

***Defense-Related Waste  
Determination for Legacy  
Transuranic Waste at the  
Idaho National Laboratory  
Test Reactor Area Warm and  
Hot Waste Systems***

**Idaho  
Completion  
Project**

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# **Defense-Related Waste Determination for Legacy Transuranic Waste at the Idaho National Laboratory Test Reactor Area Warm and Hot Waste Systems**

April 2005

**Idaho Completion Project  
Idaho Falls, Idaho 83415**

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## **ABSTRACT**

During Idaho Completion Project environmental management activities at the Test Reactor Area, specifically the remediation of the TRA-630 Catch Tank System under the provisions of the Voluntary Consent Order, it was discovered that tank system components are contaminated with transuranic isotopes such that the components, upon removal, will be considered to be transuranic waste. It is likely that similar transuranic contamination will be encountered during subsequent remediation work of the warm and hot waste systems at the Test Reactor Area. This report identifies the likely sources of transuranic isotopes in the Test Reactor Area warm and hot waste systems as being the experimental loop facilities located in the legacy test reactors at the facility and the Hot Cell Building. Due to the prevalence of defense-related research conducted in the legacy test reactors and the Hot Cell Building, particularly for the Naval Reactors Program research and development activities, it is the conclusion of this determination that this transuranic waste is in part defense related and qualifies for disposition at the Waste Isolation Pilot Plant.



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## ACRONYMS

AEC	Atomic Energy Commission
AEC-ID	Idaho Operations Office of the Atomic Energy Commission
AGN	Aerojet General Nucleonics
AGS	Annulus Gas System
ANL	Argonne National Laboratories
ANP	aircraft nuclear propulsion
ATR	Advanced Test Reactor
BAPL	Bettis Atomic Power Laboratory
CTS	Catch Tank System
D&D	Decontamination and Dismantlement
ETR	Engineering Test Reactor
FFA/CO	Federal Facility Agreement and Consent Order
GCRE	Gas-Cooled Reactor Experiment
GE	General Electric
GEANP	General Electric Aircraft Nuclear Propulsion
GEEL	General Electric Experimental Loops
GEFP	General Electric Flight Propulsion Project
GEH	General Electric Company Hanford Laboratories
HED	hot experimental drain
HWMA	Hazardous Waste Management Act
INEEL	Idaho National Engineering and Environmental Laboratory
INL	Idaho National Laboratory
KAPL	Knolls Atomic Power Laboratory
ML-1	Mobile Low-Power Reactor
MTR	Materials Test Reactor

MW	megawatt
NR	Naval Reactor
NRTS	National Reactor Testing Station
PAED	Phillips Petroleum Company Atomic Energy Division
RCRA	Resource Conservation and Recovery Act
SEM	Scanning Electron Microscope
STR	submarine thermal reactor
TMI	Three Mile Island
TRA	Test Reactor Area
TRU	transuranic
USC	United States Code
VCO	Voluntary Consent Order
WAPD	Westinghouse Atomic Power Department
WIPP	Waste Isolation Pilot Plant

# Defense-Related Waste Determination for Legacy Transuranic Waste at the Idaho National Laboratory Test Reactor Area Warm and Hot Waste Systems

## 1. INTRODUCTION

This defense-related waste determination has been prepared to address transuranic waste at the Test Reactor Area (TRA) at the Idaho National Laboratory (INL).<sup>a</sup> Remediation work at TRA will be required to close, decontaminate, dismantle, and disposition legacy facilities, which include the Materials Test Reactor (MTR), the Engineering Test Reactor (ETR), and associated waste management and support facilities. The cleanup activities at TRA in the coming years will fall primarily to three programs: Voluntary Consent Order (VCO) (DEQ 2000), Decontamination and Dismantlement (D&D), and Federal Facility Agreement and Consent Order (FFA/CO) (DOE-ID 1991). Most of the legacy waste management systems at TRA are included in the VCO. The VCO is an agreement between the U.S. Department of Energy and the State of Idaho to address potential Hazardous Waste Management Act (HWMA) (State of Idaho 1983)/Resource Conservation and Recovery Act (RCRA) (42 United States Code [USC] 6901 et seq., 1976) noncompliances at the INL. The VCO Action Plan identifies those specific items that require resolution to achieve compliance with HWMA/RCRA. The waste management systems at TRA fall into one of the following VCO Action Plans: (1) SITE-TANK-005, which addresses tank systems with inadequate hazardous waste determinations; and (2) VCO-5.8.d, which addresses the TRA-630 Catch Tank System (CTS), which is known to have contained HWMA/RCRA waste and requires closure under HWMA/RCRA.

While the VCO Service Team will address HWMA/RCRA closure of hazardous tank systems at TRA, the remainder of the legacy structures and buildings at the facility for which HWMA/RCRA closure is not required will be addressed under the Idaho Completion Project D&D Service Team.

The first portion of the TRA warm and hot waste systems to be addressed was the TRA-630 CTS. The TRA-630 CTS was sampled in 1985, 1996, and 1999 (results in Appendix B) to address concerns about hazardous waste management. It was determined that the CTS was, in fact, managing characteristic hazardous waste. Consequently, the TRA-630 CTS was placed into Action Plan VCO-5.8.d, which required submittal of a HWMA/RCRA closure plan for the tank system. While transuranic isotopes were detected in the tanks during the 1999 sampling, the levels were such that the waste within the tanks would not be considered transuranic (TRU)<sup>b</sup> and the scope of pending waste management problems was yet to be realized. The HWMA/RCRA closure plan (DOE-ID 2001) for the tank system was submitted and subsequently approved by the State of Idaho Department of Environmental Quality in 2001. Closure activities for the tank system were initially focused on retrieval and disposition of waste from the tanks, which was completed in 2003. Concurrent with tank remediation activities, work was initiated to characterize influent and effluent piping from the tank system. Characterization work consisted of video inspections and sampling of various pipes located in the courtyard near the CTS. It was determined in late 2003 that much of the piping, particularly CTS influent piping from the Hot Cell Building (TRA-632), contained transuranic isotopes such that the piping, if removed, would be considered transuranic waste. Furthermore, the radiation levels associated with much of this piping may result in the waste being considered remote handled. As a result, the HWMA/RCRA closure plan (DOE-ID 2001) is undergoing

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a. On February 1, 2005, the Idaho National Engineering and Environmental Laboratory contract split, forming INEL, which implements its continuing research mission, and Idaho Completion Project, which carries out the site's cleanup responsibilities.

b. The acronym TRU is used when the waste is greater than 100 nCi/g transuranic isotopes and greater than a 20-year half-life.

revision to defer those portions of the tank system that likely contain TRU waste to allow time to establish waste disposition pathways. This defense-related waste determination is the first step towards establishing a waste disposition pathway for TRA-630 CTS closure-generated waste at the Waste Isolation Pilot Plant (WIPP) in New Mexico.

The discovery of transuranic waste in piping associated with the TRA-630 CTS HWMA/RCRA closure has given rise to concerns about upcoming Environmental Management work at TRA. It is suspected that the problem of TRU contamination in the TRA waste management systems may not be isolated to the CTS. Preliminary samples taken from the TRA-613 Hot Waste Storage Tank System indicate that transuranic radionuclides may be contained in these tanks as well. It follows that piping connecting the two systems may also be similarly contaminated. While it is known that components of the TRA-630 CTS are contaminated with TRU waste, it is likely that future remediation work will encounter similar materials. As a result, an effort has been initiated to identify the source of transuranic waste at the TRA as a whole, and to determine if this waste is defense related.

The results of the study to assess the source of transuranic waste at TRA are delineated in this technical report. While the research and development mission at TRA since 1950 has resulted in a myriad of sources of transuranic waste, it has been determined that the waste is in part defense related, and as such, is eligible for disposition to WIPP.

## **2. WIPP ACCEPTANCE CRITERIA**

Waste acceptance criteria for the WIPP are detailed in *Contact-Handled Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (DOE-CBFO 2004). The WIPP project is authorized under Section 213 of the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (Public Law 96-174, 1979). The purpose of the WIPP is to provide safe disposal of radioactive waste materials generated by atomic energy defense activities (Public Law 102-579, 1992). Therefore, by law, WIPP can only accept radioactive waste generated by atomic energy defense activities of the United States.

U.S. Department of Energy sites must determine that each waste stream to be disposed of at WIPP is defense-related TRU waste. Because the TRA hot waste system essentially served as a common waste management system for all three test reactors (MTR, ETR, and the Advanced Test Reactor [ATR]) at TRA, the disposition of legacy contamination contained within this system is considered, for purposes of this evaluation, to be a single waste stream.

### **2.1 Definition of Defense Waste**

Under WIPP requirements, TRU waste is considered a defense waste, eligible for disposal at the WIPP facility, if it has been generated in whole or in part by one or more of the following functions (42 United States Code [USC] 2011 et seq., 1954; 42 USC 10101, 1983):

- Naval reactors development
- Weapons activities, including defense inertial confinement fusion
- Verification and control technology
- Defense nuclear materials productions

- Defense nuclear waste and materials by-products management
- Defense nuclear materials security and safeguards and security investigations
- Defense research and development.

### 3. TRANSURANIC WASTE GENERATION AT TRA

Historically, three test reactors have operated at TRA. The first test reactor in the Atomic Energy Commission (AEC) complex was the MTR, constructed in 1952. Most of the TRA hot waste system was originally constructed to manage hot waste from the MTR and was later retro-fitted to manage hot waste from subsequent test reactors. The successful operation of the MTR quickly led to construction of the ETR, which was built in 1957 to provide expanded capabilities with regard to increased neutron flux within the reactor core and provide more room for experimental loop-type experiments within the core. Finally, the ATR was constructed to further expand and improve test reactor capabilities at the facility. As the scope of this study is to assess the source of TRU waste potentially contained within legacy waste systems, this study focuses on the former two reactors, the MTR and ETR.

Transuranic waste was generated at the INL primarily as a result of irradiation of nuclear fuel, evaluation, and processing. Therefore, this study focuses on instances of nuclear fuel irradiation at TRA in the legacy test reactors. Both the MTR and ETR were designed, in part, expressly for the purpose of irradiation of nuclear fuel elements.

#### 3.1 Materials Testing Reactor

The MTR was constructed with the purpose of producing neutrons for use in various experimental programs, testing reactor components, and studying radiation damage to materials. Completed in 1952, MTR was “the first reactor to be built solely for testing materials to be used in other reactors” (NRTS, undated[a]). The MTR was a water-cooled and moderated test reactor. The reactor was used to supply a high neutron flux in support of reactor development programs subjecting potential nuclear fuels and structural materials to irradiation (Stacy 2000). “Designed primarily for testing materials and components in high intensity radiation fields, the MTR contain[ed] approximately 100 experimental irradiation spaces or holes” (NRTS 1959). The reactor was also equipped with horizontal “beam holes” that were used for basic physics and cross-section research (Stacy 2000).

By March 1960, 135 fuel charges had been satisfactorily completed. The reactor was shut down in August 1970. During its operation, numerous experiment facilities were used to support the 40-megawatt (MW) light water reactor (NRTS, undated[a]). Several facilities within the MTR were specifically designed to accommodate defense-related work, including the Knolls Atomic Power Laboratory (KAPL) L-42 and the Westinghouse Atomic Power Division (WAPD) VH-3. Knolls Atomic Power Laboratory is a government-owned and contractor-operated facility supporting research for the United States Naval Nuclear Propulsion Program, and WAPD was the contractor for Bettis Atomic Power Laboratory (BAPL), which is also a research facility supporting United States Naval Nuclear Propulsion Program.

The submarine thermal reactor (STR), later named S1W, was the first reactor for which the MTR assisted (Stacy 2000). Westinghouse was contracted “to develop, design and construct, test and operate S1W, which was a land-based prototype water-cooled reactor power plant suitable for submarine propulsion” (BAPL 2005a). The STR was located at the Naval Reactors Facility and was the prototype for the *USS Nautilus* (Stacy 2000). Final shutdown of the S1W prototype occurred in October 1989.

### 3.1.1 MTR Experiment Facilities

The MTR was constructed primarily for capsule type experiments, with experimental penetrations for capsule experiments in and surrounding the core accessed from the reactor top head. A capsule is a container, usually made of aluminum, about 1 in. in diameter and 6 in. in length. In its simplest form, the capsule has openings to allow the reactor cooling water to flow past the sample. Most capsules are sealed and used for fuels or corrosive materials. Within the capsules, the samples are submerged in a heat transfer medium (e.g., liquid metal if heat must be conducted away from the sample and an inert gas as insulator if the sample must be run hot). The capsules are stacked in tubular aluminum holders called baskets, which fit into vertical holes in the reactor core or reflectors (NRTS, undated[a]).

According to *In-Tank Irradiation Facilities at the Test Reactor Area*, “the majority of experiments irradiated at TRA [were] capsule experiments because of the ease of construction and handling. The capsule irradiations [were] primarily directed toward fuel element and control rod development, radiation damage studies on materials of construction, and radioisotope production” (Ackaret and Richardson 1966). “Large numbers of fuel samples [were] tested in capsules before a fuel design was perfected enough to justify loop tests,” which were more expensive (NRTS, undated[b]).

Fission breaks<sup>c</sup> in capsule-type samples ordinarily did not present particularly difficult handling problems. Usually the bulk of the radioactivity (fission products and transuranic isotopes resulting from fuel breach) had been swept out with reactor cooling water and the defective capsule could be handled normally (NRTS 1959). In general, fission breaks in capsules would contaminate the reactor coolant water, which would subsequently be handled as warm waste. In the event of a fission break contaminating the reactor core primary coolant, whether from an experimental capsule or in the MTR core proper, the coolant would typically be dumped to the retention basin as warm waste (Dykes et al. 1965).

Capsule-type experiments are limited, by their very nature, due to the fact that the capsule, whether positioned in or adjacent to the reactor core, is cooled by the reactor primary coolant. It was quickly recognized during MTR operations that it would be beneficial to develop experimental loops to provide experimental control of coolant temperature and pressure independent of the reactor cooling water. Consequently, the MTR was retro-fitted to operate a variety of experimental loops during its operating life. The first high-pressure, high-temperature water loop was ANL-2, located in HB-2 (Horizontal Beam Hole #2), in January 1954.

The main purpose of loops was to test fuel element samples under conditions similar to those of the nuclear reactor being designed. “At the time the MTR was built, no one knew the effect of putting loops right in the core, so the major irradiation facilities were designed as beam holes that went horizontally through the shielding to the core” (NRTS, undated[a]). Loops are typically made of Zircaloy or stainless steel (NRTS, undated[b]), making it possible for neutrons from the reactor to easily flow through the loop piping material and bombard the samples. “In the neutron bombardment from the MTR core, the samples [took] part in the chain reaction as if they were in a full-sized reactor of their own” (NRTS, undated[a]).

Experimental loops are closed systems in which a liquid circulates through the piping at flows, temperatures, and pressures that are independent of the rest of the reactor. Experiments at the MTR typically required different temperatures and pressures than the conditions at which the reactor cores operated. The equipment for each loop included pumps, pressurizers, heaters, heat exchangers, and instrument panels for environmental control and monitoring of the experiment.

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c. A fission break is the breach of a fuel element, either in an experiment loop or the reactor core, resulting in an increase in radiation (e.g., fission products) in the coolant, which generally results in a reactor scram. Scram is defined as the “sudden shutting down of a nuclear reactor...when a predetermined neutron flux or other dangerous condition occurs” (Stacy 2000).

The samples run in the experiment loops often consisted of fuel for nuclear reactor design. “With the loop acting as a pilot-scale reactor, the [experiments compared] fuel designs to see which [stood] the highest rate of burnup, which [had] the most resistance to corrosion, and which [stood] up under rapid coolant flow” (NRTS, undated[b]).

When fission breaks occurred in experimental loops, the fission products, fuel, and transuranic isotopes did not leak to the reactor coolant, as in capsule-type fission breaks. Because the experimental loop operated as a closed system within the reactor core, a fission break in an experimental loop resulted in loop coolant that was highly contaminated. The loop coolant must be handled as “hot waste” and was normally segregated from warm waste at TRA.

### **3.1.2 MTR Hot Waste System**

Capsule-type fission breaks resulted in moderately contaminated reactor core primary coolant, which was typically handled as warm waste. Fission breaks in experimental loops resulted in low volumes of highly radioactive wastewater that presented unique handling and management problems. In the publication brochure, “Materials Testing Reactor,” the National Reactor Testing Station (NRTS) identified “a type of test which create[d] cleanup problems [was] the testing of fuel elements with intentional defects in the cladding. These tests [were] aimed at determining how serious a defect must be to cause fuel element failure and how much radioactivity [was] spread through the coolant if failure [did] occur” (NRTS, undated[a]).

As noted, the MTR was not originally designed with the capability to manage contaminated loop coolant. A diagram showing the TRA hot waste system (excluding the ATR systems) is shown in Figure 1. A partial facility hot waste piping plan showing the location of various hot waste management tanks and piping is presented in Appendix A. Prior to 1960, hot waste in the MTR was managed in the reactor hot drain tank (Tank # 603-M-314), which is located in a vault beneath the basement floor of the MTR building (TRA-603) along the west wall of the building. The tank was configured to manage hot waste from a variety of sources throughout the reactor building. The reactor hot drain tank discharged, via a 2-in. stainless steel pipe, to the TRA-630 CTS, located below ground outside to the southwest of the MTR building.

The catch tanks were used to manage radioactive wastewater from various sources in the MTR complex. Inputs to the catch tanks, as originally configured, included the MTR hot drain tank, a vent scrubber located in the basement of the Reactor Wing (TRA-604), the radiochemistry laboratories located in TRA-604 and the Alpha Wing (TRA-661), and the Hot Cell Building (TRA-632). The vent scrubber was used to neutralize acidic radioactive exhaust gases from TRA-632 and TRA-604. Scrubber blowdown was discharged to the CTS. The catch tanks were used to manage both warm and hot waste originating from the MTR complex. Each time a tank was filled, the contents would be sampled to determine if the waste was warm or hot waste. Warm waste was discharged from the catch tanks to the retention basin (TRA-712) and from there to the leaching pond (TRA-758). Hot waste was transferred to the TRA-613 Hot Waste Storage Tank System. Accumulated hot waste was ultimately transferred, via tanker truck, to INTEC (then the Idaho Chemical Processing Plant). The hot waste storage tanks (TRA-713) consist of two 10,000-gal stainless steel underground storage tanks and one 9,000-gal black iron, glass-lined tank. Originally, four tanks made up TRA-713; however, one of the tanks leaked and was removed in 1970. The tanks were put into operation to facilitate the processing of hot liquid waste from TRA facilities, including the MTR and ETR. Hot waste collected in the TRA-713 tanks was typically transferred to the Tank Truck Loading Station (TRA-761) (Rolfe and Wills 1984).

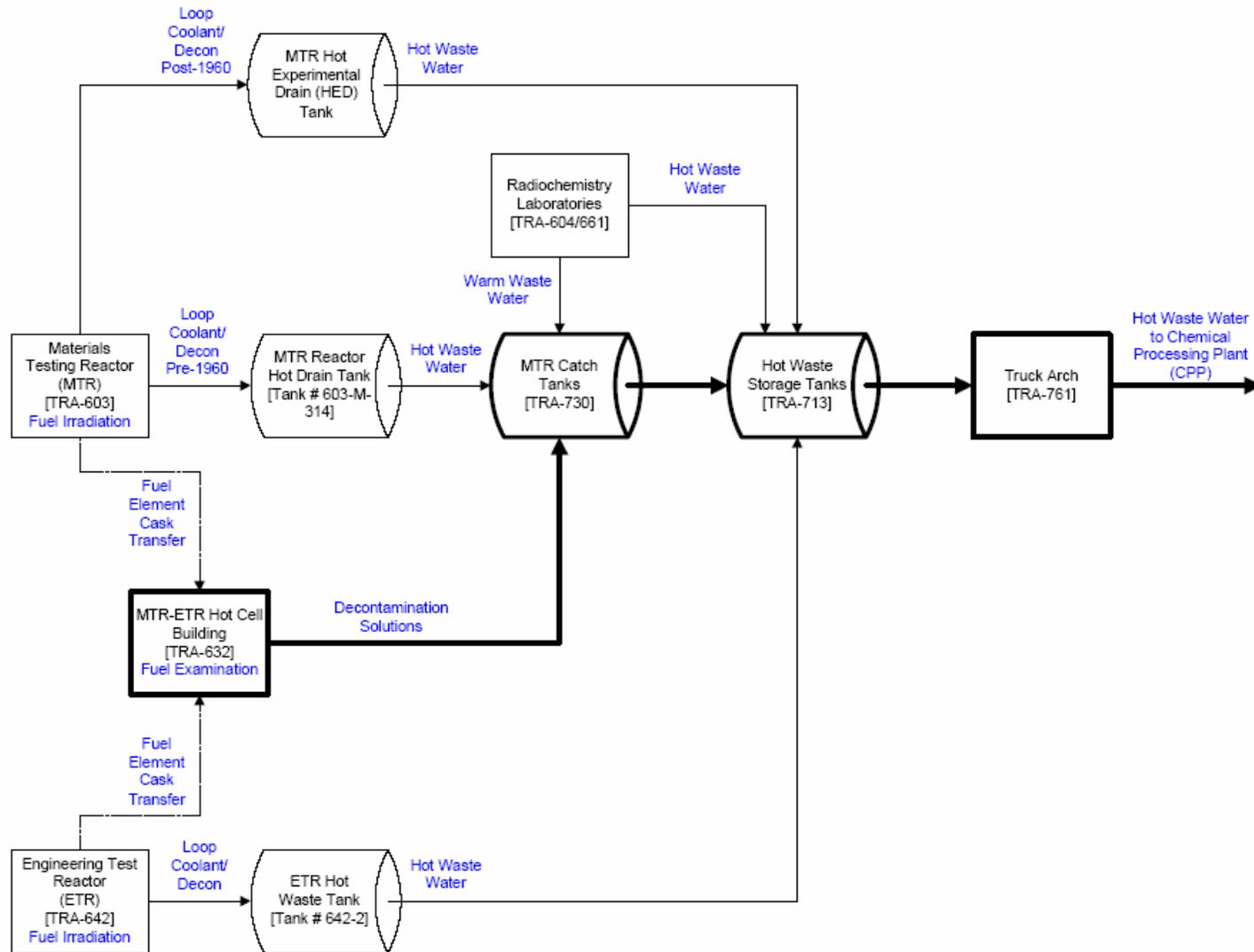


Figure 1. Diagram of the TRA hot waste system (excludes the ATR systems).

With the increasing use of loop-type experiments in the MTR, it became necessary to construct a dedicated system to manage loop coolant contaminated as a result of a fission break that bypassed the original MTR hot waste system. In 1960, the hot experimental drain (HED) tank was constructed in a vault located in the southeast stairwell of the MTR building (Rolfe and Wills 1984). The HED accumulation tank is a 600-gal stainless steel tank that was installed in 1960 to dispose of highly radioactive effluent from the MTR experimental loops through cubicle drains. “Under certain conditions, such as when a major fission break occurred in a loop or when the loop was being decontaminated, waste liquids were disposed of through the HED system” (INEEL 2001). The HED tank was equipped with a direct discharge line to the TRA-713 hot waste storage tanks, bypassing the TRA-730 catch tanks and the interfaces with the warm waste system. Contaminated loop coolant was managed (from 1960 to 1970) in the HED tank and was transferred directly to the TRA-713 tanks for subsequent transfer to INTEC.

## **3.2 Engineering Test Reactor**

In the 1950s, the usefulness of the MTR was demonstrated and a demand arose for more testing facilities with higher neutron fluxes and space for larger samples. To meet this demand, the ETR was constructed, and in 1957, construction was completed (NRTS, undated[b]). The ETR’s core was built larger and the neutron fluxes were four times that of the MTR (Stacy 2000). In addition, the power level attained at the ETR was 175 MW compared to 40 MW at the MTR. The irradiation facilities in the ETR are located inside the reactor tank, near the region of highest flux. “The spaces for experiments [were] located within the core, within the beryllium reflector, and within an aluminum region which surround[ed] the beryllium” (NRTS, undated[b]). The ETR was operated entirely on highly enriched uranium (93% U-235) (NRTS, undated[b]). “The ETR...contributed immeasurably to the American nuclear program: many...power, propulsion, and experimental reactors have been speeded through the design stages by experiments in the ETR” (NRTS, undated[b]). The reactor was used for materials research primarily for the Naval Reactors (NR) Programs (INEL 1991). The ETR has been inactive since January 1982 (INEEL 2001).

### **3.2.1 ETR Experiment Facilities**

In addition to significantly higher neutron flux than the MTR, the ETR was specifically designed with additional space and waste handling and decontamination capabilities to support loop-type experiments. While the ETR was equipped with expanded facilities for capsule-type experiments, the expanded loop facilities established the ETR as the next generation in test reactor development. Loop facilities included 17 loop positions at the ETR, “ten 3- by 3-inch openings for loops, five 6- by 6-inch openings, one 6- by 9-inch opening, and one 9- by 9-inch opening, through the core or surrounding region” (NRTS, undated[b]). One type of experimental loop at the ETR is the “through” loop, which enters near the top of the tank, passes down through the space provided in core or reflector, and exits through the bottom head of the tank. Another type of loop is the “reentrant” loop, which enters near the top of the tank, passes through the core, and leaves the tank where it entered (NRTS, undated[b]).

### **3.2.2 ETR Experimental Waste Systems**

As with MTR, the operation of test loops in which fission breaks routinely occurred required specific management facilities for hot waste. During ETR operations, waste resulting from fission breaks and subsequent loop decontamination efforts was transferred to the ETR hot waste tank. Loop coolant contaminated with fission products and transuranic isotopes was transferred from loop cubicles, located in the basement of the reactor building to the ETR hot waste tank. Part of the waste came from “tests...devised with deliberate ruptures in the cladding to determine the seriousness of a fuel element failure with spread of fission products to the coolant” (NRTS, undated[b]). The experimental loops were chemically decontaminated several times, releasing the fluid and irradiated sample from fission breaks in

the loop to the drain. From the ETR hot waste tank, the hot waste was transferred to the hot waste storage tanks (TRA-713) (see Figures 1 and A-1 [Appendix A]).

The ETR hot waste system routed cubicle experiment leakage, contaminated loop coolant, and loop decontamination solutions to a 500-gal hot waste tank (TRA-642-2). This hot waste tank was located in a vault beneath the floor on the north side of the ETR Building basement. Numerous hot drains are located on the reactor floors. Effluent from the hot waste tank was typically pumped to the TRA-713 hot waste storage tanks (INEEL 2001).

### 3.3 MTR/ETR Hot Cell Building

The MTR/ETR Hot Cell Building primarily supported the processing of materials irradiated at the nuclear reactors (MTR, ETR, and ATR) and continues to support testing at the ATR. The MTR/ETR Hot Cell Building (TRA-632), located between the ETR and MTR buildings at TRA, consists of three separate shielded hot cells with associated offices and service areas. “Hot Cell 1 was constructed in 1952, and Hot Cells 2 and 3 were added in a facility expansion completed in 1960. A distance of at least 10 meters exists from each hot cell to the next. Operations in any one hot cell are physically independent of those in the other two hot cells” (SAR-204, 2002).

The hot cell facility’s design “allows for performance of a small number of operations with relatively few personnel, little interaction between hot cells, and few operating systems” (SAR-204, 2002). Having received irradiated samples (e.g., nuclear fuels) from the three nuclear reactors, the MTR/ETR Hot Cell Building accommodates remote-manipulated operations, including disassembly and reassembly of plugs and capsules used to expose experiments to radiation in the reactor and removal of irradiated components for shipment to experiments’ home laboratories. “Capabilities include, but are not limited to, assembly and disassembly, storage, inspection, and examination of radioactive or other hazardous materials. Nuclear research and development activities use processes such as gamma scanning. Additional analysis techniques include photography and optical metallography” (SAR-204, 2002). Using remote manipulators, “any common machining operation can be done remotely within the cells, including lathe work, milling, drilling, grinding, and cutting” (NRTS, undated[a]). “Machining equipment, including lathes, power saws, a grinder, and welders, are available for the preparation or processing of materials and for the assembly of pre-irradiated reactor experiments” (SAR-204, 2002).

Many hot cell logbooks from the periods of operation of the MTR and ETR note that samples were etched. The backing on the sample was etched with a sample identification number using small etching tools. This etching was used for identification purposes and sensitization prior to examination.

While each cell has the capability to be used for any hot cell operation (with the exception of metallography and Scanning Electron Microscope [SEM] scanning), logbooks indicate each cell may have been used for separate functions as samples were often transferred from one hot cell to another. Regularly installed equipment in each of the hot cells includes “master-slave manipulators, periscopes, mechanical lifting devices, and sundry equipment required to support isotope processing” (SAR-204, 2002).

According to logbooks, Hot Cell #1 was primarily used as the transfer (shipping/receiving) cell with fabrication and milling operations. Disassembly, reassembly, and identification were also performed in this cell.

Hot Cell #2 contained a metallographic cave and scanning electron microscope for examining the physical and mechanical properties of the irradiated material. “A metallographic cave is located on the east wall of [Hot Cell #2]. A SEM cave is located on the west wall of the hot cell. The metallograph

allows visual examination of specimens under magnification to approximately 2,000 power. The SEM provides for examining specimens at a maximum resolution of approximately 1  $\mu\text{m}$ " (SAR-204, 2002). In addition to metallography and scanning, etching was also performed in Hot Cell #2.

Logbooks indicate that Hot Cells #1 and #3 were used for similar functions, such as unloading, milling, disassembly, and reassembly. Hot Cell #3 was also used for gross scanning.

Specific abrasive or physical activities, such as grinding, were performed on the irradiated samples at the hot cells, causing cell contamination due to the very nature of the operation. After samples underwent such processing, the hot cells required decontamination to remove any sample scrapings or contamination. As some of the irradiated samples were spent nuclear fuel for defense-related purposes, the hot cells frequently came into contact with transuranic isotopes and subsequent decontamination solutions would then contain transuranic waste. The following functions are examples of the type of physical processing that took place on a regular basis to irradiated samples in the hot cells:

- Etching
- Grinding, cutting, etc.
- Milling, lathe work, etc.
- Welding.

Often when a crack was identified in a sample, the SEM was used for examination at a higher resolution. Samples to be analyzed under the SEM were first prepared in a hot cell by cutting the sample with a saw and then mounting it on a stainless steel metallography mount. A mounted sample was generally cylindrical with a diameter of about 3 cm and a height of about 2 cm. The sample was then ground with sand paper, polished with a diamond paste, and rubbed on a felt pad. After polishing, the metal sample would have a mirror-like finish. At this point, the sample was ready to be scanned under the SEM and have photographs taken at various magnifications.<sup>4</sup>

Periodically, the hot cells were decontaminated by rinsing the cells. Hot Cell Facility logbooks note that the hot cells were at times decontaminated by bringing the "Hotsy" from the MTR to TRA-632. Hot Cell #1 was equipped with one floor drain and Hot Cells #2 and #3 were equipped with two floor drains (one in each sub-cell). The effluent from the hot cells was transferred to the CTS and subsequently to the TRA-713 and truck loading station (see Figures 1 and A-1 [Appendix A]).

## 4. DEFENSE-RELATED EXPERIMENTS

Experiments at the MTR and ETR often involved testing fuel for reactor designs. This fuel was typically U-235, plutonium (Pu)-239, or other fissile transuranic isotopes, which resulted in the production of transuranic isotopes upon bombardment with neutrons. A further explanation of transuranic isotope generation is provided in Appendix C. Occasionally, fission breaks occurred in the experimental loops. These breaks contaminated the liquid in the loop with transuranic isotopes from the irradiated sample. The contaminated loop coolant and subsequent decontamination solutions were discharged to TRA hot waste systems, thereby contaminating the systems with transuranic isotopes.

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4. Miller, J. J., International Isotopes Idaho Inc., Email to B. D. Welty, Portage Environmental, Inc., February 2, 2005, "RE: Hot Cell Questions."

Fuel samples were tested in capsules as well as loops. After an experiment was complete, the capsules were transferred to the MTR/ETR Hot Cell Building for examination. In the hot cells, transuranic isotopes could be released when the irradiated sample underwent disassembly, cutting, grinding, etching, or metallographic examination. Each hot cell was periodically decontaminated (e.g., a rinse with “Hotsy”), sending the transuranic wastes to the floor drains.

The transuranic waste in the TRA hot waste system would have originated primarily from loop coolant following a fission break or from decontamination of hot cells after fuel examination with the experiments resulting in the waste generation, which was in part defense related.

Throughout the operation of MTR and ETR, many experiments involved the defense-related purposes, specifically for the United States Navy, Army, and Air Force. “Fuel element samples for all the naval reactors [were] tested in loops under the sponsorship of the Bettis and Knolls atomic power laboratories” (NRTS, undated[a]). The United States Air Force sent samples to be tested at the ETR, and many of the special ETR loops had been designed to test the fuels required for a nuclear-powered aircraft (Stacy 2000).

## **4.1 TRA Defense Complex Sponsors**

“Knolls Atomic Power Laboratory (KAPL) is a Government-owned, contractor-operated research and development facility that supports the United States Naval Nuclear Propulsion Program, which is a joint Navy-Department of Energy program responsible for the research, design, construction, operation, and maintenance of U.S. nuclear-powered warships” (KAPL 2005). KAPL began operation in May 1946 with a contract between General Electric (GE) and the United States Government. GE continued as the prime contractor of KAPL until 1993. KAPL’s mission has centered on the nuclear navy propulsion. TRA has performed substantial experimental work sponsored by KAPL providing a direct link to naval nuclear propulsion research.

“The Bettis Atomic Power Laboratory (BAPL) is a Government-owned, contractor-operated research and development facility that supports the Naval Nuclear Propulsion Program” (BAPL 2005b). BAPL was built by Westinghouse Electric Corporation, and the nuclear reactors at TRA received samples for testing from BAPL and Westinghouse, indicating that defense-related fuels were received at TRA. Westinghouse was also known as Westinghouse Atomic Power Department (WAPD).

The United States Army sponsored work at the NRTS for development of nuclear reactors that were to be used for military field power supply applications. Army-sponsored reactors constructed at the Army Reactor Area (formerly the Army Reactor Experimental Area) included the Gas-Cooled Reactor Experiment (GCRE), the Mobile Low-Power Reactor (ML-1), and Stationary Low-Power Reactor. The prime contractor for research and development for the Army reactors was Aerojet General Nucleonics (AGN) (Stacy 2000). Research of INL reference drawings (341429–341443) shows early experimental facilities, including gas-cooled reactor research facilities at the MTR. The AGN-302 experiment support facilities were housed in TRA-651.

In 1951, GE was given the task to test part of the aircraft nuclear propulsion (ANP) program for the United States Air Force. The ANP program involved testing and design of a nuclear-powered aircraft (Stacy 2000).

During 1954, the General Electric Company Hanford Laboratories (GEH) “established its first major engineered facility at the NRTS to evaluate fuel element design and performance. This initial facility was installed in the MTR and [was] known as the GEH-4 fuel testing facility. Since its conception, the GEH-4 facility...demonstrated its importance and necessity as a basic tool for Hanford-

type fuel element research and development” (NRTS 1959). The ETR cubicles located on the north side of the ETR basement (now known as M-3 and P-7) were designed and exclusively used by GEH from 1957 to 1970 for this work. Research supporting Hanford fuel element design and performance was clearly defense related, as the Hanford facility has been integral to the nuclear weapons complex since its inception (Valentine 2000)].

## 4.2 MTR Defense-Related Experimental Facilities

The MTR contained experimental loops and associated cubicles, which housed the equipment necessary to support experimental loops, including pumps, heat exchangers, flow control valves, and purification columns. Often, the loop/cubicle was assigned or built for specific sponsors. The following cubicles and facilities were known to accommodate samples with defense-related purposes.

- BAPL VH-3—The BAPL VH-3 was a loop cubicle assembly installed in a vertical hydraulic rabbit penetration in the MTR core. INL reference drawings (332056, 332078, and 332090) show this experimental water loop as being operated in the MTR throughout the 1960s. The sponsorship of this test facility by BAPL and Westinghouse indicate sponsorship by the United States Navy.
- KAPL L-42—KAPL L-42 refers to Lattice Position 42, which is located in a drilled-out beryllium block in the core lattice. Most of the spare lattice positions were drilled out for capsule placement except L-42, which was an experimental loop (NRTS, undated[a]). INL reference drawings denote sponsorship of the L-42 loop by KAPL (009004, 009048, and 009049). The sponsorship of the L-42 loop in MTR by KAPL denotes this work as related to research and development of nuclear propulsion for the United States Navy.
- KAPL HB-1—Based on available INL reference drawings, the KAPL HB-1 loop facility was operated from approximately 1960 to approximately 1969. The sponsorship of the HB-1 loop in MTR by KAPL denotes this work as related to research and development of nuclear propulsion for the United States Navy.
- ANL-2—“In March 1953, a high-temperature, high-pressure circulating water loop known as ANL-2 was installed in the MTR and was approved for operation by the Idaho Operations Office of the Atomic Energy Commission (AEC-ID).” This was the first high pressure water loop to operate at the MTR. “The loop consisted of a horizontal in-pile tube located in the north face of the MTR and an out-of-pile loop located in the basement of the MTR. The ANL-2 loop was installed as part of the Central Station Water Reactor and Submarine Thermal Reactor Programs. The loop permitted the simultaneous exposure of specimens, principally fuel element prototypes, to high-level radiation and to flowing high-temperature water. The loop was operated by the MTR operating contractors, Phillips Petroleum Co., for the experimenter, Argonne National Laboratories (ANL). The ANL experimental program was terminated on June 30, 1962, and the loop was then used by Phillips Petroleum Co. Atomic Energy Division (PAED) as a loop for studying corrosion of materials. The loop then became known as PAED-HB-2. The loop was approved for operation by PAED on July 2, 1962, by AEC-ID and was operated by PAED until it was terminated on January 12, 1965” (Rolfe and Wills 1984).

## 4.3 ETR Defense-Related Experimental Facilities

The ETR also contained experimental loops/cubicles that accommodated support equipment for experiments. The following facilities and cubicles were known to house defense-related experiments for various sponsors.

- GEH P-7, G-8—“Two fuel element test facilities, the GEH P-7 and G-8 high-pressure loops, were installed at the ETR for support of GEH. These facilities housed fuel element development work for an advanced reactor design” (NRTS 1959, undated[b]).
- GEH P-7/M-3—GEH “sponsored the installation of two recirculating high temperature, high pressure water loop irradiation facilities in the ETR. The first loop system to become operative was the GEH-ETR 3x3 Experiment, identified as GEH P-7, in October 1958. The second system, the GEH-ETR 6x9 Experiment or GEH-G-7, began operation in May 1959. The purpose of the two systems was to irradiate fuel tests in support of the development of Hanford reactors and the Plutonium Fuel Recycle Test Reactor (PRTR).” In 1969, the cubicles were reidentified, P-7 as M-3 and G-7/M-3 as P-7 (Kaiser et al. 1982).
- C-13/G-16—“The purpose of the C-13/G-16 Systems was to study the rates and effect of crud deposition on fuels and structural materials as part of the Naval Reactor Test Program” (INEL 1991).
- F-10/H-10—“The [KAPL] F-10 and H-10 inpile tubes were both top reentrant type tubes. The H-10 inpile tube was removed at the end of the Naval Reactor test program” (INEL 1991; NRTS 1959). “The first test run in the clean F-10 loop was conducted to determine the cause of high water activity in an experimental reactor program. As a part of this test, portions of the primary loop piping were cut out of the loop and analyzed for deposition of fission products (Kaiser et al. 1982).
- C-7/M-13/N-14—“The C-7/M-13/N-14 primary and secondary cubicles were constructed in the west basement of the reactor building. The cubicles housed equipment to conduct tests in support of the ETR water loop programs. The cubicle has also been known as the WAPD-32, the WAPD-C-7, the C-7/L-10, and the C-7/L-10/N-14. All these names reflect the past service of the cubicle associated with experiment locations in the reactor core” (Kaiser et al. 1982).
- J-10/L-10—The WAPD J-10/L-10 became the KAPL J-10/L-10 system in July 1968 (Kaiser et al. 1982). The sponsorship of the J-10/L-10 facility in ETR by WAPD and KAPL denotes this work as related to research and development of nuclear propulsion for the United States Navy.
- L-12/M-7—“The L-12/M-7 cubicle equipment was primarily located in the primary cubicle and was initially installed in June 1959. The original loop was designed to provide irradiation facilities for a 3-MW nuclear fuel experiment” (Kaiser et al. 1982). The L-12/M-7 cubicle housed the M-13 core location, but the M-13 in-pile tube was disconnected, leaving its core position in the reactor (Kaiser et al. 1982). The L-12/M-7 cubicle has also been known as WAPD L-12/M-13 (NRTS, undated[b]).
- Annulus Gas System (AGS) Cubicle—The AGS Cubicle “housed equipment for the annulus gas system and the on-line cover gas sampling system, both of which were used to support the Sodium Loop Safety Facility project” (Kaiser et al. 1982). The cubicle at one time was also known as G-12, PAED G-12, [General Electric Flight Propulsion Project (GEFP)]-2, and the General Electric Experimental Loops cubicle. “The cubicle originally contained equipment used in support of the ANP program. This equipment was known as the General Electric Experimental Loops (GEEL) and was used to process large volumes of air which had cooled nuclear fuel samples being irradiated in the reactor” (Kaiser et al. 1982).

## 5. EXAMPLES OF DEFENSE-RELATED TRANSURANIC WASTE GENERATION AT TRA

Defense-related sponsorship of various experimental facilities at TRA is delineated above. Some specific examples of defense-related experiments, focusing on in-loop fission breaks where possible, are provided below.

### 5.1 MTR Defense Fuel Fission Breaks and Loop Decontamination

During MTR operations, fission breaks occurred in several loops. The liquid in the loops would then become contaminated with the sample (e.g., irradiated defense fuels). When such breaks took place, the loop was drained and decontaminated before experiments could resume. The following examples of fission breaks or decontamination were extracted from specific events in MTR Progress Reports and other MTR records. As indicated by the referenced loops or locations, these examples directly correspond to defense-related fuel samples tested at MTR.

*Example 1.* “KAPL-30 Fission Break Assistance was given Project Engineering in identifying which of the three fuel elements in the KAPL-30 loop was responsible for a suspected fission break...Subsequent visual examination of the suspect element, after removal from the reactor, confirmed the findings” (Keller 1957). KAPL performed government-sponsored research for the United States Naval Nuclear Propulsion Program. Thus, sample identifications associated with KAPL refer to defense-related experiments.

*Example 2.* “During the operation of the ANL-2 and PAED-HB-2 experiments, several fission breaks occurred, and corrosion products built up within the loop piping. As the corrosion products became radioactive, they were transported through the loop piping and plated out on the piping surface. This plating created radiation fields that made routine maintenance of the loop equipment very difficult during short reactor shutdown periods of three to five days. In order to reduce these fields and exposure levels during loop equipment maintenance, the loop was chemically decontaminated several times over its 11-1/2 year lifetime. The initial chemical decontamination used three separate chemical treatments followed by a water flush. This treatment resulted in the removal of approximately 70% of the corrosion film from the loop” (Rolfe and Wills 1984). The ANL-2 (also known as the PAED-HB-2) facility was designed for Central Station Water Reactor and Submarine Thermal Reactor Programs, and therefore, contained defense-related experiments.

*Example 3.* “GEH-B-3, Hanford Fuel Element Evaluation, B-3: During shutdown 173, fuel slugs GEH-4-68, -69, and -70 were discharged and a new capsule (GEH-4-72) was inserted. Just one minute after achieving full power the Reactor received a [junior] scram initiated by a significant fission break at GEH-B-3. Activity levels in the catch tank provided for this contingency, left no doubt as to the reality of the rupture and the experiment was discharged from the Reactor. During the cycle the catch tank liquid was discharged to the plant hot storage for future disposition” (Smith 1962). As previously described in Subsection 4.1, Hanford experiments received at TRA were part of defense-related fuel element research.

*Example 4.* “GEANP-3-34, Radiation Studies of Fuel Elements, A-19: ...GEANP-3-34 was first brought on-test on October 12 at 2315 hr and operated until 0119 hr, October 13. At that time a junior scram was received from high coolant temperature. On October 16 low discharge pressure on the experiment resulted in a junior scram. While returning the

experiment to on-test conditions after the last junior scram, excessively high discharge coolant activity was encountered. Since this indicated a fission break, the element was withdrawn from the high flux zone at this time” (Keller 1957). Experiments from General Electric Aircraft Nuclear Propulsion (GEANP) were sponsored by the United States Air Force.

*Example 5.* “WAPD-30, High Pressure A1W Water Loop, B-4, A-31, -33: The temperature of the loop was reduced to facilitate work in the reactor tank. This loop operated satisfactorily until March 17 when definite signs of a fission break were received. At this time the Reactor was manually scrammed and the WAPD-30 fuel element discharged” (Keller 1958). WAPD refers to Westinghouse, a contractor of BAPL, which denotes this work as research and development of nuclear propulsion for the United States Navy. A1W (A for aircraft carrier, 1 for first, W for Westinghouse) was a naval prototype for adapting nuclear power to surface vessels.

## 5.2 ETR Defense Fuel Fission Breaks and Loop Decontamination

At ETR, “minor fission breaks have occurred in all of the experiment loops. All of the experiment loops were decontaminated several times, and each has been decontaminated subsequent to its most recent use. Where contamination spills occurred in experiment cubicles, the cubicles were subsequently decontaminated to acceptable levels to allow for maintenance” (Kaiser et al. 1982). The following examples of ETR fission breaks and decontamination were extracted from specific events recorded in ETR Progress Reports and other ETR records. As indicated by the referenced loops, these examples directly correspond to fission breaks and decontamination efforts from defense-related experiments performed in ETR loops.

*Example 1.* “Subsequent to the termination of the water loop programs at the ETR, the primary systems C-7, M-13, and N-14 were decontaminated following standard operational decontamination procedures. The plumbing was flushed and drained. No attempt was made to remove undrainable water or dry the system. The primary pipes were capped in the subpile room” (Kaiser et al. 1982). C-7, M-13, and N-14 were facilities that housed Westinghouse experiments under the name WAPD for the United States Naval Nuclear Propulsion Program.

*Example 2.* “The [F-10/H-10] loop was decontaminated October 1968 because of an earlier fission break in the loop. In November 1969 the loop was again decontaminated” (Kaiser et al. 1982). The sponsorship of the F-10/H-10 loop by KAPL denotes this work as related to research and development of nuclear propulsion for the United States Navy.

*Example 3.* “During the shutdown the GEH-10-5 sample was removed to the canal for inspection and dimension check. The sample was rebasketed and reinserted into the in-pile tube. On May 17, soon after reactor start-up, the reactor was manually scrammed because of a fission break in the GEH-10-5 sample which caused high radiation fields outside the basement cubicle. During Cycle 16B shutdown this sample was removed from the in-pile tube without any major difficulty” (Thomas 1959). General Electric Hanford (GEH) experiments received at TRA were part of fuel element research for defense-related purposes.

### 5.3 Hot Cell Defense Fuel Examinations

As described in Subsection 4.3, the MTR/ETR Hot Cell Building (TRA-632) received materials irradiated at the MTR and ETR. The capsules and plugs were then disassembled for transport or for further examination. The following examples were taken directly from logbooks during the time of MTR and ETR operations. These examples refer to the use of the facility for examination of defense-related fuel samples and the subsequent decontamination of the hot cells. Table 1 includes summaries of sponsors and work noted in Hot Cell Logbooks.

*Example 1.* **MTR/ETR/ATR Fuel**

Hot Cell facility logs (Facility, Cell, and Source and Special [S.S.]) indicate that a predominance of the work performed in the cells was, not surprisingly, fuel examination supporting the operation of the MTR, ETR, and ATR. Many instances are noted in which core fuel from the reactors was examined in the hot cells. Given that the missions of these test reactors, primarily ETR from 1957 to 1970, and ATR throughout its operating history was to support the NR program, the use of the hot cells in maintaining the reactors at operational status links wastes generated in the cells as defense related. Although the ETR and ATR fuels themselves are not defense fuels, the neutrons produced by these fuels in the test reactors have been essential to research and development of the United States Naval Nuclear Propulsion Program.

*Example 2.* **TRA Hot Cell #2 Logbook 8/4/60–12/31/62**

5/31/61: GCRE Fuel Specimens – work includes labeling; etching; hardness testing; Photographing. Note that fuel is failed. Cracks/holes are noted in GCRE fuel. Grinding and polishing performed.

The Gas-Cooled Reactor Experiment (GCRE) was an experiment run by Aerojet General Corporation for the United States Army.

*Example 3.* **TRA Hot Cell #2 Logbook 1/1/63–7/30/64**

1/23/63: GCRE grinding work.  
1/29/63–2/6/63: ML-1 grinding and etching.  
3/25/64: AGN 1B-17R-2 – “fuel badly cracked,” etched and ground.

Aerojet General Nucleonics (AGN) was the prime contractor for research and development for the Army reactors.

*Example 4.* **TRA Hot Cell #2 Logbook 8/1/64–6/30/66**

3/31/66: WAPD C-7/L-10 Cracked fuel samples etched with oxalic acid.

WAPD indicates the samples came from Westinghouse, the contractor for BAPL, which is a naval nuclear propulsion research laboratory.

*Example 5.* **TRA Hot Cell #2 Logbook 7/1/66–12/31/68**

6/13/67: PM-2A fracture. 15 PM-2A samples, work includes grinding, polishing, washed, scanned, photographed, fuel noted as fractured. Samples etched (Nital and oxalic acid).

PM-2A denotes the samples were from the army test reactor.

*Example 6.* **TRA Hot Cell #2 Logbook 5/8/72–12/2/74**  
5/14/73: .KAPL-94-A-10: “Removed the experiment out of the assembly...Used the allen wrench to remove the screw from top end so that the top of capsule came free. Tried to identify experiment. Can make out the KAPL 94 but the rest is obliterated with corrosion.”  
5/15/73: KAPL-94-A-10: “Positively identified capsule... It Is KAPL-94-60117.”  
6/8/73: NASA fuel: “Removed the lid by putting a large C clamp on the can and a rod through the lid flange holes. The lid was a double O ring type with a sealant also so it had to be forced all the way.”  
6/11/73: NASA fuel: “Opened the heavy gal. bucket. It contained 2 badly broken large plastic containers. Contents scatter inside the cave and 2 smaller vials containing small items.”  
6/12/73: NASA fuel: “Removed NRBK-43 cask from the cell and cleaned it inside and out. Also cleaned the liner inside and out.”

*Example 7.* **TRA Hot Cell #2 Logbook 12/3/74–9/15/76**  
8/30/76: Cell cleanup: “Washed tables in west side with methochlor washed with sodium hydrafide(?) and then rinsed with water. Washed with a nitric acid mixture and then rinsed with water. Before we started – west side read 1 to 2 R background. Over the drain it is 5R and east side is 4R at charging hole.”  
7/1/76: Cell 2 cleanup (west side). Opened up the west side and scrubbed it down with car wash, used acid (nitric) on the drain. Got it down to 1 R over drain and 400 mR background. Removed everything but grinding table.”  
7/2/76: Cell down for west side clean up. Count is down to less than 200 m/R background. Received only 180 m/R and 140 m/R in cleanup operations.”  
7/22/76: “Cell cleanup (west side). Washed down cell again. Used Turco and also a sol of hydrochloric acid on the floor.”

*Example 8.* **TRA Hot Cell #2 Logbook 10/30/77–7/7/79**  
10/30/77–11/11/77: “Cell down for overhaul. Sand blasted interior and blew contamination out front. Many days of decontamination work followed.”  
11/14/77–11/19/77: “Cell down for cleaning. Still sandblasting interior. Decon front area over and over and over again.”  
11/20/77–12/9/77: “Cleaned up cell (sand) after sand blasting floor and metal walls. Removed met trolley cleaned out the sand. Cleaned up equipment back of cell 2. Sand sand everywhere!!!”  
3/20/78–4/4/78: BAPL TFL 3&6 16700-510-804. Bellows – grinding, sectioning, scanning, polishing, etching

*Example 9.* **TRA Hot Cell #2 Logbook 7/8/79–10/30/81**  
1/25/80: “Cell down for back area decon.”  
10/29/80: “NRF HDS 81-1 – Removed loaded NRBK-H2-1 from the cell and decontaminated it.”  
5/1/81: “WFRP...Vacuumed impregnated sample – leaving one Al disk in place as fuel was so broken and loose.”

NRF sample identification indicates that the sample came from the Naval Reactor Facility.

- Example 10.* **TRA Hot Cell #2 Logbook 11/1/81–4/11/85**  
 12/28/81: WAPD sample noted as “badly scratched” etched with cupric chloride and examined.  
 2/22/82: “Decontaminated the Leitz metallograph cave for Leitz.”
- Example 11.* **TRA Hot Cell Facility Logbook 4/15/85–6/24/85**  
 5/1/85: “Cell 1 – Brought Hotsy washer from MTR to Decon Cell. Started Deconning cell 1.”  
 5/7/85: “Found the concrete and gravel outside the hot cell entrance door highly contaminated. Possible cause: Hot broken hot waste line located under ground.” “Cell-continued deconning of cell.”  
 6/17/85: “Cell 1 – made cell entry to clean up cell. General field 50 mR/hr.”
- Example 12.* **TRA Hot Cell Facility Logbook 6/25/85–2/14/86**  
 7/2/85: “Cell 3 – Started Cell Cleanup.”  
 12/3/85: “Cell 3 – Cleaning and unplugging drains.”  
 12/4/85: “Cell 3 – Working on unplugging drains.”
- Example 13.* **TRA Hot Cell Facility Logbook 2/17/86–11/25/87**  
 5/30/86: “Cell -3 Facility upkeep deconning and clean up of cell.”  
 6/2/86: “Cell-1, cell down no hot water down any of the hot drains in the facility this day.”  
 6/3/86: “Cell-1 cell down – no hot water down any of the hot drains in the facility for the remainder of this week.”  
 6/9/86: “Cell-3 – cell down – still no hot water down the hot drains in the facility.”  
 1/5/87: “SEM/EDS – on standby – also working hot drain problem.”  
 1/6/87: “Cell-3 – deconning cell, no water used – SEM/EDS – on standby – also working hot drain problem.”  
 1/8/87: “Cell-3 – deconning cell and back area, no water used – SEM/EDS – on standby ... still working on hot drain.”
- Example 14.* **TRA Hot Cell Facility Log 11/30/87–5/26/89**  
 4-26-88: “Notified today that 1,000 gals of FP-2 Hot waste water was transferred to TRA Hot Waste Holding Tank for CPP processing on 4/1/88.”
- Example 15.* **TRA Hot Cell Facility Logbook 5/13/91–8/14/92**  
 9/4/91: “3- water level coming up in back service area “hot” drains. We will investigate cause.”  
 1/20/92: “6- Water coming in the waste drain in the back – investigating the problem.”  
 1/21/92: “3- still investigating water problem.”  
 1/27/92: “3- Hot drains are unplugged. Seems they drained on Friday afternoon according to utility records.”  
 7/16/92: “started to lay out hot drain lines in building and take radiation readings. Late entry.”  
 8/1/92: “called utility operators for tank readings – utility operator reviewed tank readings... Tank #2 online reading was 17” alarm point 46” – utility operators report no increase in tank level after washing cell down.”

*Example 16.* **TRA Hot Cell Facility Logbook 5/11/92–4/8/93**

9/11/92: “1600 Checked catch tank level and discussed lack of level changes with work leader – will – triple verify tank lineup Monday.”

9/14/92: “1000 Conducted double verification of liquid waste lineup to tank #2. The valve is locked open. This verification was made because tank level did not change during last Ir process although sufficient values to cause a change were discharged.”

## 6. CONCLUSIONS

The transuranic waste that is contained within components of the TRA-630 CTS, and may be contained within other components of the TRA hot waste system, is in part defense related being generated from defense and Naval Reactor Research and Development Activities..

The transuranic isotopes were generated as a result of fuel element irradiation in the test reactors operated at the facility since the early 1950s. These isotopes were released to the TRA waste systems from the test reactors due to fission breaks (both intentional and inadvertent) within reactor experimental facilities. Fuel testing included both capsule- and loop-type experiments. Both capsule and loop experiments experienced fission breaks throughout the operating life of the test reactors. Capsule experiment fission breaks would have contaminated the reactor primary coolant within the reactor core proper, and would have been managed primarily in the TRA warm waste system, as the fission products and transuranics would have been significantly diluted due to the large volume of primary coolant circulated through the reactor cores. Fission breaks in experimental loops resulted in highly contaminated loop coolant that was managed in the TRA hot waste system. After a loop fission break reactor scram, the loop was typically drained and then chemically decontaminated. Both loop draining and decontamination resulted in fission product and transuranic waste contamination in the TRA hot waste system.

Both the MTR and ETR served as research and development facilities for defense-related atomic energy development. The MTR, as the first test reactor constructed in the United States, was used to support research and development of fuel elements (including fission breaks within test loops) for:

- United States Navy Nuclear Propulsions Systems through the sponsorship of KAPL, BAPL, WAPD, and PAED
- United States Army portable and stationary reactor designs
- ANP Program
- GEH.

The ETR experimental loops served from 1957 until 1972 almost exclusively for defense-related research. The experimental loops in the ETR were used to support research and development of fuel elements (including fission breaks within the test loops) for:

- United States Navy Nuclear Propulsions Systems through the sponsorship of KAPL, BAPL, WAPD, and PAED
- ANP Program
- GEH.

The MTR/ETR hot cells, located in TRA-632 served to provide examination of fuels from a variety of defense-related sources. Hot cell fuel examination included breaching of fuel elements via grinding, cutting, or etching to allow examination. The breaching of fuel elements inevitably resulted in cell contamination, some of which would have found its way into the cell drain system during decontamination activities. Although later missions of the hot cells (during the late 1980s and 1990s) were commercial in nature (Three Mile Island [TMI] core examination and commercial isotope preparation), a significant portion of the early hot cell work from the 1950 to the mid-1980s was defense related. The hot cells supported not only the examination of experimental fuels but examination of fuel elements from the MTR, ETR, and ATR cores. The hot cells were vital to ensuring ongoing reactor operations, which allowed the reactors to support their defense-related missions.

The trio of test reactors located at TRA has, as described in this document, provided critical research and development support to a variety of defense-related projects. The legacy waste resulting from this research and development has accumulated in the hot waste tanks and piping systems that remain from the original construction of the test reactors. The TRU waste that is or may be identified within these legacy systems qualifies, as it was in part generated as a result of defense-related research, for disposition at WIPP.

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# **Appendix A**

## **Hot Waste Piping Plan**

See the attached drawing, Figure A-1.

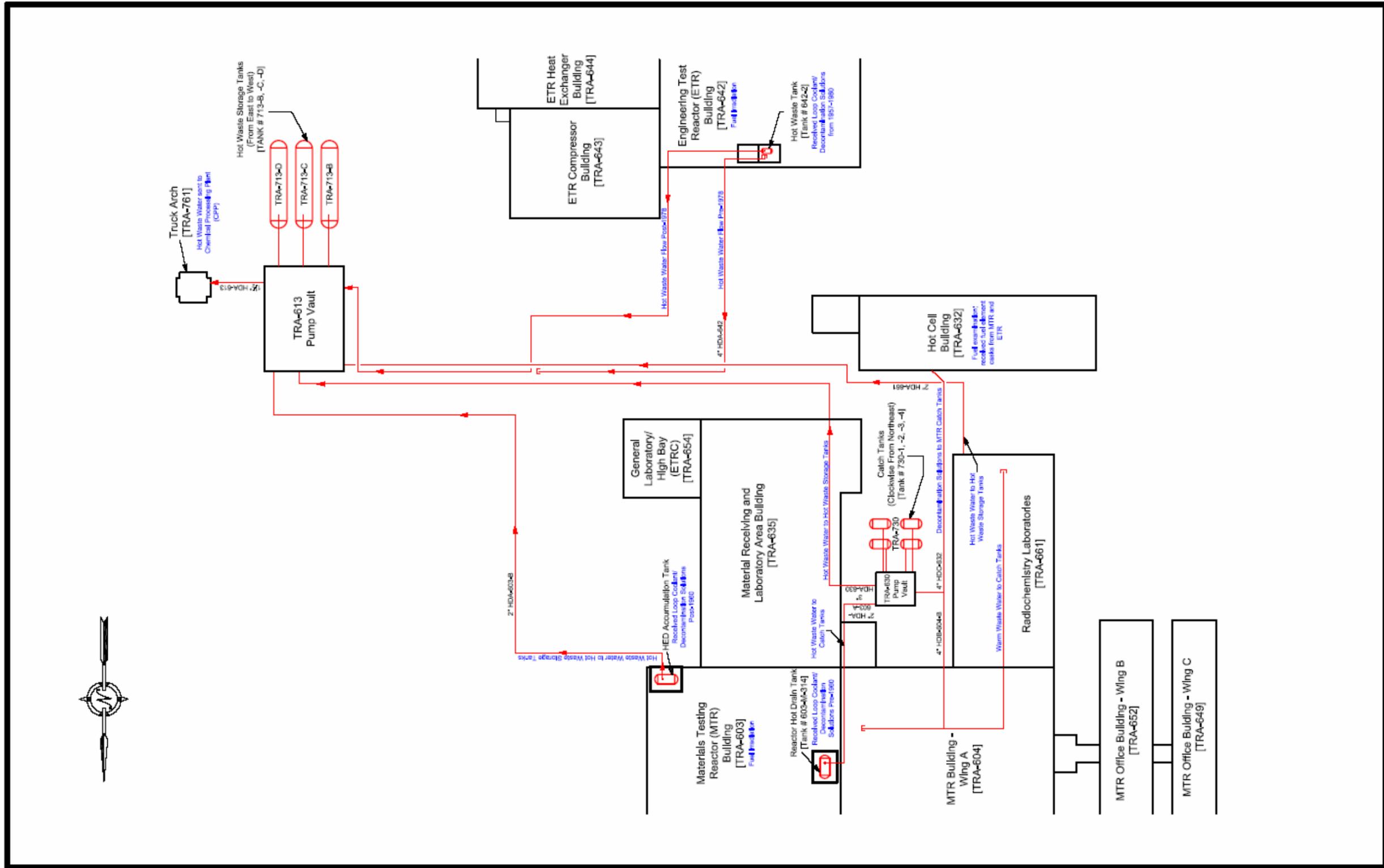


Figure A-1. Hot waste piping plan.

## Appendix B

### TRA CTS Sampling Results

Table B-1. The 1985 sampling results for the radioisotopic content of the TRA catch tanks.

Radioisotope	Tank 1 Content ( $\mu\text{Ci/g}$ ) <sup>a</sup>	Tank 2 Content ( $\mu\text{Ci/g}$ )	Tank 3 Content ( $\mu\text{Ci/g}$ )	Tank 4 Content ( $\mu\text{Ci/g}$ )
Cobalt-60	5.9E-01	1.4E-01	1.8E-01	4.9E-01
Strontium-90	4.2E+01	2.8E+01	3.6E+00	7.6E+00
Zirconium-95	--	--	--	1.5E-02
Niobium-95	--	--	--	2.0E-02
Antimony-125	7.2E-02	2.6E-02	1.6E-02	1.5E-01
Cesium-134	2.7E+00	3.0E-01	1.3E-01	2.3E+00
Cesium-137	2.9E+01	3.3E+00	4.4E+00	2.3E+01
Cerium-144	1.4E+00	3.3E-01	3.2E-02	9.2E-01
Europium-154	1.8E-01	5.2E-02	5.7E-02	4.0E-01
Europium-155	1.1E-01	3.1E-02	1.9E-02	2.3E-01
Transuranic Content				
Americium-241	1.64E-01 (1.4E-01) <sup>b</sup>	2.94E-01 (3.6E-02)	2.73E-02 (1.9E-02)	1.46E-01 (2.0E-01)
Curium-244 [Cm-243] <sup>c</sup>	4.27E-02	8.68E-02	9.28E-03	6.43E-02
Californium-252 [Cm-242]	6.9E-04	1.3E-03	5.7E-04	2.1E-02
Plutonium-239	1.56E-01	2.62E-01	4.24E-02	1.41E-01
Plutonium-238	1.43E-01	2.62E-01	5.95E-02	3.13E-01
Uranium-234 [U-233]	5.1E-03	7.95E-03	2.41E-02	1.31E-02
Uranium-238	6.3E-04	8.7E-04	--	1.75E-04
Uranium-232	1.5E-04	6.4E-05	2.02E-03	4.37E-04
Uranium-235	4.1E-04	1.32E-04	--	--
<p>a. Microcuries per gram (<math>\mu\text{Ci/g}</math>).</p> <p>b. Number in parenthesis represents the Americium concentration determined by gamma spectroscopy.</p> <p>c. The isotope in brackets represents alternate possible isotopes.</p>				

## Appendix C

### Transuranic Waste Generation

Transuranic radioactive waste is defined as “waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, with half-lives greater than twenty years, per gram of waste” (40 Code of Federal Regulations 191.02). Transuranic isotopes are isotopes of elements with atomic numbers greater than 92 (the atomic number of uranium) on the periodic table of elements, and include: plutonium (Pu)-238, Pu-239, Pu-240, Pu-242, americium (Am)-241, Am-243, neptunium (Np)-237, curium (Cm)-245, and Cm-246. Due to the long half-lives of the transuranic isotopes, TRU waste can remain radioactive for hundreds of thousands of years, and therefore, must be managed separately from other radioactive waste. The AEC first began managing TRU waste as a separate category of radioactive waste in 1970 (DOE 1997).

Most transuranic radionuclides at INL sites were produced in nuclear reactors by neutron capture. When fuel is first installed in a nuclear reactor, it is mainly U-235 and U-238, which are both naturally occurring isotopes of uranium. U-235 is used as the fuel for a nuclear reactor. Enriched uranium contains a higher percentage of U-235 than natural uranium. However, even highly enriched uranium, as used for nuclear weapons, contains some U-238 along with the desired U-235. U-235 is a fissile isotope, meaning it may easily undergo fission after neutron capture. Upon irradiation by neutrons, fission products are produced and decay (Murray 1994). Nuclear fission is the splitting of a nucleus into two or more separate nuclei of smaller atomic masses, accompanied by release of a large amount of energy. This fission reaction can also produce gamma rays, beta and other particles, and more neutrons.

U-238 is a fertile material, which means it may be converted to a fissile isotope by absorbing a neutron. When exposed to neutrons, as in a nuclear reactor, the U-238 nucleus may capture a neutron, ultimately transforming U-238 into Pu-239, which is a fissile isotope capable of being fissioned and producing large amounts of energy (Babcock & Wilcox 1978).

The transuranic isotopes are man-made radioactive isotopes produced by neutron absorption. For example, through a series of neutron captures and beta decays, U-238 is able to lead to the formation of Pu-239 and Am-241, both transuranic radionuclides (see Figure C-1). Upon capture of a neutron, U-238 is transformed into U-239. U-239 then undergoes beta decay, quickly emitting a beta particle to form Np-239. A beta particle may be emitted from Np-239, which subsequently becomes Pu-239. Some Pu-239 nuclei may capture a neutron to transform Pu-239 into Pu-240. Further neutron absorption results in Pu-240 nuclei forming Pu-241. Pu-241 then undergoes a beta decay to become Am-241 (WNA 2004). By similar successive neutron absorptions and decays, other transuranic radionuclides are also formed from uranium and plutonium isotopes.

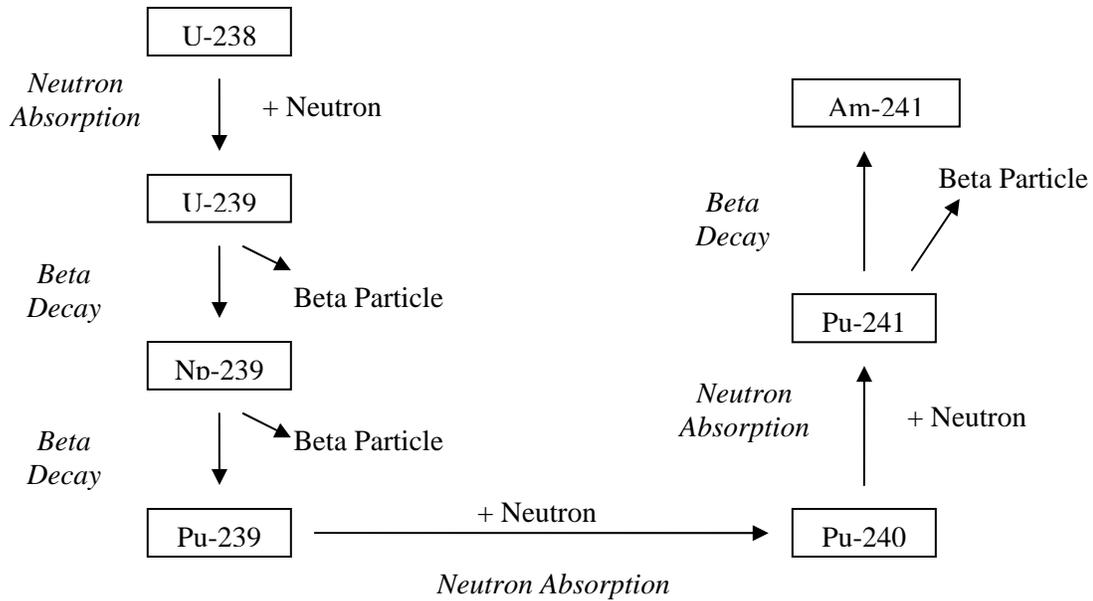


Figure C-1. Neutron capture and beta decay series from uranium-238 to americium-241.

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