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Engineering Design File

Project No. 23415

Materials Test Reactor Complex Chemical Constituent Source Team

Idaho Cleanup Project

CH2M ◆ WG Idaho, LLC is the Idaho Cleanup Project contractor for the U.S. Department of Energy

ENGINEERING DESIGN FILE

EDF No.: 6244 EDF Rev. No.: 2 Project File No.: 23415

1. Title: Materials Test Reactor Complex Chemical Constituent Source Term

2. Index Codes:
Building/Type ____ SSC ID N/A Site Area RTC

3 Commercial Level? ☒ Yes ☐ No

*4. NPH Performance Category: ____ or ☒ N/A SSC Safety Category: ____ or ☒ N/A

*5. (a) Affects Safety Basis: ☐ Yes ☒ No (b) Affects a SNF Facility: ☐ Yes ☒ No

6. Summary:
This Engineering Design File (EDF) describes and quantifies the chemical constituents source term of the Materials Test Reactor (MTR) complex. This EDF describes these chemical constituents that may pose a risk to human health or the environment, their location and use in the MTR facilities, and physical form or configuration. The quantities expressed in this document are based either on calculations (employing various assumptions) or approximations. Another objective of this EDF is to provide information for conducting a risk assessment to support decommissioning of the MTR complex to be performed in accordance with an engineering evaluation/cost analysis.

7. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

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12. Registered Professional Engineer's Stamp (if required) ☒ N/A

* **Not required for commercial level calculations**

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ACRONYMS

DOE	U.S. Department of Energy
EDF	Engineering Design File
EE/CA	engineering evaluation/cost analysis
EPA	Environmental Protection Agency
ETR	Engineering Test Reactor
INL	Idaho National Laboratory
MTR	Materials Test Reactor
PCB	polychlorinated biphenyl
PRGs	preliminary remediation goals
RTC	Reactor Technology Complex
TRA	Test Reactor Area
VCO	Voluntary Consent Order

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Materials Test Reactor Complex Chemical Constituent Source Term

1. INTRODUCTION AND PURPOSE

This Engineering Design File (EDF) describes and quantifies the chemical constituent source term of the Materials Test Reactor (MTR) complex. This EDF includes a general description of the chemical constituents present in the complex that may pose a risk to human health or the environment, their location and use in the MTR facilities, and physical form or configuration. The quantities expressed in this document are based on calculations (employing various assumptions) or have been approximated. In addition, this EDF provides information necessary to conduct a risk assessment to support the decommissioning of the MTR complex that is to be performed in accordance with an engineering evaluation/cost analysis (EE/CA).

2. FACILITY HISTORY AND DESCRIPTION

The Idaho National Laboratory (INL) is a government-owned facility managed by the Department of Energy (DOE), which is located 54 km (34 mi) west of Idaho Falls, Idaho. It encompasses 2,305 km^2 (890 mi^2) of the northeastern portion of the Eastern Snake River Plain (see Figure 1).[a]

The MTR, which consists of several buildings and structures that occupy the south-central portion of the Reactor Technology Complex (RTC), formerly Test Reactor Area (TRA), was constructed between 1950 and 1952. It operated as a high-flux, 40-MW (thermal) pressurized light-water, heterogeneous-enriched fuel, nuclear test reactor that first achieved criticality in March 1952. The reactor vessel is comprised of five integral reactor tanks and one tank extension; the reactor internals (beryllium reflector, upper and lower support castings, assembly grids, guide grids, lower cradle, grid spacer, upper locking mechanism assembly, and spider guide ring); and reactor components (top and bottom plugs, rabbits, and experiment facilities). (ANL and ORNL 1951)

As the name implies, the reactor was designed to allow testing of materials in high-intensity radiation fields. More than 15,000 different irradiation experiments were performed in MTR, which provided findings that were critical in developing safe reactor operations and for testing components for future reactors. Proposed fuels were irradiated in the MTR for use in the Navy's Nautilus and other reactor prototypes; the proposed nuclear-powered aircraft; and reactors at other national and international sites. Nondestructive techniques for the Idaho Nuclear Technology and Engineering Center used to assay the uranium in fuel assemblies were developed at MTR (Rolfe and Willis 1984). Figure 2 is a photograph of the MTR during its early operation period.

The reactor was in service from 1952 until 1970, at which time it had completed 18 years of successful testing. The reactor was shut down for the last time in August 1970, and the fuel was removed from the reactor core and transferred underwater to the MTR canal for temporary storage. The Spent Nuclear Fuel program completed MTR fuel removal in October 2002.

a. Beginning February 1, 2005, the name of the Idaho National Engineering and Environmental Laboratory was changed to Idaho National Laboratory. Test Reactor Area was renamed the Reactor Technology Complex.

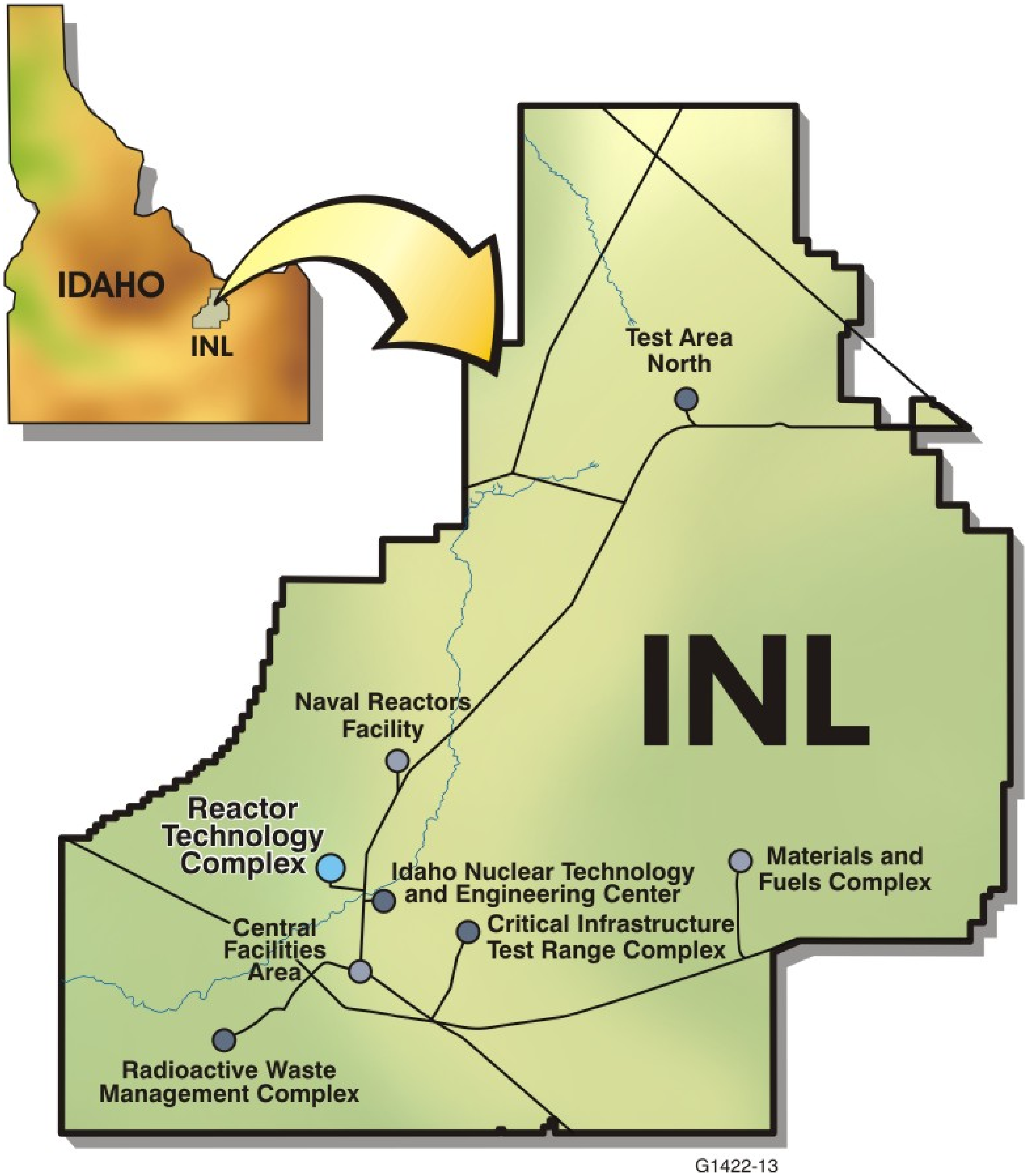

Figure 1. Map of the Idaho National Laboratory Site showing the location of the Reactor Technology Complex and other major facilities.

Figure 2. The MTR reactor (enclosed by biological shielding blocks) as seen from the southwest during its early operational days.

2.1 MTR Complex Physical Description

The MTR complex (see Figure 3) operated until 1970, but since then has been used for various projects and missions. Radioactive water has been drained from the reactor tanks, primary coolant system, water loop experiment piping and vessels, the fuel storage canal (the MTR canal was deactivated in 2004), associated piping, and resin tanks. Other water systems that were drained include the secondary coolant water (including heat exchangers), utility water, demineralized systems, and water in heating and cooling units. The fuel in the reactor was transferred to the MTR canal and later shipped to Idaho Nuclear Technology and Engineering Center for interim storage.

The MTR facility consists of the reactor building and approximately 14 support structures. The operations required to support the MTR were located in close proximity to the reactor building, and included the laboratory wing, fuel storage canal, hot cell building, plug storage building, process water building, fan house, gas exhaust stack, and other process/utility support buildings.

Figure 3. The MTR complex looking south-southwest toward Big Southern Butte (photo taken in 1996). The large concrete-sided MTR reactor building (TRA-603), along with support facilities, can be seen in the center.

For purposes of this EDF, the MTR complex includes the following buildings and structures, which are briefly described below and are presented in Figure 4:

1. TRA-603, MTR Reactor Building, is a steel-framed building with a main floor, a basement, and two above-grade floors. The building measures 136 × 112 ft and extends 58 ft above grade, and 38 ft below grade. The reactor building houses the multitank reactor vessel, along with the canal, subpile room, and the VH3 experiment cubicle in the basement. In addition, the second and third floors contained the control room, a room to house associated electrical equipment, and operation personnel offices.

2. TRA-604, MTR Reactor Building Wing A, shares a common wall with the MTR reactor building (TRA-603). The wing is constructed of 8-in. hollow concrete block construction, with dimensions of 142 × 130 ft. It has a full basement and a partial second floor (formerly called the fan loft). In the wing basement are heating and ventilation equipment, electrical switchgear, storage areas, and some offices. The wing first floor is in current use and has offices, chemical and instrumentation laboratories, a machine shop and model shops, storage areas, and the Radiation Measurements Laboratory.

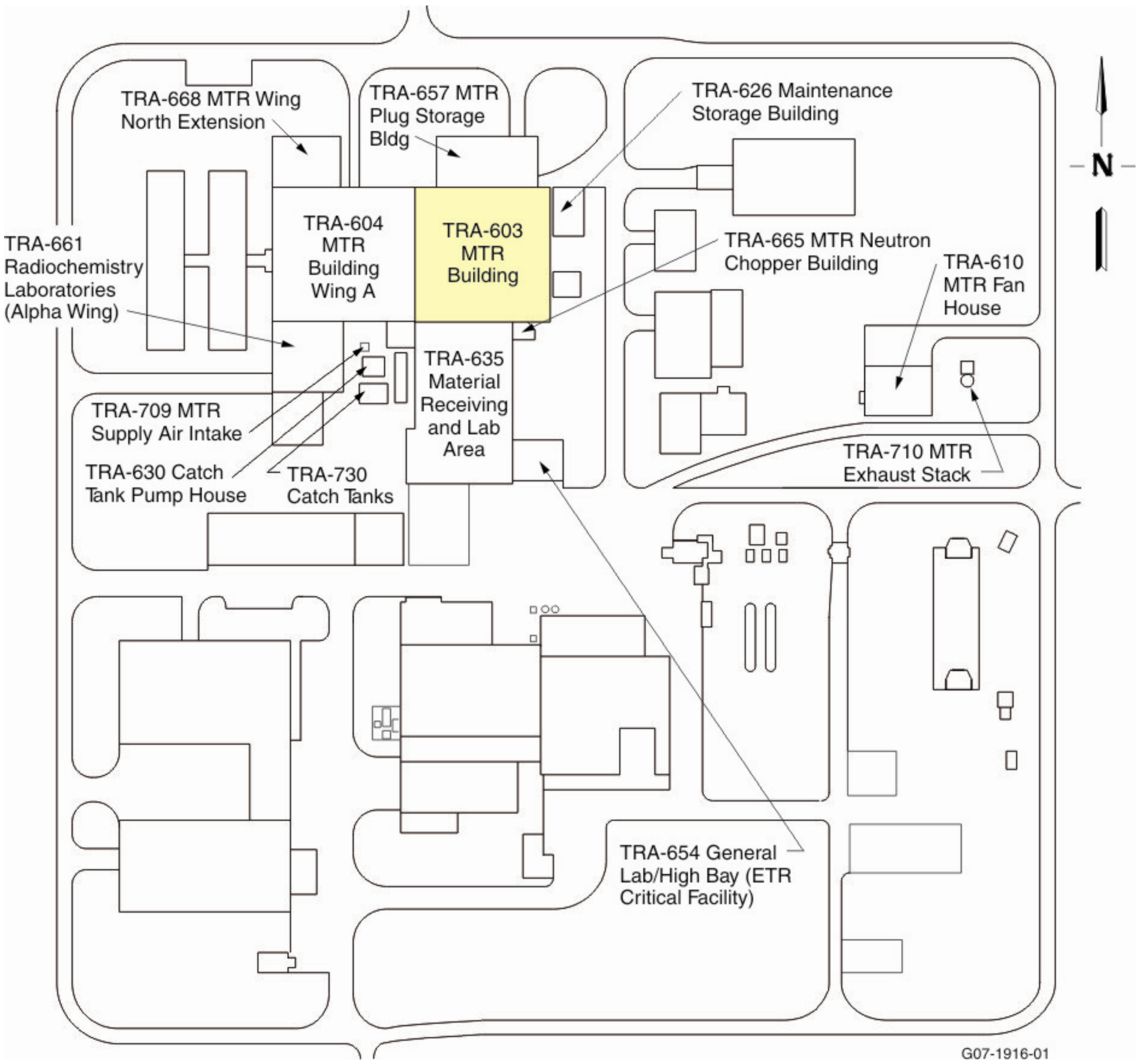

Figure 4. Map of the Reactor Technology Complex, including the south-central portion where MTR buildings and structures are located.

3. TRA-610, MTR Fan House, is a one-story building with dimensions of 66 × 48 ft and is constructed of hollow concrete block. Three large blower rooms are located on the north side.

4. TRA-626, Compressor Building, is located just east of the reactor building's northeast corner section. All compressor equipment and piping have been removed from the building interior. The building dimensions are 48 × 31 × 20 ft high.

5. TRA-630, Catch Tank Pumphouse, is located west of the reactor services building and south of the reactor building wing beneath a concrete slab.

6. TRA-635, Reactor Services Building, is adjacent to the reactor building south wall. The services building is about 160 × 97 ft. The building is a high-bay structure that is 26 ft high and is used for warehousing and storage, receiving and testing of equipment, quality inspection, and x-ray operations.

7. TRA-654, General Lab/High Bay (Engineering Test Reactor [ETR] Critical Facility), is a two-story, masonry-block, 2,055-ft^2 building that was constructed in 1959. Originally built to house the ETR critical facility (full-scale mockup of the ETR reactor), it operated in that capacity from 1957 to 1982. The facility is currently used by a variety of research and development projects.

8. TRA-657, MTR Plug Storage Building, comprises two structures adjacent to the north side of the first floor of the reactor building (TRA-603). One structure is the roofed enclosure which is used primarily as a storage area and the vehicle passageway through two 14-ft-high rollup truck doors, one each on the north and south walls. The other structure on the west end was a 40- × 50-ft-wide area that has 32 horizontal steel tubes emplaced in the 12-ft-deep gravel backfill. This second structure has been decommissioned and dismantled.

9. TRA-661, Radiochemistry Laboratories (Alpha Wing), is located immediately south of TRA-604. Originally constructed in 1962, the 8,459-ft^2 structure houses several radiochemistry laboratories. An addition was built in 1987.

10. TRA-665, MTR Neutron Chopper Building, is a one-story, 867-ft^2 reinforced concrete facility that was constructed in 1962. The facility is used for neutron source storage.

11. TRA-668, MTR Wing North Extension, is also referred to as the TRA Physics Lab. It was constructed in 1956 to support nuclear reactor research at MTR. It is a one-story, masonry-wall, 3,650-ft^2 building containing four individual laboratories that support Advanced Test Reactor operations and research and development programs.

12. TRA-709, MTR Supply Air Intake, was built in 1952 in support of nuclear reactor research at MTR.

13. TRA-710, MTR Exhaust Gas Stack (and Monitoring Building), is a 250-ft-tall concrete structure that is used for venting exhaust air systems. The stack was built in 1952. The monitoring building, which is concrete block construction and measures 11 × 11 ft, abuts the stack on its north side. It once contained sampling lines, racks, and equipment, but these were removed in 1983. New exhaust stack monitoring equipment was installed in 1984.

14. TRA-730, Catch Tanks, are four underground 1,500-gallon, stainless-steel, hot-waste tanks located south of the MTR Building Wing A (TRA-604). Installed in 1986, they were used to collect and store warm and hot radioactive waste from the MTR area. The tanks are situated in two concrete buried vaults (the pump vault [TRA-630] is located north of the tank vault). Two buildings have been erected over the pump vault and tank vault to limit access to the catch tank system and provide weather shelter for the vaults. The Catch Tanks are being remediated and closed as part of the Voluntary Consent Order (VCO) and are not considered part of this EDF.

15. TRA-784, Liquid Nitrogen Tank, was installed immediately outside TRA-657 in 2000. The tank has a single carbon-steel wall and outer stainless-steel wall. It has a 3,000-gal capacity.

3. CHEMICAL CONSTITUENTS CONSIDERED FOR SOURCE TERM

The chemical constituents within the MTR facilities and structures that were quantified are taken from the Environmental Protection Agency (EPA) Region 9 list of preliminary remediation goals (PRGs) (EPA 2004). PRGs are used for screening and for initial cleanup goals for contaminated sites. According to EPA Region 9: Superfund, "Frequently Asked Questions," exceedance of a PRG may prompt further evaluation of the potential risks posed by that contaminant (EPA 2007).

Table 1 lists the constituents taken from the EPA Region 9 list of PRGs considered for this chemical constituent source term based on what is reasonably expected to be present in the MTR facilities. These constituents compose almost exclusively materials of construction for facility operational components and systems. Section 4.1.1 discusses why certain constituents were not included as part of the source term.

Table 1. List of the constituents taken from the EPA Region 9 PRGs considered for the MTR chemical constituent source term.

Constituent	CAS No.	Use in the MTR Complex[a]
Organic compounds		
Polychlorinated biphenyls, unspecified mixture, high risk, e.g., Aroclor 1254	11097-69-1	Dielectric fluid in transformers and capacitors, lamp ballasts, additive in older paint formulations
Freon 113	76-13-1	Refrigeration and air conditioning equipment
Inorganics (metals)		
Aluminum	7429-90-5	Material of construction for various reactor vessel tanks and other reactor components
Antimony and compounds	7440-36-0	Metal alloy (hardening alloy for lead)
Barium and compounds	7440-39-3	Additive for concrete block shielding; paint pigment
Beryllium and compounds	7440-41-7	Moderator and reflector in nuclear reactors (Be reflector)
Boron	7440-42-8	Neutron absorber for reactor controls
Cadmium and compounds	7440-43-9	High neutron absorber
Chromium, total 1:6 ratio Cr VI:	7440-47-3	Significant hardening/corrosion resistance alloy

Table 1. (continued).

Constituent	CAS No.	Use in the MTR Complex[a]
Cr III		of stainless steel and inorganic pigment (paints)
Cobalt	7440-48-4	Dryer in paints, metal alloy
Copper and compounds	7440-50-8	Electric wiring, switches, plumbing, heating, alloy of brass and bronze, electroplating protective coatings
Iron	7439-89-6	Major structural material (I-beams, rebar, siding, roofing, piping and tanks, ducting, etc.)
Lead	7439-92-1	Radiation shielding, concrete wall anchors, waste pipe packing material, paint additive
Manganese and compounds	7439-96-5	Significant nonferrous alloy (hardener) of metals (e.g., stainless steel)
Mercury and compounds	7487-94-7	Mercury vapor and fluorescent lamps
Mercury (elemental)	7439-97-6	Electrical equipment (switches, thermostats)
Nickel (soluble salts)	7440-02-0	Significant alloy of metals (e.g., stainless steel, low-alloy steels, copper, and brass)
Silver and compounds	7440-22-4	Electronic equipment, electric conductors (bus bars), brazing alloys, electrical contacts
Tin (inorganic)	7440-31-5	Significant alloy of bronze, tinned wire, paint additive
Vanadium	7440-62-2	Steel alloy, sometimes found in paint
Zinc	7440-66-6	Alloy of brass and bronze and other metals, galvanized coatings for ferrous metals

a. Some uses taken from Lewis (1993).

4. QUANTIFICATION METHODS USED TO DETERMINE CHEMICAL CONSTITUENT SOURCE TERM

The total quantity of the chemical constituent source term was determined by several means. These include reviews of various historical documents, drawings, and photographs; interviews with INL personnel knowledgeable with MTR facility operations; interviews with other site personnel knowledgeable of reactor and utility systems; interviews with VCO program personnel; review of analytical data; and walk-downs of the various facilities. Some areas that were not accessed (e.g., posted and managed as a high contamination or high radiation area) were evaluated by reviewing available documents, drawings, photographs, and videos of these areas and conservatively estimating the chemical constituent source term.

4.1 Assumptions and Baseline for Source Term Calculations/Estimates

Several assumptions are included to more fully explain how source term values were calculated, or estimated, and why certain specific materials have been omitted from consideration for quantification. Quantities reported in this EDF have all been calculated in, or converted to, the international system of units and are expressed in kilograms (kg). These quantities were rounded to the nearest 10, unless the quantity was less than 10 kg or is a fractional amount.

Assumptions used as a basis for quantifying the source term, the particular chemical constituent that was quantified, and calculation/estimation methodologies used are presented in the following sections.

The baseline used for establishing the quantity of remaining hazardous constituents considers "Alternative 2–Grouting Reactor Vessels in Place" that is presented in the proposed list of alternatives for the EE/CA for the MTR and MTR vessels. Alternative 2 of the EE/CA provides that the reactor vessels would be filled with a grout, and the aboveground portions of the vessel would be encapsulated in a concrete monolith. The aboveground reactor buildings would be demolished. Belowgrade structures and systems, including piping and utility systems, would be abandoned in place. In addition, hazardous constituents not removed under the VCO and inactivation activities would remain in place and be managed under the INL Institutional Control Program. Void spaces exterior to the reactor vessel would be backfilled to grade. As such, the source accounted for in this EDF includes all materials in the MTR complex that are under consideration for abandonment below grade, the abovegrade portion of the TRA-603 reactor building, and the reactor vessel and all of its internals.

4.1.1 Assumptions for Omitting Certain Material Constituents

Certain material constituents were not included in the quantification based on the following reasons:

- The chemical source term does not include any constituents found in materials, wastes, or components that have been, or are in the process of being, removed for disposal—either under actions performed by the VCO or under the decommissioning activities described in Environmental Checklists TRA-04-006 and ICP-05-015.[b] As such, all lead shielding, which is the primary use of lead in the MTR complex, is not included in the quantity of lead calculated for this source term, with exceptions noted in Section 6.8. Other regulated materials/wastes that have been or will be removed and disposed of before performing a non-time critical removal action under the Comprehensive Environmental Response, Compensation and Liability Act (42 USC 9601) include other hazardous and mixed wastes (such as mercury switches and thermostats, mercury and sodium vapor lamps, circuit boards containing lead or silver soldering) regulated under the Resource Conservation and Recovery Act (42 USC 6901) and wastes regulated under the Toxic Substances Control Act such as polychlorinated biphenyl (PCB) articles and equipment (15 USC 2601).

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b. This document determined that the level of environmental review per the National Environmental Policy Act, for certain specific decommissioning activities within TRA-603, is a categorical exclusion (42 USC 4321).

- The source term does not include any chemical constituents contained in residual lubrication oils, hydraulic fluids, and other petroleum-based fluids that have already been drained (or are planned to be drained) from diesel generators, pump motors, elevator hydraulic systems, and other operational equipment/components.

- Freon 113 may be present in some of the facility utility equipment/components but will be removed during preliminary inactivation activities.

- This chemical constituent source term does not include asbestos-containing materials, either in friable or nonfriable forms that may be found in pipe and tank/vessel insulation, fire doors, transite panels, and other potential asbestos-containing material. Asbestos is not listed as an EPA Region 9 PRG contaminant. Friable asbestos will be removed and disposed of as required by the National Emission Standards for Hazardous Air Pollutants, “Standards for Demolition and Renovation,” 40 CFR § 61.145. Undisturbed asbestos, or asbestos found in high radiation, high contamination, and/or inaccessible locations greater than 3 ft below ground surface, may be managed in place, as allowable.

- Inorganics, such as fluorides and chlorines, are not known or suspected to be present in any locations within the MTR complex, or they are assumed to be present only in negligible amounts.

- Several inorganic constituents (all metals) are assumed to be present in materials of construction only as very small alloyed amounts, for which there are no readily available industry specifications or other material descriptions that can be used to accurately quantify. These metals include arsenic, molybdenum, selenium, thallium, and vanadium. However, some of these metals were quantified in painted surfaces, based on analytical results of paint samples collected in 2005 within the ETR complex.[c] The amounts for antimony, cobalt, copper, and vanadium (metals) calculated for painted surfaces were not considered to be significant enough quantities (all were <0.2 kg) to warrant inclusion in this report.

- Information in the MTR design and operation manual (McPherson et al. 1963) indicates that the three southern shim-safety rods, which are surrounded on three sides by beryllium reflector pieces, are made with a cadmium poison upper section that were drawn into the core during operation. However, the shim-safety rods have been removed from the core, and there are no other known components constructed from cadmium in the MTR complex.

- Strontium and uranium were not considered for the potential list because strontium is specified under the EPA Region 9 PRGs (EPA 2004) as stable form only (i.e., nonradioactive), while uranium is listed for chemical toxicity only, as opposed to radiological properties (isotopes of uranium, such as U-235). The radiological source term is detailed in EDF-6381, “Material Test Reactor (MTR) Complex Activity vs. Depth.”

Other assumptions and considerations that were identified for this EDF to simplify quantity estimation for the constituents of concern are

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c. Given similarities in the types of painted surfaces and the age of these facilities, the analytical results from ETR are considered appropriate for use at MTR.

- The coolant water within the primary and secondary coolant systems was drained and disposed of in the TRA evaporation pond during 1982 deactivation activities, and no chemical contaminants of significance are associated with either system. The remaining pipe systems were evaluated for radiological source term (i.e., residual internal contamination) and are covered under EDF-6381.

- The chemicals normally tracked by the Chemical Management System, such as solvents, adhesives, pesticides, or herbicides, will be used for their intended purpose and will not remain in any of the buildings and structures as leftover or discarded products. It is assumed that all chemicals and reagents will be removed from the radiochemistry laboratories, and the quantities of any residual chemicals in the radiochemistry laboratories are considered to be negligible. With the exception of PCBs, organic chemical constituents were not quantified for this source term.

4.1.2 Additional Assumptions for Source Term Calculations and Estimates

The following assumptions were used for calculating quantities of chemical constituents:

- The densities of stainless steel and carbon steel are assumed to be identical (7.9 g/cm^3).

- All stainless steel is assumed to be 304 type, which, on average, contains 19% chromium, 10% nickel, and 2% manganese.

- Carbon steel alloys (per ASTM A 29) contain small percentages of chromium, nickel, and manganese. The averages for these are 0.49% chromium, 0.43% nickel, and 0.81% manganese.

For painted surfaces, assumptions include

- The total surface area covered by paint is assumed to be a total area measuring

Belowgrade:	130 × 17 ft = 2,210 ft^2 × 2 = 4,420 ft^2	
	131 × 17 ft = 2,227 ft^2 × 2 = 4,454 ft^2	
	131 × 130 ft = 17,030 ft^2 × 2 = 34,060 ft^2	
	Subtotal =	42,934 ft^2
Abovegrade:	130 × 58 ft = 7,540 ft^2 × 2 = 15,080 ft^2	
	131 × 58 ft = 7,598 ft^2 × 2 = 15,196 ft^2	
	131 × 130 ft = 17,030 ft^2 × 2 = 34,060 ft^2	
	Subtotal =	64,336 ft^2
	Total Surface Area =	**107,270 ft^2.**

- Weight of applied paint is assumed to be 5 g/ft^2. This is the concentration used by Waste Generator Services in mass balance calculations for waste disposal purposes.

- The concentrations of metals in painted surfaces are based on analyses of paint chips collected and analyzed at the ETR complex during June 2005 characterization activities.

Other specific assumptions for calculating quantities of metals are detailed for each particular metal.

5. QUANTITIES OF ORGANIC CHEMICAL CONSTITUENTS IN THE MTR FACILITIES

5.1 Polychlorinated Biphenyls (paint only)

PCBs are the only organic compounds in the MTR complex being quantified for risk assessment purposes. The only PCBs accounted for in this report are found in coated (painted) surfaces such as walls, floors, and structural steel. These PCBs include the congeners Aroclor 1254 and 1260, which were summed to provide total PCB concentration. (Grigg 2005)

PCBs were averaged from samples of paint collected from the basement and main floor of ETR. PCBs were part of the paint formulation, but at relatively low concentrations, with all samples yielding an average concentration of 16 mg/kg. The total quantity of PCBs was calculated as follows:

- PCBs concentration (average of main floor and subgrade floor gray and white paints sampled): 16 mg/kg.

- Weight of PCBs in paint: total surface area (107,270 ft^2) × average weight of paint/ft^2 (5 g/ft^2) = 536,350 g × 0.001 kg/g = 536 kg paint × average PCBs concentration (16 mg/kg PCBs) = 8.6 g PCBs.

The total weight of PCBs (found as paint additives) in the MTR complex is 8.6 g, or 0.009 kg.

6. QUANTITIES OF INORGANIC CHEMICAL CONSTITUENTS IN THE MTR FACILITIES

The majority of the hazardous material quantities are from inorganic constituents, which are found in materials of construction and, to a much lesser extent, in coated (painted) exterior surfaces. The most significant materials of construction in terms of quantity include aluminum, barium, copper, chromium, lead, manganese, and nickel.

The inorganic constituents quantified for painted surfaces were based on the presence of these metals in the paint chips sampled in the subgrade areas of ETR. Due to the similar age and type of facilities, the analyses of the paints collected within ETR were deemed appropriate for calculating quantities within MTR. For this report, the paints considered representative of subgrade areas within the ETR complex include gray and white. Averages of the concentrations were used to quantity the total amount of the constituent in the painted surfaces.

6.1 Aluminum

Aluminum is a material of construction for various nuclear components at the MTR reactor facility. Aluminum components are briefly described below and summarized in Table 2.

There are several items that might include aluminum as part of their composition, in either solid aluminum form or aluminum-alloyed materials of construction (various electrical and mechanical components and equipment). However, aluminum-alloyed materials were not quantified due to the uncertainty and difficulty of deriving a definable estimate.

6.1.1 Aluminum Components and Materials

The MTR reactor vessel is made up of five individual tanks (A, B, C, D, and E). Tanks C and D are constructed of aluminum, and there are various other components made from 356 aluminum. Table 2 itemized the estimated weights of the aluminum tanks and components in the MTR complex.

The total weight of aluminum in the MTR complex is approximately 12,560 kg.

Table 2. Estimated quantity of aluminum in the MTR complex.

Structure/Component	Material	Quantity (kg)
C tank	ASTM 209-46T Alloy A2	10,205
D tank	ASTM 209-46T Alloy A2	839
Reactor internal core support	356 Al	408
Miscellaneous aluminum components (lower upport casting, etc.)	356 Al	1,104
Total quantity		12,556

6.2 Antimony

Antimony is an alloy of certain types of materials. It is alloyed with zinc and lead as a material of construction in concrete lag shield anchors, which were used with lag bolts for hanging or anchoring various utility system components/equipment. The calculated weight of antimony in paint was considered negligible due to its very small mass and is not included as part of the overall quantity of antimony.

The percentage by composition of the lag shield anchors is 75% zinc, 2% antimony, and 23% lead.

A typical (representative) lag shield anchors is assumed to be of medium duty, 0.5 in. in diameter, and 3 in. long. It has a weight of 60 g.

There are several different types of lag bolts in the MTR facilities. A rough order of magnitude estimate of the number constructed of zinc and antimonial lead is 500.

Thus, the estimated number of zinc/antimonial lead constructed lag shield anchors (500) × typical weight of an average anchor (0.060 kg) × percentage of antimony as an alloy material (2%) = 0.6 kg antimony in lag shield anchors.

The total weight of antimony in the MTR complex is 0.6 kg.

6.3 Barium and Compounds

Barium is present as an additive, in the form of barytes, or barium sulfate, to high-density (concrete containing magnetite) concrete block walls (e.g., bioshield). The baryte additives enhance the neutron shielding properties of the concrete. A significant volume of concrete at MTR contains barytes. It is also commonly found as a paint pigment.

The MTR biological shield surrounds the reactor vessel. The biological shield is constructed of concrete containing barytes and has an estimated volume of 49,023 ft^3 (1,388 m^3). An additional 186 ft^3 (5.3 m^3) of baryte concrete was used in the construction of shielding wall in the monitoring room in the northeast corner of TRA-603. The total volume of the combined concrete shielding is 49,209 ft^3 (1,394 m^3). The assumptions used to estimate constituents on concrete are as follows:

1. Densities of high-density concrete with magnetite for the MTR facility averages 218.26 lb/ft^3, or the equivalent of 3.49 g/cm^3 (3,490 kg/m^3).

2. The percent aggregate of the baryte in the concrete mixture is calculated to be 50.5%. Therefore, the barium composition in the high-density concrete is 218.26 lb/ft^3 × 50.5% = 110.3 lb/ft^3, or the equivalent of 1.76 g/cm^3 (1,760 kg/m^3).[d]

   Thus, the mass of the barium (as barium sulfate) is calculated as:

Volume of concrete (1,394 m^3) × density of the barium in the concrete (1,760 kg/m^3) = 2,453,440 kg. (1)

To derive an adjusted mass for elemental barium (in the barium sulfate compound), the weight of the barium sulfate is multiplied by the ratio of the atomic weight of barium and the atomic weight of barium sulfate ($Ba/BaSO_4$). This ratio is 137.34/233.3976, or 0.5884. Multiplied by the weight of the barium sulfate yields 1,452,924 kg.

In painted surfaces, barium was found at an average concentration of 598 mg/kg in the painted wall and floor surfaces. The total quantity of barium was calculated as follows:

- Surface area of areas considered: 107,270 ft^2.

- Barium concentration (average of gray and white paints sampled): 598 mg/kg.

- Weight of barium in paint: total surface area (107,270 ft^2) × average weight of paint/ft^2 (5 g/ft^2) = 536,350 g × 0.001 kg/g = 536 kg paint × average barium concentration (598 mg/kg barium) = 321 g barium.

- Total weight of barium in painted surfaces is 321 g (0.321 kg).

The total estimated weight of barium in the MTR complex is 1,443,604 kg.

6.4 Beryllium and Compounds

The reactor core contains a beryllium reflector that was installed in late 1969. Although the exact source of the beryllium is not known with certainty, the beryllium reflector contains a relatively high percentage of beryllium (INEEL 2003). The mass of the beryllium reflector used in this quantification is derived from the estimate found in EDF-6381, which is 4,797 lb (2,176 kg).

Given the composition of the reflector is 98.8% beryllium (assuming a calculated percentage of 98.8% for Be-9, the isotope for naturally occurring beryllium), the total weight of the beryllium is 2,150 kg.

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d. Lotus Note from Harry Heidkamp, ICP project engineer, to Walker Howell, ICP, “Calculating Methodologies for Amount of Barium,” August 18, 2005.

6.5 Boron

The only identified uses of boron for MTR nuclear research operations is the boron thermopiles and the boral curtain. The boron thermopiles were installed in the solid graphite zone and were used to provide an additional check on neutron flux level. They are located in the VG experimental holes (VG-27, -28, -42, -44, and -56, which are oriented vertically in the graphite reflector and extend to the reactor top) at the same horizontal level. They extend from the top of the reactor structure down to 0.5 ft below the reactor building main floor, for a total length of 24.5 ft (747 cm).

The thermopiles consist of a large number of thermocouple junctions in series, with alternate junctions coated with boron. The total number of thermopiles is not documented in any of the MTR operation reports and could not be found in any drawings. Given that there are five VG experimental holes in which these thermopiles were placed, it is assumed that the alternating junctions that are coated with boron account for 50% of the total number of thermopiles in each experiment hole or 24 boron thermopiles per hole. The total number is 120.

The density of boron is 2.34 g/cm^3.

The thermopiles measure 0.5 in. (1.27 cm) in diameter and are 6 in. (15.24 cm) long. It is assumed that these thermopiles are cylindrical in shape. The thickness of the boron for each thermopile is assumed to be 0.04 in. (0.10 cm).

Thus, the surface area of a cylinder is $2\pi r^2 + 2\pi rh = (2) \times (\pi) \times (0.64\ \text{cm})^2 + (2) \times (\pi)$ $(0.64\ \text{cm}) \times (15.24\ \text{cm}) = 2.6\ \text{cm}^2 + 61.3\ \text{cm}^2 = 64\ \text{cm}^2$.

Surface area of each thermopile (64 cm^2) × thickness of boron per unit (0.1 cm) × total number of thermopiles (120) × density of boron (2.34 g/cm^3) = 1,797 g = 1.8 kg.

A boral[e] curtain is situated between the thermal shield plates for the MTR, which surround the graphite reflector on six sides. It was used to capture neutrons emanating from the graphite reflector. The dimensions of the boral curtain are assumed to coincide with the dimensions of the thermal shield plates. Therefore, it is assumed that the thermal shield plates are peripheral to the graphite reflector, which is 9 ft 4 in. (284 cm) in height and measures 12 ft (366 cm) along one length and 15 ft (457 cm) along the other length. The boral curtain is 0.25 in. (0.64 cm) thick.

Thus, the total volume of the boral curtain equals the volume occupied along the six sides of the thermal shields or (2 × 284 cm × 366 cm × 0.64 cm) + (2 × 284 cm × 457 cm × 0.64 cm) + (2 × 366 cm × 457 cm × 0.64 cm) = 133,048 cm^3 + 166,129 cm^3 + 214,095 cm^3 = 513,270 cm^3.

Boron is assumed to comprise 10% by weight of the boral alloy. The density of boral is assumed to be the density of the boral-aluminum alloy or 2.7 g/cm^3.

The volume of the boral curtain (513,270 cm^3) × density of boral-aluminum alloy (2.7 g/cm^3) × assumed percentage of boron (10%) = 138,580 g = 138 kg.

The estimated total quantity of boron in the boron thermopiles and boral curtain is 140 kg.

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e. Boral is a composite material consisting of boron carbide crystals in aluminum with a cladding of commercially pure aluminum.

6.6 Chromium (total)

Chromium is not known to exist in significant quantities within the MTR facilities other than in an alloyed form, principally as a major alloy in stainless steel components. It is also found in much smaller percentages of carbon steel. For simplifying the calculated inventory estimate, it is assumed:

1. Major components are constructed of 304 stainless steel.
2. Stainless steel (such as in the form of 304 stainless) is composed of, on average, 19% by weight chromium.
3. Carbon steel contains an average percentage of 0.49% chromium.

In general, stainless steel components that were included in the estimate of the chromium inventory consist of the reactor vessel components, external thermal shield, MTR canal liner, pump pits, piping, pumps, resin columns, strainers, and other miscellaneous equipment made from stainless steel (see Table 3).

To a lesser degree, chromium is also an alloy of certain carbon steels, which for the purposes of these calculations is assumed to be 0.49%. Carbon steel components include structural steel, reactor components, tanks and piping, pipe supports, pumps, and motors.

Table 3. Estimated quantity of chromium in the MTR complex.

Component (Stainless Steel)	Quantity (mass) of Component Stainless Steel (kg)	Quantity (mass) of Component Carbon Steel (kg)
Reactor vessel	22,500	—[a]
Reactor components	23,500	282,000
MTR canal liner	10,900	—[a]
Pump pits	3,800	7,300
MTR-604 basement vent scrubber	—[b]	3,700
MTR-604 piping, pumps, resin columns, strainers, and other miscellaneous equipment	10,000	200,000
HB-2 cubicle	9,400	6,000
Primary pipe tunnel piping	—[b]	225,000
Subtotal	80,100	724,000
At 19%, the total mass of chromium in Type 304 stainless steel is 15,220 kg, while its mass in carbon steel at 0.49% equals 3,550 kg.		
Total chromium equals 18,770 kg.		

a. No carbon steel.
b. No stainless steel.

At 19%, the total mass of chromium in stainless steel is the mass of 304 stainless steel (80,100 kg) × percent chromium in 304 stainless steel (19%) = 15,219 kg.

Its mass in carbon steel is mass of carbon steel (724,000 kg) × percent chromium in carbon steel (0.49%) = 3,548 kg.

The total estimated quantity of chromium is the sum of those two values or 18,770 kg.

6.7 Copper and Compounds

Copper is found in numerous industrial materials and components, both in virtually pure forms and alloyed forms. Alloyed forms include brass (copper-zinc-lead alloy), which is assumed for calculating copper quantities to be forging brass—60% copper, 38% zinc, and 2% lead by weight, and bronze (assumed to be commercial bronze), which is 90% copper and 10% tin by weight. The MTR complex contains several components constructed of copper and copper alloys, including copper wiring, copper tubing and piping, switchgear, copper motor/pump rotors and windings, bearings, pressure fittings, gauges and flow indicators, springs, control valves, and various electrical parts, such as switches and relays (see Table 4). Copper is also found in very small fractions in paint chips collected from walls, floors, and facility components but, because of its extremely small quantity, was not included in the overall inventory.

Table 4. Estimated quantity of copper in the MTR complex.

Component	Linear ft, or Weight (kg) of Copper (adjusted for alloyed forms) per Component	Total Equivalent Weight (kg)
Wiring	Various gauge sizes	34,020
Switchgear	Based on total estimated weight	2,270
Tubing and piping	5,000 linear ft	610
Rotor motors (wound and cast)	11.4 kg/component	570
Bearings[a]	2.1 kg	630
Control and relief valves	7 kg/valve	350
Springs	2.3 kg	575
Pressure fittings	0.066 kg	26
Gauges and flow indicators[a]	0.4 kg	60
Total weight of copper		39,110 kg
a. Bearings, gauges, and flow indicators are assumed to be constructed of bronze.		

Other assumptions for calculating the total quantity of copper (within pure and alloyed copper) are presented in Sections 6.7.1 and 6.7.2.

6.7.1 Pure Copper

- Copper wiring is based on a rough order of magnitude estimate[f] of 60,000 lb (27,216 kg) for TRA-603 alone. An additional 25% of copper is added for additional buildings and structures (TRA-604, TRA-661, etc.) yielding a total 75,000 lb (34,020 kg) of copper wiring.

- Copper in switchgear is based on a rough order of magnitude estimate of 5,000 lb (2,270 kg) for TRA-603 and TRA-604.

- A total of 5,000 linear ft of copper piping and tubing, which is considered to have an average nominal size of 0.375 in. (0.95 cm) with the weight per linear ft (30.5 cm) of 0.269 lb (0.12 kg). (Copper.org 2005)

- An estimated total of 50 pump and motor rotors and windings are found in the MTR complex. The average weight of the copper per unit (based on 25-hp output) is assumed to be 11.4 kg. (Brush et al. 2007)

- An estimated 250 springs at 2.3 kg of copper per spring.

6.7.2 Copper Alloys (brass and bronze)

- An estimated 150 gauges and flow indicators (bronze construction), at 0.4 kg of copper (based on 90% copper by weight) per unit.

- An estimated 400 pressure fittings (brass), at 0.066 kg of copper per fitting.

- An estimated 50 brass control and relief valves (brass), at an average weight of copper per valve of 7 kg per valve.

- An estimated 300 bearings (bronze construction), at 2.1 kg of copper per bearing.

The total estimated weight of copper in the MTR complex is 39,110 kg.

6.8 Lead

Most of the lead in the MTR complex is used for radiation shielding. The majority of this lead, in the form of lead bricks, sheets, shot, various forms, pigs, and poured lead, will be removed and disposed of as mixed hazardous waste at an off-Site licensed disposal facility. It is also possible that some of the lead may be suitable for reuse at the INL. The quantity of lead does include, as part of the baseline "Alternative 2" assumption, the lead within the MTR reactor vessel. The reactor vessel is closed at each end by lead-shot-filled stainless steel flat heads (top and bottom plugs), which are integral to the reactor.

The lead in the reactor top plug is calculated as follows:

- The lead present in the top plug is approximately 8 in. thick, and the plug is assumed to have dimensions of the given inside diameter of tank "A," or 71 in.

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f. Conversation August 8, 2005, with Loran Marler, INL estimator for electrical utilities, who indicated that based on the type of building, 60,000 lb was typical for the poundage of copper conduit in ETR-642 and MTR-603.

- A portion of the top plug is occupied by spacers and heavy wall tubes through which the drive rods passed. The volume occupied by these spacers and tubes is estimated to be 10% of the total volume of the space of the plug between the top and bottom plates.

- Thus, the volume of lead within the top plug is πr^2 (h) × 0.9 (fractional volume occupied by lead) = (3,960 $in.^2$) × (8 in.) × 0.9 = 28,500 $in.^3$ = 467,030 cm^3.

- The density of lead is 11.35 g/cm^3.

  Thus, 11.35 g/cm^3 lead × 467,030 cm^3 = 5,300,790 g = 5,300 kg lead in the top plug.

  The lead in the reactor bottom plug is calculated as follows:

- The lead present in the bottom plug is approximately 16 in. thick, and the plug is assumed to have dimensions of the given inside diameter of tank "E," or 54.25 in.

- The void space of the bottom plug is assumed to be completely occupied by lead shielding.

- Thus, the volume of lead within the bottom plug is πr^2 (h) = (2,310 in.) × (16 in.) = 36,960 $in.^3$ = 605,670 cm^3.

- The density of lead is 11.35 g/cm^3.

  Thus, 11.35 g/cm^3 lead × 605,670 cm^3 = 6,874,350 g = 6,870 kg lead in the bottom plug.

  The total quantity of the lead shielding in the MTR reactor vessel is 12,170 kg.

It is possible that not all lead shielding can be removed safely, given that there may be some areas within MTR where conditions prevent adequate worker protection (e.g., high contamination/high radiation areas, confined space) It may also prove impractical to remove other lead that is present in the MTR buildings and structures, including concrete lag shield anchors (contains lead in alloyed form) that are embedded in concrete walls, lead wool pipe packing, and lead packing found in the pipe joints of cast iron piping.

There are several types of concrete wall anchors in the MTR complex. A conservative estimate of those constructed of zinc alloyed with antimony and lead is 500. The average lead anchor (also referred to as lag shield anchor) is assumed to be of medium duty, 0.5 in. in diameter, 3.0 in. long, and constructed of metals with the following percentages: zinc (75%) alloyed with antimonial lead (2% antimony, 23% lead). (Concrete Fastening Systems 2007)

The weight of a typical lag shield anchor (refer to Section 6.2) is 60 g.

Thus, the total number of anchors (500) × typical weight of a lag shield anchor (0.060 kg) × percent lead in each anchor (23%) = 6.9 kg lead in lag shield anchors.

Other lead includes lead wool and lead packing. The estimated quantity of these lead forms, which is a rough order of magnitude estimate due to the inherent difficulty in attempting to quantify such amounts prior to actual decommissioning activities, is 15 kg.

Lead is present in brass components at an assumed average percentage of 2%. The total estimated weight of brass fixtures and components in the MTR complex is 628 kg. Thus, the total weight of lead in these items is 12.5 kg.

In painted surfaces, lead was detected at an average concentration of 5,197 mg/kg in the painted wall and floor surfaces in the subgrade levels. The total quantity of lead in paint was calculated as follows:

- Surface area of areas considered: 107,270 ft^2.
- Lead concentration (average of gray and white paints sampled): 5,197 mg/kg.
- Weight of lead in paint: total surface area (107,270 ft^2) × average weight of paint/ft^2 (5 g/ft^2) = 536,350 g × 0.001 kg/g = 536.4 kg paint × average lead concentration (5,147 mg/kg lead) = 2,761 g = 2.8 kg lead.

The total estimated quantity of lead to be left in the MTR complex, summed from lead quantities reported for the top and bottom reactor vessel plugs, lag shield anchors, lead wool and lead pipe packing, brass, and paint is 12,205 kg.

6.9 Manganese and Compounds

Manganese is assumed to be present only in alloyed form. The quantity of manganese has been calculated based on an assumed average percentage in 304 stainless steel of 2% and an average percentage of 0.81% in carbon steel components.

Based on the calculated estimate quantity for stainless steel, the quantity of manganese is derived by multiplying the mass of 304 stainless steel by the given alloyed percentage typical of manganese in 304 stainless steel, yielding (80,100 kg) × (2%) = 1,600 kg.

Its mass in carbon steel is the mass of carbon steel (724,000 kg) × percent manganese in carbon steel (0.81%) = 5,860 kg.

The total estimated quantity of manganese in the MTR complex is the sum of the manganese in stainless steel and carbon steel, or 7,460 kg.

6.10 Nickel

Nickel is present in MTR as a significant alloy of stainless steel of 10% (under the assumption that these components are constructed from 304 stainless steel) and a much smaller average percentage of 0.43% in carbon steel components. Nickel is not known to have been used in shim and regulating rods.

Based on the calculated estimate quantity for stainless steel, the quantity of nickel is derived by multiplying the mass of 304 stainless steel in the MTR complex by the given alloyed percentage typical of nickel in 304 stainless steel, which yields: (80,100 kg) × (10%) = 8,010 kg.

Its mass in carbon steel is the mass of carbon steel (724,000 kg) × percent nickel in carbon steel (0.43%) = 3,110 kg.

The total estimated quantity of nickel in the MTR complex is 11,120 kg.

6.11 Silver and Compounds

Silver is an element that is commonly used in electronic equipment, such as electric conductors (bus bars), brazing alloys, and electrical contacts. It is most prevalent (as far as quantifiable amounts) in electrical contacts. Typical quantities are 8–10 oz (227–283 g) for large-size contacts, and 0.5–1 oz (15–30 g) for small-size contacts.[g]

A rough order of magnitude estimate for the total number of electrical contacts within motor control centers and other electrical control panels within the MTR complex is 500. Of these, 75% are assumed to be small-size contacts, and 25% large-size contacts. These contacts are assumed to be pure silver.

Small contacts:

- Number of contacts (375) × average weight of contact (17.5 g) = 6,562.5 g = 6.5 kg.

Large contacts:

- Number of contacts (125) × average weight of contact (255 g) = 31,875 g = 31.9 kg.

The total amount of silver in the form of electrical contacts is 40 kg.

6.12 Tin

Tin is present as an alloy of bronze and as a very small fractional percentage of painted coatings (incidental ingredient of paints sampled from walls and floors in the MTR facility). The calculated weight of tin in paint was considered negligible and is not included as part of the overall quantity of tin.

Tin is a component of commercial bronze, which is used in components such as water gauges, flow indicators, bearings, valves, and drain cocks. Based on literature found under Evans (2007a), commercial bronze is typically composed of 90% copper and 10% tin. The total estimated weight of bronze is based on those components identified for the calculation of copper in the MTR complex (see Section 6.7). Given that the quantity of bronze is estimated at 757.5 kg, the quantity of tin is 10% of that weight, or 75.8 kg.

The total estimated quantity of tin is 80 kg.

6.13 Zinc

Zinc is present as an alloy of brass and as a small percentage of painted coatings (as zinc chromate, a pigment used in paint formulations) sampled from walls and floors in the ETR facility (see Section 6, first and second paragraphs).

Zinc is a component of commercial brass, which is used in components such as valves and pressure fittings. Based on literature found under Evans (2007b), forging brass is typically composed of 60% copper, 38% zinc, and 2% lead. Thus, the total estimated weight of brass is based on those components

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g. Conversation with Loran Marler, INL estimator for electrical utilities, August 8, 2005, who indicated that these are typical values for electrical contacts that contain silver.

identified for the calculation of copper in the MTR complex (see Section 6.7). The total estimated weight of brass components (considered for this source term) in the MTR complex is 628 kg.

Thus, the total weigh of brass components (628 kg) × percentage of zinc in brass (38%) = 239 kg.

Galvanized conduit piping is zinc electroplated for corrosion resistance (azom.com 2007). The amount of zinc in this form assumes the following:

- The conduit piping has an average inside diameter of 3 in. (7.62 cm).
- The length of the conduit is assumed to be 15,000 linear ft (457,200 cm).
- The type of plating on electrical conduit is continuous electroplating, which produces a thickness of the zinc coating up to 25 microns (0.0025 cm). The coating is on the exterior of the conduit only.
- The coating is assumed to be 100% zinc, which has a density of 7.14 g/cm^3.
- Surface area of a conduit (cylinder) is 2 πrh = (2) × (π) × (3.81 cm) × (457,200 cm) = 10,944,880 cm^2.

Thus, the mass of the zinc = surface area of the conduit (10,944,880 cm^2) × thickness of the coating (0.0025 cm) × density of the zinc (7.14 g/cm^3) = 195,366 g = 195 kg zinc.

The weight of a typical lag shield anchor is 60 g. There are an estimated 500 lag anchors composed of a zinc-antimonial lead alloy.

Thus, the number of anchors (500) × mass of a typical anchor (0.060 kg) × percentage of zinc in each anchor (0.75) = 22.5 kg zinc in lag shield anchors.

In painted surfaces, zinc was detected at an average concentration of 5,147 mg/kg in the painted wall and floor surfaces. The total quantity of zinc in paint was calculated as follows:

- Surface area of areas considered: 107,270 ft^2.
- Zinc concentration (average of gray and white paints sampled): 5,147 mg/kg.
- Weight of zinc in paint: total surface area (107,270 ft^2) × average weight of paint/ft^2 (5 g/ft^2) = 536,350 g × 0.001 kg/g = 536.4 kg paint × average zinc concentration (5,147 mg/kg zinc) = 2,761 g, or 2.8 kg zinc.
- The estimated weight of zinc as an alloy of brass components is 239 kg.
- The estimated weight of zinc as zinc plating on galvanized conduit is 195 kg.
- The estimated weight of zinc contained in lag shield anchors is 22.5 kg.
- The weight of zinc in paint is 2.8 kg.
- The total weight of all zinc in the MTR complex is 455 kg.

7. SUMMARY OF CHEMICAL CONSTITUENT QUANTITIES IN THE MTR COMPLEX

Table 5 summarizes the estimated quantities of chemical constituents in the portions of the MTR complex that are projected to be left in place per the end state scenario of “Alternative 2–Grouting Reactor Vessels in Place” that is described in Section 4.1.

Table 5. Summary of chemical constituent quantities in the MTR complex.

Chemical Constituent	Location(s)	Use/Form	Quantity (kg)
Organics			
PCBs (Aroclor 1254 and 1260)	Painted concrete and metal surfaces	Additive to paints	0.009
Inorganics			
Aluminum	MTR reactor vessel	Reactor tanks, reactor components	12,560
Antimony	Concrete walls and floors	Minor alloy (by weight percent) used in concrete wall lag shield anchors	0.6
Barium and compounds	High-density concrete used for biological shielding	Additive for heavy concrete for nuclear shielding (cubicle walls), paint pigment	1,443,604
Beryllium and compounds	MTR reactor core	Neutron reflector in the reactor core	2,150
Boron	Boron thermopiles and boral curtain	Neutron absorber in boron thermopiles and boral curtain	140
Chromium	Piping and other operations components throughout MTR complex	Piping, vessels, and other components constructed of stainless steel	18,770
Copper and compounds	MTR complex	Wiring, tubing, rotors, bearings, brass and bronze components, electrical equipment	39,110
Lead	Wall and floor anchors, piping, reactor vessel, other various locations where shielding is required	Shielding, alloy of concrete wall lag shield anchors, pipe packing, brass alloy, paint	12,205
Manganese and compounds	Piping and other operations components throughout MTR complex	Metal alloy found in piping, vessels, and other components constructed of stainless steel	7,460
Nickel	Piping and other operations components throughout MTR complex	Metal alloy found in piping, vessels, and other components constructed of stainless steel	11,120
Silver and compounds	Electrical control panels	Electrical contacts	40
Tin	MTR complex	Alloy of bronze (used in gauges, bearings, and flow indicators)	80
Zinc	MTR complex	Significant alloy of brass and lag shield anchors, galvanized coatings	455

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