ORAU Team **Dose Reconstruction Project for NIOSH** 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	Document Number: ORAUT-TKBS-0033 Effective Date: 02/22/2005 Revision No.: 00 Controlled Copy No.: ______ Page 1 of 22
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RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
Draft	12/22/2004	00-A	New Technical Basis Document: Basis for the Development of an Exposure Matrix for Chapman Valve Manufacturing, Orchard, Massachusetts. Initiated by Patricia L. Lee.
Draft	12/28/2004	00-B	Incorporates internal review comments. Initiated by Patricia L. Lee.
Draft	02/06/2005	00-C	Incorporates OCAS comments. Also addresses new information. Extends assumes operational period from 12/31/1948 to 4/30/1949, which impacts the assigned intakes, and the 1949 external doses. Modifies external dose table slightly. Notes the possibility of radiological work for Oak Ridge prior to 1948. Initiated by Patricia L. Lee.
Draft	02/11/2005	00-D	Adds reference for 1952 newspaper article. Modifies wording regarding assumed intake dates and penetrating radiation energy assumption. Initiated by Cindy W. Bloom.
02/22/2005	02/22/2005	00	First approved issue. Initiated by Patricia L. Lee

ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
cm	centimeter
cpm	counts per minute
dpm	disintegrations per minute (also d/m)
ft	foot
FUSRAP	Formerly Utilized Sites Remedial Action Program
GA	general area
GSD	geometric standard deviation
hr	hour
ICRP	International Commission on Radiological Protection
in.	inch
IREP	Interactive RadioEpidemiological Program
keV	kilovolt-electron, 1,000 electron volts
L	liter
m	meter
mCi	millicurie
mg	milligram
mR	milliroentgen
mrad	millirad
mrem	millirem
NYDO	New York Department of Operations
NYOO	New York Operations Office
PA	posterior-anterior
pCi	picocuries
R	roentgen
s	second
uR	microroentgen
U.S.C.	United States Code
y	year
µg	microgram
µm	micrometer

1.0 INTRODUCTION

Technical Basis Documents and Site Profile Documents are general working documents that provide guidance concerning the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist the National Institute for Occupational Safety and Health (NIOSH) in the completion of the individual work required for each dose reconstruction.

In this document, the word “facility” is used as a general term for an area, building or group of buildings that served a specific purpose at a site. It does not necessarily connote an “atomic weapons employer facility” or a “Department of Energy facility” as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [42 U.S.C. Sections 7384l (5) and (12)].

This document provides an exposure matrix for workers at the facility listed as Chapman Valve Manufacturing in Indian Orchard, MA. Chapman Valve was a manufacturer of non-radioactive valves and manifolds, some of which were purchased by the federal government. In 1948, Chapman Valve machined uranium rods for Brookhaven National Laboratory. In 1959, Chapman Valve was purchased by the Crane Company.

2.0 SITE DESCRIPTION AND OPERATIONAL HISTORY

The information that follows supports an assumed period of AEC operations at Chapman Valve from January 1, 1948, through April 30, 1949, involving AEC-contracted uranium work. This analysis assumed that the residual contamination period extended from May 1, 1949, through December 31, 1993. Exposures during the decontamination period in 1994 and 1995 are not addressed.

A 1952 newspaper article (Springfield News c. 1952) stated that a small group of Chapman employees might have been involved in work with radioactive materials for Oak Ridge prior to 1948. At this time, no data have been found to substantiate or refute this statement. Additional information are being sought, and the site profile will be updated, if necessary, to address an earlier exposure period. Many reports indicate that Chapman was involved in the manufacture of nonradioactive equipment and parts for the Manhattan Engineer District.

The Chapman Valve radiological source term consisted primarily of natural uranium metal, uranium oxides, and natural uranium’s short-lived progeny. Long-lived progeny in the uranium series prevent significant ingrowth past ^{234}U in the ^{238}U decay series and beyond ^{231}Th in the ^{235}U decay series.

2.1 SITE DESCRIPTION

The Chapman Valve main office and works were located on Hampshire Street in Indian Orchard, MA. Uranium shipments were made to Oak Street and claims refer to [uranium] operations in the building on Pine Vale Street, which this document assumes to be Building 23.

A former Chapman employee recalls that in 1947, Chapman set aside approximately one-third of Department No. 40 at the Chapman site for the machining of uranium rods for Brookhaven Laboratory (Fiore 1987, Attachment). It is not clear that the Department No. 40 designation would be an indicator of whether or not someone worked in the restricted area of Building 23. The “set aside” portion of the building measured approximately 200 ft long by 60 ft wide and greater than 50 ft high. The area was separated from the remainder of the building by a floor-to-ceiling wooden partition, which has since been removed. Although there is no definitive statement regarding where the restricted area was in the building, based on later radiological surveys, it is likely that it was located in the western portion of the building. The building that contained the uranium operations has been vacant since Crane discontinued all manufacturing at Indian Orchard early in 1987.

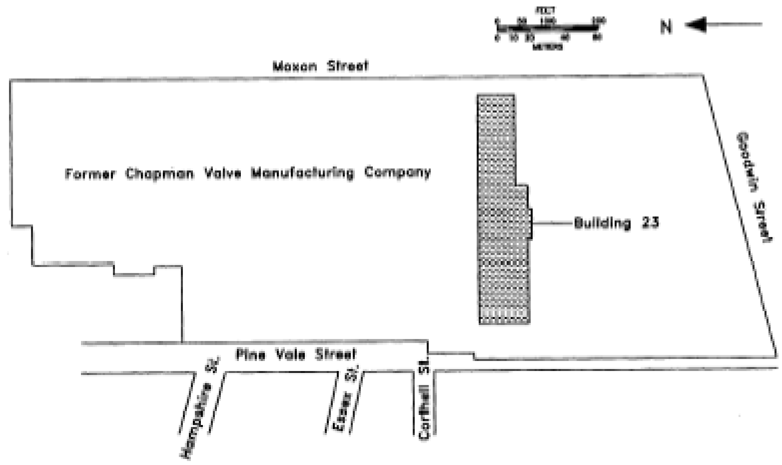

Figure 1. Chapman Valve Manufacturing Company (Ref.).

2.2 SOURCE TERM AND PROCESS DESCRIPTION

Under contract with Brookhaven National Laboratory (BNL), Chapman Valve machined uranium metal during the period January to November 1948 (Young 1987). Preparation for this effort may have begun in November 1947 with the initiation of health and safety programs (Wolf 1947). An inventory report indicated that Chapman Valve had less than 50 pounds of uranium as of January 1948 (Morgan 1948). Actual production may not have started until May 1948, but a set of contamination measurements from March 19, 1948, indicates start-up activities may have occurred prior to May 1948 (LeVine 1948). Records indicate that machining operations ceased in November of 1948 and it is assumed that all identified uranium materials and scrap were sent off site before January 1, 1949 (Fiore 1987).

The AEC Medical Director from the New York office (Wolf 1947) stated: “On November 24 [1947], a conference was held with Chapman Valve and Ferguson personnel as a result of which a complete set of health and safety recommendations were made a few days later in writing. Chapman is planning to undertake work involving the machining of uranium.”

Twenty-six tons of uranium rods were sent on January 9, 1948 to the Chapman Valve Oak Street facility (Fiore 1987). There is a single report (LeVine 1948) of 3 radioactive dust samples dated March 19, 1948, but production-scale (versus trial run) machining may not have started until May 1948, as indicated in an attachment to the Fiore (1987) letter. In January 1948, Wolf (1948b) begins “A survey of proposed uranium machining operation…” indicating that the facility was not machining large quantities of uranium. In May 1948, Wolf (1948e) also states that “Health and safety preparations at the Chapman Valve plant in Indian Orchard, Mass. for the proposed machining operation were investigated by the Radiation Survey and Safety Sections” indicating the facility had not begun machining as of May 6, 1948.

An inventory form (Morgan 1948, 1949) indicates that the beginning inventory in January 1948 was about 48 [pounds] of “SF Material” (source and fissionable material, assumed to be uranium). From January to July 1948, documentation indicated that about 141,200 pounds of SF material were received and about 42,600 pounds in the form of slugs and turnings were shipped off site. Because that same inventory form was attached to Morgan's (1949) letter, it was unclear regarding whether another shipment of SF was made. Uranium rods were brought to the facility by railroad on a track immediately adjacent to the building. Rods were cut by mechanical saw and then machined to the desired shape.

It was noted by the Crane Company (Young 1987, Enclosure 1) that "One AEC memorandum, William to Kelly, date illegible, indicates that Chapman Valve may also have conducted rolling operations on uranium metal." A review of available references (the William's memorandum was not available) and claimant provided information does not indicate that Chapman Valve ever rolled uranium rods.

In July 1992, ORNL (1992) states:

> *After contract work was completed, Chapman Valve had in their possession over 27,000 pounds of metal scrap, oxides, and sweepings. Termination of these operations is indicated in a Chapman Valve letter dated November 8, 1948, which requested termination of AEC film badge services. All radioactive residues and contaminated materials were surveyed by Brookhaven Medical Group and shipped off-site. The actual shipment date is unknown, but the shipment probably took place in December 1948.*

This off-site shipment date appears to be based on a Crane Company letter, which noted that there was correspondence that indicated that all radioactive residues and contaminated material were shipped off-site in December 1948. Another note indicates that the 27,000 pounds of metal scrap, oxides, sweepings, etc. were shipped offsite several months after the contract was complete. Morgan (1949) is unclear regarding whether another shipment of SF [source and fissionable material] would be made after January 25. An enclosure to Fiore (1987) and ORNL (1992) state that Chapman Valve had in their possession over 27,000 pounds of metal scrap, oxides, sweeping, etc., for several months beyond completion of the contract. Both documents refer to a Chapman Valve letter dated November 8, 1948 that requested termination of AEC film badge services and indicated that all radioactive residues were surveyed by Brookhaven Medical Group and shipped off-site in December 1948. About 28,000 pounds of metal from Chapman are mentioned in the Electro Metallurgical (1949) weekly production report dated April 1 through April 30, 1949, indicating that the final shipment would have been no later than April 30, 1949.

It was noted that 100 film badges were needed for the film badge program (Musgrave 1948). The film badge records show that workers were employed by Chapman Valve, H. K. Ferguson or Brookhaven National Laboratories. The film badge records indicate that at least for one week in May, two shifts may have been involved in the AEC work (AEC 1948c). The available bioassay records include 37 names. Job categories noted in the bioassay records included supervisory personnel (electrician, heat treater, steamfitting and plumbing, machine shop and maintenance, inspector, guard, personnel), engineer, guards, inspectors, trades (electrician, machine repair, master mechanic, milling machine operator, steamfitter and turret lathe operator), helpers (janitor, weigher, not specified), and several assistants to the director of research. The external dose data sheets also lists jobs such as brushing and packer. A quick review of claim information indicates that job titles listed in the claims may not always be consistent with the job titles held in 1948.

Area access controls were in place at Chapman Valve, but these controls are not clearly associated with job categories, but were an issue of both security and contamination control. A May 26, 1948, hand-written, two-page, "Plant Protection" list might indicate the number of hours in a week that workers were in the AEC work area (AEC1948c, pp.155-157 of 179). The reported number of hours ranged from none to 58, with the majority of entries at less than 40 hours. Eleven entries were greater than 40 hours. Similar lists including dates from May 3, 1948, through the week of May 19, indicate that these lists show the number of times and the number of hours a [film] badge was worn.

This document assumes that workers might have been exposed to uranium for up to 8 hours per day, 250 days per year, although it appears likely that uranium work was not in full swing until May 1948 and essentially was over in November 1948.

2.3 SAFETY

An affidavit from a former Chapman Valve employee describes some of the radiological safety controls (Ungerland 1987, Attachment 1). Workers would remove their clothes and don white coveralls prior to entering the uranium manufacturing area. Workers wore dosimeters on their uniforms. Inspectors would pass through the site carrying Geiger counters. At the completion of a day's work, the employees would return to the dressing room and remove their white coveralls. Each employee was then required to take a shower as a safety measure. The floors were swept every night. Cuttings from the machining process were stored in drums and disposed of periodically by Brookhaven.

Eisenbud (1948) indicated that employees could use the lunchroom for snacks or smoking provided the hands and face were thoroughly washed and clean laboratory coats and shoe covers were worn over protective clothing. His requirement that the lunchroom be surveyed and decontaminated, if contamination was detected, implies the expectation that these procedures may not eliminate the spread of contamination of the lunchroom and locker room. Records of surface contamination surveys in these areas have not been located. Uranium air concentration measurements indicate elevated activity in the lunch and wash rooms.

2.3.1 **Air Concentrations**

During World War II, permissible levels for uranium dust in air were set at 500 $\mu g/m^3$ for insoluble uranium compounds and 150 $\mu g/m^3$ for soluble uranium compounds. After the war, the University of Rochester lowered their recommendation for soluble uranium compounds to 50 $\mu g/m^3$ based on the chemical toxicity, which for natural uranium is equivalent to 70 dpm/m^3. This level was based primarily on animal studies. The Medical Division of the AEC New York Operations Office (NYOO) felt that a "maximum permissible level" was unknown and should be based on human data. Therefore, the 50 $\mu g/m^3$ level was referred to as the "preferred level" (AEC 1949c).

Very few records of uranium air concentration measurements taken during AEC operations were found for Chapman Valve. Results include data sets from May 4, 1948 and May 24, 1948.

2.3.2 **Contamination/Radiation**

Available documentation of radioactive contamination during the operational period was limited to 3 wipe samples, one of which could not be evaluated, from March 19, 1948. The results were 8 cpm for the cracking furnace and 300 cpm for the "centerless grinder." No measurements of radiation levels for the AEC uranium operational period were located.

2.4 INCIDENTS

Chapman Valve (Fox 1949) notes "A fire occurred in the restricted area of the AEC project and on June 11th [1948] urine for analyses … was sent to the School of Medicine and Dentistry of Rochester New York." Collection of urine samples from the workers who put out the fire and from cleanup personnel suggests that the uranium was involved in the fire. No documentation was found on the exact date of the fire.

A claimant provided a description of an explosion:

> *There was a significant event at Chapman Valve sometime during those two years* [1948-1949]*. It appears that a cupola blew up on the first shift destroying a large portion of the plant with the result being that one worker was killed and several were seriously injured. The plant was closed for some time after this incident. The resultant fire consumed three floors of one section of the building.*

No evidence could be found to support a major fire during AEC uranium operations at Chapman Valve, except as noted for June 1948. However, a newspaper search revealed that an explosion took place when power to an oil transformer was engaged in the early 1940s. Seven workers were injured and a small brick building that housed the electrical equipment collapsed. The newspaper (Springfield Union News 1942) reported 17 hours of lost production time and that:

> *pouring operations in the iron and steel foundries which turn out giant valves for the navy* [sic] *continued without interruption throughout the night, Duggan said, so that a backlog of work would be on hand for the resumption of finishing operation in the machine shop.*

2.5 PHYSICAL EXAMINATIONS – X-RAYS

No information regarding AEC-required physical examinations for Chapman Valve employees has been located.

2.6 SUMMARY OPERATIONAL PERIOD ASSUMPTIONS, WORKDAYS, WORK HOURS, WORK CATEGORIES

Because bioassay data and film badge data were used to estimate internal and external exposures during the AEC uranium operations an estimate of workdays or work-hours per year is not important.

For later years, it was assumed that workers worked 8 hours per day for 50 weeks per year, for a total of 2000 hours per year.

While different tasks resulted in differences in exposures, it is evident from the records that workers did not always perform the same tasks. Exposure assignments are based on data that are suggestive of workers' exposures and further modified by uncertainty parameters, when appropriate, to ensure that the reconstructed dose distributions capture the larger exposures. No attempt has been made to sort workers into exposure categories. Depending on the organ of interest and the ancillary data associated with a specific claim, additional considerations might be appropriate.

2.7 CLEANUP/RESIDUAL CONTAMINATION PERIOD

Crane discontinued plant operations in June 1986 and was in the process of closing down the plant for sale as of August 1987 (Young 1987). ORNL (1992, 1995) reports stated, "the building that contained the uranium operations has been vacant since Crane discontinued all manufacturing at Indian Orchard in 1987. However information in the claim files (numbers redacted) indicates that the building was not closed until February 22, 1991 or later. This document assumes that residual exposures occurred from May 1, 1949 through December 31, 1993. Site decontamination took place in 1994 and 1995. This period of exposure is not addressed in this document.

No documentation has been found indicating the radiological condition of the site when operations ceased and what cleanup efforts may have occurred. Ungerland (1987) indicates that records that might have contained information related to radiological conditions were destroyed during the 1970s. However, elevated levels of contamination were found in surveys performed in the early 1990s (ORNL 1992) under the Formerly Utilized Site Remedial Action Program (FUSRAP).

3.0 ESTIMATION OF INTERNAL EXPOSURE

The primary source of internal radiation exposure at Chapman Valve was uranium dust produced from the manipulation and oxidation of the metals during machining and related processes. It is assumed that the uranium was of natural enrichment. Recycled uranium did not enter process streams until 1952, so no recycled uranium would have been processed at Chapman.

3.1 URANIUM

Human and animal studies have indicated that oxides of uranium can be very insoluble (ICRP 1995), indicating absorption type S (0.1% and 99.9% with clearance half-times on the order of 10 minutes and 7000 days, respectively). Other *in vitro* dissolution studies of compounds found at uranium facilities have shown that oxides of uranium exhibit moderate solubility (Eidson 1994; Heffernan et al. 2001) suggesting absorption type M (10% and 90% with clearance half-times on the order of 10 minutes and 140 days, respectively). *In vitro* dissolution tests on oxides produced from uranium metal during depleted uranium armor penetrator tests have indicated multicomponent dissolution rates, with 25% of uranium dissolving with a half-time of less than or equal to 0.14 days and 75% dissolving with a half-time of 180 days. Because there was no specific information on the solubility of aerosols produced during operations, this analysis assumed that both types M and S were available. The selection of absorption type should depend on the organ of interest.

3.1.1 Uranium Bioassay

Individual uranium urinalysis data are available for some workers at Chapman Valve. Results less than 0.01 mg/L were reported as zero. A note on a sheet of uranium results (Author unknown, 1948) states, "the uranium content of those samples listed as containing less than 0.01 mg U/l is below the limit for reliable determination by the photofluorometric method." The urinalyses range from <0.01 to 0.08 mg/L. For unmonitored workers or unmonitored periods, this Technical Basis Document analyzes the bioassay results to provide estimates of coworkers' uranium intakes.

The first available bioassay samples for Chapman Valve were dated June 11, 1948 and were collected because of a fire involving uranium. Two workers who put out the fire had results of <0.01 mg/L. The five workers, who were involved in cleanup, had results ranging from 0.01 mg/L to 0.08 mg/L. The actual date of the fire is unknown and only two of the workers had later results.

Bioassay results were also available for samples collected on July 26-27, September 8-9 and October 7 of 1948 from 22, 6 and 5 workers, respectively. The median and 84th percentile were estimated for each set. The daily uranium excretion in urine was calculated by multiplying the results in mg/L by the specific activity of natural uranium (682.96 pCi/mg) and by reference man's daily urine output (1.4 L/day) (ICRP 23). Table 1 shows the bioassay results used in the intake analyses. The Table 1 bioassay values were used to estimate median and 84th percentile inhalation intake regimes based on an acute exposure in June 1948 and a chronic exposure from January 1, 1948 to April 30, 1948. When intakes are estimated from bioassay data, the mode of intake is usually assumed to be inhalation, unless there is information that indicates that other modes of intake are more likely. When using bioassay data, the inhalation intake model assumes that some of the intake behaves as ingested material. In general, intakes from bioassay will be larger when an inhalation rather than an ingestion intake is assumed.

Table 1. Bioassay results from coworker data. .

Bioassay Date	Median Bioassay (pCi/day)	84th Bioassay (pCi/day)
6/11/1948[a]	16.7	54.6
7/27/948 [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 and GSD were calculated.
b. The 22 results were log-transformed and fit to a line, from which a geometric mean and GSD were calculated.
c. Five of the six results were reported as 0.01 mg/L and one was reported as <0.01 mg/l. The geometric mean and the 84th percentile were assumed to be 0.01 mg/L.
d. Two of the five results were reported as 0.01 mg/L and three were reported as <0.01 mg/l. The geometric mean and the 84th percentile were assumed to be 0.01 mg/L.

Although the date of the 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. The coworker data fit the assumed intake regimes better, when it was assumed that the intake from the fire and the clean-up occurred closer to the date of the bioassay. The bioassay data support both the chronic and acute intake regimes for all the scenarios used to fit the data, only when the acute intake from the fire is assumed to occur during the period June 7 to June 10, 1948, inclusive. Assuming the intake from the fire occurred on June 10, 1948 resulted in the largest total intake when choosing from dates of June 7 through June 10, 1948. The intake from the fire might have occurred over several days, but it was assumed to be an acute intake when fitting the data to simplify assumptions. The intakes were calculated with IMBA Expert™ OCAS-Edition, Version 3.2.20, assuming an absolute uniform error of 1 and a normal error distribution. To calculate the level of chronic intake for workers, who might not have been exposed to the fire, the June 11, 1948 bioassay results were excluded. The geometric standard deviations (GSDs) were calculated by dividing the intake from the 84th regime by the intake from median regime. Table 2 shows the inhalation intakes from the analyses of the Chapman uranium urinalysis data.

Table 2. Inhalation intakes based on coworker data. .

Scenario[a]	Absorption type	Chronic intake 1/1/1948 to 4/30/1949 (pCi/ calendar day)	Acute intake[a] (pCi) 6/10/1948	Total intake during AEC work (pCi)	GSD (intake)
U machining and fire	M	1.50 E+2	3.69E+2	7.29E+4	1.14
U machining and fire	S	4.45 E+3	1.28E+4	2.17E+6	1.13
U machining	M	1.50 E+2	-	7.29 E+4	1.14
U machining	S	4.48 E+3	-	2.17 E+6	1.14

a. The acute intakes are associated with GSDs of about 5.

To estimate the total uncertainty in organ dose, the GSD for each intake regimes is combined with the assumed GSD of 3 for the metabolic model. These estimated GSDs are listed in Table 3.

3.1.2 Uranium Air Sampling

The AEC provided air sampling analyses for samples collected on May 4 and 24, 1948 at Chapman Valve (AEC 1948 a, b). The results from May 4 are measurements of the effluent from the furnace outlet on the roof and are not appropriate for determining workers' doses (its unlikely that any worker spent significant time 4 ft from a rooftop furnace outlet). The results from May 24, 1948 are 10-minute grab samples listed as "Inspection Bench, Packing Bench, Work Bench, Wash Room and Lunch Room". Because it is not clear how these samples relate to the workers' activities, they are not directly used in determining worker intakes. However, an inhalation intake can be calculated by assuming that the maximum result reported, 29.1 dpm alpha/m^3 measured at the workbench, was the concentration for the entire work year. Based on reported beta film badge results, it is likely that uranium workload increased during the months of June through September 1948, which would likely increase air concentrations.

The breathing rate of 1.2 m^3/hr is based on the default for light work shown in ICRP Publication 66 (ICRP 1994, Table 6, p. 23). An intake, in pCi, was calculated by dividing the maximum reported workplace air concentration by 2.22 dpm/pCi and multiplying this result by the annual breathing rate and the 2000 hours per work year and by 1.33 years. The result is an inhalation intake of 4.18 E+4 pCi. Intakes from resuspended material and ingested material might increase this number by about 10% based on similar calculations in other site profile documents. In addition, it would be reasonable to assume a factor of 2 to 4 increase in time-weighted air concentrations during the months of June through September, because of the change in workload throughout the year, which is apparent from the film badge results. Because there are more bioassay than air sample results and the bioassay results are spread throughout the work year and are likely to be a better indicator of worker exposures especially during the production period, the air sample data are not used to calculate intakes at Chapman Valve.

3.2 OCCUPATIONAL INTERNAL DOSE RECONSTRUCTION ASSUMPTIONS AND SUMMARY

The uranium photofluorimetry urinalysis reporting limit at Chapman Valve was 0.010 mg/L. Uranium oxides may be either absorption type M or S.

The assumed operational exposure period ran from January 1, 1948, to April 30, 1949, which this analysis assumes to be the uranium intake period. A uranium fire is assumed to have occurred sometime between June 1 and June 11, 1948. 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.

For **unmonitored workers or unmonitored periods**, Table 3 lists inhalation intake assumptions for natural uranium. Chronic intakes are given in units of pCi/d and acute intakes are given in pCi. Four different intake scenarios are listed. The first and second scenarios account for exposure to the uranium fire in June. The third and fourth scenarios can be used when an individual had no exposure to the fire, or these last scenarios can be used to supplement intakes for workers whose bioassays are only associated with the fire. The dose distribution is assumed to be lognormal. Geometric standard deviations (GSDs) are listed in the table.

Table 3. Inhalation intake summary for operational period.

Scenarios[a]	Start	End	Intake type	Absorption type	Intake (pCi/day or pCi)	GSD
Fire plus workplace	1/1/1948	4/30/1949	Chronic	M	1.50E+2	3.02
exposure	6/10/1948		Acute	M	3.69E+2	3.02
Fire plus workplace	1/4/1948	4/30/1949	Chronic	S	4.45E+3	3.02
exposure	6/10/1948		Acute	S	1.29E+4	3.02
Workplace exposure	1/4/1948	4/30/1949	Chronic	M	1.50E+2	3.02
Workplace exposure	1/4/1948	4/30/1949	Chronic	S	4.48E+3	3.02

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. The choice also depends on the organ of interest.

4.0 ESTIMATION OF EXTERNAL EXPOSURE

Individual external dosimetry results for Chapman Valve are reported for the weeks beginning May 3, 1948 to November 1, 1948 (AEC 1948c). Exposures reported for the weeks beginning, October 11, 18 and 25 are questionable, because one set of data indicates that no results were reported and another set indicates that results were all less than 50 mR. This apparent discrepancy may be due to the practice of expediting data entry by marking multiple results that were "less than" with an x. When a whole page of results were "less than", the entire result section appears to have been marked with a large x. Lines marked with the word "None", indicate a badge was not worn. Reporting of numerical results on an x-marked page, indicates positive results and these should be included in the record.

Because film badge data are available for Chapman Valve workers, this document does not attempt to address worker external exposures based on workplace data. When film badge results are available for a worker, the individual's dosimeter results can be used to estimate dose. This technical basis document also provides an upper estimate of external dose based on film badge dosimetry records. When coworker film badge data are tabulated and assessed, these may be used to estimate more realistic doses for unmonitored workers or unmonitored periods.

The majority of photons from natural uranium metals are in the 30 to 250 keV energy range. Solid uranium objects provide considerable shielding of the lower energy photons and harden the spectrum, causing the majority of photons emitted from a solid uranium object, such as a billet or a rod, to have energies greater than 250 keV. While it is recognized that solid uranium sources will have a hardened photon spectrum, exposure to a thin layer of uranium on a surface will result in a larger fraction of exposure to lower energy photons. This analysis assumed workers were exposed to photon energies in the 30 to 250 keV range, which is claimant favorable. Nonpenetrating dose from natural uranium consists primarily of electrons with energies >15 keV. For consistent presentation, exposure or dose is reported as:

- Penetrating, assumed to be associated with photons of energies 30 keV or greater, and
- nonpenetrating assumed to be associated with photons of energies less than 30 keV or with electrons.

4.1 SUMMARY OF AVAILABLE FILM BADGE DATA

Chapman Valve (Musgrave 1948) reported the following ancillary information regarding film badge availability and use at Chapman:

- February 2, 1948: received 50 (brass) badges from the University of Rochester.
- February 9, 1948: received duplicate shipment (with identical numbers) noted to be the pin-type.
- April 28, 1948: requested 100 badges and subsequently received 100 stainless steel snap-on badges from University of Rochester.
- May 10, 1948: returned the 50 used brass pin-type dosimeters and 50 used stainless steel snap-on badges to University of Rochester.
- May 18, 1948: received 100 stainless steel snap-on badges and noted that Chapman Valve would like to continue with this badge type.
- May 19, 1948: sent 50 brass pin-type and 50 stainless steel snap-on badges to AEC in NY per AEC request.

Less than 50 film badge results are included in each reporting period, most likely indicating that only some of the workers entered the AEC work area in a given week (AEC 1948c). A note at the bottom of some of the May reports states "Eastman Film," but does not mention the type of film. Exposure for both beta and gamma was reported in "mr" in 1948. The reporting limit was 50 mR (though at least one report mistakenly lists the reporting limit as "0.50 mr") for both beta and gamma. Some reports include names and some do not. Some external dosimetry report copies contain illegible entries. As of this writing, it has not been determined if a complete data set for a worker can be determined from the multiple copies of dosimetry reports. An entry of "None" is included on some reports, and this seems to indicate that the badge was not worn during the monitoring period. The hand-written response to the question, "where were badges kept overnight?" was "no," which probably indicates that workers left their badges onsite at the end of the workday. There is no indication of where the badges were stored or that a control badge was used.

Because it may not be possible to associate results with individuals because of the poor copies or the censored identifiers, the data have been reviewed to identify the maximum results for each week. The median beta result for May (115 mR) and the reporting limit specified on the Chapman Valve reports for gamma (50mR) were used to estimate the exposure for other weeks when film badges were not in use or for weeks when the data were suspect, e.g., three weeks in October 1948. Exposures during unmonitored weeks were likely to be lower, because records indicate that the majority of processing occurred between May and November. Some of the results for the weeks of May 17 and 24, 1948 were combined in some of the original records. No attempt was made to unfold the combined results, instead the maximum reported results the May 17 and 24, 1948, and the May 24, 1948 report were assumed respectively to be the maximum results for the week of May 17 and the week of May 24. For the weeks May 10 to September 27, 1948, inclusive, the gamma reporting limit (0.050 R) was used to estimate the maximum exposure when it was reported as <0.050 R. For the weeks May 31 to June 14, 1948, inclusive, the maximum result for the three weeks was assumed for each of these weeks, because of the uncertainty in determining which result applied to which week. When the period of the exposure is less than that included in Table 4, the exposure should not necessarily be reduced by the ratio of the actual to the total exposure period. Because recorded maximum external exposures were larger during the weeks beginning May 10 through October 4, 1948, this needs to be taken into account when estimating doses for shorter exposure periods.

Table 4. Maximum film badge results [a]

Week Beginning	Non-penetrating R	Penetrating R	Week Beginning	Non-penetrating R	Penetrating R
1/5/1948	*0.115*	*0.050*	**7/5/1948**	0.225	*0.050*
1/12/1948	*0.115*	*0.050*	**7/12/1948**	0.240	*0.050*
1/19/1948	*0.115*	*0.050*	**7/19/1948**	0.260	*0.050*
1/26/1948	*0.115*	*0.050*	**7/26/1948**	0.320	*0.050*
2/2/1948	*0.115*	*0.050*	**8/2/1948**	0.240	0.085
2/9/1948	*0.115*	*0.050*	**8/9/1948**	0.360	0.110
2/16/1948	*0.115*	*0.050*	**8/16/1948**	0.260	0.085
2/23/1948	*0.115*	*0.050*	**8/23/1948**	0.260	*0.050*
3/1/1948	*0.115*	*0.050*	**8/30/1948**	0.260	*0.050*
3/8/1948	*0.115*	*0.050*	**9/6/1948**	0.440	0.070
3/15/1948	*0.115*	*0.050*	**9/13/1948**	0.500	0.075
3/22/1948	*0.115*	*0.050*	**9/20/1948**	0.650	*0.050*
3/29/1948	*0.115*	*0.050*	**9/27/1948**	0.320	*0.050*
4/5/1948	*0.115*	*0.050*	**10/4/1948**	0.160	0.055
4/12/1948	*0.115*	*0.050*	**10/11/1948**	*0.115*	*0.050*
4/19/1948	*0.115*	*0.050*	**10/18/1948**	*0.115*	*0.050*
4/26/1948	*0.115*	*0.050*	**10/25/1948**	*0.115*	*0.050*
5/3/1948	0.065	0.070	**11/1/1948**	0.085	0.070
5/10/1948	0.100	*0.050*	**11/8/1948**	*0.115*	*0.050*
5/17/1948	0.115	*0.050*	**11/15/1948**	*0.115*	*0.050*
5/24/1948	0.140	*0.050*	**11/22/1948**	*0.115*	*0.050*
5/31/1948	*0.165*	*0.050*	**11/29/1948**	*0.115*	*0.050*
6/7/1948	*0.165*	*0.050*	**12/6/1948**	*0.115*	*0.050*
6/14/1948	*0.165*	*0.050*	**12/13/1948**	*0.115*	*0.050*
6/21/1948	0.130	0.060	**12/20/1948**	*0.115*	*0.050*
6/28/1948	0.265	*0.050*	**12/27/1948**	*0.115*	*0.050*
			Totals	**9.110**	**2.830**

Ia. Numbers in italics are assumed. The bases for the assumptions are presented in the text above.

An additional period of external exposure is assumed from January 3, 1949 through May 1, 1949. The median weekly beta result for May 1948 (0.115 R) and the gamma reporting limit of 0.050 mrem were used to estimate exposure during this period. The results are shown in Table 5.

4.2 OCCUPATIONALLY REQUIRED MEDICAL X-RAY

Information regarding whether or not occupationally required medical x-ray examinations were performed at Chapman Valve is unavailable. AEC usually, but not always, required “preemployment” and periodic medical examinations of workers involved in the larger uranium processing programs. The term “preemployment” as used here, means prior to performing AEC-contracted radiological work. The typical AEC medical program included a preliminary and annual chest x-ray examination. This analysis assumes that workers received a preemployment x-ray examination of the chest in 1947 and a second x-ray examination a year later. The type of x-ray examination should be based on current ORAU Team guidance for 1948 exposures. Organ doses can be obtained from the current revision of ORAUT-OTIB-0006, *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures* (ORAUT 2003).

4.3 MISCELLANEOUS INFORMATION RELATED TO EXTERNAL DOSE

This section includes external dose information that might be of interest for specific dose reconstructions. This analysis did not consider such information generically because of its limited applicability or because of limited information.

A fire involving uranium occurred sometime between June 1, 1948 and June 11, 1948. The fire and subsequent cleanup activities may have increased the likelihood of uranium skin contamination on some workers. Film badges were worn by Chapman Valve workers during this period, but it has not yet been verified that the workers who fought the fire and were involved in cleanup were externally monitored.

4.4 OCCUPATIONAL EXTERNAL DOSE RECONSTRUCTION ASSUMPTIONS AND SUMMARY

Individual film badge results are available to determine doses. The reporting limit for beta and gamma was 50 mR. Table 5 provides overestimating assumptions that can be used to estimate doses for some Chapman Valve claims. Prorating of the exposure to a shorter period should be based on the information in Table 4.

Table 5. External exposure summary for 1948.

Exposure Category	Exposure type	Exposure or dose rate	Basis	Year	Annual exposure	IREP distribution
Overestimate of external dose	Penetrating	-	Maximum film badge results	1948 1949	2.830 R 0.850 R	Constant
	Non-penetrating	-	Maximum film badge results	1948 1949	9.110 R 1.955 R	Constant
Medical X-ray	Current ORAU team guidance for 1948	Initial plus one exam per year		1947 1948	See ORAUT-OTIB-0006, (ORAUT 2003)	

5.0 <u>ESTIMATION OF RESIDUAL EXPOSURE</u>

The residual dose period is assumed to begin on May 1, 1949, the day after the month that Electro Metallurgical (1949) noted processing of Chapman Valve material and scraps, and is assumed to continue through December 31, 1993. The radiation exposures during cleanup operations in 1994 and 1995 are not assessed in this document.

In 1987, Department 40 and its perimeter were surveyed with a Victoreen model 492 ionization chamber, and no elevated radiation levels were detected (Sedelow 1987). The detection threshold of a Victoreen 492 is likely to be about 0.1 mR/h.

ORNL (1992) conducted a survey in August 1992 under the FUSRAP program. The reported radiation levels at various locations in the facility are summarized in Table 6. Elevated radiation and contamination levels were found in the western portion of Building 23. The survey of Chapman Valve included:

- a gamma and beta/gamma scan of the floor and walls and gamma scan of the ground surface in selected outdoor areas.
- Measurement of surface and 1-m exposure rates at the center of the north and south section of main-bay survey blocks

- Measurement of alpha activity levels at selected locations
- Analysis of 30 dust and debris samples (26 from overhead beams)
- Direct and removable alpha and beta/gamma measurements at 31 locations.
- Analysis of 2 soil samples.

Table 6. Radiation/radioactivity levels in August 1991.[a]

Measurement Type	Range	MDA
Gamma exposure (µR/hr)	5-32	-
Direct beta/gamma (mrad/hr)	0.02-4	0.01
Direct alpha (dpm/100 cm^2)	<MDA -2900	25
Removable beta/gamma (dpm/100 cm^2)	all <200	200
Removable alpha (dpm/100 cm^2)	14-90	10
Soil Concentrations (pCi/g)[b]	0.33-1.9	-
Dust Samples (pCi/g)[b]	0.2-36,000	-

a. ORNL (1992)
b. Includes ^{226}Ra, ^{232}Th, and ^{238}U

All results, except from the smears, were reported as gross results, i.e., background values were not subtracted from the results. ORNL (1992) included brief information regarding their survey methods and instrumentation.

A sodium iodide scintillation probe and rate meter were used to detect gamma. Rates measured at 2 inches from a surface were converted to uR/h. The method to measure the exposures at 1 meter, which are included in the report, was not explicitly stated. Gamma levels ranged from 4 to 32 uR/h. The highest average reading for a grid block was 13 uR/h. It is assumed that these measurements were made at one meter from the floor. To estimate the penetrating dose it was assumed that the largest average result, 13 uR/hr, was the median; and the largest result, 32 uR/hr, was at the 95th percentile. An associated GSD of 1.72 was calculated. The annual penetrating dose estimate is listed in Table 7.

A pancake GM probe measured count rates and these were converted to mrad/h of beta/gamma. The MDA was reported as 0.01 mrad/hr. A pancake GM probe is an unusual choice for making dose measurements, because of both its geometry and energy sensitivities. It is also sensitive to alpha radiation, which might have resulted in an over response if a cover or some distance from a surface were not maintained to eliminate the alpha response. ORNL (1992, Figure 7) reported a range of dose rates for each grid block surveyed. The maximum dose rates in the range were used to determine a geometric mean, which was assumed to equal a median non-penetrating dose rate, 0.12 mrad/h. The GSD was calculated to be 2.9. The annual nonpenetrating dose is listed in Table 7.

A zinc sulphide scintillation detector and rate meter were used to detect alpha count rates. The count rates were converted to dpm/100 cm^2. The MDA was reported as 25 dpm/100cm^2. The largest of 30 direct contamination measurements was reported as 2900 dpm/100cm^2. To calculate internal exposure from residual activity this analysis assumed that the median uranium exposure was associated with uniform contamination of the buildings to a level of 2,900 dpm/100 cm^2, the maximum directly measured alpha contamination. Six of 23 dust samples taken from the overhead beams and crane exceeded this value and ranged from 3500 dpm to 12,000 dpm/100 cm^2. Using a resuspension factor of 1×10^{-6}/m (NRC 2002) and an air intake rate of 2,400 m^3 per work year, the calculated uranium annual inhalation intake was 314 pCi. Using the method described in NIOSH 2004, the calculated annual ingestion intake was 6.53 pCi. GSDs of 3 are assumed. Table 7 summarizes residual period intake rates.

Samples of dust and debris, and soil were analyzed for Ra-226, Th-232 and U-238. Chapman Valve received essentially pure uranium metal (no radium) for processing. This is confirmed by the ORNL 1992 survey, which reported Ra-226 and Th-232 concentrations as consistent with background. The two soil samples were also consistent with background radioactivity concentrations. ORNL analyzed dust samples M10 and M31 for U-235. M-31 was reported as 2.16% enriched. The Chapman Valve uranium processing was related to reactor needs, and the use of enriched uranium in reactors was rare until 1950. The only other mention of Chapman Valve and enriched uranium was in ORNL 1997, which reiterated ORNL's 1992 words. Unlike the ORNL 1992 report, ORNL 1997 included the actual U-235 and U-238 results for seven soil samples. The activity ratios seem consistent with natural uranium.

The estimated annual external exposures to residual radioactivity from AEC operations at the site, listed in Table 7, were calculated by assuming that workers were exposed for 2,000 hours per year. Assumptions regarding residual exposures should be consistent with assumptions from the operational period.

Table 7. Annual internal and external exposure to residual radioactivity.

Internal	**Start**	**End**	**Exposure**	**Absorption type**	**Intake (pCi/d)**	**IREP distribution**
Uranium	5/1/1949	12/31/1993	Inhalation	M, S	8.58E-01	Lognormal GSD 3
	5/1/1949	12/31/1993	Ingestion	(a)	1.79E-02	Lognormal GSD 3
External	**Start**	**End**	**Exposure**	**Basis**	**R/y**	
	5/1/1949	12/31/1949	Penetrating	Survey Instrument	8.55E-3	Lognormal GSD 1.72
	1/1/1950	12/31/1993	Penetrating	Survey Instrument	2.60E-2	Lognormal GSD 1.72
	5/1/1949	12/31/1949	Non-Penetrating	Survey Instrument	7.75E-2	Lognormal GSD 2.9
	1/1/1950	12/31/1993	Non-Penetrating	Survey Instrument	2.36E-1	Lognormal GSD 2.9

a. Choose same f_1-value as used for inhalation per NIOSH (2004).

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