniques, at Aliquippa Forge, at Superior Steel, and at Bethlehem Steel. In addition, data gathered at Havens Laboratory and Adrian Plant were reviewed. Attachment 1 also presents airborne uranium concentrations for facilities involved in uranium machining and abrasion operations published by Harris and Kingsley (1959). A review of these data and reports provides a high level of assurance that the exposure matrix establishes a scientifically plausible and reasonable upper bound for chronic exposure of all workers at Chapman Valve.

For example, the Havens Laboratory and Adrian Plant, which were involved in uranium extrusion operations, had some operational steps that were not unlike those at Chapman Valve. Though the operations are not entirely equivalent, the urine analysis data are generally below 0.01 mg U/L, but concentrations of 0.02 to 0.06 mg U/l could have occurred over periods in excess of 1 month. Hence, a chronic exposure resulting in 0.03 mg U/L for the entire period of operations, as assumed in the exposure matrix, would seem to place a plausible upper bound on the chronic exposures that all workers at Chapman Valve might have experienced.

Of particular relevance, Table 7 in Attachment 1 presents a summary of data reported by Harris and Kingsley (1959) for airborne alpha activity associated with uranium machining and abrasive operations (with and without ventilation). These values compare favorably to the default chronic airborne concentration employed in the Chapman Valve exposure matrix of 3,278 dpm/m^3 for Type S uranium. It is noteworthy that grinding operations without ventilation, as reported by Harris and Kingsley (1959), reached levels as high as 6,000 dpm/m^3 (85 MAC). However, it is important to keep in mind that these are peak values, and that the exposure matrix assumes a chronic continuous exposure at 3,278 dpm/m^3 (47 MAC) from January 1, 1948, to May 1, 1949.

2.2.1.4 Comparison of Chapman Valve Data and Exposure Matrix with Data in HW-23352, a Hanford Report

HW-23352 is a report published by the AEC entitled *Study of Atmospheric Contamination in the Melt Plant Building* by F.E. Adley, W.E. Gill, and R.H. Scott (April 4, 1952) (AEC 1952). This report presents the results of a detailed investigation of the health physics issues associated with melting and milling uranium metal at the Melt Plant Building at Hanford. The report describes in detail each step in the handling and processing of uranium rods, and provides extensive data on airborne uranium particle/aerosol/fume loading, uranium particle size distributions, and the

chemical form of the airborne uranium associated with each type of activity. The data presented in the report were gathered from February 1947 to May 1951. As such, the report is especially pertinent to the issues associated with the Chapman Valve SEC Petition.

Methodology

The uranium operations investigated in the report were divided into the following activities:

- 14 steps associated with the remelt and recovery of uranium turning and chips that were generated during uranium machining operations
- 6 steps associated with uranium rod straightening operations
- 2 steps associated with uranium autoclaving

The report provides a description of each of these 22 steps, along with a complete characterization of the aerosols produced at each step. Many of the steps are directly applicable to the activities that took place at Chapman Valve, including offloading the rods from railcars, furnace room operations, saw room operations, and rod-handling operations. Saw room operations are particularly pertinent to Chapman Valve, because those operations included grinding, sawing, lathing, and sweeping activities.

The report presents a detailed description of the methods used to collect and characterize the aerosols associated with each operation. High volume air samplers (70 to 100 cubic feet per minute) were used to collect the samples on pleated filters with a filtering area of 73 square inches. Most air samples were collected at breathing level near the various processes, and some were obtained as close as possible to the points where dust and fume originated. Particle sizes were determined using cascade impactors and also using a thermal precipitator, which deposits particles on glass slides where they could be viewed and measured. The former was used to determine the mass median diameter and the mass distribution, while the latter was used to determine the count median diameter and number distribution.

The investigations also quantified the rate at which uranium deposited on surfaces for the different activities at the facility. This was accomplished by placing plates with filter papers throughout the plant and allowing uranium particles to passively deposit onto the filter papers over the course of several weeks.

Spectrometric methods were used to quantify the amounts of uranium in each sample, and x-ray diffraction was used to characterize the chemical form of the uranium aerosols. It is noteworthy that all samples were determined to be U_3O_8 (i.e., Absorption Type S).

Results of Investigations and Comparisons with Chapman Valve

Table 2-10 presents the results of multiple individual measurements taken at locations that appear to be particularly applicable to Chapman Valve operations. Table 2-10 shows values that were copied directly from portions of Table II of the appendix to the report. The table provides

an indication of the variability of the airborne uranium concentrations associated with a given operation.

Table 2-10. Summary of Selected Measurements Made at the Hanford Melt Plant Building Investigations (AEC 1952)

Operation	Suboperation	Results of Multiple Samples Taken from Different Locations/Suboperations within the Facility (10^{-5} micrograms U per cc of air)								
Furnace Room	Operation furnace closed	7.4	4.9	6.4	17.6	6.5				
	Charging furnace directly	93	3.7	4.2	16.8	0.9				
	Weighing furnace charge	221	45	43	44					
	Unloading furnace	147	85	58	62	79	6.2			
	Removing spillage	3300	52	132	2.2					
	Miscellaneous	18	80	95	5.4	9.5	1.2			
Saw Room Operations	Stripping molds from billets	22	0.9	15	43					
	Sawing billets	87	92	12	59	286	154	122		
	Lathing billets	442	27	4.3	97	20				
	Grinding	23,800	55							
	Sweeping floor	86								
	Miscellaneous	5.3	0.4	127	10	18				
Rod-handling Operations	Unloading rods from freight cars	39	258	15	60					
	Storage bay activities	258	34	5.8	43	65	2.4	277	28	51
Non-Production Areas	Office	0.5	1.5							
	Counting room	0.3	1.1							
	Toilet	4.2	8.7							
	Smoking room	2.3	1.2	3.5						

Table IX of the report, reproduced here in Table 2-11, converts these data into a more useful form for the purpose of estimating the doses to workers. The duties of each worker are provided in Column 1, and the approximate daily duration of each activity by each worker involved in that activity is provided in Column 2. Column 3 lists the average exposure corresponding to each activity. The product of the concentration times time in Column 4 weight the exposures for each activity, and the weights are totaled to give each operator's daily weighted exposure. Hence, the saw room operator, who is especially pertinent to Chapman Valve, is estimated to experience a daily exposure of $2{,}233 \times 10^{-5}$ µg-hours/cm^3, weighted by the work times spent on each job over the course of an 8-hour workday. This yields a daily weighted exposure average concentration

of about 280×10^{-5} μg/cm^3. This corresponds to about 2.8 mg/m^3. This yields an intake rate of about 1.83×10^4 pCi/day of uranium.[9] This would represent a best estimate of the long-term daily average uranium intake rate for saw room operators at this facility, which takes into consideration time periods where the dust loadings were very high. This value can be compared to the default intake rate of Type S uranium of 1.49×10^4 pCi/day employed in the exposure matrix. These two values are broadly, even remarkably, similar.

Table 2-11. Summary of Exposure Hours and Weighted Daily Exposures of Workers in the Melt Plant Building and at Related Operations

(Source: AEC 1959, Table IX)

Operators and Their Assignments	Estimated Daily Time per Assignment (Hours)	Average Concentration at Each Assignment (Units: 10^{-5} μg/cc)	Weighted Daily Exposures (Concentration × Time)
Maximum Permissible Concentration	8	5.0	40
Furnace Operator			
Normal Operations	4.5	8.4	37.8
Cleaning Turntable	1.0	1161	1161
Unloading Furnace	0.5	717	359
Cleanup	0.5	42.5	21.2
Miscellaneous	1.5	4.0	6.0
			1586 – TOTAL
Furnace Assistant			
Unloading Furnace	0.5	717	359
Relieving Operator	1.0	8.4	8.4
Weighing and Charging	3.0	87	261
Stripping Billets	0.3	19.1	5.7
Miscellaneous	3.2	4.0	12.8
			647 – TOTAL
Saw Room Operator			
Furnace Room Help	0.5	717	359
Stripping Billets	0.4	19.1	7.6
Sawing	3.0	67	201
Lathing	0.2	37	7.4
Grinding	0.3	5450	1635
Sweeping	0.1	86	8.6
Miscellaneous	3.5	4.0	14.0
			2233 – TOTAL
Oxide Operator			
Furnace Room Help	0.5	717	359
Stripping Billets	0.3	19.1	5.7
Setting Crucibles	0.1	2940	294
Removing Crucibles and Oxides	0.6	1340	804
Cleaning Hoods	0.3	1210	363
Sweeping Burnout Room	0.1	583	58
Loading and Unloading Oxide Furnace Trays	0.5	5180	2590
Sweeping around Oxide Furnace	0.5	5.9	3.0
Open Hearth	0.4	5070	2028

[9] The report emphasizes that these results are based on the assumption that workers did not wear respirators.

Table 2-11. Summary of Exposure Hours and Weighted Daily Exposures of Workers in the Melt Plant Building and at Related Operations

(Source: AEC 1959, Table IX)

Operators and Their Assignments	Estimated Daily Time per Assignment (Hours)	Average Concentration at Each Assignment (Units: 10^{-5} µg/cc)	Weighted Daily Exposures (Concentration × Time)
Maximum Permissible Concentration	8	5.0	40
Graphite Burner	0.4	5.1	20.
Miscellaneous	4.3	4.0	17.2
			6524 – TOTAL
Rod Handlers			
Straightening	3.0	35.8	107
Loading Table	0.3	140	42.0
Storage Bay – Stacking, etc.	0.5	81.3	40.7
Sweeping	0.2	39.9	8.0
Other duties	4.0	1.0	4.0
			202 – TOTAL
Autoclave Operators			
Loading	0.8	41.7	33.4
Pulling	0.8	3.3	206
Other Duties	6.4	1.0	6.4
			42 – TOTAL
Rod-Receiving*			
Car Unloaders	4.0	142	568
Other Duties	4.0	0	0
			568 – TOTAL
Weighing	4.0	15.2	60.8
Other Duties	4.0	1.0	4.0
			61 – TOTAL
Stacking on Truck	4.0	60	240
Other Duties	4.0	0	0
			240 - TOTAL

*This procedure has recently been changed. Rods are unloaded with a Hydrocrane by bundles and are weighed within the Melt Plant Building.

It is noteworthy that the weighted average intake rate captures time periods when the dust loadings were very high, such as during machining operations. As such, it could be argued that an assumed chronic uranium intake rate for saw room operations at the Hanford Metal Melt Building of 1.83×10^4 pCi/day takes into consideration transient high levels of exposure. The report is silent regarding whether the data from the Hanford Building Melt investigations capture any chip fires that may have occurred in the saw room. However, reference is made to the production of fumes during milling operations.

The report goes on to compare the results of the airborne dust and fume measurements, and associated daily weighted intake rates, with actual bioassay samples collected from selected workers. This aspect of the analysis is especially valuable because it helps to verify that intakes based on air samples can be used to reliably predict intake rates. Specifically, the report describes the results of bioassay measurements for two workers exposed to roughly 1 MAC in

the machining and canning building and who are known not to have worn respirators. For these workers, airborne levels of uranium were closely monitored over a 1-week period and urine samples were collected at the beginning and end of each shift. The airborne uranium concentrations were found to be fairly consistent over this time period at a level of 7×10^{-5} μg/cc (corresponding to 672 μg/day or 459 pCi/day inhalation rate of uranium). The urine excretion rate was found to be 8.7 μg/L (corresponding to 12.2 μg/day or 8.3 pCi/day of uranium excreted in urine). Hence, the normalized uranium excretion rate was determined to be about 0.018 pCi/day excreted in urine per pCi/day inhaled under chronic exposure conditions to Type S uranium (particle size unspecified). The report states that these results demonstrate satisfactory agreement between predicted and actual excretion rates.

It is instructive to compare this analysis to that presented above for Chapman Valve for Type S uranium. Type S uranium is selected for this comparison because the chemical analyses of the aerosols at the Metal Melt Building were consistently found to be U_3O_8. For Chapman Valve, the exposure matrix assumes a chronic intake of 14,300 pCi/day of Type S (5 micron AMAD) uranium, which is associated with a chronic urinary excretion rate of 28.7 pCi/day, or 0.002 pCi/day excreted in urine per pCi/day inhaled under chronic exposure conditions to Type S uranium (particle size assumed to be 5 micron AMAD).

The above data indicate that the empirically determined excretion rate per unit intake at the Metal Melt facility appears to be about 10 times higher than that inherent in the Chapman Valve exposure matrix. But it is difficult to interpret such data because there is a high variability and uncertainty in determining individual intake from air sampling data. What does this mean with respect to the exposure matrix? The Chapman Valve exposure matrix back-calculates the chronic uranium intake rate based on bioassay data. It effectively states that for every pCi/day excreted in the urine, the intake rate is about 500 pCi/day. The investigations performed at the Hanford Metal Melt facility reveals that for every pCi/day excreted in urine, the intake rate is about 50 pCi/day. Hence, as compared to the metal melt facility, the exposure matrix adopted for Chapman Valve may overestimate the chronic intake rate by about a factor of 10. The above indicates the difficulties of using data from various facilities to estimate intakes. In particular, it is known to be difficult and uncertain to estimate intake accurately from air concentration data and match it up with bioassay results. According to ICRP 2002, “the use of static [air] samplers does not ensure a representative measurement of exposure of the worker, especially in workplaces where the aerosol release points are discrete and distributed.” (ICRP 2002, Annex B, Section B.5, p. 150). Even personal air samplers may give misleading and inconsistent results in case of high specific activity radionuclides due to the low volume of air that is sampled (ICRP 2002, Annex B, Section B.6).

One of the dilemmas in using the data gathered by Adley, Gill, and Scott in the Hanford Metal Plant Building investigations (AEC 1952) to confirm, supplement, or complement the data gathered at Chapman Valve is the fact that dust loadings of uranium at a facility are dependent not only on the types of milling activities taking place, but also the engineered controls and milling practices employed. Specifically, the Recommendations section of the Metal Melt Building report describes in detail design features and operational practices that could have a profound influence on the dust levels associated with the various machining operations. In particular, the speed of the lathe, the use of well-designed local ventilation during machining, the

use of local shields, the use of grated floors, the use of abundant quenching fluids during machining, the careful loading and unloading of chips and turnings before and after furnace operations, good housekeeping, and careful handling of rods to avoid sparking were found to significantly affect dust loadings during millings and furnace operations. **SC&A met with former workers to obtain more detailed information regarding the practices at Chapman Valve so that we could better judge the applicability of the experience at the Metal Melt Building to Chapman Valve**.

As described in Attachment 2, our interviews found that Chapman Valve employed very limited dust control practices. Most importantly, the workers at the facility that observed the uranium rod machining operations[10] in 1948 stated that there were no special ventilation systems to limit the dispersal of dust during machining operations. They saw the generation of sparks and dust. Possible buildup of airborne dust levels as the workday progressed was indicated. In addition, the floors were not grated. As a result, dust deposited on the floors and was available for resuspension. Also, the lathe operators did not wear face shields and did not wear gloves. The workers SC&A interviewed remembered workers experiencing burns on their hands and forearms from sparks generated during the machining operations. Other workers stated that they could see the dust exiting the building from open windows and being discharged from the exhaust of the chip burner. However, the workers that were interviewed also recalled that water-based coolant was continuously poured on the cutting edge of the lathe to keep it cool, which reduced the amount of sparking and prolonged the life of the cutting edge. Nevertheless, large amounts of sparking were observed.

SC&A reviewed a Technical Study prepared for remediation in May 1995 (Technical Study 1995). This study provides surface contamination and dust sampling data. The average concentration of U-238 in dust samples taken from the interior trusses was 870 pCi/gram, indicating a total uranium concentration of 1,800 pCi/gram. The range of reported values for U-238 was 7 to 8,000 pCi/gram. The distribution appeared to be systematic, with the highest concentration being on Truss #2. This indicates that there was likely to have been considerable variation in spatial dust levels during the period of operation. Given that the dust samples were mixed with subsequent non-uranium production in Building 23, the high average uranium level found in 1995 may be indicative of dusty conditions in 1948.

None of the former workers we interviewed remembered how the chip burner was loaded and unloaded. The Harris and Kingsley (1959) report and the AEC (1952) report reveal that the way in which chip burners were loaded and unloaded could markedly affect the airborne dust levels and exposures experienced by the workers involved with the chip burner. The fact that few individuals were observed to have detectable levels of uranium in urine would indicate that, if elevated exposures occurred as a result of chip burning, the exposures were not widespread. Nevertheless, this does not mean that there were no workers that experienced high exposures from chip burning activities; i.e., they could have been missed by the bioassay program, especially since that program was limited to a minority of workers.

[10] Note that, at the time of the machining operations, the workers were not informed that they were working with uranium. However, they knew that they were involved in important national defense-related activities, and only later did they become aware that they were machining uranium rods.

Based on SC&A's interviews, it appears that the operations at Chapman Valve did not benefit very much from the experience that was being gained at that time by Harris and Kingsley (1959, or from the work performed by the New York Operations Office, which was published in 1952. If they did, then Chapman Valve may have avoided some of the very high short-term dust loadings that were experienced at many uranium-handling facilities at that time, especially those associated with machining operations and loading and unloading chip burning furnaces. It is encouraging, however, that there were very few bioassay results at Chapman Valve that were above the MDL. If high acute exposures were very frequent at Chapman Valve, one would have expected to observe more bioassay samples well above the MDL.

When taken in their entirety, the investigations summarized above seem to indicate that the exposure matrix for chronic exposure is scientifically sound and is likely to be claimant favorable for a large majority of workers. Nevertheless, we must remain cognizant of the language in the rule presented above that deals with uncertainty and the problem of exposures at the high end of the scale. Furthermore, it is difficult to judge the degree to which the conservative assumptions imbedded in the exposure matrix for chronic exposures account for high episodic exposures.

The portion of the exposure matrix that deals with episodic exposures is discussed in more detail in the next section. In addition, the next section also explores the degree to which the conservative assumptions inherent in the chronic exposure portion of the exposure matrix may accommodate unaccounted for short-term acute exposures associated with chip fires, loading and unloading the chip furnace, and other activities and practices that may have resulted in short-term exposures to relatively high concentrations of airborne uranium dust.

Before moving on to a discussion of acute exposure, it is appropriate to address the particle size distribution observed in the Metal Melt Plant investigations and the very small particle sizes associated with fumes. The Metal Melt Plant investigation included an evaluation of the particle size distribution for numerous locations in the plant, expressed in terms of the percentage of particles of a given size and the percentage of particles of a given mass. In general, the mass median diameter of air particles collected from the saw room was about 2 microns, with a standard deviation of about 4. The implications are that the default AMAD of 5 microns employed in the Chapman Valve exposure matrix may be too large. However, as noted above, it is difficult to translate findings from one facility to another at this level of detail. An analysis of a claimant-favorable approach to particle size is needed in the Evaluation Report, at least to the extent needed to ensure that an approach to dose reconstruction with sufficient accuracy in this regard has been developed.

2.2.2 Discussion of Acute Exposures (January 1, 1948, through April 30, 1949)

The exposure matrix assumes that, in addition to chronic exposures that all workers at Chapman Valve experienced, some workers were also exposed acutely due to firefighting and subsequent cleanup of a chip fire, which, based on historical records, was assumed by NIOSH to have occurred some time in early June 1948. Given this exposure scenario, NIOSH used the seven bioassay samples collected on June 11, 1948, as indicative of both the chronic exposures these workers experienced up until that time and also the acute exposures from the fire. As may be

noted in Table 2-2, the highest bioassay values are for those seven workers. Using the bioassay data and the IMBA computer code, NIOSH determined that an acute intake of either 2,170 pCi of Type M or 73,900 pCi of Type S uranium (5 micron AMAD) **on June 10, 1948,** would be consistent with the observed bioassay data. To place these values into perspective, if it is assumed that the intake associated with the fire occurred over a 4-hour time period, the average airborne uranium concentration over that time period would have been 15,396 pCi/m^3 or about 22 mg/m^3, or about ten times the chronic exposures employed in the exposure matrix. Table 2-6 above presents SC&A's independent assessment of the uranium excretion rates in urine for the exposure scenario adopted in the exposure matrix. Note that the peak excretion rate of uranium in urine for the indicated combination of chronic and acute exposures, as estimated by SC&A, is about 76 pCi/day, which agrees extremely well with the observed maximum excretion rate of 76.5 pCi/day (i.e., 0.08 mg U/L) presented in Table 2-2 for worker No. 7. The implications of these findings are that the acute intake rates adopted by NIOSH in the exposure matrix to account for the elevated bioassay samples observed in the June 11, 1948, samples appear reasonable, **given the exposure paradigm adopted by NIOSH in the exposure matrix**.

However, there are some questions regarding the way in which the exposure matrix deals with "the fire." First, the exposure matrix acknowledges that the date of the fire is unknown. That being the case, the urine samples collected on June 11, 1948, could have been collected one or more days after the fire. Inspection of columns 3 and 6 of Table 2-6 reveals that the excretion rate appears to peak one day after the acute exposure and then quickly declines to levels below those associated with chronic exposures. The implications are that the actual exposures associated with the fire could have been substantially different than those adopted in the matrix. What if the concentration of uranium in urine of person No. 7 in Table 2-2 was due to chronic exposure, or was due to acute exposures that occurred several days before the sample was taken on June 11, 1948, or the uranium had an AMAD of 1 micron or less? Furthermore, petitioners claim that there were many fires at the facility. Is it possible that the samples collected on July 27, 1948, September 9, 1948, and October 7, 1948, could have missed "spikes" associated with other fires? If so, what are the implications with respect to dose reconstruction? These questions are addressed in the following paragraphs, and a detailed evaluation of these questions is provided in Attachment 3 to this report.

First, it seems clear that an assumption of a fire on June 10, 1948, is not claimant favorable. As described in the TBD, the fire most likely occurred some time between June 1 and June 10, 1948. An assumption that the fire was several days before the sampling date of June 11, 1948, instead of just one day, would make a material difference to the acute intake estimate and may make a significant difference in the overall intake estimate (depending on what date is eventually chosen as reasonable and claimant favorable, and what data there are to support such a choice).

As to other fires that may have occurred, it could be argued that a completely different construct might be more appropriate as an exposure matrix, one that assumes that acute exposures to different uranium types and particle size distributions were experienced periodically by all workers. The challenge would be to determine how often such exposures occurred. Given these concerns, SC&A believes that the exposure matrix developed by NIOSH for reconstructing the internal doses for all workers is not necessarily claimant favorable, and it is not apparent how to go about building an exposure matrix that is scientifically valid and claimant favorable for all workers. **However, SC&A also acknowledges that there are realistic limits on the number**

of "incidents" that could have occurred at Chapman Valve and the magnitude and characteristics of those incidents. SC&A's interviews with former workers did not indicate very frequent fires, but since none of the workers interviewed worked in the concerned department full time, the lack of observation of fires by any of them provides only limited evidence in this regard. There might be a way to place a plausible upper bound on the exposures to all workers by drawing upon the experience at other AWE facilities. However, in its current form, the available bioassay and air sampling data, along with process knowledge, are not adequate to support the exposure matrix as it stands to address episodic exposures.

Finally, there is a gap in the exposure data related to the incinerator. NIOSH's point of reference of the concentration of uranium in the incinerator exhaust is not relevant to the conditions of exposure at such a facility for the time period in question. The Hanford data cited above show that the handling of the dusts (weighing, charging, unloading, and cleaning spillage) were among the most dusty operations. If a worker were involved in cleaning up spills for just an hour at the rate specified in Table 2-7 (33 mg/m^3), he would have an intake of about 27,000 pCi at a breathing rate of 1.2 m^3/hour. At this rate, the maintenance worker would experience an intake comparable to the fire for every three hours of spill cleanup. At the same time, this intake must be viewed from the perspective of how it might add to the total time-integrated chronic intake rate of 14,900 pCi/day.

Furthermore, the rates of dust loading for maintenance operations can be highly variable. For instance, at Fernald, a periodic maintenance operation had contamination levels of 18,000 MAC in one year, while the same operation had a level of 97,000 MAC the prior year for a specific conveyor clean-out operator, with both figures being averages, rather than peak measurements (see SC&A Fernald TBD Review, p. 58). The reduction in the exposure was achieved by a change in the geometry of the job—that is, in the location of the worker relative to the most contaminated area to be cleaned out.

Another example is provided by the thorium chip furnace at Fernald, which showed dust levels in 1962 for one job ("raking excessive cold residue into furnace") of 1,260 MAC (see SC&A Fernald TBD Review, pp. 28-29). Since Th-232+228 has a specific activity three times lower than natural uranium, the uranium dust loading for the same mass loading would be ~4,000 MAC.

Another problem with estimating episodic exposures due to maintenance and manual furnace operations is that they are highly variable. The incinerator remains the one big gap for the operating period under consideration. We note that none of the bioassay samples specifically include workers involved with chip burning, or loading and unloading the furnace. However, we acknowledge that some of the workers that were monitored might have been involved in chip-burning operations. In addition, if such exposures were widespread, they should have been captured in the bioassay samples. As may be noted, we are on the horns of a dilemma. But, there is also a real possibility that very high short-term exposures may have been missed and not necessarily accounted for in the exposure matrix. At the same time, there is reason to believe that such exposures may not have occurred, or, if they did occur, they might be accounted for by the conservative assumptions adopted in the chronic exposure matrix, or they might not be large enough to add substantially to the time-integrated exposures inherent in the exposure matrix.

One way to explore some of the implications of the above questions is to estimate how the total uranium intake may change, given alternative assumptions regarding exposures some of the workers may have experienced as a result of one or more fires or possible acute exposures associated with furnace operations.

Acute Exposures Associated with the Early June 1948 Fire

It must be kept in mind that the assumptions adopted by NIOSH in the exposure matrix regarding chronic exposures have been found by SC&A to be scientifically sound and, in the main, claimant favorable. Chronic exposures are assumed to take place from January 1, 1948 to April 30, 1949, 8 hours per day 5 days per week, and consisted of a uranium intake rate of either 14,900 pCi/day Type S or 496 pCi/day Type M uranium. As best we can tell, this means that all workers not involved in one or more fires are assumed to have a chronic intake that covers about 70 weeks, 5 days per week, for a total intake of either 5.22×10^6 pCi of Type S uranium or 1.74×10^5 pCi of Type M uranium.

Superimposed on this intake is the acute intake associated with the one fire that occurred in early June. The exposure matrix assumes that the acute intake from that fire was either 7.39×10^4 pCi for Type S, or 2.17×10^3 pCi for Type M uranium. Hence, that one fire contributes about 1.5% to the total intake for Type S, which is the likely form of uranium for a fire. This means that fires or even incinerator operation may not invalidate the exposure matrix. However, the problem of determining a suitable date for the early June 1948 fire and of intakes associated with incinerator operation still needs to be resolved in a scientifically supportable manner.

We have done an exploratory calculation of the effect of changing the assumption of the date of the fire, which NIOSH has assumed as June 10, 1948. The evidence is strong that the urine samples collected from the 7 workers on June 11, 1948, were in fact collected because of a fire. However, we do not know when the fire occurred. For example, what if the intake associated with the fire occurred on June 1, 1948, which is acknowledged in the source documents as being plausible? What would the intake have had to be in order to observe 0.08 mg U/L in urine samples collected on June 11th?

In order to answer this question, we ran IMBA and determined that the acute intake on June 1, 1948, would have had to have been about 50 times higher than if the acute exposure occurred on June 10, 1948, and still result in 0.08 mg U/L of urine on June 11, 1948. Hence, the acute intake from the fire would have had to be about 3.7×10^6 pCi on June 1, 1948. Under these circumstances, the total intake from both chronic and acute intake during operations would have been 5.22×10^6 pCi from chronic intake and 3.7×10^6 from a single acute intake, for a total of about 9×10^6 pCi. Under these rather extreme assumptions, the upper-bound total intake from a combination of chronic intake plus a single acute intake from a fire would increase by almost a factor of two above the values derived using the exposure matrix. However, this scenario is not very plausible because an acute intake of 3.7×10^6 pCi is associated with a uranium dust loading of over 500 mg/m^3, if it is assumed that the intake occurred over an 8-hour period. We believe that a person would not be able to breathe air with a dust loading of this magnitude over such a long period of time. Appendices 4 and 5 present our rationale for this judgment. In addition,

even if this scenario is considered plausible, the total time-integrated intake of uranium would increase by less than a factor of two.

An intermediate date would yield a higher intake estimate but would not make as much of an impact on the total intake estimate. However, the issue is large enough that a date based on a fuller analysis of the documents that is claimant favorable needs to be determined. The method of choosing a date for the fire will also have to be cognizant of the problem of making an assumption that would result in an arbitrarily large dose, resulting in a loss of consistency across sites and SEC evaluations.

One last point is if there were multiple fires, and if the acute intakes were on the order of 1 to 3 million pCi due to the fire, the uranium concentration in the urine of those workers would have remained well above the MDL for many weeks if not months. It does not seem to be plausible that such a situation could have existed, yet virtually none of the urine samples collected after June 11, 1948, contained concentrations above 0.01 mg/L.

Acute Exposures Associated with Furnace Operations or Other Possible Acute Exposure Scenarios

A similar issue can also be raised with respect to the possibility that some workers may have experienced very high uranium dust loadings for short time periods while loading and unloading and cleaning the furnace (see the above examples at the Hanford Metal Melt Building (AEC 1959) and the paper by Harris and Kingsley (1959)). The data provided in the reports cited above indicate that these exposures could have been well above the chronic levels. Like the fire issue, if these types of exposures occurred frequently and without respiratory protection, the exposure matrix may underestimate the exposures to some workers. We are at a point where one can conclude that the exposure matrix is claimant favorable for the majority of workers, but, depending on what judgments are considered reasonable with regard to short-term acute exposures, the exposure matrix may not be claimant favorable for all workers.

Before leaving this topic, it is important to recognize that, if a worker did, in fact, experience a very high short-term intake, the uranium excretion rate in urine would remain high for a long period of time. Since virtually every urine sample, except those associated with the fire, were at or below the LOD (i.e., 9.56 pCi/day or 0.01 mg U/L), it is unlikely that very many workers experienced high acute exposures because the elevated exposures would have been observed in at least some of the urine samples. For example, Figure 2-2 shows how the uranium excretion rate in urine changes as a function of time following a single acute intake of either 1 million or 3 million pCi of Type S uranium (5 micron AMAD). These values were selected because they capture the range of the highest plausible acute intakes that workers might have experienced as a result of a uranium milling operations (see Table 2-8 above which shows a peak uranium dust loading of 0.238 mg/cm^3 due to grinding operation).[11] Keeping in mind that the MDL is a uranium excretion rate of about 10 pCi/day, such intakes would be detectable for anywhere from 1 to several months after intake.

[11] Table 2-10 above shows a peak uranium dust loading of 0.238 mg/cm^3. Assuming an 8-hour exposure and a breathing rate of 1.2 m3/hr, the intake from such a scenario would be about 1.5×10^6 pCi.

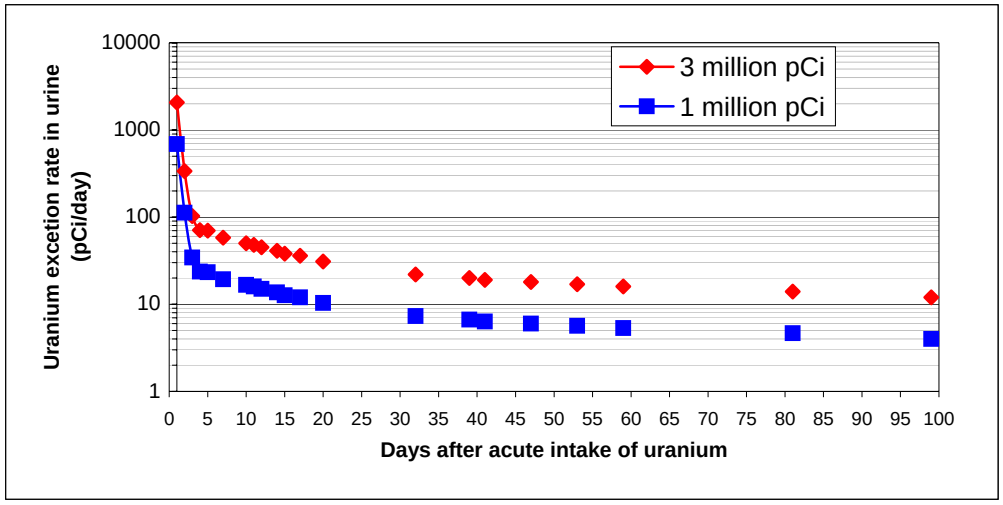

Figure 2-2. Type S Uranium Excretion Rates

2.3 EXTERNAL EXPOSURES DURING OPERATIONS (JANUARY 1, 1948, THROUGH DECEMBER 31, 1949)

2.3.1 Penetrating and Non-Penetrating Radiation

Section 4.0 of the site profile presents the exposure matrix for reconstructing external exposures for all workers. Before evaluating the matrix itself, it is important to note that, as long as the facility handled only natural uranium, a plausible upper bound can be placed on the exposure to penetrating and non-penetrating external exposures for all workers, even if there were no monitoring data of any kind. Using well-established computer codes, such as MCNP and Varskin, external penetrating and non-penetrating dose rates at contact or at any distance can be estimated for any geometry of uranium. Hence, there does not appear to be an SEC issue associated with reconstructing external exposures to penetrating or non-penetrating radiation during operations.

A review of the literature and records cited in the exposure matrix reveals that workers at Chapman Valve were monitored for external penetrating and non-penetrating radiation, and that the program appears to be quite comprehensive. Specifically, 81 workers were issued film badges with weekly changeouts, the first one beginning May 3, 1948, and the last readout on November 1, 1948. According to the records reviewed by SC&A, it appears that all workers that entered the controlled area were badged. However, SC&A's discussions with former workers revealed that not all workers that entered the controlled area were given dosimeters.

The highest 1-week penetrating dose recorded among all the badged workers was 110 mrem, which corresponds to a dose rate of about 2 mrem/hr. It is instructive to note that 2 mrem/hr is the approximate penetrating dose rate one would calculate for an individual standing adjacent to an infinite slab of pure uranium. It is also worth noting that the vast majority of the changeouts were less than the MDL of 50 mrem.

The highest non-penetrating dose in a 1-week period was 650 mrem, which corresponds to about 130 mrem/hr, which is about one half the contact beta/gamma dose rate for pure uranium. The majority of the workers experienced non-penetrating doses in excess of the LLD of 50 mrem/changeout.

This characterization of the film badge data is consistent with the characterization provided in Section 4 of the exposure matrix.

Table 4-1 of the exposure matrix presents default external doses to penetrating and non-penetrating radiation by workweek, intended to be assigned to all workers. Actual film badge measurements did not start until May 3, 1948. However, default doses are assigned to all workers beginning January 5, 1948. For the weeks beginning January 1, 1948, to April 26, 1948, there is evidence that no significant machining operations took place at Chapman Valve. Nevertheless, the exposure matrix assigns 115 mrem/week for non-penetrating radiation and 50 mrem/week for penetrating radiation for all workers for each of these weeks.

Beginning on May 3, 1948, and continuing until October 25, 1948, the large majority of workers that entered the controlled area were issued a film badge. For each of those weeks, the exposure matrix assigns default penetrating and non-penetrating exposures based on the highest film badge reading observed among all workers for that week. This is a reasonable bounding approach to reconstructing the doses for all workers. Beginning November 11, 1948, badging ceased, because it appears that operations ceased. Beginning at that time, and extending up to the week beginning December 27, 1948, the exposure matrix assigns a weekly penetrating gamma dose of 50 mrem and a weekly non-penetrating dose of 115 mrem for all workers. The net result of these assumptions is that the exposure matrix assigns all workers a penetrating dose of 2.83 rem and a non-penetrating dose of 9.11 rem. SC&A considers this to be a scientifically plausible and claimant-favorable strategy for assigning doses to all workers.

2.3.2 Contact External Dose

A subject that is not addressed in the exposure matrix is the non-penetrating contact dose associated with handling uranium rods and/or the direct deposition of small uranium particles on skin. It is highly likely that such exposures occurred, and the exposure matrix is deficient in not addressing this issue. However, this deficiency is not considered an SEC issue because plausible bounding estimates of non-penetrating contact doses to any size particle can be reconstructed using standard dose calculational methodologies, such as MCNP and Varskin.

We have calculated the dose to the skin from a metallic chip composed of natural uranium in secular equilibrium with its short-lived progeny. Absent specific knowledge of the size and shape of a chip that might be projected during the machining of uranium metal, we have postulated that the chip would have a generic shape—a circular, cylindrical disk—with a range of dimensions. The dose rate was averaged over the region of the skin just beneath the epithelial layer that is directly under the hypothetical disk—the exposed area is equal to the area covered by the disk.

The calculation used two different methodologies that are widely used and accepted for dose calculation. The most precise method uses MCNP Version 5 (LANL 2004). For comparison purposes, we repeated the calculations using the beta version of Varskin 3. Table 2-12 and Figure 2-3 present the results of the MCNP calculations.

Table 2-12. Dose Rates to Skin Using MCNP

Diameter Cm	Thickness Cm	MCNP mrad/h	Error
0.01	0.01	11.7	±1.2%
0.03	0.01	55.9	±0.7%
	0.03	62.3	±1.1%
0.1	0.01	115	±0.5%
	0.03	137	±0.8%
	0.1	136	±1.6%
0.3	0.01	159	±0.5%
	0.03	190	±0.8%
	0.1	190	±1.5%

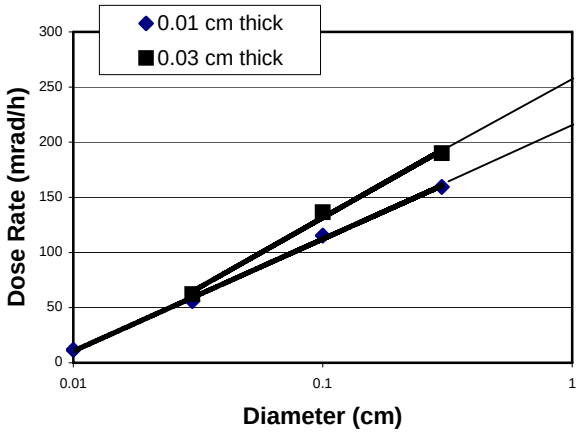

Figure 2-3. Dose Rate to Skin from Small Particles of Uranium

Several observations can be made about these results. First, increasing the thickness of the uranium chip to greater than 0.03 cm does not result in greater dose, due to the self-absorption of the β particles in the uranium metal. Second, the MCNP calculation of the dose due to x-ray and γ-ray photons showed that for the largest chip, where the contribution would be the largest, the photon dose accounted for less than 0.5% of the total dose. Since this is less than the statistical uncertainty in the MCNP calculations, the contribution of the photon radiation was omitted in the other analyses. A plot of the dose rate vs. the disk diameter for two thicknesses shows that the dose rate increases linearly with the log of the diameter. Extrapolating to the unlikely diameter of 1 cm shows that the maximum dose rate for a 0.03-cm-thick chip would be about 260 mrad/h.

As may be noted, the dose rates are relatively small. It can be assumed that the exposure to any location from a given particle will last no more than about 8 hours, because Chapman Valve required workers to shower at the end of each workday.

2.4 RESIDUAL EXPOSURE (SECTION 5 OF THE SITE PROFILE)

The source documents reviewed in Section 2 above provide compelling evidence that uranium milling operations ceased in November 1948, at which time a cleanup operation was implemented. The source documents also indicate that the majority of the cuttings and other "waste" that was produced as a result of milling operations were shipped offsite by May 1, 1949. Accordingly, uranium contamination that remained in the controlled area of Chapman Valve as of May 1, 1949, is appropriately characterized as residual contamination.

A review of Section 5 of the site profile reveals that the reconstruction of exposures to workers during the residual radioactivity period are to be based on radiological data collected in 1987, and then again in 1992. It is SC&A's judgment that these data were collected at a time period that is applicable to exposures that may have occurred in the 1980s and 1990s, but not during the 1940s through the 1970s. However, we do not believe this deficiency in the site profile necessarily constitutes an SEC issue because (1) this time period is not covered in the petition, and (2) the data from 1987 can be used for the later 1991–1993 period, which is part of the SEC petition. The issue of application of 1987 data to the May 1, 1949, to December 31, 1949, period remains however. There are no data that are contemporaneous with that period to support a residual radioactivity dose reconstruction for that 8-month period. It may be possible, however, to glean information from other sites to address this issue.

For example, in the Metal Plant Building investigation described above, part of the investigation included determining the rates at which dust accumulates by settling on floors, ledges, beams, equipment and other settling surfaces. This was accomplished by placing a 4-inch deep crystallizing dish containing a filter paper at 13 locations throughout the facility. The dishes were placed during the winter months when the doors to the facility were closed. The plates passively collected deposited dust over a 158-day period, at which time the filter paper was collected and analyzed for deposited uranium. This procedure was repeated a second time for 117 days, but with the doors left open to determine the effects of natural ventilation on the deposition rate of uranium dust. Table XIII of the report presents the results of the investigation expressed in units of mg U deposited per square foot per day. The deposition rates ranged from 0.25 mg/day per square foot in the office area to 5.72 mg per square foot per day in burnout room. One approach to bounding the amount of residual contamination on surfaces after cleanup is to assume one day of buildup.

Alternatively, it could be assumed that the cleanup operation continued until the residual radioactivity left on surfaces was at or below the LOD for the radiation detection instruments in use at that time. A useful default value for residual uranium contamination on surfaces is 5000 dpm/100 cm^2 (see Regulatory Guide 1.86, NRC 1974). This strategy would be consistent with the affidavit filed by a former employee regarding the extent of the wash-down that was performed following the termination of milling operations at Chapman Valve.

Once an upper-bound estimate is made of the amount of residual uranium on surfaces following cleanup, upper bound external exposures to workers can be derived using conventional shielding codes (such as Microshield or MCNP). Upper-bound internal exposures via inhalation can be estimated by employing bounding assumptions regarding resuspension factors for activity

deposited on indoor surfaces. Upper-bound estimates of uranium intake rates via inadvertent ingestion of residual radioactivity on surfaces can be derived using the default values recommended by the EPA and NCRP, or the protocol recently developed by NIOSH and used in the latest version of the Bethlehem Steel site profile. However, the protocol for exposure that is supportable for Chapman Valve remains to be developed.

3.0 REVIEW OF NIOSH'S EVALUATION REPORT OF THE CHAPMAN VALVE SEC PETITION

On November 9, 2005, NIOSH qualified SEC Petition-00043 for Chapman Valve. On August 8, 2006, NIOSH submitted to the Board *SEC Evaluation Report for Petition SEC-00043*. The NIOSH proposed definition for the class is defined as follows:

> *All AWE employees who were monitored, or should have been monitored, for radiological exposures while performing Atomic Energy Commission Work in Building work at the Chapman Valve Manufacturing Company in Indian Orchard, Massachusetts, from January 1, 1948 through December 31, 1949 and from January 1, 1991 through December 31, 1993.*

For the purpose of this evaluation, NIOSH divided the period of the evaluation into two time periods: January 1, 1948 through December 31, 1949, and January 1, 1991 through December 31, 1993, referred to as the residual radioactivity period. The class definition in the petition was somewhat different than that proposed by NIOSH in that the original petition provided a detailed breakdown of individual job categories that comprised the cohort. However, NIOSH elected to include all workers in the covered time periods as members of the cohort, thereby simplifying the evaluation. This was considered appropriate and petitioner-favorable because job descriptions were not always entirely descriptive of the type of work performed by individual workers. In addition, the time period covered by the original petition extended through 1995. NIOSH elected to not include 1994 and 1995 in the evaluation because this was the time period when the facility underwent another round of remediation. At the time of the evaluation, NIOSH had developed an exposure matrix for the operation and residual radioactivity periods, but had not yet developed an exposure matrix for the remediation period. As a result, NIOSH determined that it was in a position to evaluate the operation and residual radioactivity time periods but not the remediation period, and, because of this, determined that the remediation time period should be addressed separately in order to expedite the review process.

For the purpose of the evaluation report, NIOSH extended the definition of the operational period through April 30, 1949, because of some evidence that chips and turnings associated with operations may have been onsite until that date. In addition, NIOSH divided the residual radioactivity period into two time periods: May 1, 1949 through December 31, 1949, and January 1, 1991 through December 31, 1993.

As cited in the evaluation report,

> *NIOSH has established that it has access to sufficient information to: (1) estimate the maximum radiation dose incurred by any member of the class; or (2) estimate doses more precisely than a maximum dose. Information available from the site profile and additional resources are sufficient to document or estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances during the specific period.*

So far as routine exposures are concerned, SC&A generally concurs in this determination based on the analyses provided in Section 2 of this report, interviews with workers and petitioners, and an independent evaluation of the key issues performed by Dr. Michael Thorne (see Attachment 1), which was commissioned by SC&A. SC&A also explicitly considered correspondence by petitioners and petitioner representatives. However, there are some weakness in the available records regarding possible exposures associated with the June 1948 fire, the possibility of other fires, and possible short-term, acute exposures that may have been associated with some operations, especially grinding operations and the loading and unloading of the furnace.

This section of our review of the evaluation report is organized according to each of the specific petitioner statements contained in SEC-00043 (ORAUT 2006a). First, each petitioner statement is restated. This is followed by a summary of NIOSH's evaluation of each statement. This is followed by SC&A's technical review of NIOSH's position regarding each statement. Extensive reference is made to SC&A's analysis of the exposure matrix provided in Section 2 of this report, since NIOSH's determinations regarding the petitioners' statements are based primarily on the exposure matrix.[12]

3.1 AVAILABLE URANIUM BIOASSAY DATA

The petitioners claim that the bioassay data are not adequate to support the reconstruction of doses with sufficient accuracy. They claim that the data (1) are not representative of the exposed worker population, (2) were collected without any understanding of the individuals' exposure histories, and (3) do not assess exposures from a number of industrial processes, such as the cracking furnace, chip incinerator, or possible rolling operations.

NIOSH disagrees with these claims related to the available bioassay data and contends that the bioassay data are representative of the potential exposures from uranium operations performed by Chapman Valve, because bioassay samples were collected from employees accessing the restricted Chapman AEC areas in job categories that are considered representative of the workers involved in the AEC project. In addition, NIOSH states that the bioassay data are consistent with the available air sampling data, and with information from uranium operations at other sites.

SC&A's review of this issue, as described in detail in Section 2, concurs with the petitioner that the bioassay data from Chapman Valve alone are not sufficient to support internal dose reconstruction with sufficient accuracy for the very reasons cited by the petitioners. However, there is a vast amount of air sampling data and bioassay data collected at other uranium metal handling and processing facilities at the time that can be used to supplement and complement the bioassay data available from Chapman Valve.

The air sampling data collected at Chapman Valve are of little or no use to support the exposure matrix. However, air sampling data collected at many other facilities reveal that the exposure

[12] It is important to point out that the evaluation report describes the dose reconstruction exposure matrix presented in Revision 0 of the site profile. As pointed out in the introduction of this report, Revision 1 of the site profile was issued on October 16, 2006. We assume that the evaluation report will be revised to reflect the most recent version of the exposure matrix. We point this out because we found significant deficiencies in the exposure matrix contained in Revision 0, many of which were corrected in Revision 1.

matrix adopted by NIOSH in Revision 1 of the site profile, which is based on the bioassay data, establishes a plausible upper bound on the chronic exposures experienced by all workers at Chapman Valve. Specifically, the exposure matrix is based on the assumption that all workers were chronically exposed to that level of airborne uranium that would result in 0.03 mg U/L of urine. Not including the 7 urine samples collected on June 11, 1948, from workers exposed to the fire and subsequent cleanup activities, 0.03 mg U/L is the highest urine concentration observed among the other 33 urine samples collected on or about July 27, 1948; August 8, 1948; and October 7, 1948. However, these data alone are not sufficient to establish a plausible upper bound on the chronic exposures experienced by workers, because the urine samples were collected from only a fraction of the workers and were largely limited to a single sample from the workers that participated in the bioassay program. In addition, it is theoretically possible that some of the monitored and unmonitored workers may have experienced intakes that resulted in urine concentrations at some days during operations that exceeded 0.03 mg U/L.

However, for a number of reasons, we believe that it is unlikely that workers experienced chronic exposures that would have resulted in uranium concentrations in urine that would be chronically at 0.03 mg/L, which is effectively the assumption made by NIOSH in its exposure matrix. Such an excretion rate would be associated with a chronic intake of either 481 pCi/day of Type M uranium or 14,300 pCi/day of Type S uranium. These excretion rates are associated with a chronic airborne uranium concentration of 50.1 pCi/m^3 of Type M or 1490 pCi/m^3 of Type S uranium.

Hence, the question becomes, is it scientifically plausible and claimant favorable to assume that all workers were chronically exposed to these concentrations of airborne uranium from January 1, 1948 to April 4, 1949? The answer is yes, for the following reasons. The first reason is that, if such exposures actually occurred, many more than one urine sample would likely have contained 0.03 mg U/L. Second, there is strong evidence that full-scale milling operations occurred from May through October 1948. Hence, the assumptions employed in the exposure matrix regarding exposure duration are likely to be highly conservative as applied to the months prior to and following full-scale milling operations. Finally, a chronic dust loading of 1,490 pCi/m^3 corresponds to 3,278 dpm/m^3 or about 47 MAC or 2 mg/m^3. Inspection of dust loading data collected during the late 1940s and early 1950s at a large number of uranium handling/processing facilities, including facilities involved in the full range of operations that took place at Chapman Valve and facilities with minimal radiation protection controls, reveals that 47 MAC represents a reasonable upper bound for chronic exposures (see Section 2.1.1).

3.2 URANIUM BIOASSAY DATA DETECTION LIMITS

The petitioners express concern that NIOSH concedes that they have no documentation about why bioassay samples were collected, and that most of the data were below the LOD. It appears that the petitioners are concerned that the bioassay program was poorly designed and did not detect intakes for the more highly exposed individuals.

NIOSH explains that it was standard practice at that time for urine samples to be collected in order to assess exposure conditions at the site. In addition, NIOSH states that, although the exact selection criteria regarding who should be included in the bioassay program are not stipulated in

any of the records, it was standard practice for AEC to want to know what were the worst-case exposures so that they could determine where additional controls might be needed.

This judgment by NIOSH is not unreasonable when one considers the types of air sampling and bioassay programs that were implemented at uranium facilities at that time (see Section 2.1.1). In addition, it is noteworthy that, though most of the urine samples were below the LLD for uranium, the LLD was 0.01 mg/L, which is associated with a relatively high dust loading (i.e., about 15 MAC). Hence, the exposures of all workers could have been well above the maximum allowable airborne concentrations at that time (1 MAC or 70 dpm/m^3) and still be below the LLD for uranium in urine. Hence, we believe that petitioner concerns regarding why bioassay samples were collected and the LLD do not preclude NIOSH from using the bioassay data and data from other facilities to develop and implement an exposure matrix that can be used to reconstruct chronic exposures to workers with sufficient accuracy.

3.3 ESTIMATION OF UPPER-BOUND DOSE

Petitioners claim that there is insufficient bioassay data with which to estimate a plausible upper-bound dose, that process information is too limited to characterize exposures, and there is only one day of air monitoring data. As such, it is not feasible to estimate dose with sufficient accuracy.

NIOSH disagrees with these claims because the bioassay program was consistent with such programs at that time, and that enough is known about Chapman Valve production to estimate doses with sufficient accuracy. NIOSH also states that air-monitoring data were not used to reconstruct doses, and, as a result, the fact that the amount of air monitoring data is extremely limited is not a significant issue. Finally, NIOSH summarizes the basic approach used to develop the exposure matrix and explains that those assumptions are compatible with experience at Y-12 at that time.

SC&A concurs with the petitioners' stated concerns. The bioassay program, though very useful, was not, in and of itself, adequate to support the exposure matrix adopted to reconstruct doses for all workers. In addition, though NIOSH did not use the very limited air sampling data to reconstruct doses, NIOSH does use the data as a means to assess compatibility of the bioassay data with the air sampling data, and concludes that the air sampling data are consistent with the bioassay data. SC&A believes that such a comparison is virtually meaningless because of the very limited extent of the air sampling data.

SC&A does believe, however, that the bioassay data and the limited information regarding uranium milling operations at Chapman Valve, together with a great deal of data collected from many uranium facilities at that time, allows NIOSH to develop an exposure matrix for internal doses (as described in Revision 1 of the site profile) that is scientifically plausible and claimant favorable for chronic exposures. SC&A's reasons for this opinion are described in detail in Section 2.1 above. In brief, the default chronic airborne exposure level of 47 MAC adopted in the exposure matrix for all Chapman Valve workers seems to be representative of the high-end chronic exposures experienced by most, if not all, uranium-handling facilities at that time.

We must keep in mind that only 1 of the 33 urine samples for workers not involved in the June 1948 fire contained 0.03 mg U/L. The rest of the samples were either at or below the LOD of 0.01 mg U/L. NIOSH nevertheless assumed that all workers were chronically exposed at a level (i.e., 47 MAC) that would result in all workers experiencing a 0.03 mg U/L in urine. It is possible, and even likely, that some workers experienced uranium concentrations in urine above 0.03 mg/L at some point in time. This could have occurred if workers were exposed to short-term, high levels of intake and if the urine samples were collected immediately following the exposure. However, given the bioassay data and the information we have collected at other uranium handling and processing facilities, it seems very unlikely that any worker could have experienced exposure that resulted in a chronic uranium concentration in urine of 0.03 mg U/L. The site profile could do a better job in describing the reasons this approach, as adopted in the exposure matrix for chronic exposures, is in fact a scientifically plausible but claimant-favorable approach for reconstructing the chronic exposures to all workers.

3.4 ESTIMATION OF URANIUM EXPOSURES FROM A SITE FIRE

Petitioners claim that, since the actual date of the fire is not known, the actual uranium intakes associated with the May/June 1948, fire cannot be estimated.

NIOSH's response to this concern simply re-states quotes taken from historical records that a fire occurred in early June, and that the exposure matrix takes the exposures associated with the fire into consideration using the urine bioassay data collected on June 11, 1948, from 7 workers that were involved in putting out the fire and cleanup following the fire.

SC&A believes that NIOSH's response to the petitioners' concerns regarding this matter is non-responsive. SC&A concurs that the petitioners' concerns are valid, and we performed extensive analyses in Section 2.3 above to evaluate the potential significance of the concerns raised by the petitioners. In summary, we found that, if one assumes that there was only one fire and that it occurred on June 10, 1948, then the protocol adopted in the exposure matrix for estimating the uranium intake associated with the fire is valid. We determined this by demonstrating that, under the stipulated conditions, the uranium intakes associated with the fire would result in 0.08 mg U/L of urine on June 11, 1948. However, we acknowledge that there may have been more than one fire, and we also acknowledge that the intake that resulted in 0.08 mg U/L on June 11, 1948, may have occurred as early as June 1, 1948, based on a review of the historical records.

Section 2.3 explores the implications of both these concerns. Let us assume for the moment that the uranium concentration observed on June 11, 1948, of 0.08 mg/L was due to an acute intake of uranium on June 10, 1948. Under this assumption, the acute intake of Type S uranium would have been 73,900 pCi. It turns out that this intake is only 1.5% of the total intake associated with chronic exposures over the approximate 70 weeks of uranium operations assumed in the exposure matrix. Hence, even if there were several fires, the contribution of the fires to the total uranium intake would be minimal. It is worth noting that SC&A's meetings with former workers revealed that the workers do not recall any fires other than the one fire that occurred in June 1948. Hence, if there were additional fires, they were not likely of the same magnitude as the June 1948 fire.

With regard to the second issue, we determined that, if the acute intake of uranium occurred on June 1 instead of June 10, 1948, then the intake of Type S uranium would have had to have been about 50 times higher in order to result in 0.08 mg U/L of urine on June 11, 1948. If that were in fact the case, the total uranium intake associated with the chronic plus acute intake would approximately double. However, we determined that, for this to occur, the uranium dust loading due to the fire would have had to have been in excess of 500 mg/m^3 for an 8-hour period. Based on the analyses and literature review provided in Attachments 4 and 5, it does not appear to be plausible for a person to remain in such an environment for an extended period of time without respiratory protection. Hence, we do not believe this scenario is realistic. At the same time, if it is assumed that the acute intake occurred on June 9, 1948, the intake of Type S uranium would have had to be about 16 times higher compared to the intake associated with the assumption that the fire occurred on June 10, 1948. This level of exposure would also be associated with a protracted exposure to a uranium dust level in excess of 100 mg/m^3. On this basis, we conclude that the methods employed by NIOSH in the exposure matrix to address the fire are reasonable, but not necessarily claimant favorable. We believe that NIOSH should reconsider the approach it has adopted for assigning an acute intake associated with the fire or at least explore some of the issues identified here in order to ensure that the approach for assigning acute intakes associated with the fire is, in fact, scientifically plausible and claimant favorable. However, we believe that this is a tractable issue and does not represent an SEC issue (i.e., we believe a method can be developed for placing a plausible upper bound on the exposures associated with the fire).

3.5 ESTIMATION OF ENRICHED URANIUM EXPOSURES

The petitioners express concern that enriched uranium may have been machined at Chapman Valve. This concern is based on an airborne dust measurement taken in the 1990s as part of the site remediation program.

NIOSH's response to this concern is to disregard the cited measurement for a number of reasons. First, the historical records indicate that Chapman Valve was commissioned by the AEC to machine uranium rods for the Brookhaven reactor. The historical records reveal that, at that time, Brookhaven only used natural uranium for its reactor (BNL 2006). NIOSH also stated that the 1997 report, where the slightly enriched uranium was observed, attributed the value to background levels. In addition, NIOSH cites evidence that enriched uranium was only handled by government facilities at that time. Finally, NIOSH concludes that whether or not enriched uranium may have been processed at Chapman Valve has no bearing on the feasibility of dose reconstruction, and does not pose an SEC issue.

SC&A generally concurs with NIOSH's position that natural uranium was processed at Chapman during the period under consideration (1948-1949). However, for the reasons discussed in Section 2.1, some additional investigation is needed. As discussed above, the TBD made no effort to try to secure the underlying data where a dust sample was found that may have contained slightly enriched uranium. Measurements must have been made of U-235 and possibly U-234 to conclude that it was enriched to 2.16%. The TBD is correct in stating that NIOSH has looked at the range of possible enrichments. SC&A currently does not know whether the lower bound of enrichments was natural or something more or something less than

that. In case it was natural or less, then the case for setting it aside would be stronger. But given evidence that Chapman held contracts with the Manhattan Engineering District (MED) during WWII, it is difficult to entirely dismiss the 2.16% enrichment issue without further investigation. In addition, some consideration must be given to the DOE document that states that salts and oxides were received at Chapman.

During SC&A's meetings with former workers, we determined that Chapman Valve received manifolds from Oak Ridge for pressure testing. The manifolds were delivered to the main Chapman Valve site by rail and then shipped to another location for pressure testing. It is possible that, since these manifolds came from Oak Ridge, they could have contained some residual levels of enriched uranium. The implications are that the soil sample that was observed to contain 2.16% enriched uranium may be real (i.e., not a false positive) and may be due to enriched uranium deposition during the transfer from train to truck. The indicated slight enrichment of one soil sample may also have a similar origin. However, based on SC&A worker interviews, the indicated period for exposure to enriched uranium would be during the Manhattan Project and not during the period under consideration here. SC&A has therefore not pursued the matter further. Additional investigation of this issue is warranted, including a sampling of the Dean Street site, where the maintenance and repair work took place.

3.6 CONSIDERATION OF OTHER INDUSTRIAL PROCESSES

The petitioners expressed concern that the site profile does not take into consideration other industrial processes that may have taken place at Chapman Valve, such as the use of a cracking furnace, chip incinerator, or possible rolling operations.

NIOSH's response to these concerns is that the site profile does take into consideration the fact that there was a chip burner at the facility and cites data collected at the burner's exhaust location. In addition, NIOSH states that the bioassay data upon which the exposure matrix is based captures any exposures that may have been associated with a chip burner. With respect to possible rolling operations, NIOSH states that there is no documented evidence that rolling operations took place at Chapman Valve. NIOSH further states that, even if rolling operations took place, the bioassay data would have captured such exposures.

SC&A believes that the petitioners' concerns regarding exposures associated with a chip burner and possible rolling operations are valid, and that NIOSH's response to those concerns is not convincing. SC&A believes that there could have been short-term elevated exposures associated with chip burning or possible rolling operations that the bioassay program could have missed. As we have discussed, the work at the incinerator is not adequately covered in the NIOSH analysis. There are no bioassay samples for incinerator operators, or at least none that can be discerned from the records. NIOSH's reasoning based on exhaust sampling is irrelevant.

Hanford and Fernald data indicate that incinerator loading and unloading may have exposed some workers to very high levels of uranium dust for short periods of time. Such exposures could have been missed by the bioassay program. Unfortunately, our meetings with former workers were not able to shed any light on the nature of the loading and unloading of the furnace and the potential periodic acute exposures experienced by these workers, or any information

regarding rolling operations. NIOSH should consider using the data cited in the Hanford Melt Plant Building investigation described above to explore the need to incorporate such exposures into the matrix. Alternatively, using these data, NIOSH may be able to demonstrate that the conservative assumptions inherent in the chronic exposure portion of the matrix accounts for the possibility of such exposures. In its current form, the site profile is deficient in terms of adequately exploring these issues and taking full advantage of the large amount of data that are available from other contemporaneous facilities.

3.7 AVAILABLE AIR-SAMPLING DATA

Petitioners express concern that there is only one day of uranium air samples, and that one set of samples shows that there were elevated levels of uranium throughout the facility. NIOSH agrees with petitioners' statements and concerns, but explains that the limited air sampling data were not used for dose reconstruction, and that the bioassay data that were used for dose reconstruction are compatible with the limited air sampling data.

SC&A concurs with NIOSH's position on this matter. However, in other sections of the evaluation report and the site profile, NIOSH states that the results of the very limited air sampling data are compatible with the bioassay data. We believe that these statements are somewhat misleading, because the air sampling data are too limited to draw any conclusions regarding exposures at the facility.

3.8 URANIUM FIRES

Petitioners express concern that there may have been numerous fires at the facility that NIOSH has not taken into consideration.

NIOSH explains that the records only indicate one significant fire in early June that is taken into consideration in the exposure matrix. They also explain that the assumptions used in the exposure matrix for chronic exposure account for the possibility that other fires may have occurred, because, if the bioassay results were in fact associated with incidents, the approach used by NIOSH overestimates the exposures.

SC&A believes that the method adopted in the exposure matrix to model the acute exposures associated with the June fire is not claimant favorable for the reasons discussed above (i.e., much higher intakes would have been derived if NIOSH assumed that the fire occurred before June 10, 1948). However we believe that this is a tractable problem also for the reasons discussed above, since a claimant favorable and scientifically defensible exposure estimate can be derived based on the available data. It would be desirable to investigate the issue of the date of the fire in more detail. SC&A interviews indicated that Indian Orchard Fire Department documents that may throw some light on the date may exist in some other fire station.

Finally, our interviews with former workers revealed that additional large fires may not have occurred at the facility during uranium operations. However, this indicated conclusion should be treated with caution, since none of the workers interviewed worked in Department 40 of Building 23 full time. We do not believe the exposure matrix needs to explicitly consider the

possibility of multiple fires, but some exploration of the frequency of fires at similar facilities during the period in question would be useful as a confirmation. The site profile should explore this issue in more detail.

3.9 RESIDUAL RADIOACTIVITY PERIODS

SC&A is not in agreement with the use of data from the 1980s and 1990s to reconstruct doses due to residual radioactivity in the May 1, 1949 to December 31, 1949, time frame. They are adequate for the 1991–1993 time frame. Accordingly, the site profile needs to develop a more scientifically plausible and claimant-favorable approach to reconstructing doses to workers for the residual radioactivity period extending from May 1, 1949 to December 31, 1949.

4.0 CONCLUSIONS

SC&A cannot entirely agree with NIOSH's conclusion that exposures to all members of the proposed class of workers at Chapman Valve can be reconstructed with sufficient accuracy and in accordance with the requirements of 42CFR83 using the methods described in the exposure matrix. In addition, we believe that the Evaluation Report and supporting exposure matrix did not fully meet all the draft acceptance criteria for an evaluation report as established by the Working Group.

The NIOSH exposure matrix largely meets the test as a claimant-favorable approach for intake estimates due to *chronic* exposure in the operation period (January 1, 1948, to April 30, 1949). The approach for the 1991–1993 period also seems appropriate. However, the estimate of intake from the June 1948 fire is not claimant favorable, much less bounding. NIOSH's analysis of exposures due to work associated with incinerator operation is unconvincing. This remains a question mark since there are no data from Chapman Valve itself and data from other facilities vary widely, but nevertheless should be consulted. Finally, an adequate exposure scenario for the May 1, 1949 to December 31, 1949, period remains to be developed.

As described above, we do not believe that enriched uranium is an important issue at the site for the period under consideration, but may be an issue during the Manhattan Project, based on available information. There is information about only one significant fire at the site during the period of uranium operations. There is also a need to explore the possibility and potential significance of short-term, high exposures associated with grinding operations and loading and unloading the furnace. If such scenarios are determined to have been plausible, a demonstration needs to be made that the exposures associated with these scenarios could not have resulted in cumulative exposures during the operations period that were significantly greater than those derived using the exposure matrix. This may be accomplished by taking advantage of the large amount of contemporaneous air sampling and bioassay data available from other uranium handling and processing facilities, with due consideration of the Chapman Valve bioassay data and operational practices.

The key considerations regarding an evaluation report, as identified in the report of the Working Group, include the following:

- Timeliness
- Fairness
- Understandability
- Consistency
- Credibility and validity of the data set, including pedigree of the data, methods used to acquire the data, relationship to other sources of information, and internal consistency
- Representativeness and completeness of the exposure data with respect to the area of the facility, the time period of exposure, the types of workers and processes covered by the data

The working group guidelines also recommend that NIOSH include in their SEC evaluations a demonstration that it is feasible to reconstruct individual doses for the cohort, including sample dose reconstructions. Discussion with NIOSH revealed that dose reconstructions are being performed and revised using Revision 1 of the exposure matrix, but they have not yet been adjudicated. However, given the highly prescriptive nature of the exposure matrix, example dose reconstructions are not essential to this review at this time.

With respect to **timeliness**, the SEC petition was qualified on November 8, 2005, and the SEC Evaluation Report was due, under the terms of 42 CFR 83, on May 9, 2006. The Evaluation Report was issued on August 31, 2006. Hence, the issuance of the Evaluation Report did not meet the criteria set forth in the regulations regarding timeliness.

Another issue related to timeliness, and perhaps also related to **fairness**, is the fact that Revision 0 of the site profile, dated February 22, 2005, was issued only one day after a public meeting was held with the workers. Hence, Revision 0 of the exposure matrix could not have taken into consideration new information collected during the interview.

NIOSH issued Revision 1 of the site profile on October 16, 2006, well after the issuance of the Evaluation Report. This revision incorporates extensive new information gathered during the worker interviews and reflects a major revision to the exposure matrix. These revisions were needed because Revision 0 had significant deficiencies, many of which were corrected in Revision 1. Unfortunately, the Evaluation Report still contains the exposure matrix employed in Revision 0. SC&A assumes that the Evaluation Report will be corrected in an expeditious manner, and that dose reconstructions performed using the exposure matrix described in Revision 0 will be corrected. This chain of events, and the need to close out issues identified in this review, raises questions regarding timeliness and fairness that will need to be taken into consideration by the Board in its review of the Evaluation Report and its recommendations.

With regard to **understandability**, we found the methods used by NIOSH to prepare Revision 1 of the site profile and the Evaluation Report to be understandable except for one particular matter. The date that NIOSH assumed for the acute intake associated with the June fire is not clearly defined. SC&A found it necessary to call NIOSH on this matter and was told that NIOSH assumed that the acute exposure occurred on June 10, 1948. It is also not apparent in the exposure matrix why NIOSH's approach to developing this aspect of the exposure matrix is claimant favorable. We determined that, if the acute intakes associated with the fire occurred on June 10, 1948, the intakes derived by NIOSH due to the fire are consistent with the analysis of the urine samples collected on June 11, 1948. We also determined that if the exposures that caused the elevated urine concentrations on June 11, 1948 occurred earlier than June 10, 1948, the acute intakes would have been substantially higher than those assumed in the exposure matrix and still result in 0.08 mg U/L of urine on June 11, 1948. We also determined that it is unlikely that such exposures actually occurred as early as June 1, 1948, because the dust levels would have had to have been so high (about 500 mg/m^3) that it would not have been possible for workers to be able to remain in such a dusty atmosphere for such an extended period of time without respiratory protection. It is conceivable that acute exposures could have occurred a few days before June 11, 1948, whereby acute intakes could have been substantially higher than

those used in the exposure matrix. Hence, it is not apparent that the assumption employed by NIOSH regarding the timing of the acute exposure associated with the fire is claimant favorable.

With respect to **consistency**, SC&A found that the exposure matrix and the data upon which it is based are generally consistent with the experience at other uranium facilities at that time. Also, the level of conservatism imbedded in the exposure matrix is consistent with the methodologies adopted by NIOSH for reconstructing the chronic doses to workers at other uranium processing and handling facilities.

With respect to **credibility**, NIOSH was able to capture the original internal and external exposure data and interpret and use the data in a highly transparent and credible manner. NIOSH also made use of air sampling data at other uranium facilities that were in operation at the same time as Chapman Valve. However, NIOSH could have been more thorough in accessing the available data. Specifically, though NIOSH took advantage of data available from Simonds Saw and Y-12, there are many other sources of data that could have been used to support the site profile and Evaluation Report. SC&A included a review of these data as part of this report.

With respect to **representativeness**, NIOSH collected all available data, and these data generally represented a cross-section of the different workers and activities that took place at the site, except for the category of incinerator workers. However, SC&A found that the Chapman Valve data had some significant deficiencies, and that it was necessary to supplement that data with data from other facilities in order to evaluate the scientific validity and claimant-favorability of the exposure matrix presented in Revision 1 of the site profile. Because the time periods of interest to the class were limited to 1948–1949 and 1991–1993, and data for those time periods were available, we consider the Evaluation Report to be generally representative of the time periods of interest for all workers except incinerator workers. It is not clear that the available data are representative of incinerator workers because there were no bioassay samples specifically identified as being representative of incinerator workers. Available data for similar operations at other facilities indicate a wide variation in dust conditions, but nevertheless should be consulted by NIOSH in order to address this deficiency. Furthermore, the data collected after the September 9, 1948, sampling are not representative overall of the job types, leading to an open question about exposures for process operators (e.g. machinists) after that date. An important piece of factual information, the date of the fire in early June 1948 is not known, leading to a significant uncertainty in the acute intake estimate due to that fire. Finally, data from the 1980s and 1990s cannot be assumed to be representative of the May 1, 1949 to December 31, 1949, period.

With respect to **feasibility and sufficient accuracy**, our review found the exposure matrix proposed for use by NIOSH to reconstruct the chronic doses for all Chapman Valve workers to be scientifically valid and claimant favorable, in the main. For both chronic and acute exposures, the methodology is simple and therefore feasible to perform within the constraints of the program. All the data and assumptions needed to reconstruct doses are explicitly defined by the exposure matrix. Also, the exposure matrix is designed to be used for all workers, and the method employed for different workers need only take into consideration the type of cancer and whether a given worker may have been involved in the June fire. The date of the June 1948 fire has not been determined with sufficient accuracy.

Finally, with respect to **sample dose reconstructions**, the Evaluation Report refers to numerous dose reconstructions already completed by NIOSH for Chapman Valve workers. However, these dose reconstructions will likely need to be revisited in light of the major revision made to the exposure matrix in Revision 1 of the site profile, with due consideration to the issues raised in this review. SC&A has not yet evaluated the dose reconstructions that NIOSH has completed to date, but intends to do so once adjudicated dose reconstructions become available.

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ATTACHMENT 1: INDEPENDENT ANALYSIS OF THE CHAPMAN VALVE SITE PROFILE

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EXTERNAL MEMORANDUM

Date: 20 October 2006
From: M. C. Thorne
To: J. Mauro, A. Makhijani, K. Behling
Copies:
Subject: Potential for setting an upper bound on internal exposures to uranium at Chapman Valve Manufacturing Company

John

As requested, I attach a report on this issue. This comprises the following pages of this memorandum.

Regards

Mike Thorne

Potential for Setting an Upper Bound on Internal Exposures to Uranium at Chapman Valve Manufacturing Company

M C Thorne
Mike Thorne and Associates Limited

1. Introduction

A Special Exposure Cohort Petition has been submitted for the Chapman Valve site in Indian Orchard, Springfield, Massachusetts [1]. In its evaluation of that petition [2], the ORAU Technical Evaluators identified seven issues cited in the petition. The identified issues have been reviewed against the original petition and are considered to be a reasonable summary of the issues raised. Those grounds are reproduced below and are discussed in detail in subsequent sections of this report.

The seven grounds are that:

1) There were only three periods (33 samples) of available bioassay monitoring for the AEC contract period at Chapman Valve, and there are no data to support why the samples were collected;
2) There are insufficient data to support the determination of a plausible upper-bound dose estimate (there is a lack of monitoring data and a lack of process and source term information);
3) There is insufficient data regarding a documented uranium fire in May–June 1948;
4) The Chapman Valve Site Profile does not account for the potential of enriched uranium;
5) The Chapman Valve Site Profile does not account for potential exposures at the cracking furnace and uranium chip incinerator, or the potential for a uranium-rolling operation;
6) There is only one day of uranium air sample data;
7) There is no assumption in the Chapman Valve Site Profile to address the potential for uranium fires or the potential frequency of uranium fires.

Relevant information on these issues is discussed in the following sections of this paper before coming to a conclusion on the issues themselves.

2. Available Bioassay Data

The petition review [2] identified the available bioassay data to comprise:

- Urine data for individuals involved in the fire of May/June 1948;
- 33 samples collected from workers in July, September, and October 1948.

The source of these data was identified [3] and acquired. As none of the secondary references consulted (including [1, 2]) appears to have reproduced these data, the full set of information (suppressing only the names of the individuals involved) is given in Table 1.

Table 1. Full Set of Urinalysis Results for Uranium from Chapman Valve

Set	Date	Sample	Job	Conc. (μg U/liter)
1	6/11/48	1	[Redacted]	20
	6/11/48	2	[Redacted]	20
	6/11/48	3	[Redacted]	70
	6/11/48	4	[Redacted]	80
	6/11/48	5	[Redacted]	10
	6/11/48	6	[Redacted]	0
	6/11/48	7	[Redacted]	0
2	7/26/48	1	[Redacted]	0
	7/27/48	2	[Redacted]	0
	7/27/48	3	[Redacted]	10
	7/27/48	4	[Redacted]	0
	7/27/48	5	[Redacted]	10
	7/27/48	6	[Redacted]	0
	7/27/48	7	[Redacted]	0
	7/27/48	8	[Redacted]	10
	7/27/48	9	[Redacted]	10
	7/27/48	10	[Redacted]	0
	7/27/48	11	[Redacted]	10
	7/27/48	12	[Redacted]	0
	7/27/48	13	[Redacted]	0
	7/27/48	14	[Redacted]	10
	7/27/48	15	[Redacted]	10
	7/27/48	16	[Redacted]	10
	7/27/48	17	[Redacted]	10
	7/27/48	18	[Redacted]	0
	7/27/48	19	[Redacted]	0
	7/27/48	20	[Redacted]	0
	7/27/48	21	[Redacted]	0
	7/27/48	22	[Redacted]	30
3	9/8/48	1	[Redacted]	10
	9/8/48	2	[Redacted]	10
	9/8/48	3	[Redacted]	10
	9/9/48	4	[Redacted]	10
	9/9/48	5	[Redacted]	10
	9/9/48	6	[Redacted]	0
4	10/7/48	1	[Redacted]	10
	10/7/48	2	[Redacted]	0
	10/7/48	3	[Redacted]	0
	10/7/48	4	[Redacted]	0
	10/7/48	5	[Redacted]	10

In interpreting these data, it should be noted that all the results were determined by the photofluorometric method, which is stated to have a limit of reliable determination of 10 μg U/liter for all the datasets recorded in Table 1. Also, all results appear to have been rounded to integral multiples of 10 μg U/liter. The basis of rounding has not been established.

Some individuals are associated with more than one sample. This has been established by comparing both full names and job descriptions. Thus:

- Set 1, Sample 5 is from the same individual as Set 2, Sample 17
- Set 1, Sample 6 is from the same individual as Set 2, Sample 16
- Set 2, Sample 22 is from the same individual as Set 4, Sample 1

This analysis confirms the conclusion in Section 7.1.2.2 of [2] that the urinalysis provides 40 results from 37 individuals.

From evidence cited in the Technical Basis Document (TBD) for Chapman Valve [4] in the introduction to Section 2.4, it is clear that the Set 1 data were collected from the seven employees involved in a firefighting episode that occurred in June 1948. The letter that provides this date is dated January 27, 1949, and describes the urinalysis results as "collected from the seven employees involved in the fire fighting episode last June." However, internal evidence from the data suggests that only four of the individuals were significantly exposed during the episode. All of these individuals exhibited uranium in urine concentrations of 20 μg U/liter or higher. In Sets 2, 3, and 4, there was only a single sample (Set 2, Sample 22) that exhibited a concentration of 20 μg U/liter or higher. In contrast, three individuals exhibited concentrations of 10, 0, and 0 μg U/liter. In Sets 2, 3, and 4, these three individuals are recorded as exhibiting urine concentrations of 10 μg U/liter, so such concentrations are not necessarily associated with incidents.

This distinction of Set 1 into two groups of individuals also seems plausible, in that technical staff exhibit the higher urine concentrations whereas guards exhibit lower concentrations. It seems likely that technical staff would have had the technical expertise to fight a uranium fire and would likely have been trained to do so. As stated by Harris and Kingsley [5]:

> *Since speed is very important in extinguishing a uranium fire, the operators should be thoroughly trained.*

An important consideration in interpreting the urinalysis results is establishing the date of the fire. From the evidence of transmittal, the likely date is June 1948. This interpretation requires assurance that the letter of transmittal was written in correct English. If rather casually written, it might have been intended to imply that the samples were collected last June from seven individuals involved in a firefighting episode that occurred earlier. However, this seems unlikely, as an alternative form of wording should have readily occurred to the writer if this was the intention. Thus, the earliest reasonable date on which the fire might have occurred was Tuesday, June 1, 1948. (Note that days of the week are not given in the references cited herein, but have been determined using http://scphillips.com/units/dayform.html, accessed on 20 October 2006).

The urinalysis results were recorded as having been obtained on Friday, June 11, 1948. It seems likely that the fire occurred some time in that week, but it also seems possible that the urinalyses were acquired only at the end of the working week in which the fire occurred. Thus, it seems most likely that the exposures occurred between Saturday, June 5, 1948 and Friday, June 11,

1948, rather less likely that they occurred between Tuesday, June 1, 1948 and Friday, June 4, 1948, and highly implausible that they occurred before Monday, May 31, 1948. Therefore, it is reasonable to assume that the fire could have occurred as early as June 1, 1948. Also, a case could be made for Monday, May 31, 1948, as this could have been considered as lying within the first week of June 1948.

Overall, a date of June 1, 1948, seems a cautious, but reasonable date, and it is very difficult to argue that ambiguities of interpretation could allow for a significantly earlier date.

Not only is the date of the fire reasonably constrained, so also are the magnitudes of the exposures involved. The interval between exposure and urinalysis would have been almost identical for the four most highly exposed individuals, so differences between uranium concentrations in urine reflect differences in individual exposure and inter-personal differences in biokinetics. Attributing the full range of variation to differences in exposure, the range of variation is a factor of four (possibly between five and six if one of the values of 20 is rounded up and the value of 80 is rounded down). This range of variation seems plausible for individuals involved in different aspects of fighting a fire.

Thus, the degree of exposure to the identified fire seems well established, in that both the date of the fire and the resulting concentrations of uranium in urine are closely constrained.

Incidentally, in respect to interpreting these data, an error in the TBD should be noted. In Section 3.1.1 [4], it states that 'For the co-worker data, assuming the intake from the fire occurred on June 10, 1948 resulted in the largest total intake.' However, beyond the first few hours after exposure, the longer the interval between an intake and a urinalysis, the larger the inferred intake, so it seems reasonable to infer that June 1, 1948 rather than June 10, 1948 was intended in the TBD. This is confirmed by the text in Section 7.2.1.1 (at page 28) in the response to the petition [2], where it is stated that "When analyzing individual bioassay data, the intake from the fire can be assumed to be acute and to have occurred on June 1, 1948, if no other information is available."

This leaves Sets 2, 3, and 4 to be considered. Set 2 was obtained on July 26–27, 1948 and comprises a general survey across job categories. There are 12 samples of 0 μg U/liter, 9 samples of 10 μg U/liter and one sample of 30 μg U/liter. Set 3 was obtained on September 8, 1948. Of the six individuals included, three might be expected to be amongst the higher exposed. However, their uranium in urine concentrations were no higher than those of two others in the group. There was 1 sample of 0 μg U/liter and 5 samples of 10 μg U/liter. On the basis of Set 2, about 3 samples of 0 μg U/liter and 3 samples of 10 μg U/liter would have been expected. However, the distinction between the two sets is clearly not significant. Set 4 was obtained on October 7, 1948. None of the five individuals involved is explicitly identified as a machine operator. There were 3 samples of 0 μg U/liter and 2 samples of 10 μg U/liter. Again, the distinction between the results and those for Set 2 is clearly not significant.

As to the three individuals that were sampled twice, two were associated with the fire (Set 1) and were measured again in Set 2. Their uranium in urine values were either the same in Set 1 and Set 2 or increased from Set 1 to Set 2. This indicates that they were not significantly exposed in the fire. The third individual exhibited the highest uranium in urine concentration in Set 2 (30 μg

U/liter), but only 10 μg U/liter in Set 4. As there was an interval of just over 70 days between these two measurements, this difference is not surprising. Indeed, the interval is sufficient that these two samples are reasonably treated as being independent consequences of exposure in the following analysis.

Overall, results are available for three occasions and there is no reason to treat the datasets as deriving from anything other than a single distribution. Thus, in summary, there are 33 measurements with 16 values of 0 μg U/liter, 16 values of 10 μg U/liter and 1 value of 30 μg U/liter. Thus, the one value of 30 μg U/liter is an outlier beyond the 95th percentile of the available data. Furthermore, for the individuals that were likely to be most exposed, there is no evidence of values greater than 10 μg U/liter.

It is important also to consider the duration and type of operations that occurred at Chapman Valve. From Section 2.2 of the TBD [4], although 26 tons of uranium rods were sent to the facility on January 9, 1948, production-scale machining does not appear to have begun until May 1948. Termination of operations is indicated by a Chapman Valve letter of November 8, 1948, which requested termination of AEC film badge services. Thus, Sets 2, 3, and 4 of the urinalysis samples appear to have been collected after full production-scale machining had begun. Indirect evidence of this can be obtained from Table 4-1 of the TBD [4], which lists maximum film badge results for non-penetrating radiation by week. The non-penetrating exposure is a reasonable index of intensity of work with uranium in this context. Values through the week beginning April 26, 1948, are assumed, default values. Actual values are recorded from the week beginning May 3, 1948, to the week beginning October 4, 1948, with a single isolated actual result in the later week beginning November 1, 1948. The highest value of 0.65 R is recorded in the week beginning September 20, 1948 and values above 0.20 R are recorded from the week beginning June 28, 1948, to the week beginning September 27, 1948. Based on this information, Set 2 was collected well after full production-scale machining had begun and Set 3, which includes machine operatives, was collected at the time when maximum non-penetration radiation doses were close to their peak. However, Set 4 may have been collected at, or just after, cessation of full production-scale machining.

As to the type of operations, Chapman Valve was primarily involved in the machining of uranium metal. As discussed at page 10 of the TBD [4], one AEC memorandum indicated that Chapman Valve may also have conducted rolling operations on uranium metal. However, as pointed out in the evaluation of the petition [2], the assessment that only machining operations were performed is supported by the job title information in the dosimetry records provided for Chapman Valve. Furthermore, four former employees from the period were interviewed. Their job titles/duties included work in the maintenance group; work in support of turning, cutting, milling, and drilling operations; and work with heavy equipment. None of the interviewees could recall any operations associated with uranium rolling. As the restricted area in Building 23 at Chapman Valve was about 200 feet long by 60 feet wide [4, page 8], it seems very unlikely that individuals with these job titles/duties could work in the area without being aware that rolling operations were being conducted. In summary, there is documentary and interview-based evidence to support the position that rolling operations were not conducted at Chapman Valve.

As discussed by Harris and Kingsley [5], uranium is a freely machinable but pyrophoric material. When machined, contamination occurs only when the metal catches fire. However, Harris and Kingsley [5] report, in an article published in 1959, that such fires may occur frequently, and this was undoubtedly the case at earlier dates. However, the incidence of chip fires resulting from uranium machining can be markedly reduced by following various simple rules. These include flooding the operation with coolant, use of low cutting speeds and deep cutting, use of very sharp (carbide-tipped) tools, and use of a chip breaker to facilitate quenching. Thus, in uranium machining operations, exposure conditions may be very variable, with normal operations being associated with low exposures, but with multiple small-scale fires resulting in short-term peaks in exposure. This consideration influences the interpretation of the urine monitoring data. As data were collected on only two occasions during the period of production-scale machining, it is quite possible that over the periods immediately preceding these occasions, air concentrations were low and that this was reflected in the urinalysis results recorded.

The situation was rather different in facilities where rolling operations were undertaken. Where a gas-fired, air-atmosphere furnace was used (as was the case on a regular basis at Simonds Saw & Steel before January 1950 [6, page 7]), copious oxidation occurred and substantial air contamination by oxide scales occurred [5]. These problems were substantially reduced by the introduction of lead and, more effectively, salt-bath furnaces [5]. Thus, where rolling operations were conducted using gas-fired, air-atmosphere furnaces, air contamination would have been a more chronic problem than in machine shops where it was associated with fires, albeit that these could have occurred quite frequently and resulted in significant residual contamination of the workplace.

Having recognized these differences between rolling and machining facilities, it is of interest to compare the urinalysis data for Chapman Valve reported in Table 1 with those for Simonds Saw & Steel. These data are given in Appendix A of the TBD for that facility [6]. Only data from 1948 and 1949 are presented and discussed here, as concentrations from 1950 onward are substantially lower, presumably at least partly because of the introduction of improved furnace types.

The uranium urinalysis data from the ten surveys undertaken in 1948 and 1949 are listed in Table 2. In all cases, the data are ordered by increasing concentration. For the first nine surveys, all zero values are shown explicitly. However, for the tenth survey there were 26 zero values, so for conciseness these have been condensed to a single entry shown as 0 (26).

Table 2. Uranium in Urine (μg/liter) at Simonds Saw & Steel in 1948 and 1949

11/1/48	11/3/48	11/4/48	11/8/48	11/11/48	11/15/48	1/6/49	4/27/49	11/4/49	11/17/49
						Pre-roll	Pre-roll	Nitric acid treated, pre-3rd roll	Last day of roll
10	10	10	0	0	0	0	7	4	0 (26)
10	10	10	0	10	0	1	8	7	1
10	10	10	10	10	10	2	10	7	1
10	10	20	10	10	10	8	11	7	1
10	20	20	10	10	10	9	17	11	2
20	20	20	10	20	20	9	19	13	2
20	20	20	10	20	20	10	19	13	3
30	30	20	10	20	20	13	23	13	3
30	30	40	20	40	40	13	23	14	3
40	40	70	20	50	40	15	24	15	3
40	40	70	30		50	18	29	16	4
140	90						36	21	4
								24	6
								27	6
								28	7
								272	10
									11
									11
									13
									14
									14
									15
									17
									29
									30
									36
									164

The TBD [6, Section 3.1.1] includes a comment from AEC that the 272 μg/liter sample was obviously contaminated, but notes that the only basis for this statement appears to be that the result was large. The TBD treats this result as valid.

The results from 1949 include values of < 10 μg U/liter and specify results with a precision of 1 μg U/liter at higher concentrations. It is not clear that this degree of precision is justified.

Over the period considered, there does not appear to be a strong trend in the results recorded, except in the tenth survey, for which a large number of low values were recorded. However, the number of samples obtained was also much larger, so the most highly exposed worker group may have been diluted by the inclusion of many less exposed individuals. If concentrations are rounded to the nearest 10 μg U/liter, the numbers of individuals with concentrations at different levels from the various surveys are as shown in Table 3.

Table 3. Binned Analysis of Urinalysis Data from Simonds Saw & Steel

Conc. (µg U/liter)	11/1/48	11/3/48	11/4/48	11/8/48	11/11/48	11/15/48	1/6/49	4/27/49	11/4/49	11/17/49
0				2	1	2	3		1	37
10	5	4	3	6	4	3	6	4	8	9
20	2	3	5	2	3	3	2	6	4	2
30	2	2		1				1	2	2
40	2	2	1		1	2		1		1
50					1	1				
60										
70			2							
80										
90		1								
100										
110										
120										
130										
140	1									
150										
160										1
170										
180										
190										
200										
210										
220										
230										
240										
250										
260										
270									1	
280										

The excess of zero concentration values in the tenth survey is clear. However, if zero values are excluded, there is no substantial difference in the distribution of values from the tenth survey from that in previous surveys. Therefore, it is reasonable to treat the results from the ten surveys as if they came from a single population. This gives the aggregated results shown in Table 4.

Table 4. Aggregated Binned Analysis of Urinalysis Data from Simonds Saw & Steel

Conc. (μg U/liter)	Number	Fraction per 10 μg U/liter bin
10	52	0.464
20	32	0.286
30	10	0.089
40	10	0.089
50	2	0.018
60	0	0.000
70	2	0.018
80	0	0.000
90	1	0.009
100	0	0.000
110 – 200	2	0.0018
210 – 300	1	0.0009

In fact, the limited statistics from 50 to 100 μg U/liter make the results per 10 μg U/liter bin of limited relevance, and it is better to report the result as 0.0074 per 10 μg U/liter bin over this range.

At Chapman Valve, from Sets 2, 3, and 4, there were 16 values of 0 μg U/liter, 16 values of 10 μg U/liter and 1 value of 30 μg U/liter. Based on 17 non-zero values, from the Simonds Saw & Steel data given in Table 4, the expected numbers are 8 of 10 μg U/liter, 5 of 20 μg U/liter, 3 of 30 or 40 μg U/liter and 1 of 50 μg U/liter or more. This illustrates, as expected, that the Chapman Valve results are low relative to the Simonds Saw & Steel results. It should also be noted that if a reference value of 30 μg U/liter is adopted, as proposed in the TBD for Chapman Valve [4, Section 3.1.1], only 10 results out of 112 at Simonds Saw & Steel are above that value, i.e. it is at the 91st percentile of the observations.

The petition evaluation [2, Section 7.1.2.2] makes a comparison between the Chapman Valve urinalysis data and data from both Simonds Saw & Steel and Y-12. The comparisons with data from Simonds Saw & Steel relate to either the period 1948–1952 or to 1948 only. The period 1948–1952 is considered to be too extensive, as new furnace technology was put in place in January 1950. The period of 1948 only is rather restrictive, but gives results similar to those reported above, i.e. both the geometric mean and 95th percentile concentrations at Simonds Saw & Steel were higher than the corresponding values for Chapman Valve. The comparison with Y-12 is for April 1952. Although the mean and 95th percentile concentrations at Y-12 were higher than the values at Chapman Valve, it is difficult to know how to interpret these data, as the diversity of operations at Y-12 and the difference in date (and hence protection measures) make it impossible to say *a priori* whether concentrations of uranium in urine would be expected to be higher or lower than at Chapman Valve.

Data from other facilities that processed uranium metal, and for which TBDs are available, are also of potential relevance. From Appendix B of [7] and examination of the NIOSH/OCAS web site, four relevant TBDs were identified [8, 9, 10, 11].

At Aliquippa Forge [8], rolling mill operations were undertaken. Individual urinalysis data are available for some workers [12]. These have not yet been acquired, but it seems unlikely that these data would add substantially to the comprehensive data sets documented for Simonds Saw & Steel and discussed above.

At Superior Steel [9], flat-plate rolling was undertaken. A salt bath process was used, so exposures would have been expected to be low [5]. Individual uranium urinalysis data are not available for workers at this facility, so no useful conclusions can be drawn regarding potential exposures at Chapman Valve.

At Bethlehem Steel [10], various experimental rolling operations were conducted. No uranium urinalysis data appear to be available, so no useful conclusions can be drawn regarding potential exposures at Chapman Valve.

Havens Laboratory and Adrian Plant undertook the extrusion of uranium metal [11]. The main factors contributing to airborne radioactivity were:

- Fumes and smoke from intrusion press discharge
- Oxidation of extruded rod surface to oxide, which subsequently flaked off upon rod movement and became airborne
- Transfer of rod from run-off table to cart
- High concentrations at run-off table area due to presence of loose oxide scale on surface of rod and rollers
- Storage of hot crops in open area near tool-heating furnace
- Cutting off the butt end of extruded rod and deburring of the die block
- Flaking of loose oxide scale in the vicinity of the straighteners upon stretching

Thus, conditions at the two facilities would seem to have more closely resembled those at a rolling facility than those in a machine shop. Extensive urinalysis data are available for the period 1952–1962. Geometric mean and 84th percentile values from the various surveys are listed in Table 5.

Table 5. Results of Analyses of Uranium in Urine from Havens Laboratory and Adrian Plant [11, Table 3-1]

Havens Laboratory			Adrian Plant		
Date	Geometric Mean (µg U/liter)	84th Percentile (µg U/liter)	Date	Geometric Mean (µg U/liter)	84th Percentile (µg U/liter)
9/10/1952	2	5	12/14/1954	<10	<10
9/11/1952	4	4	1/12/1955	<10	<10
9/1/1953	1	1	4/6/1955	<10	<10
10/1/1953	1	1	8/3/1956	<10	<10
2/4/1954	3	9	8/22/1958	4	9
6/1/1954	2	4	10/10/1958	<10	<10
2/27/1956	3	7	10/16/1959	2	8
10/7/1957	9	21	11/13/1959	<10	<10
1/27/1958	4	9	7/14/1960	6	14
7/3/1958	2	3	8/23/1960	6	19
9/15/1958	2	4	9/6/1960	7	20
1/19/1959	3	8	9/12/1960	11	40
2/25/1959	2	7	9/19/1960	5	14
3/16/1959	3	11	9/22/1960	3	8
8/28/1959	0	0	10/14/1960	5	9
10/19/1959	1	2	11/18/1960	6	11
2/5/1960	0	0	12/19/1960	3	10
5/26/1960	3	5	1/13/1961	4	9
10/26/1960	18	54	1/23/1961	3	7
1/9/1961	2	5	1/30/1961	6	12
4/1/1961	6	7	2/10/1961	23	56
4/20/1961	64	239	2/28/1961	19	28
4/21/1961	13	46	3/13/1961	19	27
4/24/1961	10	19	3/27/1961	17	25
5/22/1961	17	37	4/10/1961	12	47
5/26/1961	14	14	4/24/1961	3	6
9/25/1961	1	3	5/8/1961	5	9
9/26/1961	1	4	5/22/1961	3	6
3/3/1962	2	5	6/5/1961	3	7
3/9/1962	2	5	6/26/1961	12	24
3/12/1962	1	2	7/25/1961	7	14
			7/28/1961	10	30
			7/31/1961	2	8
			10/2/1961	2	7
			10/6/1961	3	15
			10/9/1961	2	5

These data are not directly applicable at Chapman Valve, but they do indicate that uranium in urine concentrations at extrusion facilities where airborne contamination was an issue were typically less than 10 µg U/liter, but that concentrations of 20 to 60 µg U/liter could occur over periods in excess of one month.

It is also relevant to note that apart from the machining operations, concentrations of uranium in air at Chapman Valve would have been generated from a furnace that has variously been

described as a chip incinerator, chip burner and cracking furnace [4, Section 2.1.1]. The terms 'chip incinerator' and 'chip burner' are clearly synonymous and the presence of a chip burner is appropriate to a uranium machining operation, as conversion of chips to oxide was sometimes advisable to allow it to be handled as oxide scrap [5]. It is not obvious why the term 'cracking furnace' should have been used for a chip burner. However, there is no evidence that a second furnace or incinerator was present, and there is no obvious reason why a second furnace or incinerator would have been required. The term 'cracking furnace' is found in a letter of March 19, 1948, from the N. D. LeVins, the Assistant to the Chief, Radiological Laboratory to Mr. V. T. Malcolm [13]. It relates to counting of four dust samples, comprising a blank and three identified as lathe, cracking furnace, and centerless grinder, respectively.

There is evidence that the furnace was exhausted to the outdoor atmosphere through a nearby window. Air concentration measurements were made on May 4, 1948, at the furnace outlet and on the roof 4 feet from the outlet [4, Section 2.2.1]. These results have little relevance to exposure evaluation, being made outside the building and at the beginning of the period of production-scale machining, i.e. before significant quantities of chips would have been produced.

3. Air Concentration Measurements and Their Interpretation

The TBD [4, Section 2.3.1] identifies that air concentration measurements were made at Chapman Valve on May 4, 1948 and May 24, 1948. Thus, these sets of measurements were made at the beginning and early in the period of production-scale machining. The original hand-written records [14] have been acquired and examined. The values from May 4, 1948, relate to the furnace outlet and 4 feet from the outlet on the roof. As noted above, these values are of little relevance to exposure evaluation.

The data from May 24, 1948, are listed in Table 6. These values have been transcribed from the hand-written original. Although some of the results are difficult to read, because total count, count time, counts per minute and alpha dpm/m^3 are given, the values could all be confirmed by checks for internal consistency.

Table 6. Air Monitoring at Chapman Valve on May 24, 1948

Sample	Description	Alpha dpm/m^3	Total Count	Count Time	Counts per Minute
1	Inspection bench	11.6	6	10	0.6
2	Packing bench	19.9	10	10	1.0
3	Work bench	29.1	15	10	1.5
4	Wash room	15.5	8	10	0.8
5	Lunch room	15.5	8	10	0.8
6	Control	5.83	3	10	0.3

These data may be set in context by a comparison with typical concentrations recorded for uranium machining facilities by Harris and Kingsley [5]. These values are shown in Table 7.

Table 7. Typical Alpha in Air Concentrations for Machining and Abrasive Operations with Uranium Metal

Operator	Concentration (dpm/m^3)	
	No Ventilation	Ventilation
Machining operations		
Automatic lathe	200 – 300	30 – 70
Turret lathe	150	40 – 50
Facing	~100	-
Cut-off	~100	20 – 30
Milling	~100	20 – 30
Slotting	~100	20 – 30
Drill	20	10
Radius cutting	100 – 300	30
Milling	40	-
Shaping	<10	-
Planing	<10	-
Abrasive operations		
Cut-off	-	<1
Surface grinder	2,000 – 5,000	50 – 200
Portable grinder	400	50 – 200
Belt sander	3,000	<10
Centerless grinder	5,000 – 6,000	50 – 300

Thus, the observed concentration at the workbench (Table 5) was toward the low end of the range expected for machining and abrasive operations with uranium metal.

These values can be compared with the University of Rochester recommended level for soluble uranium compounds in air of 50 μg/m^3. For natural uranium, this corresponds to 70 dpm/m^3 [4, Section 2.3.1].

Overall, the air concentration data for Chapman Valve do not place any useful constraints on worker exposures. However, it is of interest to evaluate what uranium in urine concentrations would have been expected with chronic exposure to air concentrations typical of machining and abrasive operations with uranium metal. From Table 6, it seems reasonable to adopt 100 dpm/m^3 as an illustrative basis for the calculation.

In the TBD [4, Section 3.1.1] it is reported that IMBA Expert was used to equate a maintained bioassay concentration of 30 μg U/liter to a chronic intake rate of 496 pCi/d for Type M material and 14,900 pCi/d for Type S material. Assuming a typical occupational breathing rate of 1.2 m^3/h and a 48-hour working week, at 100 dpm/m^3 (1.6 Bq/m^3), the effective chronic intake rate would be 1.2×48×1.6/7 = 13.2 Bq/d or 355 pCi/d. Thus, the expected concentration of uranium in urine would be 22 μg U/liter for Type M material and 0.7 μg U/liter for Type S material. Thus, the observed urinary concentrations are consistent with what might be expected from machining and abrasive operations.

4. Potential for Handling of Enriched Uranium

Information relating to the suggestion that enriched uranium was processed at the Chapman Valve facility is properly summarized at Section 2.2 of the TBD [4]. As noted there, Chapman Valve uranium processing was related to reactor needs, and the use of enriched uranium in reactors was rare until 1950. The Chapman Valve contract with Brookhaven National Laboratory was to machine uranium for a reactor pile, which is thought likely to have been the Brookhaven Graphite Research Reactor. This first went critical in 1950 and was initially loaded with natural uranium.

The case for enriched uranium being handled rests on a single sample collected north of a west door of Building 23. Bearing in mind that this sample dates from 1992, and that plausible reasons have been suggested as to why the enrichment reported might have been an artifact of analysis [4], it does not provide a substantial basis for proposing that enriched uranium was handled at the facility in 1948. This view is supported by the observation that enriched uranium was not typically sent to non-government-controlled sites without extra precautions.

5. Comments and Conclusions

In respect of the seven grounds raised in the Special Exposure Cohort Petition [1], the following comments are made.

5.1 Available Bioassay Monitoring

The available data derive from three occasions (Sets 2, 3, and 4). Two of these were collected during the period of full production-scale machining and one was collected at, or just after, cessation of full production-scale machining. There is no reason to treat the datasets as deriving from anything other than a single distribution. Although only a limited number of the samples were from machine operatives, there is no evidence that these individuals exhibited higher concentrations than others who were present in the restricted area. Furthermore, the restricted area was limited in extent and exposures would likely have resulted mainly from general air contamination. Although there is no specific data to determine why the samples were collected, they relate to a wide range of worker categories. In the context of setting an upper bound on uranium in urine concentrations, there is no reason to suppose that the potentially most highly exposed individuals were excluded from the surveys. Although Sets 3 and 4 could have been derived from special monitoring following from incidents, this would result in values being biased high rather than biased low.

There are 33 uranium-in-urine determinations (excluding Set 1, which was related to a known fire). Of these, 16 gave values of 0 μg U/liter and 16 gave values of 10 0 μg U/liter. One gave a value of 30 0 μg U/liter and this is proposed as a basis for dose evaluation [4, Section 3.1.1].

An examination of uranium-in-urine concentrations for other facilities supports this value as a cautious upper bound. At rolling mills and extrusion plants, oxide generation and the production of aerosols was an intrinsic aspect of the production process in the early years, though aerosol production was typically suppressed during the 1950s, e.g. through the use of salt baths rather

than gas-fired, air-atmosphere furnaces. In contrast, in uranium machining facilities, in normal operations aerosols should not have been generated in significant quantities. Uranium fires were a problem, but the aim was to limit their frequency of occurrence by appropriate machining techniques. In the early years this aim was not always realized. Nevertheless, exposures to airborne contamination in machining facilities would have generally been lower than exposures in rolling mills.

In this context, it is relevant to note that at Simonds Saw & Steel, only 10 uranium-in-urine determinations out of 112 were above 30 μg U/liter, i.e., this value lay at the 91st percentile of the observations. Also, data from Havens Laboratory and Adrian Plant indicate that uranium in urine concentrations at extrusion facilities where airborne contamination was an issue were typically less than 10 μg U/liter, but that concentrations of 20 to 60 μg U/liter could occur over periods in excess of 1 month. Thus, data from these plants, at which airborne contamination was likely to have been more of an issue than at Chapman Valve, do not indicate the need to adopt a representative air concentration of more than 30 μg U/liter.

Further indirect evidence for the reasonableness of this figure is obtained from the Set 1 monitoring data. Following an identified fire, four individuals are identified as likely to have been significantly exposed. Their uranium urinalysis results ranged from 20 to 80 μg U/liter. In this case, monitoring was specifically targeted at individuals likely to have been exposed no more than a few days earlier, so longer-term average concentrations in urine would have been substantially less than the recorded values.

5.2 Lack of Monitoring Data, and Lack of Process and Source-term Information

As discussed in Section 5.1, the uranium-in-urine monitoring data seem well-targeted on the likely period of highest exposures. The processes involved in giving rise to exposures are well-defined and the restricted area was limited in extent, constraining the range of exposure conditions that were likely to have been encountered. Details of the spatial and temporal distribution of the source term are of limited relevance, where direct use is made of urinalysis data to estimate cumulative exposures.

5.3 Documentation of the Uranium Fire

The main lack of information relates to the date of occurrence of the uranium fire. However, it seems highly implausible that it would have been before May 31, 1948. Furthermore, the uranium-in-urine data collected after the fire indicate that it was a minor contributor to assessed overall uranium exposure. In Table 3-2 of [4], the chronic intake rate is given as 481 pCi/d (Type M) or 14,300 pCi/d (Type S), compared with an acute intake due to the fire of 2,170 pCi (Type M) or 73,900 pCi (Type S). Thus, the fire is assessed as equivalent to 4.5 days (Type M) or 5.2 days (Type S) of chronic intake. However, this conclusion seems to be based on a date of intake of June 10, 1948. Intake at an earlier date would make it a larger contributor to overall uranium exposure.

5.4 Potential for Enriched Uranium

As discussed in Section 4, there is no substantial basis for supposing that enriched uranium was handled at Chapman Valve in 1948.

5.5 Potential Exposures at the Chip Incinerator

It is highly likely that the cracking furnace is a synonym for the chip incinerator. Exposures to aerosols arising from this equipment would have been included in overall exposures evaluated through uranium urinalysis. Furthermore, it is known that the chip incinerator was ventilated to outside the building, again limiting the potential for high exposures.

5.6 Air Sample Data

The very limited air sample data that are available do not place any useful constraints on worker exposures at Chapman Valve. However, the uranium in urine concentrations that would be expected with chronic exposure to air concentrations typical of machining and abrasive operations with uranium metal at other facilities are 22 μg U/liter for Type M material and 0.7 μg U/liter for Type S material. Thus, the observed urinary concentrations at Chapman Valve are consistent with what might be expected from machining and abrasive operations.

5.7 Significance of Uranium Fires

Minor fires during machining operations, together with releases from the chip incinerator, would have been the principal contributors to exposures at Chapman Valve and are implicitly addressed through the uranium urinalysis data.

6. References

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7. Technical Information Bulletin, Estimating the Maximum Plausible Dose to Workers at Atomic Weapons Employer Facilities, ORAUT-OTIB-0004, Revision 03, Effective Date 08/12/2005.
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11. An Exposure Matrix for Bridgeport Brass: Havens Laboratory and Adrian Plant, ORAUT-TKBS-0030, Revision 00, Effective Date 09/15/2005.
12. AEC (U.S. Atomic Energy Commission), untitled, June 24, 1949, New York Operations Office, Medical Division, New York, New York [Eml2Bx24VulcanUrine&Feces1949.pdf].
13. Letter from N D LeVine, Assistant to the Chief, Radiological Laboratory to Mr. V. T. Malcolm, Chapman Valve Company, Indian Orchard, Massachusetts, March 19, 1948.
14. Sample Record #4, Measurements by Thos. P Musgrave, Record dated August 1948, but relating to samples collected on 5-24-48 at 4:00 p.m.

ATTACHMENT 2: SUMMARY OF SC&A INTERVIEWS WITH PETITIONERS, SITE EXPERTS, CLAIMANTS, AND SURVIVORS

The following represents a summary of interviews conducted by SC&A with petitioners, claimants, and survivors regarding the Chapman Valve SEC Petition as part of the review of the NIOSH SEC Evaluation Report. Interviews were conducted at the Pioneer Valley AFL-CIO Union Hall, 640 Page Boulevard, Springfield, Massachusetts, 01104, from 4 to 7 p.m. on November 28, 2006.

Note: **The original interviews containing personal information were sent for review and comments were received and addressed in this summary report; however, the participants have not reviewed this summary report. Comments not of a personal nature relating to Chapman Valve are reflected in this summary.**

Those present during the November 28, 2006, interviews include the following:

Advisory Board: John Poston, Chair, Chapman Valve SEC Working Group

NIOSH: Mark Rolfes

SC&A: John Mauro and Arjun Makhijani

Interested Individuals: Three petitioners
Two former workers
One individual who has assisted the petitioners and claimants
Two community members
Mr. Bill Tranghese,
Representative from Congressman Richard Neal's office

This is a summary of the technical substance of what was said in regard to processes and working conditions at Chapman Valve. All references to individual workers and individual claims and claimants have been deleted.

The meeting began with an introduction by Arjun Makhijani (SC&A) on where the interviews fit into the SC&A review of the NIOSH SEC Evaluation Report for Chapman Valve, and by John Mauro (SC&A) giving a sense of where we are in the process of preparing the review.

There were two projects that were done at Chapman Valve relating to the AEC. First, manifolds were brought in from Oak Ridge during World War II to a facility on Dean Street. This was called the Dean Street Project. Second, there were uranium machining operations at the main plant site.

A. Uranium Machining at the Main Plant Site

Uranium machining operations were done in Building 23. One interviewee said that as a boy, he went in and out of Building 23 during the uranium machining period "at will." The guard, used

to say “come on across,” and he would go and have lunch with all those grown-ups. The workers may not have known that they were working with uranium. There was no way of detecting cracks magnetically in the uranium rods. Drilling or machining could create a surface crack. They used Zyglo to detect cracks. It was a clear liquid sprayed on the part and it would pick up a current. You would spray on an orange liquid. Wherever there was a separation because there was fault, the material would just gather up there.

The uranium rods came in by railroad car. They would offload them into a storage shed. There was a monorail that connected the storage shed to Department 23. That was wide open. The rods used to be stored outside, sometimes 2 or 3 days at a time.

The longest rods were 20-footers. They were 4 or 4.5 inches in diameter.

The turnings were collected. Everything was done with water soluble oils. They did not use [regular] oils – there were fires even with water based coolants. The coolant was being used and poured on the cutting edge of the tool [when uranium was being machined]. They had two-wheeled carts with wagon wheels and pressurized tanks for fire fighting. They wheeled the tank carts in until they got the fire under control, or until the fire department came.

The used coolants were collected in tanks, placed on a dump truck, and sprayed on parking lots near homes. We have the best paved parking lots in the City of Springfield! The lots were always covered with coolant.

There were sparks during uranium machining operations. The workers had no face shields, no protective equipment. You could actually see sparks; the metal was red hot. Sparks and dust came off the machines. Face shields may have been available but their use was not mandatory.

Workers wore regular street clothes—Levis. They sent them to the laundry. There were gang showers. Workers took their clothes home to be washed with other clothes. One former worker said he had twelve pairs of coveralls at the time, and every so often, he put on two pairs. They were issued white coveralls.

The tool crib was about 10 steps from the machines. There were about 15 machines—lathes, drills with a palette that came around. The person responsible for that would give the machine operator the jig and he would drill.

Sometimes the air was dusty. One could start seeing the dust in the afternoon. When they started in the morning, the air in the machining room was not bad. But it may be that in the afternoon you’d get the sunlight and in the rays of the sun you’d see the dust that was not evident in the morning. Another interviewee stated the dust was there even in the morning.

There was dust in the tiny passageway between Building 23 and the next building. The dust rose into the laboratory upstairs all day long. It came in through the windows. The windows were open.

The area was dusty, but the dust was never heavy enough to limit visibility. One could see across the room.

Mark Rolfes, pointing to furnaces at the east end of the room on a layout diagram, stated that there were other furnaces operating in the area [Building 23] that were not uranium, so there were multiple sources of dust.

An interviewee stated that those [non-uranium] furnaces were not there in the 1940s. However, there were grinding operations for steel in the foundry and that was a source of dust then.

The uranium part of the area was partitioned off with wood. There was a crane above it that ran the whole length of the building, so the partition did not extend to the ceiling. That is why they found radioactive dust on the crane rails. The partition wall was about 16 feet high, leaving the top open for crane access and product movement.

After the machines were shut down, they had to gather the chips. If the dust got to be too much for some worker, he would be transferred to Department 10. That would be the person who was drilling stuff. Some of them were casting. As you were drilling that stuff [the dust] was coming up. The coolant was supposed to be on one side. This was mostly castings. One interviewee stated that "It was part of the job to breathe the dust." No one considered it hazardous at that time – OSHA wasn't even established then.

A former worker stated that workers did not know that they were working with uranium. The workers knew it [the uranium operation] was something different when they said "mind your own business."

There were a variety of machining operations in that department at that time before it became 100% welding in the late 1950s. There were vertical mills, radial drills – they used those for steel parts. That was not uranium, but it was in the same department. So the dust that was being permeated in the partition wall—it was all mixed up [uranium and steel dust].

The rods that were being machined were similar to what you would see for a reactor. They were round rods and they were used in a reactor. There was no ventilation hood, only the wooden partition. They turned the uranium on a lathe and reduced it down to the required diameter. It was machining with water-soluble oil coolants and carbide tools. They probably could not cut it with high speed tools. The machining operation – the metal was almost red hot. There was no face mask, no protection. The workers had gloves, but they did not wear gloves when working on a piece of equipment. Gloves were used to pick up stuff. Wearing loose gloves or clothing around turning machines is always a hazardous practice. There have been cases related to skin cancer. People remember that workers got nicks and cuts and they did not have protective clothing.

The EPA found that the earth [at the Chapman plant site] was contaminated, and it had to be removed. One person asked, "Why it is so difficult to figure out that if it could get into the earth, it could have gotten it into our bodies? Why is it so hard for them [NIOSH] to understand that it got into our bodies?"

The coworkers were maintenance workers, plumbers—they did not work in those buildings full time. NIOSH should take the evidence into account and ask people. One interviewee attached floor plans to show the lunch and other areas of the plant.

Mark Rolfes then explained that NIOSH is taking evidence into account by using the highest measured values to estimate dose.

One interviewee stated that it would be interesting to know who the workers at the incinerator were and how often it was used. Were those bioassay results obtained when the incinerator was being used? We do know the incinerator exhausted outside the building and vented into the other work areas on the site. All of the soot was being exhausted elsewhere. The cracking furnace was different from the chip burner. The cracking furnace was used to drive off impurities. Two of those present said that that the cracking furnace might have been a pretreatment furnace to heat up the bar stock before it could be milled, though they stated that this was a guess on their part.

One worker, who recently passed away, had, a few years before, described one of his jobs, which was to sweep up the dust and shavings. He is quoted in a newspaper article about how he would unload uranium stock. His job was to clean up the shop everyday and dispose of the waste material. They were not doing the uranium machining every day, but there were probably peaks and valleys. [SC&A contacted the reporter, but he could not recover his notes from several years ago.]

None of the former workers present could recall a uranium fire, but none of them worked full time in the uranium department.

The floors in Department 23 were cement. They turned it to wood blocks later. It was suggested that someone should do some core sampling where they dumped the waste.

Those present were unsure exactly how many workers there were at Chapman, but there were thousands on the site. Building 23 had three shifts a day. The materials from there were being leaked out all over the site. The interviewees questioned whether the limited amount of bioassay data really was enough to cover the range of doses that could have been received. Moreover, not everyone was badged. There were people who were on temporary assignments. One person stated that in later work during the 1950s not connected with uranium, work with x-rays and gamma radiation sources, workers were not given badges. Even full-time workers in those operations did not get badges in the 1950s.

SC&A asked whether the premise that anyone doing AEC operations was issued a film badge on a 1 week cycle was correct. The response was that that it was not correct. The badge [that everyone had] was an ID badge and not a film badge. The color coding told the guard where the worker was supposed to go.

B. Summary of SC&A Interview with a Fireman

Firemen never thought of the radiation at Chapman Valve. The only thing we knew was the "hush-hush" room. No one ever told the firemen about uranium. In the 1940s, there were a couple of good fires in the iron foundry at Chapman Valve. There were two fires in the laboratory, and there were also several fires in the steel foundry. We also went down there [to the main Chapman Valve site] during inspections. In those days they had inspections on industry. You'd go in and look around for cigarettes and dust and look at the patterns and look at grease and do an inspection. It was a fire hazard inspection. The Chief of the fire department would send us down there about twice a year from 1942 into the 1950s and beyond.

We burned our hands fighting fires. We did not have the equipment in those days that they have now. There were also several fires at Monsanto. That was not as hazardous as Chapman, as we found out later.

SC&A asked about fires in Building 23.

The 100 Building had several fires. It was built in the 1950s or 1960s. It was a very dirty building. The only time we knew about radiation – it was the laundry place at the corner of Oak and Parker St. There was radiation there. They had drainage into the Demmick Pond there, and it killed all the fish. But so far as Chapman, there was no word of any radiation. But the laundry had nothing to do with Chapman Valve. That was in the 1960s. It was not from the 1940s. The 100 Building was the big one. Then in the rear of the building there was the foundry. And the labs were large, too.

SC&A: Do you remember a fire in 1948?

There were several fires in the 1940s. We used to work 80 hours a week. The lab [fire] was in the 1940s and the iron foundry fire was in about 1948. The office was between Hampshire and Essex. The 100 building was on the other side of the railroad tracks. The iron and steel foundry was in the old building.

Mark Rolfes: The foundry is likely Building 23. The southwest portion of Building 23 was an access-controlled point.

Chapman Valve started in the early 1930s; they made a lot of valves. When the war came, they got into Navy contracts.

The fire department kept detailed records of the fires. The records stayed in the fire station. We had logbooks. They had information on the fire, the equipment we used, what happened at the fire, and what time we got back. I can't believe that they did not keep them. Our recordkeeping was very strict. The Chief said that everything had to be down on paper. The records could be in some station some place. The books may go with the piece of equipment. Try the citizen council of Indian Orchard for the fire records. At a dedication for firemen who had died fighting fires, it was found that they did not have records at HQ. Of course, we had records at Indian Orchard. I can't figure out why they don't have records now. If three stations go to a fire, they

all have a record of it. There may be one or two other stations that may have records of the [1948] fire.

When the mall was built, they moved the fire station to Odessa Street, in 1968, so the station would be closer to the mall. Monsanto protested. The Odessa Station is still there. So it is possible that the records are still there.

Every box and book in the fire department records is labeled. Even the half-hour allowed for dinner was in the records. There was an explosion probably at Monsanto. They had vats of nitrate, and it broke some windows. There were no explosions at Chapman.

[Other persons present said that there had been an explosion at Chapman Valve in 1942.]

Between 1942 and 1948, there were a lot of fires. That is when we had the lab fire and the iron foundry fire. The iron foundry was dirty. It was bad, too. They had fires going on. Dust. There was a partition between the foundry and the lab. Chapman never had a fire department.

C. The Dean Street Project

The Dean Street Project was for the repair of the manifolds that came in from Oak Ridge. It was a huge thing. They used it to test air pressure per square inch. They used some kind of explosive testing. This was a separate project from the later work on uranium metal. It was not in Department 40. The manifolds would come on trains in the night and no one was to see them. The Dean Street facility was at least a mile from the main Chapman Valve site.

The manifolds were first shipped to the main plant by train. From there they were taken to Dean Street by truck. This went on for at least 3 years. The manifolds were big solid tanks. [Pointing to window that was about 8 ft by 8 ft] It was about double the size of that. They were pressure tested before they were shipped.

The correspondence for the Dean Street Project went to a Boston Post Office. The Army and servicemen would come to the plant. The Stone and Webster men came also. They would sometimes change the pressure specifications. There were engineers from Boston who would come. The military people were from Oak Ridge. They went out to the work area.

The Dean Street Project was just for that work. It was the only thing that was done there. There were three shifts. Perhaps between the 3 shifts, maybe about 60 people worked there. Among the contacts named for follow-up were [Name] from Stone and Webster and a [Name]. [These were just remembrances of names, but without knowledge of their whereabouts or whether they were still living]. They were mostly concerned about the records that were kept and the results of the pressure testing. To the best of an interviewee's recollection, there was also a Colonel [Name] and who came to Dean Street as well.

The manifolds were sent for cleaning and repair and welding. They were cleaned with pressurized air and a liquid. They used silica gel. Also, on the repair of the manifold, a product called silica was used. It was like white sand. Many workers had trouble breathing. The work

was done in a building that was formerly a car repair shop that had the big sunken areas, and it seemed to fit in well with the type of repair they had to do. They would bring them in with big pulleys and take them off the truck, and they had a lot of instrumentation they used. And everyone there was exposed to whatever there was. There were no divisions.

They started packing as soon as the bomb was dropped [on Hiroshima]. They knew they were going to close the [Dean Street] plant. The interviewee recollected that the plant was closed a few months after the bombing—in early 1946.

The connection of Chapman to the Manhattan Engineer District is mentioned in the Site Profile, but the fact that equipment was sent for repair and cleaning to Chapman from Oak Ridge during World War II, when uranium enrichment was being done at Oak Ridge, was new. In this context, there was a discussion of the enriched uranium samples found at Chapman during the 1990s.

Mark: The 2.16% sample was near the cracking furnace in Building 23. It was sample M31. This was not connected to the Dean Street Project, which was not in the same place.

One potential explanation may be that the manifolds were unloaded at the main plant site, but not repaired and tested there. They were transferred to trucks and sent to the Dean Street facility. Any enriched uranium at the main plant site may have been deposited in that context.

D. Records Made Available during the Interview

After the meeting, Arjun Makhijani examined records provided. They contained names and Chapman employee numbers and wage data, which would be useful for employment verification, but no data that would apparently be helpful in the review of NIOSH's SEC Evaluation Report.

E. Individual Claimant Issues

There was some discussion of individual cases. Mark Rolfes explained the situation as follows.

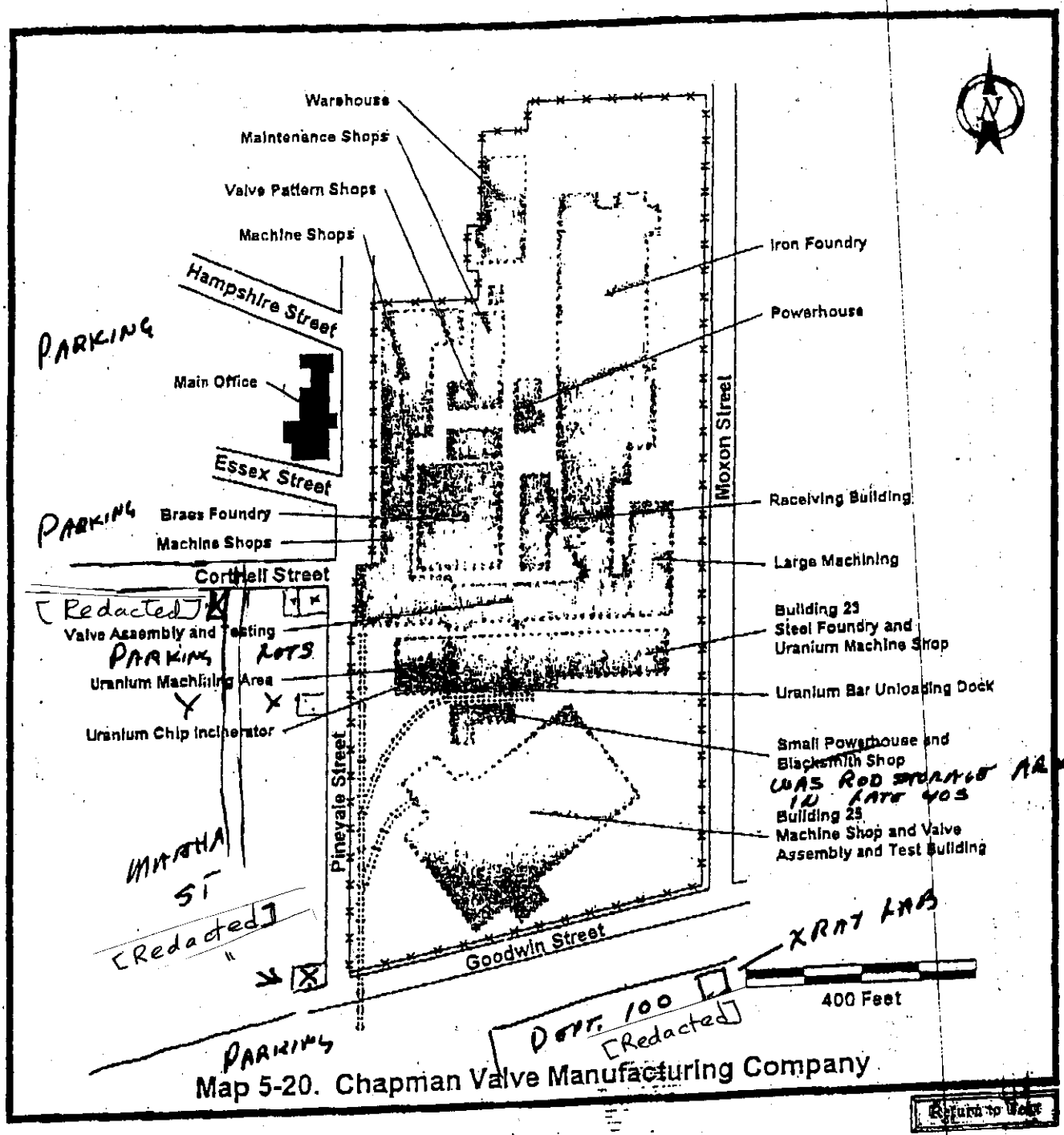
Mark: After the worker outreach meeting [in 2005], we [NIOSH] took that information and the information in the SEC petition and the programmatic changes regarding coworker intake models, and put it all together into a revised Site Profile. The dose reconstructions previously done will be re-evaluated. We have redone several dose reconstructions with the new Site Profile. At this time we are not working on any dose reconstructions for Chapman. We are waiting until the Advisory Board has deliberated on the SEC Petition and our Evaluation Report. For internal dose, alpha radiation is the most important. The changes we have made to the Site Profile will increase uranium intakes for everyone. This was based on information that we received from former workers, from interviews, and from re-evaluation of the bioassay data. The previously assigned gamma dose is unchanged.

Interviewee: I want to know why some people were compensated and we are not.

Mark: The reason that some are compensated is the different doses for different organs. We are using the same intake for everyone. There are other factors about how much radiation affects a given organ. The biggest factor is the cancer type. For instance, lung cancer is more affected by uranium than, say, prostate cancer.

One person disagreed that radiation is concentrated in the lung and stated that there was a NIOSH document, a dose reconstruction that said that beta-emitting fission products could get into the GI tract. According to him, this affects the bladder and colon as indicated in the NIOSH report. Mark Rolfes made a note of the NIOSH report, of which the interviewee has a copy.

Some discussion of individual dose reconstructions followed. Mark said that he would look at individual dose reconstructions and get back to the claimants who had questions. He said that the gamma dose in the residual contamination period has been increased in the new Site Profile.



Map 5-20. Chapman Valve Manufacturing Company

THE PARKING LOTS INDICATED ARE NOW COVERED WITH HOUSING

THIS IS THE 1990'S LAYOUT OF CHAPMAN VALVE AFTER CRANE DOWN SIZED.

THIS IS NOT THE LAYOUT 1948-49 ERA.

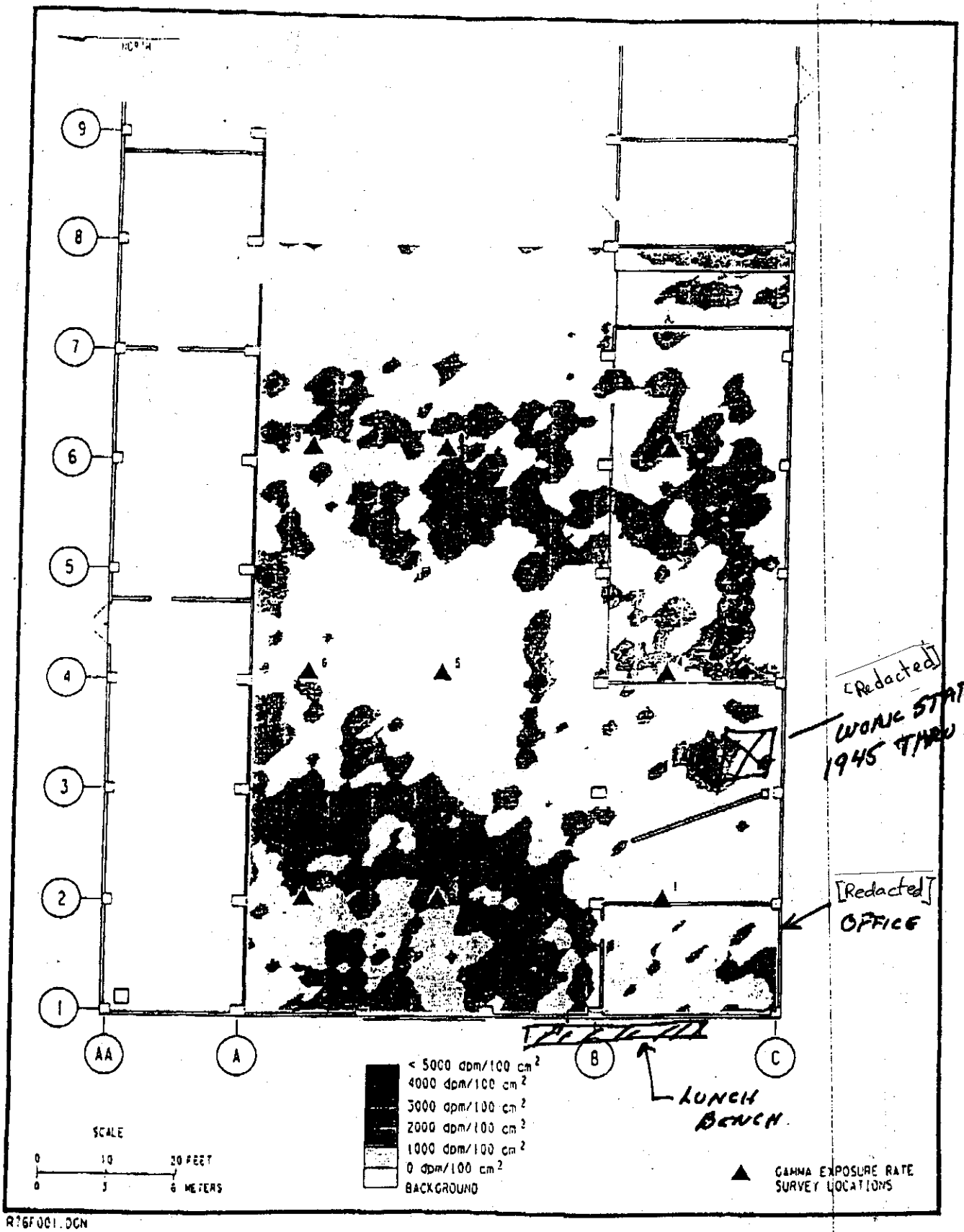


Figure 10
Chapman Valve Post-Remedial Action Floor Survey

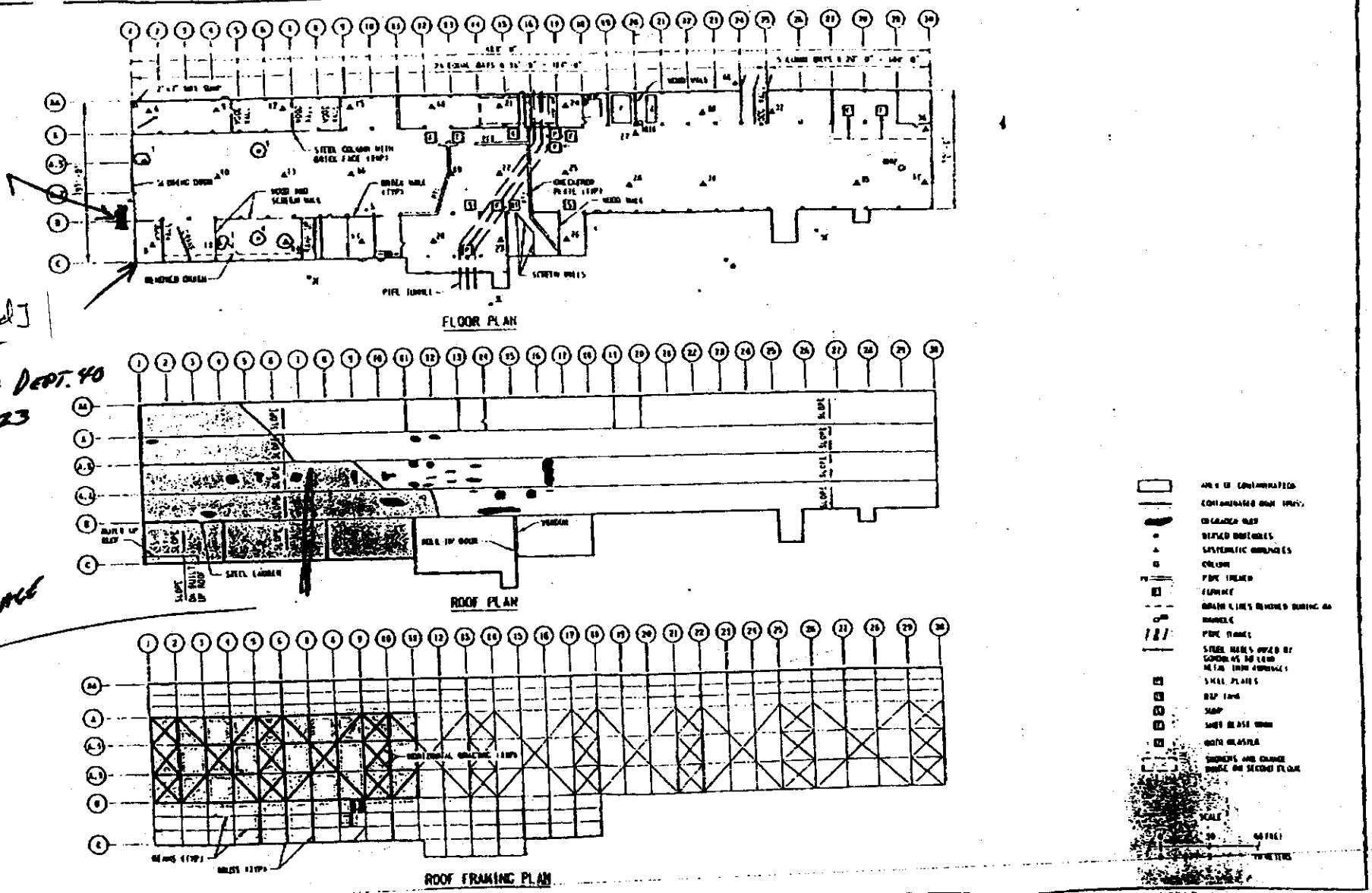


Figure 3
Chapman Valve - 1994 Characterization Results
Plan Views

ATTACHMENT 3: ANALYSIS OF MATRIX FOR INTERNAL EXPOSURE IN CHAPMAN VALVE MANUFACTURING COMPANY PRESENTED IN DOCUMENT ORAUT-TKBS-0033

From: **Dunstana Melo**
To: **John Mauro**
Date: **October 27, 2006**

INTRODUCTION

Based on just 40 results of urinalysis NIOSH has defined a matrix of exposure presented in Table 3-3, on page 18/32, presented here as Table 1. The first urine measurements were performed on June 11, 1948, the urine samples were collected because of a fire involving uranium. Just seven workers were monitored: the two workers who put out the fire had results equal to MDA (9.56 pCi/day), the five workers involved in cleanup had results ranging from 9.56 pCi/day to 76.5 pCi/day.

In the TKBS is stated that:

paragraph 2 on page 15/32:

> *The actual date of the fire is unknown, although AEC(Fox 1949) noted in the transmittal of the urinalysis results that the samples had been collected from the seven employees involved in the fire or in the fighting episode last June (1948).*

paragraph 5 on page 15/32:

> *Although the exact date of the June 1948 fire is unknown, it seems reasonable to assume that it could have occurred as early as June 1, 1948, and this should be considered when fitting individual bioassay data. For the coworker data, assuming the intake from the fire occurred on June 10, 1948 resulted in the largest total intake for the period January 1, 1948 to April 30, 1949, and provided a satisfactory fit to the data; the other assumed June fire dates produced total intakes that were within 3.6% of this largest intake. The intake from fire might have occurred over several days, but it was assumed to be an acute intake when fitting the data to simplify assumptions.*

Table 1. Inhalation intake summary for operational period (Table 3.3 TKBS)

Scenarios	Start	End	Intake Type	Absorption Type	Intake (pCi/day or pCi)
Fire plus workplace exposure	1/1/1948	4/30/1949	Chronic	M	4.81E+02
	6/10/1948	-	Acute	M	2.17E+03
Fire plus workplace exposure	1/1/1948	4/30/1949	Chronic	S	1.43E+04
	6/10/1948	-	Acute	S	7.39E+04
Workplace exposures	1/1/1948	4/30/1949	Chronic	M	4.96E+02
Workplace exposures	1/1/1948	4/30/1949	Chronic	S	1.49E+04

In the sections that follow, the results of a series of biokinetic analyses are presented that demonstrate the importance of knowing the time delay between the time when a given exposure occurs and the time when a urine sample is collected and analyzed for the purpose of estimating the quantity of uranium inhaled.

It is important to keep in mind that the acute exposures are to be superimposed on the chronic exposures assumed to be 496 pCi/day Type M or 14900 pCi/day Type S. The implications are that the baseline chronic exposures over a 50 week work year would be 124,000 pCi/yr Type M or 3,725,000 pCi/yr Type S uranium. These exposures were developed by NIOSH to capture the episodic nature of the exposures, but it is assumed that they do not capture acute exposures that may be associated with one or more fires. Hence, the question is, does the exposure matrix deal with acute exposures from one or more fires in a manner that is claimant favorable, or is it possible that acute exposures from fires could add significantly to the time-integrated intakes associated with the assumed chronic exposures.

BIOKINETIC ANALYSES

The exposure matrix is based on the assumption that an acute intake from a chip fire occurred on June 10, 1948. Tables 2 and 3 presents the intake retention fraction for urine and their respective intake values for uranium activity in urine equal to 47.8 pCi/day of urinary excretion, assuming acute inhalation of uranium Type M (AMAD=5um) and Type S (AMAD=5um), respectively.

The way to interpret Table 2 (and Table 3 also) is a follows. Assume that at time zero, a person experiences an acute intake of some unknown quantity of Type M natural uranium with an AMAD of 5 micron. Then, let us assume that a urine sample is taken at some unknown number of days after the acute intake, and the results of that bioassay analysis indicates that the uranium excretion rate on that day is 47.8 pCi. This value was selected for this analysis because it is the value used in Revision 1 of the exposure matrix. In the exposure matrix, it is assumed that the observed uranium excretion rate of 47.8 pCi/day is based on an analysis of a urine sample collected one day after the acute exposure. In Table 2, the first column is the number of days after the acute intake. Column 2 is the intake retention fraction, which should be interpreted as follows. One day after an acute intake, the intake retention fraction is 2.34E-02 pCi/pCi. This means that for every pCi inhaled at time zero, one would expect to see 2.34E-02 pCi excreted in urine over a 1-day period beginning one day after the acute intake. For day number 2, the intake retention fraction is 1.11E-03. This means that 2 days after an acute exposure, one would expect to see 1.11E-03 pCi excreted in urine that day for every pCi originally inhaled at time zero, etc.

The third column is the important column. It indicates the quantity of uranium that would have had to have been inhaled at time zero in order to observe a uranium urinary excretion rate of 47.8 pCi/day at the indicated day after intake. For example, if a bioassay program observed a uranium excretion rate of 47.8 pCi/day in urine collected over a 1-day period beginning one day after an acute exposure, the intake of uranium at time zero would have had to have been 2,040 pCi. This is in fact the approximate acute intake used in the exposure matrix. However, if the one day urine sample were collected beginning 2 days after the acute intake, and a uranium excretion rate of 47.8 pCi/day were observed in the urine sample, then the acute intake at time zero would have had to have been 43100 pCi; i.e., about 20 times higher. The implication is, if

you are trying to estimate the amount of uranium that was inhaled due to an acute exposure based on urine analysis, it is critical that you know the time when the acute intake occurred relative to the time when the bioassay sample was collected, especially for the first few days after the acute exposure.

According to the data presented in Table 2 and Table 3 there is a large variation in the urinary excretion for both uranium compounds in the first days after intake. For inhalation of uranium Type M AMAD 5um, the first month after intake is the largest period of uncertainty, the intake can vary about 2 orders of magnitude, from 2.04E+03pCi if the sample was taken one day after intake to 1.81E+05 pCi if the sample was taken 30 days after intake. Even in the first two days, it varies by a factor of 20, from 2.04E+03pCi to 4.31E+04pCi (Table 2).

The same happens for inhalation of uranium Type S AMAD 5um, the first month after intake is the largest period of uncertainty; i.e., the intake can varies about 2 order of magnitude, from 6.73E+04 pCi if the sample was taken one day after intake (which is the approximate intake assumed in the exposure matrix) to 6.22E+06 pCi if the sample was taken 30 days after intake. Even in the first two days, it varies by a factor of 16, from 6.73E+04 pCi to 1.10E+06 pCi (Table 3).

Though the difference in the back-calculate acute intake differs significantly depending on the assumed day of intake, the question becomes, can this increase in calculated acute intake significantly affect the time-integrated intake over the course of the year. The time-integrated intake would increase from 3,725,000 pCi/yr to 4,825,000 pCi/yr for a 2-day delay for exposure to Type S uranium. However, if one were to assume a 30-day delay between exposure and sample collection, the time integrated annual intake of uranium would increase to 9,945,000 pCi/yr. The latter is a large increase but it is unlikely that the time delay between exposure and intake was that large.

Table 2. Intake Retention Fraction in Urine and Respective Intake Values based on Urine Measurement of 47.8pCi/day, assuming a Single Intake of Uranium Type M AMAD 5um

Days after Intake	IRF Urine (pCi/pCi)	Intake (pCi)	Days after Intake	IRF Urine (pCi/pCi)	Intake (pCi)
1	2.34E-02	2.04E+03	20	3.50E-04	1.37E+05
2	1.11E-03	4.31E+04	21	3.38E-04	1.41E+05
3	8.38E-04	5.70E+04	22	3.28E-04	1.46E+05
4	7.75E-04	6.17E+04	23	3.18E-04	1.50E+05
5	7.22E-04	6.62E+04	24	3.08E-04	1.55E+05
6	6.76E-04	7.07E+04	25	3.00E-04	1.59E+05
7	6.36E-04	7.52E+04	26	2.92E-04	1.64E+05
8	5.99E-04	7.98E+04	27	2.84E-04	1.68E+05
9	5.66E-04	8.45E+04	28	2.77E-04	1.73E+05
10	5.36E-04	8.92E+04	29	2.71E-04	1.76E+05
11	5.09E-04	9.39E+04	30	2.64E-04	1.81E+05
12	4.85E-04	9.86E+04	31	2.59E-04	1.85E+05
13	4.62E-04	1.03E+05	40	2.18E-04	2.19E+05
14	4.42E-04	1.08E+05	50	1.88E-04	2.54E+05

Table 2. Intake Retention Fraction in Urine and Respective Intake Values based on Urine Measurement of 47.8pCi/day, assuming a Single Intake of Uranium Type M AMAD 5um

Days after Intake	IRF Urine (pCi/pCi)	Intake (pCi)	Days after Intake	IRF Urine (pCi/pCi)	Intake (pCi)
15	4.23E-04	1.13E+05	60	1.67E-04	2.86E+05
16	4.06E-04	1.18E+05	90	1.25E-04	3.82E+05
17	3.90E-04	1.23E+05	120	9.81E-05	4.87E+05
18	3.76E-04	1.27E+05	150	7.94E-05	6.02E+05
19	3.62E-04	1.32E+05	180	6.53E-05	7.32E+05

Table 3. Intake Retention Fraction in Urine and Respective Intake Values based on Urine Measurement of 47.8 pCi/day, assuming a Single Intake Of Uranium Type S AMAD 5um

Days after Intake	IRF Urine (pCi/pCi)	Intake (pCi)	Days after Intake	IRF Urine (pCi/pCi)	Intake (pCi)
1	7.10E-04	6.73E+04	20	1.01E-05	4.73E+06
2	4.36E-05	1.10E+06	21	9.80E-06	4.88E+06
3	2.55E-05	1.87E+06	22	9.49E-06	5.04E+06
4	2.32E-05	2.06E+06	23	9.20E-06	5.20E+06
5	2.16E-05	2.21E+06	24	8.93E-06	5.35E+06
6	2.01E-05	2.38E+06	25	8.68E-06	5.51E+06
7	1.89E-05	2.53E+06	26	8.45E-06	5.66E+06
8	1.77E-05	2.70E+06	27	8.24E-06	5.80E+06
9	1.67E-05	2.86E+06	28	8.04E-06	5.95E+06
10	1.58E-05	3.03E+06	29	7.85E-06	6.09E+06
11	1.50E-05	3.19E+06	30	7.68E-06	6.22E+06
12	1.42E-05	3.37E+06	31	7.52E-06	6.36E+06
13	1.35E-05	3.54E+06	40	6.43E-06	7.43E+06
14	1.29E-05	3.71E+06	50	5.68E-06	8.42E+06
15	1.23E-05	3.89E+06	60	5.18E-06	9.23E+06
16	1.18E-05	4.05E+06	90	4.28E-06	1.12E+07
17	1.13E-05	4.23E+06	120	3.80E-06	1.26E+07
18	1.09E-05	4.39E+06	150	3.50E-06	1.37E+07
19	1.05E-05	4.55E+06	180	3.29E-06	1.45E+07

Acute Intake of Uranium Type M AMAD 5um

Based on the NIOSH assumption of acute intake occurring on June 10th 1948, the expected uranium activity in urinary excretion is presented in Table 4, assuming inhalation of uranium Type M AMAD 5um. The comparison of the values presented in Table 4 with those from Table 5, which represents the expected urinary excretion assuming intake occurring on June 9th, 1948, shows that the NIOSH assumption for acute intake on June 10th does not result in the largest total intake for the period from January 1st, 1948 to April 30th 1949. Hence, the method

adopted in the exposure matrix for dealing with acute exposures associated with the fire does not appear to be claimant favorable.

The way to interpret Table 4 (and Table 5) is as follows. We know the dates when the 40 urine samples were collected (column 1 in Table 4). Column 2 presents the excretion rate we would expect to see in urine if all the workers experienced a chronic intake of 481 pCi/day of 5 micron, Type M uranium, as is assumed in the exposure matrix. As may be noted, we would expect to observe about 26 to 29 pCi/day, which is the highest excretion rate that was observed among the workers that are assumed to have experienced chronic exposures, but did not experience acute exposures associated with the fire (i.e., an excretion rate of 0.03 mg U/L). In Column 3, an estimate is made of the excretion rate in urine that would be associated with an acute intake of 2170 pCi on June 10, 1948; i.e., the assumption used in the exposure matrix. In table 4, that excretion rate is estimate to be 50.8 pCi on June 11, 1948. Hence, given this scenario, one would expect to observe a total excretion rate of 79.6 pCi/day on June 11, 1948 from the combination of the chronic and acute intakes. This is in fact the excretion rate actually observed in one worker involved in fighting the June fire (i.e., 0.08 mg U/L).

Moving down the tables, we see that one would not expect to see an elevated level of uranium in urine on the later dates that urine was collected even if the urine samples from workers that were exposed acutely were collected just two days after the June fire (assuming the fire occurred on June 9, 1948). Keep in mind that Tables 4 and 5 address Type M uranium.

Table 4. Expected U Activity in Urine due to Inhalation of Compound Type M AMAD 5um on June 10th, 1948

Date of Measurement	U Activity in Urine due to Inhalation of Compound Type M AMAD 5um		
	Chronic Intake of 481pCi/day (1/1/1948 – 4/30/1949)	Single Intake of 2170 pCi on 6/10/1948	Total Daily Urinary Excretion
6/11/1948	2.61E+01	5.08E+01	7.69E+01
7/27/1948	2.75E+01	4.25E-01	2.79E+01
9/9/1948	2.85E+01	2.68E-01	2.88E+01
10/8/1948	2.91E+01	2.13E-01	2.93E+01

Table 5. Expected U Activity in Urine due to Inhalation of Compound Type M AMAD 5um on June 9th, 1948

Date of Measurement	U Activity in Urine due to Inhalation of Compound Type M AMAD 5um		
	Chronic Intake of 481pCi/day (1/1/1948 – 4/30/1949)	Single Intake of 2170 pCi on 6/9/1948	Total Daily Urinary Excretion
6/11/1948	2.61E+01	2.40E+00	2.85E+01
7/27/1948	2.75E+01	6.89E-01	2.75E+01
9/9/1948	2.85E+01	4.19E-01	2.79E+01
10/8/1948	2.91E+01	3.88E-01	2.81E+01

Acute Intake of Uranium Type S AMAD 5um

Based on the NIOSH assumption of acute intake occurring on June 10th 1948, the expected uranium activity in urinary excretion is presented in Table 6, assuming inhalation of uranium Type S AMAD 5um. The comparison of the values presented in Table 6 with those from Table 7, which represents the expected urinary excretion assuming intake occurring on June 9th, 1948, shows that the NIOSH assumption for acute intake on June 10th does not result in the largest total intake for the period from January 1st, 1948 to April 30th 1949. Again, based on this analysis, the exposure matrix is not claimant favorable with respect to acute exposures.

Table 6. Expected U Activity in Urine due to Inhalation of Compound Type S AMAD 5um on June 10th, 1948

Date of Measurement	U Activity in Urine due to Inhalation of Compound Type M AMAD 5um		
	Chronic Intake of 1.43E+04pCi/day (1/1/1948 – 4/30/1949)	Single Intake of 7.39E+04 pCi on 6/10/1948	Total Daily Urinary Excretion
6/11/1948	2.45E+01	5.25E+01	7.70E+01
7/27/1948	2.67E+01	4.34E-01	2.71E+01
9/9/1948	2.86E+01	3.15E-01	2.89E+01
10/8/1948	2.98E+01	2.81E-01	3.01E+01

Table 7. Expected U Activity in Urine due to Inhalation of Compound Type S AMAD 5um on June 9th, 1948

Date of Measurement	U Activity in Urine due to Inhalation of Compound Type M AMAD 5um		
	Chronic Intake of 481pCi/day (1/1/1948 – 4/30/1949)	Single Intake of 2170 pCi on 6/9/1948	Total Daily Urinary Excretion
6/11/1948	2.45E+01	3.22E+00	2.77E+01
7/27/1948	2.67E+01	4.29E-01	2.71E+01
9/9/1948	2.86E+01	3.13E-01	2.89E+01
10/8/1948	2.98E+01	2.80E-01	3.01E+01

Matrix of Exposure

The TKBS-0033 matrix of exposure was derived based on 40 urinalysis results. Based on those bioassay results, different scenarios can be derived, some of which are presented below:

a) Maximum acute intake:

Since there is considerable uncertainty regarding the date of the early June fire and the associated internal exposures of workers involved in fighting the fire and cleaning up after the fire, the acute intake associated with the fire is highly uncertain, ranging from one or two order of magnitude depending on assumptions made regarding when the acute intake(s) occurred relative to the urine collection date of June 11, 1948. As seen in Table 2, for uranium Type M AMAD 5um, the calculated intake based on 47.8pCi/day of urinary

excretion could be in a range from 2.04E+03 pCi if the sample is taken 1 day after the intake to 7.32E+05 pCi if the sample was taken six months after intake, or if it is assumed that the intake occurred in the first day of work (January 1st, 1948). As seen in Table 3, for uranium Type S AMAD 5um, the calculated intake based on 47.8pCi/day of urinary excretion could be in a range from 6.73E+04 pCi if the sample is taken 1 day after the intake to 1.45E+07 pCi if the sample was taken six months after intake, or if it is assumed that intake occurred on the first day of work (January 1st, 1948).

The maximum internal exposure is obtained assuming an acute intake on January 1st, 1948 and the result of uranium measurement in urine is attributed to that exposure. The intake values for different urine results and different scenarios of acute intake on January 1st, 1948 are presented in Table 8.

Table 8. Intake derived for different urine results and different scenarios of acute intake on January 1st, 1948

AMAD	Uranium Compound	Single Intake (pCi) based on Different Urine Results (6/11/1948)			
		9.56pCi/d	28.7pCi/d	76.5pCi/d	116.2pCi/d
5 um	Type M	1.30E+05	3.91E+05	1.04E+06	1.58E+06
	Type S	2.80E+06	8.42E+06	2.24E+07	3.41E+07
1 um	Type M	6.83E+04	2.05E+05	5.46E+05	8.30E+05
	Type S	1.46E+06	4.38E+06	1.17E+07	1.77E+07
0.5 um	Type M	6.05E+04	1.82E+05	4.84E+05	7.35E+05
	Type S	1.29E+06	3.87E+06	1.03E+07	1.57E+07

In order to point out the possibility of missing acute intakes during the working period, two scenarios of exposure were simulated, and presented below. Comparing the expected urinary excretion for these two scenarios with the ones expected assuming NIOSH exposure matrix it is concluded that acute intakes could be easily missed if the urine samples were not taken right after the intakes. Due to the large MDA value the acute intakes would not be reflected in the urine measurements.

b) Chronic intake of 1.43E+04 pCi/day of uranium from 1/1/1948 to 04/30/1949 plus nine acute intakes of 5.0E+04 pCi occurring each first day of the month from 1/1/1948 to 04/30/1949 (compound Type S, AMAD = 5um):

Assuming a scenario of chronic intake of 1.43E+04 pCi/day of uranium Type S-AMAD=5um, as in TKBS, plus acute intakes in the first day of each month during whole period of exposure, the total intake for the period from 1/1/1948 to 4/30/1949 is 7.74E+06 pCi, assigning 8.0E+05 pCi for 16 acute intakes of 5.0E+04 pCi (January/1948 to April/ 1949) and a total of 6.94E+06 pCi due to chronic intake of 1.43E+04 pCi/day from 1/1/1948 to 4/30/1949. This scenario is presented in Table 9 and the summary is presented in Table 10. Although the total intake for this scenario is about the same compared to the one presented in the TKBS, it is important to note that the acute intakes would not be reflected on the urine results.

b) Chronic intake of 1.43E+04 pCi/day of uranium from 1/1/1948 to 04/30/1949 plus nine acute intakes of 9.0E+04 pCi occurring each first day of the month from 1/1/1948 to 04/30/1949 (compound Type S, AMAD = 5um):

Assuming a scenario of chronic intake of 1.43E+04 pCi/day of uranium Type S AMAD=5um, as in TKBS, plus acute intakes in the first day of each month during whole period of exposure, the total intake for the period from 1/1/1948 to 4/30/1949 is 8.38E+06 pCi, assigning 1.44E+06 pCi for 16 acute intakes of 9.0E+04 pCi (January/1948 to April/ 1949) and a total of 6.94E+06 pCi due to chronic intake of 1.43E+04 pCi/day from 1/1/1948 to 4/30/1949. This scenario is presented in Table 9 and the summary is presented in Table 10. Although the total intake for this scenario is higher compared to the one presented in the TKBS, it is important to note that the acute intakes would not be reflected on the urine results.

c) Chronic intake of 1.43E+04 pCi/day of uranium from 1/1/1948 to 04/30/1949 plus nine acute intakes of 2.7E+05 pCi occurring each first day of the month from 1/1/1948 to 04/30/1949 (compound Type S, AMAD = 5um):

Assuming a scenario of chronic intake of 1.43E+04 pCi/day of uranium Type S-AMAD=5um, as in TKBS, plus acute intakes of 2.7E+05 pCi in the first day of each month during the entire period of exposure, the total intake for the period from January 1, 1948, to April 30, 1949, is 1.13E+07 pCi, assigning 4.40E+06 pCi for 16 acute intakes of 2.7E+05 pCi (January 1948 to April 1949) and a total of 6.94E+06 pCi due to chronic intake of 1.43E+04 pCi/day from January 1, 1948, to April 30, 1949. This scenario is presented in Table 11 and the summary is presented in Table 12. Although the total intake for this scenario is higher compared to the one presented in the TKBS and about the same value for maximum intake presented in Table 8 (2.24E+07 pCi assuming a single intake scenario based on the urine result of 76.5pCi/day). It is important to note that the expected uranium activities in urine are below to the maximum value in the Chapman Valve records.

Even if one assumes acute intakes from January to May, 1948, the total intake would be 8.3E+06 pCi; 1.38E+06 pCi due to the five acute intakes plus 6.94E+06 pCi due to chronic intake of 1.43E+04 pCi/day from 1/1/1948 to 4/30/1949. This total intake is even slightly higher than the one suggested in the TKBS and the maximum activity of uranium in urinary excretion was about 30 pCi/day.

CONCLUSION

Based on the analysis presented in this report, it is concluded that NIOSH assumption for acute intake does not appear to be claimant favorable. This conclusion is based on the large uncertainty associated with interpreting the results of urine measurements and also the lack of enough bioassay data and air monitoring data.

Table 9. Expected U Activity in Urine due to Chronic Intake of 1.43E+04pCi/d (January 1, 1948, to April 30, 1949) Plus Monthly Acute Intakes of 9.0E+04 pCi (Type S AMAD 5um)

Date	Chronic Intake of 1.43E+04pCi/d (1/1/48 – 4/30/49)	Acute Intakes of 9.04E+04 pCi occurred in the First Day of the 9 Months (Jan-Sept)									Total activity in urine (pCi/d)
		1/1/1948	2/1/1948	3/1/1948	4/1/1948	5/1/1948	6/1/1948	7/1/1948	8/1/1948	9/1/1948	
	Activity of Uranium Expected in Urine Samples (pCi/d)										
1/2/1948	6.79E+00	3.52E+01									4.20E+01
2/2/1948	1.62E+01	3.70E-01	3.52E+01								5.18E+01
3/2/1948	1.87E+01	2.57E-01	3.86E-01	3.52E+01							5.45E+01
4/2/1948	2.08E+01	2.12E-01	2.57E-01	3.70E-01	3.52E+01						5.68E+01
5/2/1948	2.25E+01	1.89E-01	2.13E-01	2.55E-01	3.77E-01	3.52E+01					5.87E+01
6/2/1948	2.41E+01	1.74E-01	1.89E-01	2.11E-01	2.55E-01	3.70E-01	3.52E+01				6.05E+01
6/11/1948	2.45E+01	1.70E-01	1.84E-01	2.03E-01	2.39E-01	3.17E-01	8.01E-01				**2.64E+01**
7/2/1948	2.55E+01	1.64E-01	1.74E-01	1.88E-01	2.12E-01	2.55E-01	3.77E-01	3.52E+01			6.21E+01
7/27/1948	2.67E+01	1.57E-01	1.65E-01	1.76E-01	1.92E-01	2.17E-01	2.68E-01	4.25E-01			**2.83E+01**
8/2/1948	2.69E+01	1.56E-01	1.64E-01	1.73E-01	1.88E-01	2.11E-01	2.55E-01	3.70E-01	3.52E+01		6.36E+01
9/2/1948	2.83E+01	1.50E-01	1.56E-01	1.63E-01	1.73E-01	1.87E-01	2.11E-01	2.53E-01	3.70E-01	3.52E+01	6.52E+01
9/9/1948	2.86E+01	1.48E-01	1.54E-01	1.61E-01	1.71E-01	1.84E-01	2.04E-01	2.40E-01	3.27E-01	9.00E-01	**3.11E+01**
10/8/1948	2.98E+01	1.45E-01	1.50E-01	1.56E-01	1.63E-01	1.73E-01	1.88E-01	2.11E-01	2.55E-01	3.77E-01	**3.16E+01**

Table 10. Expected U Activity in Urine due to Chronic Intake of 1.43E+04pCi/d (January 1, 1948, to April 30, 1949) Plus Monthly Acute Intakes of 9.0E+04 pCi (Type S AMAD 5um)

Date of Measurement	U Activity in Urine (pCi/d)		
	Chronic Intake of 1.43E+04pCi/d (1/1/48 – 4/30/49)	Acute Intakes of 9.04E+04 pCi (Jan-Sept)	Total
6/11/1948	2.45E+01	1.91E+00	2.64E+01
7/27/1948	2.67E+01	1.60E+00	2.83E+01
9/9/1948	2.86E+01	2.49E+00	3.11E+01
10/8/1948	2.98E+01	1.83E+00	3.16E+01

Table 11. Expected U Activity in Urine due to Chronic Intake of 1.43E+04pCi/d (January 1, 1948, to April 30, 1949) Plus Monthly Acute Intakes of 2.7E+05 pCi (Type S AMAD 5um)

Date	Chronic Intake of 1.43E+04pCi/d (1/1/48 – 4/30/49)	Acute Intakes of 2.7E+05 pCi occurred in the First Day of the 9 Months (Jan-Sept)									Total activity in urine (pCi/d)
		1/1/1948	2/1/1948	3/1/1948	4/1/1948	5/1/1948	6/1/1948	7/1/1948	8/1/1948	9/1/1948	
	Activity of Uranium Expected in Urine Samples (pCi/d)										
1/2/1948	6.79E+00	1.92E+02									1.99E+02
2/2/1948	1.62E+01	1.99E+00	1.92E+02								2.10E+02
3/2/1948	1.87E+01	1.39E+00	2.07E+00	1.92E+02							2.14E+02
4/2/1948	2.08E+01	1.14E+00	1.39E+00	1.99E+00	1.92E+02						2.17E+02
5/2/1948	2.25E+01	1.02E+00	1.15E+00	1.38E+00	2.03E+00	1.92E+02					2.20E+02
6/2/1948	2.41E+01	9.37E-01	1.02E+00	1.14E+00	1.38E+00	1.99E+00	1.92E+02				2.23E+02
6/11/1948	2.45E+01	9.19E-01	9.91E-01	1.10E+00	1.29E+00	1.71E+00	4.26E+00				**3.48E+01**
7/2/1948	2.55E+01	8.84E-01	9.40E-01	1.02E+00	1.14E+00	1.38E+00	2.03E+00	1.92E+02			2.25E+02
7/27/1948	2.67E+01	8.50E-01	8.93E-01	9.48E-01	1.04E+00	1.17E+00	1.45E+00	2.28E+00			**3.53E+01**
8/2/1948	2.69E+01	8.42E-01	8.84E-01	9.35E-01	1.02E+00	1.14E+00	1.38E+00	1.99E+00	1.92E+02		2.27E+02
9/2/1948	2.83E+01	8.09E-01	8.42E-01	8.81E-01	9.35E-01	1.01E+00	1.14E+00	1.36E+00	1.99E+00	1.92E+02	2.29E+02
9/9/1948	2.86E+01	8.02E-01	8.34E-01	8.71E-01	9.21E-01	9.91E-01	1.10E+00	1.30E+00	1.76E+00	4.78E+00	**4.20E+01**
10/8/1948	2.98E+01	7.76E-01	8.10E-01	8.41E-01	8.82E-01	9.35E-01	1.02E+00	1.14E+00	1.38E+00	2.03E+00	**3.97E+01**

Table 12. Expected U Activity in Urine due to Chronic Intake of 1.43E+04pCi/d (January 1, 1948, to April 30, 1949) Plus Monthly Acute Intakes of 2.7E+05 pCi (Type S-AMAD 5um)

Date of Measurement	U Activity in Urine (pCi/d)		
	Chronic Intake of 1.43E+04pCi/d (1/1/48 – 4/30/49)	Acute Intakes of 2.7E+05 pCi (Jan-Sept)	Total
6/11/1948	2.45E+01	1.03E+01	3.48E+01
7/27/1948	2.67E+01	8.63E+00	3.53E+01
9/9/1948	2.86E+01	1.34E+01	4.20E+01
10/8/1948	2.98E+01	9.87E+00	3.97E+01

ATTACHMENT 4: MAXIMUM LIKELY DUST CLOUD – INDEPENDENT ANALYSIS BY WESLEY VANPELT

Dr. Wesley VanPelt's analysis presented on the following pages.

WESLEY R. VAN PELT ASSOCIATES, INCORPORATED

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30 January 2005

Dr. John Mauro
SC&A
209 Ueland Road
Red Bank, NJ 07701

Subject: Maximum Likely Dust Cloud

Dear John,

At your request I have considered the issue of how much airborne dust would be likely in an industrial setting. The question, as I understand it, is what is the largest reasonable dust concentration that one would expect before other issues intervened such as limited visibility, irritation, coughing, sneezing, eye irritation, etc. Other limitations on the maximum likely concentration of airborne dust include physical and environmental forces which tend to reduce or dissipate the dust cloud.

Physical Limits

There is a limit on the amount of dust in the air that can sustain itself beyond a very short time. The natural processes of sedimentation, attachment, coagulation, eddy diffusion, dilution, etc. will reduce the concentration of airborne dust. For aerosols, the upper bound for a stable cloud of inhalable dust has been estimated as 500 mg/m^3 (Craig, et. al.).

Occupational Limits and Standards for Dust Concentrations in Air

Non-toxic or nuisance dusts are now called Particulates (insoluble) Not Otherwise Classified (PNOC). The American Conference of Governmental Industrial Hygienists, Inc. (ACGIH) recommends a total dust, 8-hour TLV-TWA of 10 mg/m^3 for inhalable PNOCs containing no asbestos and <1% crystalline silica; and 3 mg/m^3 for respirable dust. Inhalable dust is airborne particulate that can deposit anywhere in the respiratory tract and includes particle sizes from the finest dust to very large particles (diameters up to 100 micrometers and larger).

PNOCs refer to airborne insoluble materials whose only known hazards are physical irritation, discomfort, impaired visibility and enhancement of accident potential, but not health impairment. Although these materials may not cause fibrosis or systemic effects,

they are not necessarily biologically inert. They can inhibit the clearance of toxic particulates from the lung and, at high concentrations, cause alveolar proteinosis.

The TLV-TWA is defined by the ACGIH as the time-weighted average airborne concentration for a normal 8-hour workday and a 40-hour workweek to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse health effects.

For substances, such as PNOC, without a Short Term Exposure Limit (a 15 minute TWA, which can not be exceeded at any time during the workday), ACGIH recommends a concept called an *excursion limit* which is defined by the following:

- Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday.
- Under no circumstances should excursions in worker exposure levels exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded.

Thus, PNOCs in a reasonably well controlled industrial setting, where workers were not wearing respirators, would not be expected to exceed:

10 mg/m^3 (the TLV-TWA for an 8-hour day),
30 mg/m^3 (the excursion limit for not more than 30 minutes per day), and
50 mg/m^3 (the absolute excursion limit any time period).

Actual Industrial Dust Concentrations

Pertinent to the problem at hand would be exposure to airborne dusts consisting of metal oxides such as that produced when welding metals. A large compendium of actual metal fume[1] concentrations during welding operations can be found in reference 3, The Welding Environment. This document summarizes actual measurements of welding fume concentrations as published in the literature and those under test conditions where specific welding operations were conducted for the purposes of measuring airborne concentrations and assessing potential occupational exposures to fumes and toxic welding gas products. I summarized the measured dust concentrations in mg/m^3 from this document. Many entries specify the location of the sampler with respect to the source and receptor as well as the local ventilation conditions. Therefore, the airborne dust concentration data were extracted and listed in the following categories as shown in the attached Appendix 1:

- outside helmet
- inside helmet

[1]Fume: Finely divided airborne particles created when volatilized solids condense in cool air, such as a heated process like welding, smelting, furnace work and foundry operations.

- unventilated
- ventilated
- breathing zone
- other or general air

The data are reported in reference 3 in a variety of ways including the mean and the range of dust concentration. When the range was given, both the low and high values of the range were recorded in Appendix 1. This was done to include the highest (and lowest) values of measured dust concentration rather than have them "buried" in a mean value.

For welding fume concentrations in each of the above six exposure categories, I calculated the mean, standard deviation ("sigma"), mean plus standard deviation, minimum, maximum and number of values. These summary data are shown in the table below.

	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3
Mean	115	28	183	40	21	35
Sigma	164	34	235	42	27	89
Mean + Sigma	279	63	417	82	47	124
Minimum	5	1	4	3	0	1
Maximum	713	166	850	136	124	560
Number of Items	23	48	18	20	47	56

To gain a sense of the maximum likely dust concentration in an industrial setting we should look at both the Maximum and the (Mean + Sigma) entries in the table above. The Maximum value ranges from about 100 to 700 mg/m^3. This is in good agreement with the estimated upper bound for a stable cloud of inhalable dust of 500 mg/m^3 (Craig, et. al.)

A better predictor of the maximum likely dust concentration is the (Mean + Sigma) value. Assuming a normal distribution of values, this value represents a statistic such that only 16% of the individual values are greater than the (Mean + Sigma). The (Mean + Sigma) value ranges from about 50 to 400 mg/m^3.

Summary and Conclusion

While it is impossible to predict the maximum likely dust concentration to which a worker would be exposed in an industrial setting, it is possible to construct some likely bounds on the largest dust concentration likely to occur. Considering the physical forces, the occupational limits and standards on airborne dust concentrations, and the range of metal oxide (fume) dust concentrations found in welding operations, it is my opinion that the maximum likely dust concentration in the breathing zone of a worker without a respirator would be about 30 mg/m^3 for exposures lasting many hours per day and about 300 mg/m^3 for exposures lasting only 5 or 10 minutes or less.

Note that these maximum likely dust concentrations would exceed present industry standards and governmental limits covering occupational exposure to airborne Particles Not Otherwise Classified.

References

1. Douglas K Craig and C. Ray Lux, METHODOLOGY FOR DERIVING TEMPORARY EMERGENCY EXPOSURE LIMITS (TEELs), Westinghouse Safety Management Solutions, Westinghouse Savannah River Company, Project Engineering & Construction Division, Aiken, SC 29808

2. 2001 TLVs and BEIs: Threshold Limit Values for chemical substances and physical agents - Biological Exposure Indices, Cincinnati, OH, American Conference of Governmental Industrial Hygienists, 2001.

3. The Welding Environment, A Research Report on Fumes and Gases Generated During Welding Operations, Research performed at Battelle-Columbus Laboratories under contract with the American Welding Society and supported by industry contributions, Miami, FL, American Welding Society, 1973.

4. Documentation of the threshold limit values and biological exposure indices, Cincinnati, OH, American Conference of Governmental Industrial Hygienists, Inc., 1991.

Best regards.

Very truly yours,
WESLEY R. VAN PELT ASSOCIATES, Inc.

Wesley R. Van Pelt, Ph.D., CIH, CHP
President

Attachment: Appendix 1

Appendix 1
Measured Fume (Dust) Concentrations Taken from: "The Welding Environment, A Research Report on Fumes and Gases Generated During Welding Operations," American Welding Society, 1973.

	Fume Concentration, mg/m3						
Table No.	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air	comment
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	
1.1						26	
1.3					3.5	2.2	min
					29.7	15	max
					2.8	1.3	min
					54	7.7	max
					3.1	2.5	min
					45	6.4	max
					3.7	1.4	min
					41	13.7	max
					2.2	0.5	min
					46	7.2	max
					5.3	2.4	min
					47	8.5	max
					7.4	1.4	min
					103	8.9	max
					21	0.8	min
					79	8.1	max

Table No.	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air	comment
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	
					10.6	1.6	min
					124	12	max
					2.1	9.3	min
					35	24	max
1.6			18.5	2.7			
			75	36.9			
			19	74			
			67	62			
				83			
				12			
				16			
				130			
				136			
				5.6			
				30			
				5.6			
				8			
			12				
			148				
			34				
			187				
			3.5				
			252				

Table No.	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air	comment
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	
			45				
			120				
1.18						218	
						136	
						35	
						35	
						17	
						34	
						22	
						64	
						34	
						20	
						17	
						12	
1.22						12	
						5	
						27.9	
						8.1	
1.25	117.6			23.1			
	52.8			8.5			
				6.2			
				2.8			
1.33			20	40			

Table No.	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air	comment
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	
			55	90			
1.34	14.5	1.56					
	45	4.4					
	17.3	1.85					
	169	7.69					
	83.4	4.2					
	158	5.1					
	19.6	1.1					
	199.9	6.1					
1.35	5.3	1.3					
	60.5	6.8					
	9.3	1.8					
	192.6	7.4					
	9	1.3					
	71.8	8.4					
	10.7	1.8					
	85	5					
1.40					31.1		
					24.5		
					0.41		
					5.7		
					0.7		
					0.5		

Table No.	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air	comment
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	
					35.1		
					13.9		
					35.1	16.2	
						11.9	
						19.6	
1.41					3.3	7.7	
					3.1	10.1	
					4.1	9.4	
					4.3	10.1	
					3.7	9.3	
						65.8	
						5.9	
1.42					12.4	9.1	
						7.2	
1.45			580			560	
			850			320	
			450				
			350				
1.46					11.9		under air extracted hood
					9.8		
					11.6		
					15		

Table No.	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air	comment
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	
					27.8		
1.47					2.8		in open air
					3		
					3.3		
					3.4		
					12.9		
1.48				35.5			
1.54					18.87	6.8	
						24.46	
1.55		4.22			2.5		
		14					
1.56						1.34	
						7.7	
						7.2	
2.18	102.73	14.13					
2.19	39.65	11.75					
2.20	451.34	26.8					
2.21	713	47.2					
	14.4						
2.25		28					100% arc time
		43					100% arc time
		43.8					100% arc time
		44					100% arc time

Table No.	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air	comment
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	
		28					100% arc time
		50					100% arc time
		166					100% arc time
		68					100% arc time
		23					100% arc time
		23.7					100% arc time
		19					100% arc time
		19.1					100% arc time
		23.4					100% arc time
		23.8					100% arc time
2.26		19.8					100% arc time
		46.3					100% arc time
		12.4					100% arc time
2.28a		28.3					100% arc time
2.28b		43.5					100% arc time
2.28c		43.8					100% arc time
2.28d		44.2					100% arc time
2.28e		28					100% arc time
2.28f		50					100% arc time
2.29a		166					
2.29b		68.2					
2.30a		23.4					

Table No.	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air	comment
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	
	outside helmet	inside helmet	unventilated	ventilated	breathing zone	other or general air	comment
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	
Mean	115	28	183	40	21	35	
Sigma	164	34	235	42	27	89	
Mean + Sigma	279	63	417	82	47	124	
Minimum	5	1	4	3	0	1	
Maximum	713	166	850	136	124	560	
Number of Items	23	48	18	20	47	56	

ATTACHMENT 5: SETTING LIMITS ON DUST LOAD IN AIR – INDEPENDENT ANALYSIS BY MIKE THORNE

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EXTERNAL MEMORANDUM

Date: 5 September 2005
From: M. C. Thorne
To: A. Makhijani
Copies:
Subject: Setting Limits on the Dust Load in Air

Arjun

The following note is a compilation of information relevant to the estimation of maximum dust loads in air. It addresses the following issues:

a) Whether considerations of visibility constrain maximum dust loads;
b) The maximum transient dust loads that can exist;
c) Typical peak and chronic dust loads that might be applicable;
d) Implications of peak and chronic dust loads for time-weighted average dust loads to be used in claimant-favorable assessments.

Considerations of Visibility

Visibility can be modelled using:

$$V = \exp [-Sx]$$

where V is the fraction of light that reaches the observer;
S is the linear attenuation coefficient (m^{-1});
x is the distance from the object being viewed to the observer (m).

Furthermore:

$$S = AN$$

where A is the cross sectional area of the dust particles (m^2);
N is the particle density of particles with area A (m^{-3}).

Now, let the mass loading in a particular size range be C mg m^{-3} and let the characteristic diameter of a particle in that size range be d μm. If the density of material comprising the particle is ρ kg m^{-3}, then the mass of a single particle, M (kg), is given by:

$$M = (4/3)\times\pi\times(d/2)^3\times10^{-18}\times\rho$$

where 10^{-18} converts from the cube of the diameter in μm to the cube of the diameter in m.

As C has units of mg m^{-3}, the number of particles per unit volume, N (m^{-3}), is given by:

$$N = 10^{-6}C/M$$

However, the geometrical area of each particle, A (m^2), is given by:

$$A = \pi\times(d/2)^2\times10^{-12}$$

Combining these various expressions, NA (m^{-1}) is given by:

$$NA = \{10^{-6}C\}\times\{\pi\times(d/2)^2\times10^{-12}\}/\{(4/3)\times\pi\times(d/2)^3\times10^{-18}\times\rho\} = C/\{(4/3)\times(d/2)\times\rho\}$$

or

$$NA = 1.5C/d\rho$$

A small spreadsheet has been written to perform this calculation (provided with this memorandum). The reference version of that spreadsheet is reproduced below.

			Diameter Range	Reference Diameter	Mass Fraction	Mass Loading (mg/m^3)	NA
			>850	1000	0.033	33	1.87E-05
			850–300	575	0.027	27	2.66E-05
			300–150	225	0.012	12	3.02E-05
			150–75	112.5	0.092	92	4.63E-04
C	1000	**mg/m^3**	75–45	60	0.078	78	7.36E-04
Rho	2650	**kg/m^3**	45–20	32.5	0.385	385	6.71E-03
			20–5	12.5	0.354	354	1.60E-02
			<5	2.5	0.03	30	6.79E-03
			Total				3.08E-02

Distance (m)	Visibility
1	9.70E-01
2	9.40E-01
5	8.57E-01
10	7.35E-01
20	5.40E-01
50	2.14E-01
100	4.59E-02

This is the case for a dust load of 1000 mg m^{-3} and the particle density used is similar to that of soil.

A particularly interesting point in the analysis is that NA = 1.5C/dρ implies that, for a predefined dust load in air, the degree of attenuation increases as the particles get smaller. This is easily understood. The specific surface area of the particles increases inversely as their diameter. For 2.5, 1 and 0.1 μm diameter cases at a dust loading of 1000 mg m^{-3} the visibility values are as shown in the following table.

Distance (m)	Visibility		
	2.5 μm	1.0 μm	0.1 μm
1	7.97E-01	5.68E-01	3.48E-03
2	6.36E-01	3.22E-01	1.21E-05
5	3.22E-01	5.90E-02	5.11E-13
10	1.04E-01	3.48E-03	2.61E-25
20	1.08E-02	1.21E-05	6.83E-50
50	1.21E-05	5.11E-13	1.22E-123
100	1.47E-10	2.61E-25	1.49E-246

This analysis shows that with a realistic mix of particle sizes and a dust load of 1000 mg m^{-3} (reference calculation), visibility is only marginally impaired at 5 to 10 metres. However, with a sub-micron aerosol at this dust loading, visibility could be substantially impaired at 2 m or less. In the following table, visibility is estimated for dust loadings of from 100 to 3000 mg m^{-3} and for particle sizes in the range 0.1 to 3 μm.

Dust Loading (mg m^{-3})	Distance (m)	Visibility			
		0.1 μm	0.3 μm	1.0 μm	3.0 μm
100	1	5.68E-01	8.28E-01	9.45E-01	9.81E-01
	2	3.22E-01	6.86E-01	8.93E-01	9.63E-01
	5	5.90E-02	3.89E-01	7.54E-01	9.10E-01
	10	3.48E-03	1.52E-01	5.68E-01	8.28E-01
	20	1.21E-05	2.30E-02	3.22E-01	6.86E-01
	50	5.11E-13	8.00E-05	5.90E-02	3.89E-01
	100	2.61E-25	6.39E-09	3.48E-03	1.52E-01
300	1	1.83E-01	5.68E-01	8.44E-01	9.45E-01
	2	3.35E-02	3.22E-01	7.12E-01	8.93E-01
	5	2.05E-04	5.90E-02	4.28E-01	7.54E-01
	10	4.22E-08	3.48E-03	1.83E-01	5.68E-01
	20	1.78E-15	1.21E-05	3.35E-02	3.22E-01
	50	1.34E-37	5.11E-13	2.05E-04	5.90E-02

Dust Loading (mg m^{-3})	Distance (m)	Visibility			
		0.1 µm	0.3 µm	1.0 µm	3.0 µm
	100	1.79E-74	2.61E-25	4.22E-08	3.48E-03
1000	1	3.48E-03	1.52E-01	5.68E-01	8.28E-01
	2	1.21E-05	2.30E-02	3.22E-01	6.86E-01
	5	5.11E-13	8.00E-05	5.90E-02	3.89E-01
	10	2.61E-25	6.39E-09	3.48E-03	1.52E-01
	20	6.83E-50	4.09E-17	1.21E-05	2.30E-02
	50	1.22E-123	1.07E-41	5.11E-13	8.00E-05
	100	1.49E-246	1.14E-82	2.61E-25	6.39E-09
3000	1	4.22E-08	3.48E-03	1.83E-01	5.68E-01
	2	1.78E-15	1.21E-05	3.35E-02	3.22E-01
	5	1.34E-37	5.11E-13	2.05E-04	5.90E-02
	10	1.79E-74	2.61E-25	4.22E-08	3.48E-03
	20	3.19E-148	6.83E-50	1.78E-15	1.21E-05
	50	0.00E+00	1.22E-123	1.34E-37	5.11E-13
	100	0.00E+00	1.49E-246	1.79E-74	2.61E-25

This illustrates that for very fine aerosols, such as welding fumes, visibility considerations could place constraints on air concentrations in the range of 100 to 300 mg m^{-3}, but that for aerosols more typical of general air in industrial environments (~1 µm diameter or larger), visibility constraints are only of potential significance at dust loads above 1000 mg m^{-3}.

Maximum Transient Dust Loads

In a mining environment, very high transient concentrations of dust in air can exist and their impacts on visibility have been assessed. Relevant work in the UK is reported in the Safety and Health in Mines Research Advisory Board Annual Review 2002. This is available at: http://www.hse.gov.uk/aboutus/meetings/shmrab/shmrab02a.htm.

There it was reported that a project was set up to investigate the feasibility of using visual judgment to establish if a flammable coal dust cloud exists within a mine. The intention was that this could then be used by mine staff caught in emergency situations where they are in, or close to a coal dust cloud to decide if items of potentially incendive equipment should be switched off or not.

The work involved developing an enclosure with an internal mixing system to allow coal dust clouds of controlled concentrations to be maintained so that a visual assessment could be made. To produce such clouds a system of fans and airlines was developed to keep the cloud in suspension. Weighed quantities of coal dust were then introduced to produce the concentration required. Illumination was provided using a miner's cap lamp in isolation and with background lighting.

Working with HSL photographers, a series of tests were carried out to try and assess changes in visibility for dust concentrations. The results of these tests showed that at relatively low concentrations , around 10 g m^{-3}, objects at a distance of approx 1.5 m were visible. At 33 g $m^{-3,}$ objects at 0.75 m were totally obscured. It was also possible to observe varying levels of obscuration at intermediate concentrations, however, the level of analysis required was far in excess of what a worker could rapidly achieve in an emergency situation.

Thus, in carefully controlled conditions, dust clouds of micron-size particles or larger (judged from the degree of visual obscuration achieved) could be maintained and concentrations of 10,000 mg m^{-3} or more for long enough for measurements of visual obscuration to be made.

Typical Peak and Chronic Dust Loads

Van Pelt (2005) commented that for aerosols, the upper bound for a stable cloud of inhalable dust has been estimated as 500 mg m^{-3}. For non-toxic or nuisance dusts, he estimated that in a present-day, well-controlled industrial setting, where workers were not wearing respirators, concentrations would not be expected to exceed the following values:

- 10 mg m^{-3} (the TLV-TWA for an 8-hour day);
- 30 mg m^{-3} (the excursion limit for not more than 30 minutes per day); and
- 50 mg m^{-3} (the absolute excursion limit any time period).

From a compilation of data on exposure to welding fumes, he estimated the following concentrations.

Measure	Concentration (mg m^{-3})					
	Outside Helmet	Inside Helmet	Unventilated	Ventilated	Breathing Zone	Other or General Air
Mean	115	28	183	40	21	35
Sigma	164	34	235	42	27	89
Mean+Sigma	279	63	417	82	47	124
Minimum	5	1	4	3	0	1
Maximum	713	166	850	136	124	560
Number of Items	23	48	18	20	47	56

On the basis of these data, Van Pelt concluded that while it is impossible to predict the maximum likely dust concentration to which a worker would be exposed in an industrial setting, it is possible to construct some likely bounds on the largest dust concentration likely to occur. Considering the physical forces, the occupational limits and standards on airborne dust concentrations, and the range of metal oxide (fume) dust concentrations found in welding operations, it was his opinion that the maximum likely dust concentration in the breathing zone of a worker without a respirator would be about 30 mg m^{-3} for exposures lasting many hours per day and about 300 mg m^{-3} for exposures lasting only 5 or 10 minutes or less.

Implications for Time-weighted Average Dust Loads

In establishing dust loads to be used for claimant-favorable inhalation calculations, it is important to bear in mind that the periods of exposure of greatest interest were during the 1950s and 1960s, when current industrial hygiene standards would not have been applicable and dust levels would have typically been higher than at the present day. Also, the data presented by Van Pelt are for welding operations that might typically have generated a sub-micron fume. As noted above such fumes create much greater obscuration of visibility than aerosols of larger particle diameter. Although these data are indicative of the high concentrations that can occur, they should not be regarded as definitive, or generally applicable.

Overall, it seems reasonable to conclude with Van Pelt that 30 mg m^{-3} is a reasonably claimant-favorable value for continuous exposure during an entire working day. It is consistent with the mean values listed for the breathing zone and other or general air listed in the above table. Although an argument could be made for using the mean plus sigma value of 47 or 124 mg m^{-3} (average 85 mg m^{-3}), it has to be kept in mind that the data reported are spot samples, so that when multiple samples were taken at a particular location some convergence towards the mean would occur. Full convergence would not be expected, as there would be different long-term average concentrations at the different locations studied. Also, there is a need to avoid double counting of short-term incidents involving high concentrations. As these are addressed separately below, it seems appropriate to consider them to be imposed on a long-term mean generally characteristic of industrial conditions.

In respect of short-term enhanced concentrations, 500 mg m^{-3} seems an appropriate maximum sustainable dust load. However, short-term loads are not necessarily sustainable. In carefully adjusted experimental conditions, loads in excess of 10,000 mg m^{-3} can be maintained on spatial scales of a few meters, i.e. large enough to make visibility measurements. Welding fume data include values of up to 850 mg m^{-3} in unventilated conditions.

It seems appropriate to consider two situations. These are repetitive jobs in which high dust or fume concentrations arise repeatedly. Based on the maximum sustainable dust load and the welding observations, a concentration of around 500 mg m^{-3} seems appropriate in this context. It is possible to envisage such a concentration being achieved for 10% of the time, e.g. for 1 minute in a job with 5 minute repetition rate undertaken for 50% of the working day. If this was the case, the time-weighted average concentration would be $0.9\times30 + 0.1\times500 = 77$ mg m^{-3}. If the fraction of the day was taken from 0.05 to 0.2 and the dust load was taken from 300 to 1000 mg m^{-3}, the range in time-weighted average concentrations would be from $0.95\times30 + 0.05\times300 = 43.5$ mg m^{-3} to $0.8\times30 + 0.2\times1000 = 224$ mg m^{-3}.

In the second situation, isolated incidents could occur, with much higher dust loads, possibly 2,000 to 10,000 mg m^{-3}. Individuals would not be expected to work regularly in such conditions, so they would not be associated with repetitious jobs. If such incidents occurred once per working week (48 hours or 2880 minutes) for repetitive jobs, they would contribute $(1/288)\times(2{,}000 \text{ to } 10{,}000) = 6.94$ to 34.7 mg m^{-3} to the time-weighted average.

On the basis of the above, a reasonable value for a claimant favorable time-weighted average would be in the range 50 to 260 mg m^{-3}. In order to avoid implications of undue precision, a rounded value of 100 mg m^{-3} might reasonably be used.

Reference

Van Pelt, W R, Maximum Likely Dust Cloud, Memorandum to J Mauro, SC&A, 30 January 2005.