ORAU Team **Dose Reconstruction Project for NIOSH** Technical Basis Document for the Y-12 National Security Complex – Site Description	Document Number: ORAUT-TKBS-0014-2 Effective Date: 10/11/2005 Revision No.: 01 PC-1 Controlled Copy No.:_____ Page 1 of 33
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ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
Ci	Curie
CEDE	Committed Effective Dose Equivalent
COLEX	Column exchange
CY	Calendar Year
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DU	Depleted Uranium
ELEX	Electrical exchange
EU	Enriched Uranium
HEU	Highly Enriched Uranium
IAEA	International Atomic Energy Agency
ICPP	Idaho Chemical Processing Plant
ICRP	International Commission on Radiological Protection
keV	kiloelectron volt
kg	kilogram
LLW	Low Level Waste
mCi	millicurie
MED	Manhattan Engineering District
MeV	megaelectron volt
mg	milligram
NPDES	National Pollutant Discharge Elimination System
NU	Natural Uranium
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
ORR	Oak Ridge Reservation
RWP	Radiological Work Permit
RCRA	Resource Conservation and Recovery Act
RU	Recycled Uranium
SM	Source Material
SNM	Special Nuclear Material
SRS	Savannah River Site
TEC	Tennessee Eastman Corporation
TRU	Transuranic

UNH	Uranyl nitrate hexahydrate
U.S.C.	United States Code
WETF	West End Treatment Facility

2.1 INTRODUCTION

The Y-12 Plant (currently, the Y-12 National Security Complex) is located at the eastern section of the Oak Ridge Reservation in Oak Ridge, Tennessee. The plant occupies approximately 811 acres (0.67 mile wide and 3.2 miles long) and consists of approximately 531 buildings that cover more than 7.5 million square feet of space. Construction of Y-12 was initiated in late 1942 and completed in 1943 as part of the Manhattan Engineering District (MED).

The specific mission of Y-12 was to separate fissionable isotopes of uranium (^{235}U) for use in atomic weapons. Of the four wartime Manhattan Project plants, Y-12 was one of the most urgently needed because it was thought to be the fastest and surest of the gambles in its race with Germany to build an atomic bomb. At its peak, Y-12 employed approximately 22,000 workers. Today, Y-12 is focused on support of US Nuclear Defense Policies.

The information in this part is based on reports and other sources of information that are not classified. In some cases, classified documents have been redacted to allow their release as unclassified information. We are fully aware that more information is available that may be of use in reconstructing worker doses. However, due to classification restrictions, such information can not be included in this document.

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 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. § 7384l (5) and (12)). EEOICPA defines a DOE facility as “any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the Department of Energy (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program).” 42 U.S.C. § 7384*l*(12). Accordingly, except for the exclusion for the Naval Nuclear Propulsion Program noted above, any facility that performs or performed DOE operations of any nature whatsoever is a DOE facility encompassed by EEOICPA.

For DOE employees with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled “Exposure in the Performance of Duty.” That provision (42 U.S.C. § 7384n(b)) says that an individual with cancer “shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the [probability of causation] guidelines established under subsection (c) ….” 42 U.S.C. § 7384n(b). Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation) define “performance of duty” for DOE employees with a covered cancer or restrict the “duty” to nuclear weapons work.

As noted above, the statute includes a definition of a DOE facility that excludes "buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program." 42 U.S.C. § 7384*l*(12). While this definition contains an exclusion with respect to the Naval Nuclear Propulsion Program, the section of EEOICPA that deals with the compensation decision for covered employees with cancer (i.e., 42 U.S.C. § 7384n(b), entitled "Exposure in the Performance of Duty") does not contain such an exclusion. Therefore, the statute requires NIOSH to include all radiation exposures in its dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external dosimetry results are considered valid for use in dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction.

The First Era – 1942 to 1947
Mission: Uranium Isotope Separation
The Y-12 Plant, conceived in 1942 by the MED of the U.S. Army Corps of Engineers (USACE), was constructed by Stone and Webster Construction Company at a cost of about $427 million. Prior to completion, the operating contractor, the Tennessee Eastman Company (TEC) of Kingsport, TN, moved its people in to start operations. The first building to begin operations was the Calutron pilot plant/training building (9731) in the fall of 1943.

Despite technical problems, this first of a kind electromagnetic isotope separation (Calutron) plant, succeeded in its mission. In a little over two years, the uranium fuel was separated for the Hiroshima nuclear weapon. The gaseous diffusion process at the K-25 Site was the Manhattan Project's backup for enriching uranium. Since this process was workable and much less costly, Y-12 was shutdown in December 1946 and employment was cut drastically.

The Second Era – 1947 – 1992
Mission: Manufacturing Nuclear Weapons Components During the Cold War
The Y-12 Plant eventually became one of twelve production facilities with a unique role. Its new mission was to produce the key components of nuclear weapons and test devices needed for the expanding nuclear weapons stockpile, and for the safekeeping of our nation's highly enriched uranium (HEU) stockpile. Many supporting tasks were given to Y-12, notably the production of the enriched lithium urgently needed for the thermonuclear program in the 1950's and 1960's. Y-12 succeeded in carrying out these challenging missions in developing state-of-the-art technologies demanded by new weapons designs over a period of almost 50 years.

The Third Era – 1992 to present
Multiple New Missions
The Nation's stockpile of nuclear weapons was reduced by 90% during this time. The number of operational buildings was reduced and Y-12's manufacturing technology was transferred to industry, where allowed. Ongoing missions include:

- Storing HEU for the Department of Energy (DOE)
- Disassembling weapons/components to study aging and other effects
- Producing a small number of nuclear weapons parts and assemblies
- Decontaminating and decommissioning of unused buildings
- Conducting major efforts in environmental and waste management.

By the end of 1992, fifty research and development agreements were negotiated between Y-12 and governmental and commercial entities. Informally termed "Work for Others," challenging problems were successfully solved for other Federal Agencies.

2.2 OPERATING CONTRACTORS

The TEC was the original Y-12 contractor under agreement with the USACE. On January 1, 1947, in accordance with the Atomic Energy Act of 1946, all atomic energy activities including Y-12 were turned over to the United States Atomic Energy Commission (U.S. AEC). During the same year, the MED was disbanded and TEC was replaced by Carbide and Carbon Chemicals Corporation as the Y-12 site contractor. The name "Y-12," a code name for the plant during the Manhattan Project, has been in use since that time. The following is a list of the site prime contractors throughout Y-12's history.

Operating Contractor	Period
Tennessee Eastman Corporation	1943 to 1947
Carbide and Carbon Chemicals Corporation	1947 to 1950
Carbide and Carbon Chemicals, Division of Union Carbide and Carbon Corporation	1951 to 1956
Union Carbide Nuclear Company, Division of Union Carbide and Chemicals Corporation	1957 to 1963
Union Carbide Corporation, Nuclear Division	1963 to 1984
Martin Marietta Energy Systems, Incorporated	1984 to 1994
Lockheed Martin Energy Systems	1994 to 1998
BWXT Y-12, L.L.C.	1998 to present

2.3 SITE ACTIVITIES

From inception, Y-12 was specifically designed to enrich uranium via an electromagnetic separation process. The actual device used for enrichment, the Calutron (from California University Cyclotron), used a massive magnetic field to separate isotopes of uranium based on slight differences in mass. Two stages of separation and enrichment were required. The first and larger stage, designated Alpha, produced slightly enriched feed material for the second stage, known as the Beta Stage. The Alpha and Beta chemical operations were required to produce feed material for the calutrons, to recover valuable waste and by-products, and to produce the final material for use in an atomic weapon.

The early operations at Y-12 were narrowly focused. The primary hazards at the facility were uranium-bearing chemicals including, but not limited to:

- Uranium oxide (U_3O_8)
- Uranium dioxide (UO_2),
- Uranium trioxide (UO_3),
- Uranium hexafluoride (UF_6),
- Ammonium diuranate [$(NH_4)_2U_2O_7$],
- Uranyl nitrate [$UO_2(NO_3)_2$],
- Uranium peroxide ($UO_4 \cdot 2H_2O$),
- Uranium tetrachloride (UCl_4),
- Uranium pentachloride (UCl_5), and
- Uranium tetrafluoride (UF_4)

In addition, bulk quantities of industrial chemicals, e.g. carbon tetrachloride (CCl_4), hydrogen peroxide (H_2O_2), dibutyl carbitol ($C_{12}H_{26}O_3$), nitric acid (HNO_3), and hydrochloric acid (HCl), were used or produced at the plant. Because Y-12 was basically a heavy industry site, many other common

industrial materials, such as, asbestos, solvents, acids, alkalis, and oils, were used and available for potential worker exposure.

Electromagnetic operations at Y-12 continued for a number of years after 1947. However, these activities were chiefly directed toward research on new radionuclides for medical or other uses.

Over the following years, Y-12 became a highly sophisticated nuclear weapons component manufacturing facility and development engineering organization. The plant receives, stores, and protects uranium and lithium materials and parts; dismantles nuclear weapons components; and serves as a government repository for enriched uranium (EU). In addition, Y-12 has many treatment, storage, and disposal facilities for hazardous and radioactive materials. Today, the primary mission of Y-12 consists of dismantling nuclear weapons components, storing nuclear material, pursuing new technologies, and serving as the Department of Energy's (DOE) primary repository for HEU. Table 2.3-1 shows the radionuclides of concern at Y-12. Some building numbers and their corresponding radionuclides are not available at this time.

Table 2.3-1. Radionuclides of concern

Radionuclide	Type of emission	Radioactive half life (y)	Building number	Solubility class
^{99}Tc	Beta	2.13×10^{5}		
^{228}Th	Alpha	1.91	9201-1, 9201-5, 9202, 9204-4, 9206, 9215, 9766	
^{230}Th	Alpha	7.54×10^{4}	9215, 9720-5	100% S
^{232}Th	Alpha	1.45×10^{10}	9201-5, 9207-5, 9215, 9998	100% S
^{234}U	Alpha	2.47×10^{5}	N/A[(a)]	S,M,F
^{235}U	Alpha, some gamma	7.4×10^{8}	N/A	S,M,F
^{236}U	Alpha	2.34×10^{7}	N/A	S,M,F
^{238}U	Alpha	4.47×10^{9}	N/A	S,M,F
^{237}Np	Alpha	2.14×10^{6}	9201-5, 9202, 9215, 9720-5	100% S
^{238}Pu	Alpha	86.4	9201-5, 9720-5	100% S
^{239}Pu	Alpha	2.4×10^{4}	N/A	
^{241}Am	Alpha	4.32×10^{2}	9212	100% S

2.4 SITE PROCESSES

Over the years, the mission of Y-12 has evolved from uranium isotope separation to a multitude of new missions. Manufacturers conduct their own research using unique machinery available at Y-12 as well as expertise throughout the Oak Ridge Complex. In addition, Y-12 provides landlord services for DOE as well as other types of management, such as the Transportation and Safeguards Division, and the Oak Ridge National Laboratory. Other responsibilities include environmental restoration and waste management; putting facilities into a safe, legally compliant condition for shutdown; and providing protection of government property. Tables 2.4-1 and 2.4-2 summarize Y-12 processes and operations from the very beginning to the present.

Table 2.4-1. Process chronology of operations

Building	1943-1948	1949-1951	1952-1963	1964-1995	1996-2003
9201-1	Tracks 1 and 2, α - I calutrons (uranium enrichment)	Uranium enrichment operations	Uranium salvage operations	Fusion energy research operations	General manufacturing for tooling, including work for others. Almost all clean work.

9201-2	Tracks 3 and 4, α - I calutrons (uranium enrichment)	Uranium enrichment operations	COLEX Lithium/Hg enrichment operations	Development/research operations	ORNL
9201-3	Track 5, α - I calutrons	Uranium enrichment operations	Uranium salvage operations	Fusion energy research operations	Currently used for office space.
9201-4	Tracks 6 and 7, α - II calutrons (uranium enrichment)	Uranium enrichment operations	COLEX Lithium/Hg enrichment operations	Engineering and administrative facilities	Awaiting D&D
9201-5	Tracks 8 and 9, α - II calutrons (uranium enrichment)	Uranium enrichment operations	COLEX Lithium/Hg enrichment operations	Normal/depleted uranium press, rolling, and machining operations	Normal/depleted uranium press, rolling, and machining operations
9202	α and chemical preparation/recover y operations	Uranium product recovery operations	Uranium process development & improvement operations	Uranium process development & improvement operations	Technology Development
9203	^{235}U analysis and initial uranium product processing	Uranium product recovery operations	Recovery and salvage operations	Y-12 production development and research operations	Technology Development
9204-1	Tracks 1 and 2, ß - calutrons (uranium enrichment)	Uranium enrichment operations	Stable isotope separation operations	Fusion energy research operations	ORNL facility, however BJC occupies office space
9204-2	Tracks 3 and 4, ß calutrons (uranium enrichment)	Uranium enrichment operations	Uranium assembly operations	Uranium assembly operations	Uranium assembly operations
9204-3	Tracks 5 and 6, ß calutrons (uranium enrichment)	Uranium enrichment operations	Stable isotope (*e.g.*, copper) separation operations	Stable isotope (*e.g.,* copper) separation operations	ORNL facility
9204-4	Tracks 7 and 8, ß calutrons (uranium enrichment)	Uranium enrichment operations	ELEX Lithium/Hg pilot-scale operations	Normal/depleted uranium press and rolling operations	Depleted uranium press operations and quality evaluations for weapon components storage
9206	ß chemical recycle and product processing	Uranium product recovery/salvage	Uranium chemical processing and metal production operations	Uranium chemical processing and metal production operations	Currently undergoing deactivation. No longer an MAA, D&D scheduled for future.
9207	Uranium salvage operations	Uranium recovery/salvage	Maintenance/salvage operations	ORNL biological research Operations	ORNL facility, mostly vacated.
9211	Uranium salvage operations	Uranium salvage and product recovery operations	Uranium salvage and product recovery operations	ORNL biological research operations	ORNL biological research operations
9212	ß product processing	Uranium conversion/recovery operations	UF_6 conversion, chemical operations, and weapon production operations	Chemical operations and weapons production operations	Chemical operations and weapons production operations
9215	--	--	Enriched uranium machining and metal finishing operations	Enriched uranium machining and metal finishing operations	Enriched uranium machining and metal finishing operations
9998	--	Normal uranium H-1 foundry operations	Depleted uranium H-1 foundry operations	Depleted uranium H-1 foundry operations	Depleted uranium H-1 foundry operations

Table 2.4-2. Key uranium operations

Key uranium operations	Buildings involved	Dates of operation
Electromagnetic Enrichment: Y-12 processed roughly 50,000 kg of UCl_4 in calutrons that were housed in both alpha and beta enrichment buildings. To obtain a desired enrichment, UCl_4 was processed through many calutrons and recycled frequently. Alpha operations enriched up to 20 – 30% ^{235}U. Beta operations were designed to further enrich partially enriched, alpha recycle material up to 95% ^{235}U. Enriched U compounds were recovered and converted to oxide for shipment or recycled for further alpha or beta enrichment. DU was removed from process equipment and disposed of through building vents and storm sewer drains.	**Alpha buildings 9201-1,2,3,4,5** **Beta buildings 9204-1,2,3,4**	1943–1947

Key uranium operations	Buildings involved	Dates of operation
Feed Preparation and Product Processing: Volatile UCl_4 was the chemical form of U fed to alpha and beta electromagnetic enrichment operations. UCl_4 was produced using one of two chemical conversions involving UO_3 and carbon tetrachloride. The first method was liquid phase chlorination in which U and carbon tetrachloride were heated under pressure. The UCl_4 crystals formed were collected and placed in charge bottles which were then loaded into calutrons for U enrichment. A second method was vapor phase chlorination in which carbon tetrachloride was gradually added to UO_3 and heated conditions inside a chemical reactor bowl for roughly eight hours and then purged with nitrogen to exhaust phosgene vapors from the system. From both methods, UCl_4 crystals were collected and loaded in calutrons.	**9202, 9203, 9206, 9212** 9202 and 9203 housed alpha U feed preparations and product recovery operations. They also handled EU, DU and normal U. 9206 was used to recover beta product with higher enrichment levels (>50%). Highly enriched material was converted to UCl4 for further enrichment. 9212 received ~ 4,700 kg of UF_6 with an average ^{235}U content of 30% between 1945-1947.	1943–1947
Uranium Recovery and Recycle: Y-12 stopped enriching U after WWII and operations now centered on U recovery and recycling of residual U found on equipment and scrap material. Operations included mechanical scraping and brushing, nitric acid washing, and distillation and recovery of solid U compounds adhered to surfaces. Uranium contaminated materials included condensates, scrubber solutions, raffinates, destructive distillates, oils, and miscellaneous residues. These facilities handled mostly normal U and DU.	**9202, 9203, 9206, 9212** 9202, 9203 received DU, slightly EU, and normal U. 9206 was the main U recovery and recycle facility and housed sanding, grinding, chemistry and incinerator operations.	1945–1951 1950s–1990s
Uranium Salvage: Salvage operations involved recovery of U from materials not considered production equipment, such as liquid and solid waste materials from maintenance/cleanup activities such as mop water, laundry washes, and floor drain residues. Combustible materials such as wood, rags, sponges, filter paper, and carbon solids were burned in muffle furnaces and incinerators to recover U. Other salvage operations included mechanical scraping and brushing, nitric acid washing, and distillations and recovery of U compounds.	**9206, 9207, 9211** 9206 housed salvage operations and process operations were similar to 9207 and 9211. 9207, 9211 processed incinerated solid waste and recovered normal and slightly EU.	1945–1951
Uranium Preparation/Recycle: Y-12 began a continuous growth of U weapons component manufacturing operations handling a variety of U compounds and enrichment. EU prepared for reduction to metal involved conversion of UF_6 to UF_4 purification of uranyl nitrate solutions, precipitation for U recovery, and then reduction to U metal.	**9202, 9206, 9211, 9212** 9212 housed the largest chemical operations for EU purification, recovery and chemical conversion, as well as normal and DU machining operations.	1952–1995
Uranium Forming/Machining: Y-12 had operations capable of casting, rolling, and machining U metal. These operations handled EU, DU and normal U. Uranium was pressed, rolled, shaped, and machined into finished weapon components.	**9201-5, 9204-4, 9215, 9998** 9201-5, 9204-4 housed DU 9215 housed EU 9998 contained H-1 foundry operations that included DU recycle and parts manufacturing.	1952–1995
Uranium Component Assembly: Machined components were sent through finishing operations that included drilling, welding, brazing, polishing and final specification checks. Bldg. 9202 was primarily used for early pilot scale operations that involved design and implementation of fabrications and assembly processes and final inspection procedures. Assembly operations generally were not associated with significant releases of U compounds. Any measurable amounts of U wee recovered and recycled back into the production stream. U was routinely recovered from articles such as rags, paper towels, oils and liquid waste products. Process exhaust stacks were equipped with HEPA filtrations and periodically inspected for buildup of U.	**9202, 9204-2, 9204-2E** 9204-2, 9204-2E housed uranium assembly operations.	1952–1995

2.4.1 Electromagnetic Enrichment (1943–1947)

Uranium was enriched for use in atomic weapons by processing large amounts of UCl_4 in calutrons. These operations were housed in the Alpha buildings (Buildings 9201-1, 9201-2, 9201-3, 9201-4, and 9201-5) and Beta buildings (Buildings 9204-1, 9204-2, 9204-3, and 9204-4) that contained the first and second stages, respectively, of the enrichment processes.

2.4.2 Feed Preparation for Enrichment Operations (1943–1947)

Feed preparation involved conversion of large quantities of uranium oxides (including UO_2, UO_3, and U_3O_8) into UCl_4 - the feed material for the calutrons. Most operations were done in Buildings 9202, 9203, 9206, and 9212.

2.4.3 Uranium Recovery and Recycle Operations (1944–1951)

An elaborate system of mechanical and chemical processes was used to recover and recycle uranium feed and product material that had ^{235}U content worth recovering. These operations were primarily done in Buildings 9202, 9203, and 9206.

2.4.4 Uranium Salvage Operations (1947–1951)

Salvage operations involved recovering EU from all non-product components or byproduct of the operations. Calutron parts and associated equipment containing small amounts of uranium were cleaned and decontaminated. Some uranium was recovered for future use, while that in wash fluids was discharged to East Fork Poplar Creek. Scraps and materials that could not be decontaminated were buried within the Oak Ridge Reservation (ORR). These operations were primarily done in Buildings 9206, 9207, and 9211.

2.4.5 Uranium Preparations and Recycle for Weapon Component Operations (1949–1995)

Uranium for weapon production was first processed in recovery, purification, and conversion operations. From about 1949 to 1964, Y-12 received cylinders of 93.5% UF_6 as feed material for nuclear weapon parts manufacturing. Once purified and converted to its metallic form, uranium was transferred to metal processing operations for forming and shaping the metal into weapon part configurations. After 1964, the majority of EU processed at Y-12 was recycled from nuclear weapons stockpiles. Uranium recycle and purification processes continued through present day operations. These operations were primarily done in Buildings 9202, 9206, and 9212. Recycled uranium (RU) contains transuranic (TRU) material (e.g. plutonium, neptunium), fission products, (e.g. technetium), and reactor-generated uranium products (e.g. ^{236}U). Thus, the processing and re-enrichment of RU may present an increased potential hazard for occupational and environmental exposure that is greater than that normally associated with the processing of un-irradiated uranium. The RU encompassed a variety of material forms. These included uranyl nitrate solutions (UNH), molten UNH, uranium oxide (UO_2), UO_3, UF_4, uranium metal, uranium alloys, and a variety of associated wastes. Y-12 was involved with highly enriched RU processing operations at five different locations. Until the early 1970's, chemical processing of highly enriched RU occurred in the 9212 complex, and later in Building 9206. The EU product was stored in Building 9720-5. The S-3 ponds served as impoundment for process wastewater until the mid-1980's. After the ponds were closed, the RU process wastewater was treated by a variety of methods at the West End Treatment Facility (WETF).

2.4.6 Uranium Forming and Machining for Weapon Component Operations (1949–1995)

Formed uranium metal parts were machined into finished weapon parts and then transferred to Y-12 assembly operations. Numerous buildings were needed to support these diverse operations and the buildings were frequently modified to meet changes in production needs. These operations were primarily done in Buildings 9201-5, 9204-4, 9215, and 9998. Depleted uranium (DU) operations for the production of weapon components have existed at Y-12 since the early 1950's. DU is a form of uranium consisting of over 99.8% ^{238}U and less than 0.72% ^{235}U by mass. The DU and DU alloy operations typically included melting and casting, forging and rolling into plates, forming or extruding

into shapes, and final heat treating to obtain desired properties. The depleted forms were then machined into the final design specifications for weapons components. Buildings 9998, 9215, 9201-5, and 9204-4 housed the majority of Y-12's DU processing operations. Particle or dust collectors, such as cyclones and bag houses, were used in most of the processes to capture the larger sized particles. Airborne losses from the foundry and other operations were fairly large from 1948 to 1956. When production levels increased, additional filters were installed sometime in 1955. Potentially large uranium losses may have occurred in 1954 and July 1956, because minimal dust was collected or filtered compared to the amount of uranium collected after the new filtering equipment was operating efficiently. The losses during 1956 were estimated from stack monitoring to be about 0.1 kg of DU per day. Continuous monitors were installed on the exhaust stacks in the mid 1950's.

2.4.7 Weapon Component Assembly Operations (1952–1995)

Weapon parts were assembled into finished products, inspected and tested against design criteria, and then shipped off-site. The majority of these operations were housed in Buildings 9204-2 and 9204-2E. Tables 2.4.7-1 and 2.4.7-2 show the key operations over time at Y-12.

2.4.8 Stockpile Stewardship and Maintenance (1996–2003)

DOE is responsible for maintaining the safety and reliability of the Nation's weapons. Y-12 supports DOE in their mission by providing resources to address safety, programmatic and operational considerations. This includes maintaining critical skills and physical assets for weapons production and maintaining critical technology.

2.5 FACILITIES

Building 9731: The first building to become operational was the Calutron pilot plant building, 9731, in the fall of 1943. This building, also known as XAX/XBX, contained two each of the Alpha and Beta calutrons. This facility was also used as a training facility. During the first four months, only 4% of the uranium in the source "charge bottle" actually ended up in the receivers, while the remaining 96% either remained in the source, coated the electrodes, missed the receiver slits, and/or was splattered all over the liner. All side streams were collected in order to recover EU. A major concern was the growing amount of partially EU in recycle streams that needed to be purified and further enriched.

Building 9212 Complex: The 9212 Building Complex includes buildings 9212, 9809, 9812, 9818, 9815, and 9980. More than 100 operations or processes have been performed in this complex. The largest building, 9212, has four wings, A, B, C, and D, and its primary activity was uranium recovery. Originally, this complex recovered HEU from the calutrons. After WW II, the 9212 building was expanded to accommodate the increased production of uranium from the Oak Ridge Gaseous Diffusion Plant (ORGDP) and to provide the capability to recover uranium from waste materials. In 1948, new structures were built between the four wings. In 1951, the E Wing was added to facilitate the casting and machining of uranium components. The UF_6 conversion facility in the D wing was shutdown in 1964, essentially stopping the introduction of new HEU metal in the weapons stockpile.

Building 9212 currently performs four primary functions:

- Casting of HEU metal,
- Accountability of HEU from plant activities,

- Recovery of HEU in a form suitable for storage,

- Serving as the U.S. source of all HEU used in test, research, or propulsion reactors and for isotope production.

Building 9212 also supports the International Atomic Energy Agency (IAEA) in sampling surplus EU, the packaging of HEU for offsite shipment, and producing specialized uranium compounds and metal for research reactor fuel.

Building 9202: Building 9202 became operational late in 1943. This is a bulk treatment facility and was designed to process UO_3 to UO_2 to UCl_5 to UCl_4 – the feed material for the Alpha Calutron sources**.**

Building 9203: Building 9203 became operational in November 1943. In this building, UCl_4 was made from UO_2 for the Alpha Calutron feed (the sources were called “charge bottles”). Other activities included washing Alpha collector pockets to recover the product, developing two different Beta chemical recycle processes (precipitation and electrochemical and later extraction processes), analytical chemistry labs, and mass spectrometry and fission counting labs to determine enrichment levels (assays).

Alpha Buildings and Beta Buildings: Over the course of one year starting in 1943, Y-12 put into operation eight of nine electromagnetic enrichment process buildings, including five first-stage enrichment operations called **alpha** buildings (9201-1, 9201-2, 9201-3, 9201-4, 9201-5) and three second-stage enrichment operations called **beta** buildings (9204-1, 9204-2, 9204-3). A fourth beta building, 9204-4, was operating by November 1945. As part of the war effort, Y-12 processed roughly 50,000 kilograms of UCl_4, in both the Alpha and Beta calutron buildings. The calutrons were arranged in large groups called "racetracks", typically with 96 calutrons per alpha track and 36 calutrons per beta track (1248 calutrons total). Each building typically housed two tracks. To obtain a desired enrichment, UCl_4 was processed through many calutrons and recycled frequently. Alpha operations enriched uranium up to 20-30% ^{235}U. Beta operations further enriched alpha recycle material up to 95% ^{235}U. Enriched uranium compounds were recovered and converted to an oxide form for shipment to Los Alamos, or recycled for further alpha or beta enrichment. The DU was removed from process equipment and disposed of through building vents and storm sewer drains.

Building 9206 Complex: Building 9206, centrally located at Y-12, has been used extensively for the chemical processing of uranium. Related structures that house supporting or process services and/or equipment, are 9768, 9720-17, 9409-17, 9510-2 and 9767-2 and the east and west tank farm pits.

The 9206 facility has carried out several EU processes and activities (times in parentheses):

- Chemical recycle, charge preparation, HEU recovery, and product processing for the electromagnetic process (1945-1946),

- Recovery of EU from programs at Y-12 and many other sites (1947-1994),

- Production of uranium compounds for other sites (1949–1972),

- Conversion of UF_6 to UF_4 to uranium metal for weapons (1954–1964),

- Casting and machining of HEU metal for weapons (1955–1965),

- Recovery of HEU from the Savannah River Site (SRS) solutions and other scrap for return to SRS as uranium metal (1972–1989),

- Conversion of excess HEU metal to oxide feed for the Portsmouth Gaseous Diffusion Plant (1980–1985),

- Storage of in-process materials (1950–present).

The following non-enriched uranium processes and activities at the 9206 facility include (times in parentheses):

- Recycling DU chips (1951-late 1950's),
- Production of uranium compounds for other sites (1949-1972),
- Canning of normal-assay uranium slugs for nuclear reactor use (1950-1952),
- Storage of in-process materials (1950-present).

Building 9720-5: Building 9720-5 is used as a warehouse for short and long term storage of strategic materials. Built in 1944, it has been renovated several times. This building serves as a shipping/receiving facility for Special Nuclear Material (SNM) and the primary storage facility for interim and prolonged low maintenance storage of HEU.

Building 9215: Building 9215 was used to manufacture parts from DU and EU. The uranium was pressed, rolled, shaped, and machined into finished weapon components.

Building 9995: Building 9995 is used as an analytical laboratory to assay nuclear components. The building allowed Y-12 to move into the forefront of the Nuclear Weapons Complex plant in the analytical chemistry field during the years following 1952.

See Table 2.5-1 for the key uranium facilities.

Table 2.5-1. Key uranium facilities

Facility	Facility Description
Building 9201-4, Alpha 4	**Constructed** in 1945 **Mission:** originally used for electromagnetic separation of uranium, later used for lithium isotopes separation. **Square footage:** 562,000 square feet **Status:** Facility is deteriorating, but in good condition, currently shut down, however all major Y-12 plant utilities run through this facility as well as the entire electrical system. **Concerns**: large quantities of mercury and other hazardous materials, such as asbestos, lithium, lithium hydroxide, and mixed wastes.
Building 9201-5, Alpha 5	**Constructed** in 1945 **Mission**: process and manufacture depleted uranium and non uranium materials. Beryllium, lithium, and depleted uranium in various forms are stored in this facility. Combustibles contaminated with enriched uranium are also stored in 9201-5. **Square footage**: 591,500 square feet of space. **Status:** Plans to relocate the arc melting operation to the 9998 H-1 foundry. **Concerns**: EU, DU
Building 9201-5N/5W, Alpha 5N/5W	**Constructed** in 1972 **Mission:** machine depleted uranium **Square footage:** 80,500 square feet **Status**: Work for others **Concern:** Some risk of depleted uranium exposure or uptake to workers
Building 9204-2, Beta 2	**Constructed** in 1954 **Mission:** manufacture non-nuclear components for weapon production, includes salvage and recycle of weapon components made from lithium hydride and lithium deuteride, storage of these and other lithium-based materials for possible reuse. Today's lithium operations are generally industrial types: non-nuclear, non-radiological, chemical, foundry, and metal working processes.

Facility	Facility Description
	Square footage: 270,000 square feet **Status:** Much of the original equipment has been replaced or upgraded by the lithium process replacement project and other projects since the late 1980s with significant improvements in safety, waste minimization, and process control. **Concerns**: EU
Building 9204-2E, Beta 2E	**Constructed** in 1969 **Mission**: (1) processing cleaning, assembling, welding, and preparing nuclear components for shipment; (2) disassembling, storing, and preparing non-nuclear components for shipment; (3) dismantlement, and (4) quality evaluation and component certification. **Square footage:** 151,200 square feet **Status:** Operations resumed in March 1996. **Concerns:** A major hazard is the significant quantities of special nuclear material (SNM). While the risks are relatively low, the workers are exposed to radiological and industrial hazard and to possible nuclear criticality.
Building 9204-4, Beta 4	**Constructed** in 1949 **Mission:** disassembly, testing, and storage of warhead components produced at Y-12. Sections of this facility have become active as part of receipt, storage, and shipping (RSS) operations. **Other activities**: quality evaluation (QE), are being performed under special operation packages. The mission of this facility is being moved to Building 9204-2E. In addition, depleted uranium and non-uranium metals are processed in this facility. Plans are to relocate this activity to Buildings 9212, 9996, and 9998. **Square footage:** 273,000 square feet. **Status**: DU and non-uranium metals are processed in the facility. **Concerns**: presence of significant quantities of SNM and hazardous substances; while the risks are relatively low, workers are exposed to hazardous substances and to possible nuclear criticality.
Building 9206 Related structures: 9768, 9720-17, 9409-17, 9510-2, 9767-2, and east and west tank farm pits	**Constructed** in 1946 **Mission**: It was used to recover enriched uranium from scrap and trash. However, it is in stand-down with limited operations, due to conduct of operations concerns identified by the DNFSB. **Square footage**: 67,294 square feet **Status:** currently undergoing deactivation. **Concerns:** A major hazard is the presence of significant quantities of SNM and hazardous substances. While the risks are relatively low, the workers are exposed to hazardous substances and to possible nuclear criticality.
Building 9212 Complex Related structures: 9212, 9809, 9812, 9818, 9815, 9980	**Constructed** in 1940s **Mission**: It is used for recovery, purification, and processing of enriched uranium into usable products or forms suitable for storage. **Square footage**: 311,325 sq. ft. **Concerns**: The major hazards are nuclear, radiological, and hazardous chemicals present in the facility, and standard industrial hazards. Significant events: 1) the required annual test of the baghouse Halon system did not test all required components; 2) CSA requirements were not strictly enforced; and 3) there was uptake of radiological material by workers. An internal investigation by the contractor resulted in a detailed report that identified the causes of the uptake and the recommendations to prevent a recurrence. The uptake resulted in a committed effective dose equivalent of 5 mrem for all of the attested workers. The Price-Anderson Amendment Act audit conducted in October 1996 focused on this event. **Status:** The facility is in stand-down with limited operations due to conduct of operations concerns.
Building 9215	**Constructed** in 1950 **Mission:** It was used to manufacture parts from depleted and enriched uranium. Portions of this facility have become active as part of RSS operations. The remainder will be reactivated as part of the enriched uranium operations restart. **Square footage**: 157,000 square feet **Status:** EU machining and metal finishing operations. **Concerns:** The major hazard is the presence of significant quantities of enriched and depleted uranium.
Building 9720-5	**Constructed** in 1944 **Mission:** It is used for storing enriched uranium weapons parts, assemblies, and other SNM for Y-12. **Square footage**: 53,949 square feet **Status:** Storage facility **Concerns:** The major hazard is a significant quantity of SNM.
Building 9995	**Constructed** in 1952 **Mission:** It is an analytical laboratory used, among other tasks, to assay nuclear components. This facility is maintained as a continuing operation. **Square footage:** 84,000 square feet **Status:** Plant laboratory, analysis of waste **Concerns**: hazardous and mixed waste
Building 9202	**Constructed** in 1942 **Mission:** It is used as a bulk treatment facility and was designed to produce feed material used in the Alpha Calutron sources. **Square footage:** 128,800 square feet **Status:** Technology development **Concerns:** U processed materials
Building 9731	**Constructed** in 1943

Facility	Facility Description
	Mission: It is the Calutron Pilot Plant Building and was also used for training of supervisors. **Square footage:** 37,300 square feet **Status:** Standby mode **Concerns:** The amount of partially EU in recycle streams that needed to be purified and further enriched.
Building 9203	**Constructed** in 1942 **Mission:** Calutron feed production, washing alpha collector pockets to recover the product, developing beta chemical recycle processes, analytical chemistry labs, and mass spectrometry and fission counting labs to determine enrichment levels. **Square footage:** 30,800 square feet **Status:** Technology development **Concerns:** RU

2.6 WASTE TREATMENT AND DISPOSAL OPERATIONS

The S-3 Ponds: Between 1951 and 1984, four seepage pits known as the S-3 ponds were used to dispose of over 2,700,000 gallons of a variety of liquid wastes including concentrated acids, caustic solutions, mop waters, and byproducts from the uranium recovery processes, including uranium and other heavy metals. These unlined pits, referred to at one time as a "witch's cauldron," were designed to allow liquid either to evaporate or percolate into the ground. Various metal impurities and radionuclides stripped from HEU during the solvent extraction steps in Buildings 9212 and 9206 [approximately 10% to 30% of RU, plutonium, neptunium, and technetium] were discharged with the dilute nitric acid and other process-derived acid wastewater to the S-3 ponds prior to the mid 1980's.

The S-3 Ponds served as an impoundment for process wastewater until the mid-1980's. The four earthen basins comprising the S-3 ponds had no direct discharge to any local creek or river tributary. After the ponds were closed, RU process wastewater was treated by a variety of methods at the West End Treatment Facility (WETF). New Hope Pond (see below) served as a surface water impoundment that captured entrained solids from rainwater and secondary wastewaters.

Clean-up and closure of the ponds began in 1984. The site has been covered with gravel and clay, paved, lined, and it is now used as a parking lot. Sludge removed from the sediments of the ponds is stored in above-ground tanks. The S-3 ponds were finally closed in 1989 in accordance with the Resource Conservation and Recovery Act (RCRA) act. Prior to capping the ponds, sludge samples were taken from each pond to ascertain the airborne (internal) exposure potential for workers placing the cap materials. Based on the first evaluation, no special precautions were needed for this work, other than the normal requirements for handling DU. However, the second evaluation included the effects from thorium and strontium and concluded the material should be treated as a mixture of 45 wt. % ^{230}Th and ^{228}Th.

West End Treatment Facility, Building 9616-7: Beginning in the mid-1980's, after closure of the S-3 ponds, the WETF was constructed for treating mixed low level waste (LLW) and LLW- contaminated wastewater generated by Y-12 production and other DOE Oak Ridge Reservation (ORR) processes. Nitrate wastewater contaminated with EU was mixed with much larger quantities of wastewater contaminated with DU. The EU component was diluted to less than normal assay uranium. Wastewaters are discharged into East Fork Poplar Creek, under the National Pollutant Discharge Elimination System (NPDES) permit.

In 1997, sludge from the WETF was analyzed for radionuclides. Elevated levels of ^{228}Th, ^{230}Th, and ^{237}Np were found. Sampling is now conducted on an ongoing basis. Both the tanks as well as incoming tankers are sampled periodically.

New Hope Pond: New Hope Pond was constructed and placed in operation in the 1950's to provide a retention basin on East Fork Poplar Creek at the east end of Y-12. The pond facilitated mixing of

water and offered a sampling point for rainwater runoff, once-through cooling water, steam plant boiler blow-down, and secondary production process wastewaters. The pond also functioned to remove any suspended contamination from rainwater, miscellaneous releases from various tank farms and storage yards, and inadvertent releases from process buildings.

In 1973, New Hope Pond was dredged, and the resultant sludge was transferred to a basin located on Chestnut Ridge. In 1983, samples were taken to determine if the sediment that had accumulated in the pond was hazardous. It was concluded that the data from the leach test showed no hazardous material per the RCRA definition.

2.7 CRITICALITY ACCIDENT

On June 16, 1958, there was an accidental, prompt–critical neutron chain reaction that occurred in a solution system at Y-12. The accident occurred in the C-1 Wing of the 9212 building, in a 55-gallon stainless steel drum. The cause of the accident was a super-critical quantity of highly enriched uranyl nitrate solution being accumulated in the drum due to a leaky valve.

The accident occurred in a process phase that was a temporary arrangement encompassing portions of a new and an old installation. Both installations were necessary to maintain production during an interim phase of remodeling a process. This temporary arrangement split the responsibility for the operation among three different supervisors in three physically separated areas. This contributed to the cause of the accident by complicating communications and control. The incident occurred while they were draining material thought to be water from a safe geometry, 5-inch storage pipes, into an unsafe geometrical drum.

Eight employees were in the vicinity of the drum. Based on their reported proximity to the drum and on the activation of the indium foil strip in their badges, these eight employees received the highest radiation doses of any who may have been exposed. One of the eight employees was within three to six feet of the drum. The other seven employees were from 15 to 50 feet away. Special, post hoc methods were used to determine the neutron and gamma exposures of the employees involved.

As employees left the plant for the day, their badges were collected and taken to the secondary control center to obtain activity readings on the indium foil. A list was compiled of the 31 employees with potentially significant neutron doses. These employees were routed through the medical test routine.

During this incident 1.3×10^{18} fissions occurred. (*See* TID-5360, Suppl. 2, p. 25; *USAEC Serious Accidents* Issue #136, 8-25-59; *USAEC Health and Safety Information Issue* # 82, 9-5-58; 1959 *Nuclear Safety,* Vol. 1, #2, p. 59.)

2.8 RADIONUCLIDES AND RADIATION SOURCES

The three main exposure fields at Y-12 are from process and other radioactive materials, radiation generating equipment (x-rays and accelerators), and criticality or nuclear accidents. The most common process materials are EU (^{235}U) and DU (^{238}U). Both radionuclides are primarily alpha emitters. Most of the external dose from DU results from ^{234}Th and ^{234}Pa daughter products. The assumption is that all uranium activity is due to ^{234}U.

2.8.1 Uranium

Uranium is a naturally occurring radioactive element that is used for nuclear reactor fuel and in nuclear weapon components. The two principal natural isotopes are ^{235}U (0.7%) and ^{238}U (99.3%). Natural U also includes a trace amount of daughter ^{234}U by mass (0.0057%). The ^{234}U activity is more significant as the ^{235}U enrichment increases. When hit by thermal neutrons, uranium can achieve nuclear fission, in which the ^{235}U isotope splits into fragments and releases energy. The DU contains less than 0.7% ^{235}U and has an isotopic distribution by mass of 0.001% ^{234}U, 0.199% ^{235}U, and 99.8% ^{238}U. The EU contains more than the natural concentration of ^{235}U, typically in the range of 0.99% to 99% by mass. A common isotopic distribution by mass is 1% ^{234}U, 93% ^{235}U, and 6% ^{238}U.

The first known records for EU below 20 %^{235}U are dated in calendar year (CY) 1947. At that time, the product had been produced by the electromagnetic process at Y-12. Subsequent to CY 1947, the below 20% ^{235}U product was produced by the diffusion plants.

2.8.2 Recycled Uranium

The RU is defined as any uranium that has been irradiated in a reactor. As a result, RU contains TRU material, fission products and reactor generated uranium products. The primary buildings and facilities that handled RU were: 9212, 9206, WETF and S-3 ponds. In addition, RU is stored 9720-5.

2.8.3 X-Ray and Electron Generating Equipment

The x-ray or electron generating equipment used at Y-12 includes linear electron beams, electron beam welders, scanning electron microscopes, x-ray photoelectron spectrometers, secondary ion mass spectrometers, enclosed beam diffraction equipment, and medical diagnostic x-ray equipment. The emitted energy range is from 15 keV to 9 MeV.

2.8.4 Radionuclide and Neutron Sources

The most common radionuclide source facilities are segmented gamma scanners containing ^{169}Yb (emits 63.1 keV gamma ray), a ^{60}Co (1.33 and 1.17 MeV gamma rays) well source used for calibration of radiation monitoring equipment, and ^{252}Cf spontaneous fission (average energy 2 MeV) neutron sources used for non-destructive testing and material inventories.

Three gamma-ray sources, 4.55 mg ^{226}Ra, 23.0 mg ^{226}Ra, and 250 mCi ^{60}Co, are used in the calibration of personnel meters and low range radiation instruments. A nine-Ci ^{60}Co source is used in the calibration of high range survey meters. A large gamma source, 15 Ci ^{60}Co, is used in the Radiographic Laboratory. The types of sources and location are in Table 2.8.4-1.

Table 2.8.4-1. Known sealed radiation sources

Sources	Building
Ra-Be, Po-Be	9203
Ra, Co, Ta, Po-Be	9983
Po-Be, ^{226}Ra	9737, 9201-2, 9204-3
^{226}Ra	9212
^{226}Ra, Co	9212
^{226}Ra	9206,9706-2

2.8.5 Special Nuclear Material

There is a wide variety of special nuclear material (SNM), source material (SM), and other nuclear materials accounted for at Y-12. The various materials include EU above 20% of ^{235}U, EU below 20% of ^{235}U, DU, normal uranium, thorium, enriched lithium (40%, 60% and 95% ^{6}Li), ^{2}H, plutonium, and ^{233}U.

Since the weapons material flow was initiated, pure metal has been shipped and received as 100% uranium. The SNM metal generated in the early days of weapons production at Y-12 was not as pure as that produced subsequently. The primary impurity was carbon.

2.8.6 Transuranics

The primary sources of transuranic materials (TRU) [$^{238-240}Pu$ and ^{237}Np] were RU from the Savannah River Site (SRS) and the Idaho Chemical Processing Plant (ICPP). The Rocky Flats Plant (RFP) returned HEU parts that had potential TRU contamination, and special development projects. Y-12 proactively evaluated RU receipts from its inception against a specification that would maintain uranium as the dominating dose hazard. Dose estimates did not indicate a significant TRU problem. Compared to the current regulatory monitoring criteria, it would not warrant the initiation of special bioassay sampling beyond that needed for uranium. Recent workplace sampling confirms that the historical specification ensured that uranium was the dominating radiological hazard, even against current regulatory requirements. The exception was waste streams as evidenced by sludge samples from the WETF. The other radionuclides present were: ^{99}Tc, ^{237}Np, $^{238-240}Pu$, and ^{241}Am.

2.8.7 Thorium

The first record of thorium at Y-12 was in January 1947. At that time, the inventory was used in research and development studies primarily by Oak Ridge National Laboratory (ORNL) personnel at Y-12. It was not until FY 1952 that the thorium activity increased significantly. Shipments and receipts were primarily between Y-12 and ORNL.

Processing of thorium at Y-12 began in the early 1960's. The thorium metal in pellet form was pressed into electrodes and two arc meltings were made. The metal from these melts was pressed and/or rolled, formed, and machined. Metal scraps and chips were salvaged and also pressed into electrodes to be used in the arc-melting process.

The following activities by facility occurred as part of the process:

- Pellet/scrap preparation, arc melting, crop and trim machining, and sawing occurred in 9205-1,
- Mold press sintering, ingot forging, canning and annealing after first cold roll, and final inspection/assembly were preformed in 9204-4,
- Ingots were canned prior to first cold roll in 9201-1,
- Cold rolling was conducted in 9215,
- Decanning, cleaning, and final plating was conducted in 9206,
- Decanning and machining activities were conducted in 9766,

- Development activities were performed in 9202.

Sludge samples were taken from the S-3 ponds prior to capping to determine whether there was any airborne (internal) exposure potential for workers placing the cap materials. No special precautions were needed for this work, other than the normal requirements for handling DU. However, there was a dramatic increase in the exposure potential of ^{228}Th and ^{230}Th that contributed to 90% of the internal exposure potential.

2.8.8 Lithium

Significant quantities of lithium material were machined and crushed to fine dust. Some unmeasured quantity ended up in the ventilation system, in mop water, in cleanup solutions, and in non homogeneous salvage awaiting recovery.

Impurities that are present in the lithium metal react with deuterium. In many cases, the reaction productions distill out the lithium deuteride at the reaction temperatures and condense wherever the vessel is cooler (lid and upper 2 or 3 inches of the reactor). This represents a loss of deuterium which is not accounted for.

2.9 SOLUBILITY AND INSOLUBILITY

Y-12 has mainly processed uranium in the form of UO_2 and uranium metal. Chemical conversions from UNH to both UO_2 and uranium metal are performed as well. Although the solubility class for uranium metal is not addressed by the guidance documents, experience at uranium process facilities has shown that uranium metal generally behaves as a Class M compound. However, the possibility of slow oxidation of a significant portion of the surface of the metal to UO_2 and/or U_3O_8 over time must be considered.

Y-12 has defined a Class Q material as a mixture of 90% Class W and 10% Class Y. The Class Q represents the circumstance when there is only a thin layer of UO_2 on the surface of uranium metal. It may also provide a reasonable representation of the solubility half-time that has been observed for UO_2 that has not been “high-fired” (approximately 120–140 days) than would the assumed half-time for Class W (50 days). However, the use of the International Commission on Radiological Protection (ICRP, 1994), Publication 66 lung model would overcome the need for the contrived compound Class Q since Type M assumes 90% of the material has a half-time of 140 days. Under the ICRP Publication 66 (1994) lung model, only uranium that is “high-fired” UO_2 or the product of slow oxidation of uranium metal should be classified as Type S.

Y-12 uses three default solubility assumptions for workers who participate exclusively in the urine bioassay program (see Section 5 for more detail):

- 100% Type S
- 75% Type S/25% Type M
- 50% Type S/50% Type M

These defaults are designed to be conservative and provide adequate protection for workers while, at the same time, being representative of the actual exposure material. The defaults are determined by the Radiological Work Permit (RWP) bioassay indicator code, the last character of the RWP identifier. When working with soluble materials such as uranyl nitrate, the solubility may be defaulted to 100% Type M or 100% Type F, depending on the material. However, to be conservative, persons working exclusively with soluble uranium are defaulted to 50% Type M/ 50% Type S. If an individual uses

RWPs that indicate the work is with insoluble uranium materials, such as uranium oxide, then the solubility should be determined by dose calculation software. If the RWP indicates work with uranium has both a soluble and insoluble component, then the solubility will be defaulted to 25% Type M/75% Type S. If the RWP is for low exposure potential insoluble uranium requiring urinalysis only, then the solubility is defaulted to 100% Type S. The RWP bioassay indicators used for routine U handling jobs are 'F', 'Y', 'W', and 'M' and are summarized in Table 2.9-1.

Table 2.9-1. Chemical formulas and solubility class

Chemical formula	Chemical name	Solubility class [a]
$(NH_4)_2U_2O_7$	ammonium diuranate[b]	M
CCl_4	carbon tetrachloride	
$C_{12}H_{26}O_3$	dibutyl carbitol	
HCl	hydrochloric acid	
H_2O_2	hydrogen peroxide	
HNO_3	nitric acid	
UF_6	uranium hexafluoride	F
UO_2	uranium dioxide	S
U_3O_8	uranium oxide	S
UCl_5	uranium pentachloride	
$UO_4 \cdot 2H_2O$	uranium peroxide	
UCl_4	uranium tetrachloride	M
UF_4	uranium tetrafluoride	M
UO_3[c]	uranium trioxide	M
$UO_2(NO_3)_2$	uranyl nitrate	F
$UO_2(NO_3)_2 \times 6H_20$	uranyl nitrate hexahydrate (UNH)	

a. F, M, S are inhalation solubility classes established by the ICRP. F material is very soluble, M class material is moderately soluble, S material is relatively insoluble.
b. Ammonium diuranate is known to contain U as UO_3 and should not be assigned to a single inhalation class. The solubility of U oxides is very dependent on heat treatment. The rate of oxidation may also affect solubility.
c. ICRP Publications 54 (ICRP 1988) notes that there is evidence from animal studies that industrial UO_3 may behave more like class S material; UF_4 may behave more like class S material depending on the method used to produce it.

Historically from 1990 to 1998, the default solubility class for internal dose assessments was 90% W and 10% Class Y for both EU and DU. Almost all internal exposures at Y-12 involve uranium that has either been enriched or depleted in ^{235}U through the process of gaseous diffusion.

In 1999, DOE gave the Y-12 Radiological Control Dosimetry Department permission to use the ICRP Publication 66 (1994) lung model for estimating intakes and doses received by personnel. Prior to this, the ICRP-30 (1979) lung model was used from 1989-1999. The ICRP 66 (1994) report includes a considerably more detailed respiratory tract model than ICRP-30 (1979). The default material assumptions recommended in ICRP-66 (1994) more closely reflect those observed at Y-12.

A number of Y-12 studies has been conducted in an attempt to better characterize the work area with regard to material solubility at Y-12 using the Dose 66 Code. These studies include a three month investigation using participants from various areas during October to December 1999, recalculation of solubility of 1999 incident investigations, and a review of the 2000 incident investigation. The results of these studies have been combined and are given in Table 2.9-2.

Table 2.9-2. Solubility of material for various buildings and work areas as calculated by DOSE 66[a] code

Building	N[b]	%Type S	%Type M
9202	1	51	49
9206	2	31	69
9212	48	68	32
9215	54	82	18
9995	4	78	22
9998	2	64	36
9201-5	2	36	64
9201-5N	12	77	23
9204-2E	5	89	11
9204-4	8	74	26
9704-2	1	0	100

a. DOSE 66 code was developed and validated during CY 2000 at Y-12. This code utilizes the more recent ICRP 66 methodology for inhalation intakes.
b. N represents the number of data points.

Y-12 developed the Dose 66 code and it was validated and verified in CY 2000. This code utilizes the ICRP 66 methodology for inhalation intakes. A major advantage of the DOSE-66 code is the calculation of a derived mixture for intake material class when both urine and fecal bioassay data is available. The code calculates an intake based on fecal bioassay results only. It then estimates an intake based on the urine results. If the fecal and urine intake estimates differ by a significant amount (set by the user), it adjusts the solubility of the material until the urine estimate of intake matches that of the fecal data.

Uranium is considered to be primarily an internal dosimetric hazard since it emits alpha particles, beta particles and only weak gamma and x-ray photons. Y-12 is unique in that workers are assumed to be routinely exposed to low levels of uranium. This chronic intake assumption places a premium on accurately assessing Committed Effective Dose Equivalent (CEDE) values received by workers. Review of the DOSE 66 data reveals the high correlation between the assumed solubility type and estimated CEDE values when urine bioassay data alone is used. As the solubility of the material is increased, the CEDE value drops dramatically. This phenomenon, coupled with the potential for exposure of workers to varying solubility mixtures, illustrates the importance of solubility in internal dose assessments. Fecal sampling is the preferred bioassay method for areas and work that could lead to significant insoluble uranium intakes. For areas and work functions that could lead to intakes that are both soluble and insoluble, urine sampling alone is sufficient provided the insoluble intakes result in CEDE less than 100 mrem.

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GLOSSARY

Alpha stage – the first stage of the calutron that enriched uranium up to 20-30% ^{235}U.

Beta stage – the second stage of the calutron process that further enriched the uranium from the alpha stage up to 95% ^{235}U.

Calutron – an electromagnetic apparatus for separating isotopes according to their masses. Strong magnetic fields were used to separate the lighter ^{235}U isotope from the heavier, more naturally-abundant ^{238}U isotope.

Class Q – a mixture of 90% Class W and 10% Class Y uranium. The Class Q represents the circumstance when there is only a thin layer of UO_2 on the surface of uranium metal.

COLEX – a column-based chemical exchange process to enrich natural lithium in its ^{6}Li isotope.

Committed Effective Dose Equivalent (CEDE) – the sum of the committed dose equivalents to various tissues in the body, each multiplied by its weighting factor, for 50 years post intake. It does not include contributions from external doses. Committed effective dose equivalent is expressed in units of rem or seivert.

Depleted uranium (DU) – a form of uranium that contains less than 0.7% ^{235}U and has an isotopic distribution by mass of 0.001% ^{234}U, 0.199% ^{235}U, and 99.8% ^{238}U.

ELEX – an electrical exchange process to enrich natural lithium in its ^{6}Li isotope.

Enriched uranium (EU) – contains more than the natural abundance of ^{235}U than found in natural uranium, typically in the range of 0.99% to 99% by mass. A common isotopic distribution by mass is 1% in ^{234}U, 93% ^{235}U, and 6% ^{238}U.

Feed material – uranium tetrachloride (UCl_4) produced by the conversion of uranium oxides (including UO_2, UO_3, and U_3O_8) for use in the calutrons.

Fusion – the process in which nuclei of lighter elements (e.g., deuterium and tritium) combine to form the nucleus of a heavier element, with the release of energy.

Highly enriched uranium (HEU) – uranium having an enrichment above 20 percent of the fissionable isotope ^{235}U.

Natural uranium (NU) – uranium as it is found in nature. It consists of two principal isotopes, ^{235}U (0.72%) and ^{238}U (99.28%), and includes a trace amount of ^{234}U by mass (0.0057%).

Normal uranium – uranium that has been isotopically blended to approximate the natural isotopic range of uranium.

Recycled uranium (RU) – any uranium that has been irradiated in a reactor. As a result, RU contains transuranic (TRU) material, fission products and reactor-generated uranium products.

Solubility type – type F, M, and S are inhalation solubility types established by the ICRP. Type F material is very soluble, type M material is moderately soluble, and type S material is relatively insoluble. These types are equivalent to the older Class D, W, and Y, respectively.

Source material – (1) material containing any combination of uranium or thorium in any physical or chemical form, or (2) ores containing 0.05 wt.% or more uranium, thorium, or both. Source material excludes special nuclear material.

Special Nuclear Material (SNM) – plutonium or uranium enriched to a higher-than-natural assay, and includes plutonium-239, uranium-233, uranium containing more than the natural abundance of uranium-235, or any material artificially enriched in one of these isotopes.

Thermal neutrons – low speed neutrons that are in thermal equilibrium with their surroundings and have energies less than approximately 0.5 eV.

Transuranic (TRU) – elements with an atomic number greater than uranium (atomic number 92), e.g., $^{238\text{-}240}$Pu and ^{237}Np.

ATTACHMENT B – SITE DESCRIPTION

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B.1 SOURCES OF EXPOSURE

Y-12 became a highly sophisticated nuclear weapons component manufacturing facility and development engineering organization. The plant receives, stores, and protects uranium and lithium materials and parts; dismantles nuclear weapons components; and serves as a government repository for EU. In addition, Y-12 has many treatment, storage, and disposal facilities for hazardous and radioactive materials. Today, the primary mission of Y-12 consists of dismantling nuclear weapons components, storing nuclear material, pursuing new technologies, and serving as the DOE primary repository for HEU. Table B.1-1 shows the radionuclides of concern and its associated buildings. Table B.1-2 shows the location of known sealed radiation sources. Some building numbers and their corresponding radionuclides are not available at this time.

Table B.1-1. Radionuclides of concern

Radionuclide	Type of emission	Radioactive half life (y)	Building number	Solubility class
^{99}Tc	Beta	2.13×10^{5}	Not available	
^{228}Th	Alpha	1.91	9201-1, 9201-5, 9202, 9204-4, 9206, 9215, 9766	
^{230}Th	Alpha	7.54×10^{4}	9215, 9720-5	100% S
^{232}Th	Alpha	1.45×10^{10}	9201-5, 9207-5, 9215, 9998	100% S
^{234}U	Alpha	2.47×10^{5}	Not available	S,M,F
^{235}U	Alpha, some gamma	7.4×10^{8}	Not available	S,M,F
^{236}U	Alpha	2.34×10^{7}	Not available	S,M,F
^{238}U	Alpha	4.47×10^{9}	Not available	S,M,F
^{237} Np	Alpha	2.14×10^{6}	9201-5, 9202, 9215, 9720-5	100% S
^{238}Pu	Alpha	86.4	9201-5, 9720-5	100% S
^{239}Pu	Alpha	2.4×10^{4}	Not available	
^{241}Am	Alpha	4.32×10^{2}	9212	100% S

Table B.1-2. Known sealed radiation sources

Sources	Building
Ra-Be, Po-Be	9203
Ra, Co, Ta, Po-Be	9983
Po-Be, ^{226}Ra	9737, 9201-2, 9204-3
^{226}Ra	9212
^{226}Ra, Co	9212
^{226}Ra	9206,9706-2

B.2 CHRONOLOGY Y-12 URANIUM OPERATIONS

Tables B.2-1 and B.2-2 contain descriptions of historical Y-12 uranium process operations. Specific key buildings and their functions are highlighted to better understand the Y-12 uranium operations. Y-12 experienced significant changes from their original mission of electromagnetic enrichment to their current multiple missions of storing HEU, weapons disassembly, and major efforts in environmental and waste management.

Table B.2-1. Primary uranium operations

Key uranium operations	Buildings involved	Dates of operation
Electromagnetic Enrichment	Alpha buildings 9201-1,2,3,4,5 Beta buildings 9204-1,2,3,4	1943–1947
Feed Preparation and Product Processing	9202, 9203, 9206, 9212	1943–1947
Uranium Recovery and Recycle	9202, 9203, 9206, 9212	1945–1951, 1950s–1990s
Uranium Salvage	9206, 9207, 9211	1945–1951
Uranium Preparation/Recycle	9202, 9206, 9211, 9212	1952–1995
Uranium Forming/Machining	9201-5, 9204-4, 9215, 9998	1952–1995
Uranium Component Assembly	9202, 9204-2, 9204-2E	1952–1995
Stockpile Stewardship and Maintenance	9201-5, 9204-4, 9215	1952–2003

Table B.2-2. Process chronology of operations

Building	1943-1948	1949-1951	1952-1963	1964-1995	1996-2003
9201-1	Tracks 1 and 2, α - I calutrons (uranium enrichment)	Uranium enrichment	Uranium salvage	Fusion energy research	Manufacturing for tooling, work for others. Clean work.
9201-2	Tracks 3 and 4, α - I calutrons (uranium enrichment)	Uranium enrichment operations	COLEX Lithium/Hg enrichment operations	Development/research operations	ORNL
9201-3	Track 5, α - I calutrons	Uranium enrichment	Uranium salvage	Fusion energy research	Office space.
9201-4	Tracks 6 and 7, α - II calutrons (uranium enrichment)	Uranium enrichment operations	COLEX Lithium/Hg enrichment operations	Engineering and administrative facilities	Awaiting D&D
9201-5	Tracks 8 and 9, α – II calutrons (uranium enrichment)	Uranium enrichment operations	COLEX Lithium/Hg enrichment operations	Normal/depleted uranium press, rolling, and machining operations	Normal/depleted uranium press, rolling, and machining work.
9202	Alpha and chemical preparation/recovery operations	Uranium product recovery operations	Uranium process development & improvement operations	Uranium process development & improvement operations	Technology Development
9203	^{235}U analysis and initial uranium product processing	Uranium product recovery operations	Recovery and salvage operations	Production development and research operations	Technology Development
9204-1	Tracks 1 and 2, ß - calutrons (uranium enrichment)	Uranium enrichment operations	Stable isotope separation operations	Fusion energy research operations	ORNL facility, however BJC occupies office space
9204-2	Tracks 3 and 4, ß calutrons (uranium enrichment)	Uranium enrichment operations	Uranium assembly operations	Uranium assembly operations	Uranium assembly operations
9204-3	Tracks 5 and 6, ß calutrons (uranium enrichment)	Uranium enrichment operations	Stable isotope (*e.g.*, copper) separation operations	Stable isotope (*e.g.,* copper) separation operations	ORNL facility
9204-4	Tracks 7 and 8, ß calutrons(uranium enrichment)	Uranium enrichment operations	ELEX Lithium/Hg pilot-scale operations	Normal/depleted uranium press and rolling operations	DU press operations, quality evaluations for weapon components storage
9206	ß chemical recycle and product processing	Uranium product recovery/salvage	Uranium chemical processing and metal production operations	Uranium chemical processing and metal production operations	Currently undergoing deactivation. D&D scheduled for future.
9207	Uranium salvage operations	Uranium recovery/ salvage	Maintenance/salvage operations	ORNL biological research Operations	ORNL facility, mostly vacated.
9211	Uranium salvage operations	U salvage and product recovery operations	U salvage and product recovery operations	ORNL biological research operations	ORNL biological research operations
9212	ß product processing	Uranium conversion/ recovery operations	UF_6 conversion, chemical operations, and weapon production	Chemical operations and weapons production operations	Chemical operations and weapons production operations
9215	--	--	Enriched uranium	Enriched uranium	Enriched uranium

Building	1943-1948	1949-1951	1952-1963	1964-1995	1996-2003
			machining and metal finishing operations	machining and metal finishing operations	machining and metal finishing operations

B.3 Y-12 FACILITIES

Table B.3-1 lists the key facilities and gives details of the facility, including the year of construction and current status of the building.

Table B.3-1. Key uranium facilities

Facility	Facility Description
Building 9201-4, Alpha 4	**Constructed:** 1945 **Mission:** Electromagnetic separation of U, lithium isotopes separation. **Square footage:** 562,000 square feet. **Status:** Deteriorating, shut down; all utilities run through facility. **Concerns**: EU hazardous materials and mixed wastes.
Building 9201-5, Alpha 5	**Constructed**: 1945 **Mission**: Process and manufacture DU and non uranium materials. Storage of DU in various forms and combustibles contaminated with EU. **Square footage**: 591,500 square feet. **Status:** Plans to relocate the arc melting operation to the 9998 H-1 foundry. **Concerns:** EU, DU
Building 9201-5N/5W, Alpha 5N/5W	**Constructed:** 1972 **Mission:** Machine DU. **Square footage:** 80,500 square feet **Status**: Work for others **Concerns:** Some risk of DU exposure or uptake to workers
Building 9204-2, Beta 2	**Constructed** in 1954 **Mission: M**anufacture non-nuclear components for weapon production. Salvage, recycle, store lithium materials. Industrial lithium operations. **Square footage:** 270,000 square feet. **Status:** Original equipment replaced/upgraded by lithium process project. **Concerns:** EU
Building 9204-2E, Beta 2E	**Constructed**: 1969 **Mission**: Processing, cleaning, assembling, welding, and preparing nuclear components for shipment; other non-nuclear work. **Square footage:** 151,200 square feet **Status:** Operations resumed in March 1996. **Concerns:** significant quantities of SNM.
Building 9204-4, Beta 4	**Constructed:** 1949 **Mission:** Disassembly, testing, and storage of Y-12 warhead components. **Square footage:** 273,000 square feet. **Status**: DU and non-uranium metals are processed in this facility. **Concerns**: Significant quantities of SNM.
Building 9206 Related structures: 9768, 9720-17, 9409-17, 9510-2, 9767-2, and east and west tank farm pits	**Constructed:** 1946 **Mission**: Recover EU from scrap/trash. It is in stand-down, limited work. **Square footage**: 67,294 square feet. **Status**: currently undergoing deactivation **Concerns:** Significant quantities of SNM and hazardous substances.
Building 9212 Complex Related structures: 9212, 9809, 9812, 9818, 9815, 9980	**Constructed:** 1940's **Mission**: Recovery, purification, and processing of EU. **Square footage**: 311,325 sq. ft. **Status:** Facility is in stand-down with limited operations. **Concerns**: Major hazards are nuclear, radiological, and chemicals.

Facility	Facility Description
Building 9215	**Constructed:** 1950 **Mission:** Manufacture parts from DU and EU. Will be reactivated as part of the EU operations restart. **Square footage**: 157,000 square feet **Status**: EU machining and metal finishing operations. **Concerns:** Significant quantities of DU and EU.
Building 9720-5	**Constructed**: 1944 **Mission:** Storing EU weapons parts, assemblies, and other SNM. **Square footage**: 53,949 square feet. **Status:** Storage Facility **Concerns:** Significant quantity of SNM.
Building 9995	**Constructed:** 1952 **Mission:** Analytical laboratory. **Square footage:** 84,000 square feet **Status:** Plant laboratory, analysis of waste **Concerns**: hazardous and mixed waste
Building 9202	**Constructed:** 1942 **Mission:** Bulk treatment facility, produced feed material for Alpha Calutrons. **Square footage:** 128,800 square feet. **Status:** Technology development **Concerns:** U processed materials
Building 9731	**Constructed:** 1943 **Mission**: Calutron Pilot Plant Building used for training. **Square footage:** 37,300 square feet. **Status:** Standby mode **Concerns:** Partially EU in recycle streams that needed to be purified and further enriched.
Building 9203	**Constructed:** 1942 **Mission:** Calutron feed production, washing alpha collector pockets to recover the product, developing beta chemical recycle processes, mass spectrometry and fission counting labs to determine enrichment levels. **Square footage:** 30,800 square feet. **Status:** Technology Development **Concerns:** RU

B.4 SOLUBILITY OF RADIONUCLIDES AND OTHER CHEMICALS

Workers at Y-12 routinely perform work with various compounds of uranium. These compounds have differing retention times and clearance pathways. Since the clearance of soluble materials is primarily through the blood, urine bioassay is the preferred method for detecting these forms of compounds. For insoluble compounds, the material is cleared from the lungs. The majority of the insoluble material will be excreted via the feces, with only a small fraction clearing through the urine. Tables B.4-1 and B.4-2 show the solubility class of different radionuclides and radioelements.

Table B.4-1. Radionuclides and solubility class

Radionuclides	Solubility class
^{99}Tc	F and M
^{237}Np	M
^{238}Pu	M
^{239}Pu	S
^{241}Am	M

Table B.4-2. Radioelements and default solubility class

Radioelement	Solubility class
Americium	M
Neptunium	M
Plutonium	S
Strontium	S
Technetium	M
^{3}H	Vapor
Uranium	As determined by RWP

Y-12 uses three default solubility assumptions for workers who participate exclusively in the urine bioassay program: 100% Type S, 75% Type S/25% Type M and 50% Type S/50% Type M. These defaults are designed to be conservative and provide adequate protection for workers while at the same time being representative of the actual exposure material. Table B.4-3 summarizes the bioassay indicators.

Table B.4-3. Radiological work permit bioassay indicators for routine uranium handling jobs

Bioassay indicator	Solubility	Bioassay method
F	Primarily (>75%) insoluble. Derived solubility will be determined by DOSE 66	Bi-monthly urine and fecal sampling
Y	Primarily (>75%) insoluble but low exposure potential. Assumed solubility for dose calculations is 100% Type S.	Quarterly urine sampling
M	Insoluble component between 25% and 75%. Assumed solubility for dose calculations is 75% Type S and 25% Type M.	Quarterly urine sampling
W	No insoluble component expected. Assumed solubility for dose calculation is 50% Type S and 50% Type M.	Quarterly urine sampling

A number of studies has been conducted in an attempt to better characterize the work areas at Y-12 with regard to material solubility. These studies have included a three month investigation using participants from various areas during October to December 1999. The results are shown in Table B.4-4 (Veinot and Souleyrette, 2003).

Table B.4-4. Solubility of material for various buildings and work areas as calculated by DOSE 66[(a)] code

Building	N[(b)]	%Type S	%Type M
9202	1	51	49
9206	2	31	69
9212	48	68	32
9215	54	82	18
9995	4	78	22
9998	2	64	36
9201-5	2	36	64
9201-5N	12	77	23
9204-2E	5	89	11
9204-4	8	74	26
9704-2	1	0	100

a. DOSE 66 code was developed and validated during CY 2000 at Y-12. This code utilizes the more recent ICRP 66 methodology for inhalation intakes.
b. N represents the number of data points.