

**DEPLETED URANIUM CHIP
HISTORICAL TREATMENT
ALTERNATIVES REPORT**



**RESOURCE
TECHNOLOGIES
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HISTORICAL TREATMENT
ALTERNATIVES REPORT**

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1.0 INTRODUCTION

As part of the accelerated remediation of the Trench T-1, located inside the Protected Area (PA) at the Rocky Flats Environmental Technology Site (RFETS), a review of treatment alternatives has been completed. This review consisted of evaluating available literature and conducting personal interviews to collect information on projects of a similar nature. The remainder of this section serves to provide the necessary background information on the project, the waste characteristics, and the potential treatment options. The subsequent sections present the available information on each treatment option for projects conducted within the DOE complex and at other sites that manage similar wastes.

1.1 ROCKY FLATS TRENCH T-1 REMEDIATION PROJECT

Trench T-1 is approximately 250 feet long, 16 to 22 feet wide, and 10 feet deep. Between 1954 and 1962, approximately 125 drums of depleted uranium (DU) metal chips from lathe and machine turnings were buried in the west end of the trench. The DU metal chips were packed in lathe coolant due to the potentially pyrophoric nature of the material. The drums were double stacked end-on-end in the trench and covered with one to two feet of soil. Anecdotal information indicates that the remaining two thirds of the trench was used to dispose of trash and debris and includes such material as pallets, paper, and empty drums.

The remediation of the trench involves the excavation of drums, any loose contents of the drums, debris, and surrounding soils. The excavated material

is to be managed by the appropriate treatment technology. The final waste form is expected to be a low-level radioactive waste that can be transferred offsite to an appropriate disposal facility. Two primary forms of wastes are expected to be generated during the trench excavation including

- Material with a potential to be pyrophoric - drums of DU, DU chips associated with the drums, and drum fragments
- Loose debris and soil in the trench - DU no longer in drums and surrounding soils

This report focuses on a review of historical treatment alternatives for the DU material.

1.2 DEPLETED URANIUM PROPERTIES

DU is the remaining uranium material after the separation of the fissile U_{235} isotope. Nonenriched uranium, including DU, is a radioactive metal that is also combustible (or pyrophoric). Because of the low thermal conductivity of uranium, larger pieces must be completely heated to the ignition temperature before ignition occurs. Therefore, most uranium is handled in massive forms that do not present a significant fire risk unless exposed to severe and prolonged external fire. Unless covered with oil, massive uranium forms burn with virtually no visible flame. Uranium surfaces treated with concentrated nitric acid are subject to explosion or spontaneous ignition in air.

Uranium in the finely divided form is readily ignitable, and uranium scrap from machining operations is subject to spontaneous combustion. This reaction can usually be avoided by storage under dry (without moisture) oil. Grinding dust has been known to ignite even under water, and fires can occur.

spontaneously in drums of coarser scrap after prolonged exposure to moist air. Moist dust, turnings, and chips react slowly with water to form hydrogen.

Actinide metals, such as uranium, have a silvery or greyish silver appearance when a freshly cut surface is exposed but this tarnishes rapidly in air owing to oxidation. At room temperature the oxidation does not proceed beyond the formation of a film on massive pieces but at elevated temperatures the rate of attack increases and oxidation of the mass becomes complete. Reaction with water vapor forms the oxide and hydrogen, which can react with the metal to form a hydride, aiding in the disintegration of the metal mass.¹

1.3 TREATMENT ALTERNATIVES

The purpose of the Trench T-1 remediation project is to excavate the material which was buried in the trench and prepare it for disposal at a licensed disposal facility. In order to safely transport and dispose of DU metal chips, the waste must be treated. This report addresses three potential treatment technologies for uranium chips and fines which have been utilized within the DOE complex. Specifically, these three technologies are

- Thermal Oxidation
- Chemical Oxidation, and
- Stabilization

¹ K. W. Bagnall, *The Actinide Elements*, Elsevier Publishing Company, 1972

The following Sections discuss the historical experience with each treatment alternative Following descriptions of historical experience, advantages and disadvantages for each technology are discussed

2.0 THERMAL OXIDATION

2.1 HISTORICAL EXPERIENCE

Thermal oxidation involves roasting reactive uranium metal in air. This method has been used extensively within the DOE complex. To perform this evaluation, RTG reviewed information describing thermal oxidation processes used at Hanford, Oak Ridge, Fernald, and Rocky Flats.

2.1.1 Thermal Oxidation at Hanford

UNC Nuclear Industries (UNC) constructed an incineration facility at Hanford to convert uranium and Zircaloy metal chips and fines generated in fuel production to oxides. The facility was designed with a nominal throughput of 960 pounds of chips and fines per eight hour shift. The chips and fines were a combination of metallic uranium ($\approx 70\%$), Zircaloy ($\approx 4\%$), and copper-silicon alloy ($\approx 26\%$) produced during fabrication of fuel elements.²

Chips were collected in water-filled drums for transport to the facility. Following dewatering and weighing, the chips were fed to a chip chopper for size reduction and sampling. Chip chopping was accomplished under water. Following chopping and draining, the chips were loaded using non-sparking shovels. The chopped chips and fines were collected in five pound maximum batches in combustible containers which were placed one at a time in 30 gallon drums. The chips were ignited with a hand held propane torch. The

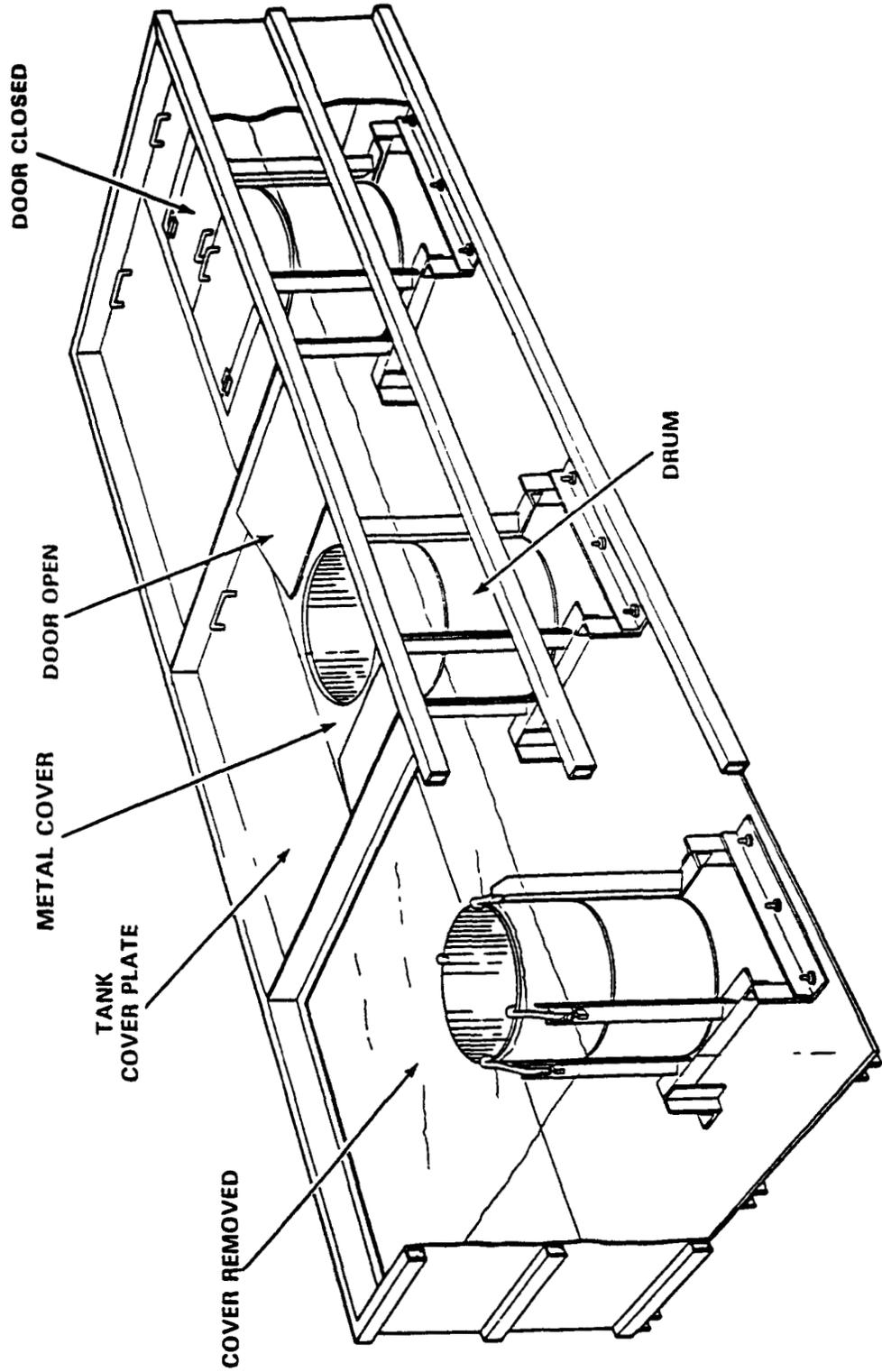
² *Safety Analysis Report, Fuels Manufacturing Uranium Oxide Facility, DOE, 1983*

oxidation reaction was allowed to go almost to completion before another batch of scrap was added. When the 30 gallon drum was full of U_3O_8 it was cooled, sampled, closed, stored, and shipped offsite for reprocessing. The drums were reacted under a ventilation hood which passed the air heated by the oxidation reaction through a baghouse and HEPA filters. The Facility was maintained at a negative pressure to prevent releases to the surrounding environment. The exhaust stack incorporated a continuous alpha monitor and a gamma criticality detection system.

Two tanks holding three drums each were available for incineration, but only one tank was used at any one time. Figure 2-1 depicts an incinerator tank. The tanks were filled with water for cooling the drums. Following ignition of the chips, the hood door was closed and the gas temperature was monitored. When the temperature had reached a maximum and begun to decrease, the incineration process was begun in the second drum and, later, in the third drum. The water bath absorbed approximately one third of the heat generated while the remaining two thirds was transferred to the exhaust system.

FIGURE 2-1
HANFORD INCINERATOR TANK

URANIUM OXIDE FACILITY
INCINERATOR TANK



2.1 2 Thermal Oxidation at Oak Ridge

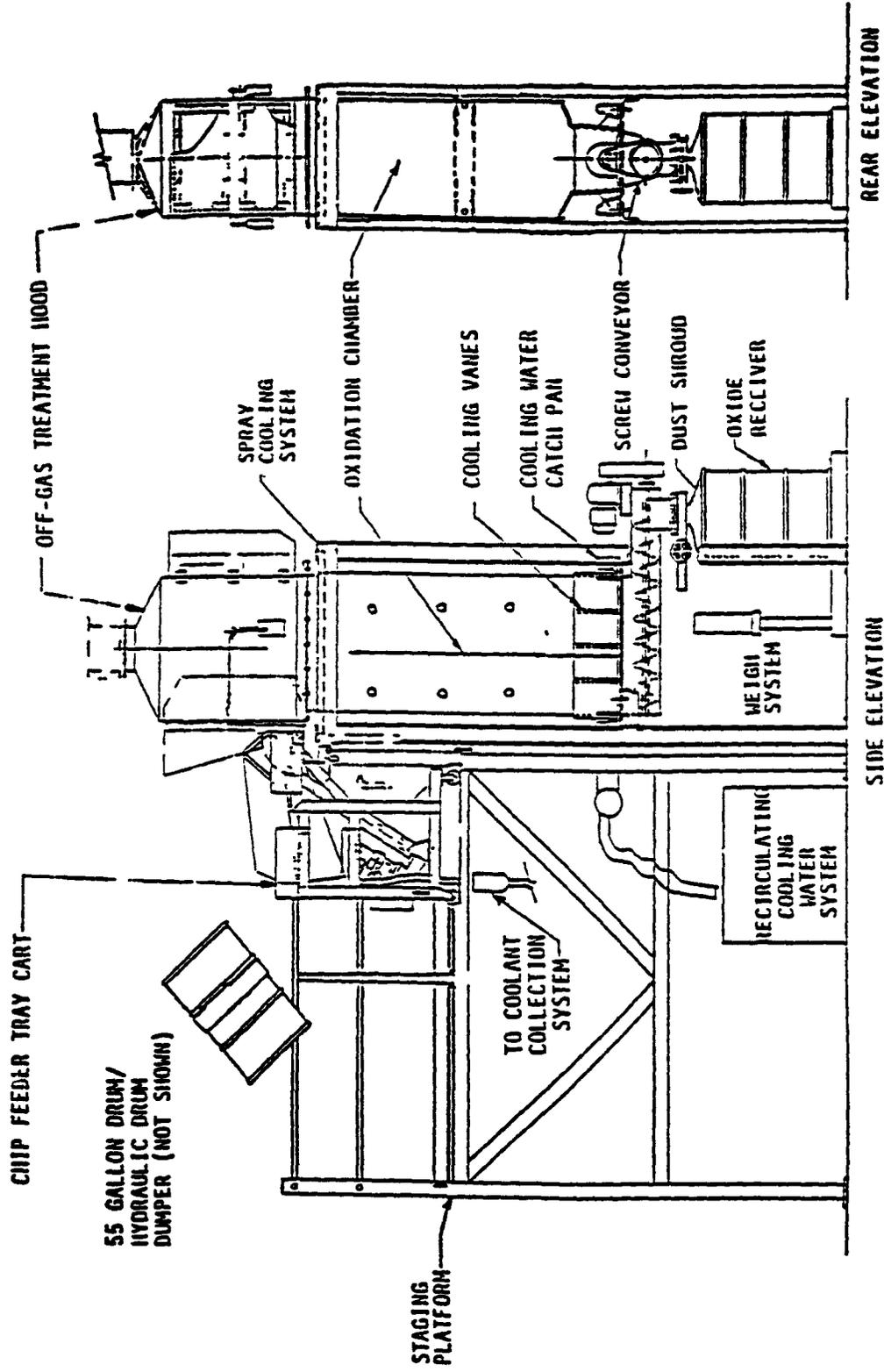
The Uranium Chip Oxidation Facility (UCOF) is located at the Oak Ridge Y-12 Plant and was used to convert uranium chips to uranium oxides. The facility was not designed to handle "sawdust-like" chips³

Chips were collected in drums and 5 gallons of water/coolant was added. Special metal pallets providing a 4 inch space between drums were used for transport to the UCOF. The purpose of the pallets was to isolate a drum from other drums in the event of an unplanned drum fire. The chips were loaded onto a drum dumper and dumped onto the feeder/drain table. Following dewatering, the chips were discharged into the reaction zone of the oxidizer. Chips were ignited using a burning wad of paper tossed into the oxidizer. Subsequent batches were ignited by the hot oxide bed. The oxidation chambers were constructed of 304L stainless steel and were cooled by a continuously recirculating spray system. The ventilation system passed the air heated by the oxidation reaction through HEPA filters. The UCOF building was maintained at a negative pressure to prevent releases to the surrounding environment. The exhaust stack incorporated a continuous radionuclide monitor and filter differential pressure instrumentation.

Figure 2-2 depicts the oxidizer platform. The UCOF contained six oxidizer units. Following cool down, the chips were screw-conveyed out of the oxidizer into a 55-gallon drum.

³ *Final Safety Analysis Report For Uranium Chip Oxidation Facility (Y-12 Building 9401-5), DOE, 1987*

FIGURE 2-2
URANIUM CHIP OXIDIZER PLATFORM



URANIUM CHIP OXIDIZER AND STAGING PLATFORM

2.1 3 Thermal Oxidation at Fernald

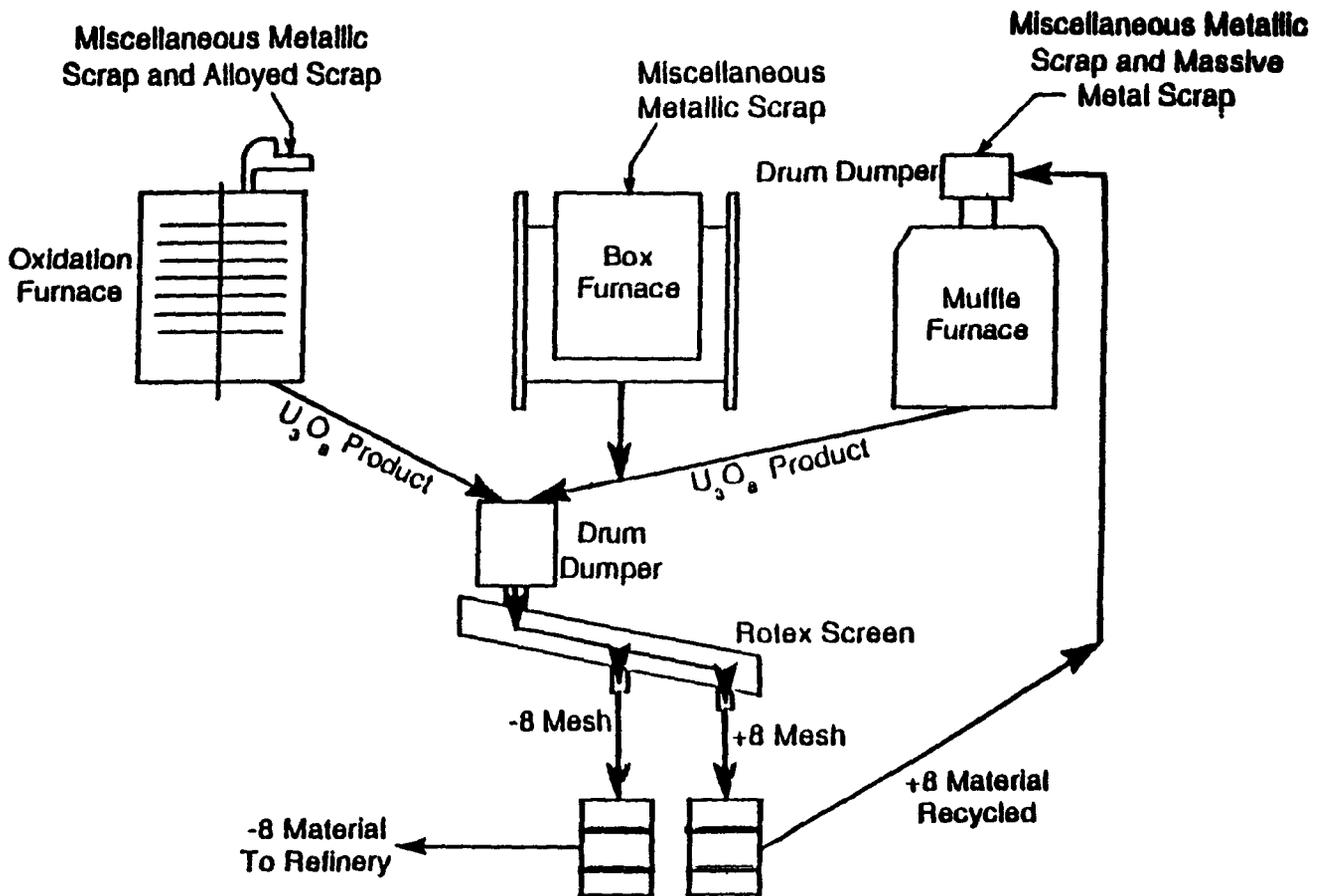
Scrap impure uranium metal and residues generated in each of the production plants at Fernald were sent to the Recovery Plant (Plant 8) for processing. Machining chips and turnings were burned to U_3O_8 in rabble-arm furnaces. A vibrating screen operation separated +8 mesh solids for further oxidation. The -8 mesh fraction was drummed as product and sent to the digestion/denitrification plant⁴.

High grade scrap was processed through Oxidation Furnace No. 1 which was a six-hearth, rabble arm furnace. The oxidized product was returned as feed material to the digestion system. The furnaces were vented to caustic scrubbers and the screening operation was vented to a monitored dust collector. Emissions from the scrubber stack were sampled continuously. Figure 2-3 depicts the flowsheet for high grade scrap.

Low-grade residues, such as sump cake, floor sweepings and dust collector residues were also processed through the rabble-arm furnaces.

⁴ *Addendum to FMPC-2082 "History of FMPC Radionuclide Discharges", DOE, 1988*

FIGURE 2-3
HIGH GRADE SCRAP FLOWSHEET



Flowsheet - Feed Preparation from High Grade Scrap

2.1 4 Thermal Oxidation at Rocky Flats

The "chip roaster", sometimes referred to as the chip incinerator or ore roaster, was used to oxidize DU chips in preparation for disposal. The chip roaster began operations in 1956 and operated continuously (with the exception of 1959) through 1961. The chip roaster was located in Building 447⁵.

In the 1980's, it was determined that chip roasting was incidental thermal treatment of RCRA waste due to low levels of RCRA-regulated solvents in the cooling oils. To prevent noncompliance with RCRA requirements, as of June 1994 the final roasting process included steam cleaning the chips and allowing them to drain in the drum. The chips were then placed in the roaster. The chip roaster exhaust was vented to the building plenum after passing through a heat exchanger. Following oxidation, the oxide was collected in 30-gallon drums for disposal.

2.2 THERMAL OXIDATION EVALUATION

Thermal oxidation has historically been used in the DOE complex for treatment of uranium metal chips prior to reuse or disposal. The principal advantage for thermal oxidation is that the exothermic and pyrophoric qualities of uranium metal are removed by conversion to uranium oxide. If the resultant uranium oxide was accepted for disposal without further treatment, advantages in container and disposal volume efficiencies would be realized.

⁵ "Building Histories, Historical Release Report, Building 447", DOE 1994

The disadvantages of thermal oxidation are initial capital cost and safety. The thermal oxidation equipment described in the preceding sections requires extensive cooling, ventilation, and monitoring equipment to address the environmental and personnel safety concerns. For instance, the unit described for Hanford (Section 2.1.2 above) reportedly cost \$950,000 in 1982 dollars.

Safety is a principal concern with thermal oxidation. The exothermic reaction rate is higher for smaller pieces of uranium metal. Under the right chemical conditions such as a fine powder containing moisture and exposed to air, the reaction can occur with explosive violence⁶. The temperatures generated during oxidation in the combustion zone have been determined experimentally to be in the 1300 to 1500 °C range⁷. The reaction is essentially uncontrolled and hot spots can form in close proximity to the container walls. The temperature range noted is approaching the melting point of stainless steel (1450 °C). A loss of coolant can very quickly lead to a failure of the container wall. In addition, another potential melting scenario is the eutectic problem. The lowest eutectic temperature when stainless steel is in direct contact with uranium is about 725 °C. Contact at the eutectic temperature can bring about a eutectic transformation which could change the stainless steel from a solid to an essentially liquid state. Introduction of small quantities of water during incineration (i.e., failure of a containment vessel allowing intrusion of cooling water) would result in the formation of uranium hydrides and hydrogen gas. Larger quantities would quench the reaction.

⁶ *Safety Analysis Report, Fuels Manufacturing Uranium Oxide Facility*, DOE, 1983

⁷ *Final Safety Analysis Report For Uranium Chip Oxidation Facility (Y-12 Building 9401-5)*, DOE, 1987

The failure of containment vessels for thermal oxidizers has occurred at the Oak Ridge site for the unit described in Section 2.1.2 above. The failure included the thermal shell of the oxidation unit.

Another concern with thermal oxidation is the generation of uranium particulates and high temperature gas, requiring a reliable off-gas treatment system. The emissions factor for the Recovery Plant at Fernald was reported as 0.371 grams uranium per hour, resulting in a total calculated emission from 1954 through 1984 of 47,151.4 kilograms of uranium.⁸ In addition to the emission uranium particulates, a concern for the T-1 Trench material is the potential presence of RCRA-regulated compounds which would be essentially incinerated and could require a permit or waiver.

⁸ *Addendum to FMPC-2082 "History of FMPC Radionuclide Discharges", DOE, 1988*

3.0 CHEMICAL OXIDATION

3.1 CHEMICAL OXIDATION

Chemical oxidation involves reacting uranium metal in an oxidizing solution such as hypochlorite. This method has been tested on a pilot-scale basis at in the DOE complex and used at the Army Materials Testing Laboratory (AMTL). To perform this evaluation, RTG reviewed available information describing chemical oxidation processes at Los Alamos and the AMTL.

3.1.1 Chemical Oxidation at Los Alamos

Pilot-scale testing of chemical oxidation of uranium metal has been performed at Los Alamos National Laboratory⁹. Chemical oxidation of uranium at low temperature was investigated for methods to dissolve and oxidize uranium to forms suitable for purification and reprocessing. The method was tested to investigate alternatives to thermal oxidation due to concerns over uncontrolled oxidation and explosion and the presence of flammable materials (e.g., machining lubricants) as well as release of off-gas associated with roasting or incineration.

Two hypochlorite solutions were tested: calcium hypochlorite in water and an aqueous solution of sodium hypochlorite. Oxidation with calcium hypochlorite was slow, due in part to the low solubility of calcium

⁹ N. Sauer, CST-18, Los Alamos National Laboratory, "Hypochlorite Oxidation of Uranium Metal Scrap"

hypochlorite Sonication of the solution enhanced the rate of oxidation, but calcium hypochlorite remained slower than sodium hypochlorite

Oxidation of uranium in sodium hypochlorite proceeded rapidly (hours) at room temperature and yielded a clear solution and a yellow precipitate At least four equivalents of sodium hypochlorite were required, presumably due to the decomposition of hypochlorite An increase in temperature increased the decomposition rate of the hypochlorite much more than the oxidation rate of uranium was increased, so optimal temperature appeared to be at or near room temperature The best results were obtained with 5% solutions of hypochlorite Solutions as concentrated as 11% were evaluated and did not enhance the rate of reaction The assumption made by the researchers is that the higher concentration solution decomposed more rapidly than the 5% solution The heat of reaction was determined and presented no difficulties at bench scale, but large scale chemical oxidation could require the use of an external cooling method In addition to the exothermic reaction, the hypochlorite method also generated a small amount of chlorine gas which could require an off-gas scrubber

Los Alamos built a production size unit at a cost in excess of \$1 million The unit had automatic controls incorporated in the design and was capable of dissolving drum quantities of chips However, personal communications with Los Alamos personnel indicate that the unit is not available and is currently in use for purposes other than the dissolution of uranium

3 1 2 Chemical Oxidation at the Army Materials Testing Laboratory

Chemical oxidation was employed by Morrison Knudsen at the Army Materials Testing Laboratory in Watertown, Massachusetts The material

which was oxidized was DU powder. The process was performed under a laboratory hood. Following oxidation, the oxide material was stabilized as discussed in Section 4.0 below.

3.2 CHEMICAL OXIDATION EVALUATION

Chemical oxidation has been tested in a pilot-scale at Los Alamos and performed on fine powder under a laboratory hood but has not been used in full-scale on uranium chips. The principal advantage of chemical oxidation is that it achieves the same non-reactive oxide state as thermal oxidation without the high temperature and air emissions problems noted for thermal oxidation. The solvent is a common material (bleach) which would easily gain acceptance by the public. The low temperature of the process minimizes the potential for airborne radionuclide release, explosion, or uncontrolled oxidation.

The disadvantages with this technology is the lack of full scale experience in the DOE complex and the capital equipment required. Pretreatment may be necessary for oils, solvents, and other foreign material (e.g., soil). Following treatment, the precipitated uranium may require stabilization for disposal. The results of the Los Alamos experiments indicated that some uranium was present in the solution, particularly when a combination of hypochlorite and hydrogen peroxide was employed. This would require treatment of a secondary waste stream by some method such as precipitation.

4.0 STABILIZATION

4 1 STABILIZATION OF URANIUM CHIPS

Direct stabilization of uranium chips and fines has been accomplished at several sites. Stabilization involves mixing the waste material with a cement-based mixture to form a solid monolith which isolates the uranium from oxygen and moisture, rendering it stable.

4 1 1 Stabilization at Hanford

From the late 1970's through the early 1980's, Hanford treated uranium chips utilizing a cement-based stabilization method¹⁰. The method involved mixing chips with concrete in a portable cement mixer. The mixture was poured into drums and transferred to the DOE disposal site at Hanford.

In the 1980's, Hanford treated uranium chips in the thermal oxidation facility described in Section 2 1 1.

In 1993, Hanford found more uranium chips requiring treatment. They chose a stabilization method which employed masonry cement. The masonry cement was mixed with the chips directly in a 30-gallon drum. The drum was modified with "paddles" attached in the interior. Following filling, the drums were rolled on a drum roller to mix the cement and waste.

¹⁰ John Ramaize, private communication, January 8, 1997

4.1 2 Stabilization at Nuclear Fuel Services

Uranium chips were stabilized using a concrete-based formula at the Nuclear Fuels Services (NFS) facility in Erwin, Tennessee.¹¹ The chips were mixed in drums with a concrete mixture. Mixing was performed with a drum lid-mounted mixer under a purge of inert gas. Following stabilization, the drums were shipped for disposal at the commercial Low Level Radioactive Waste Facility operated by Chem-Nuclear Systems, Inc (CNSI) in Barnwell, South Carolina. The stabilization process employed by NFS was reviewed and approved by CNSI (and presumably the state of South Carolina) prior to disposal.

4.1 3 Stabilization by Chem-Nuclear Systems, Inc

Chem-Nuclear Systems, Inc (CNSI) performed stabilization of DU at the General Electric facility in Evendale, Ohio. The stabilization process involved mixing chips with a Portland cement-based formula in the drum.¹² While the stabilization process was successful, CNSI noted bulging of the drums during the curing process. Investigations revealed that the drum deformation was due to the generation of hydrogen gas from the water which was available in the cement mixture. CNSI also noted some difficulty in obtaining a homogeneous mixture with a drum lid mounted mixer. They reported that the uranium settled in the drums.

In spite of these difficulties the material was successfully stabilized and disposed at the CNSI commercial disposal site in Barnwell, SC.

¹¹ Alan Vaughn, private communication, January 8, 1997

¹² James Staehr, private communication, January 21, 1997

4 1 4 Stabilization at Rocky Flats

Chips and turnings of DU, stainless steel and aluminum coated with small amounts of TrimSol machine coolant, machine cutting oil and Freon 113 were stabilized in Building 447 at Rocky Flats. The process involved mixing the turnings and chips with Portland cement, sand and water and pouring in an unlined 55-gallon drum. A layer of pure cement was placed in the drum prior to adding the waste mixture. This operation was suspended in 1993.¹³

4 1 5 Stabilization at Army Materials Testing Laboratory

Morrison Knudsen stabilized depleted uranium chips and oxidized uranium powder (see Section 3 1 2 above) with cement at the Army Materials Testing Laboratory in Watertown, Massachusetts. The process involved mixing the waste material in a portable mixer with cement and then pouring in three 10-inch lifts in B-25 boxes. The operation was performed in a negative pressure HEPA ventilated enclosure. The waste was shipped for disposal to the commercial low level waste disposal facility in Barnwell, South Carolina.

4 1 6 Stabilization at Los Alamos

Los Alamos stabilized uranium which had been stored in diesel fuel for 35 to 40 years. The stabilization was performed with "Petroset" in individual drums. The stabilization was performed under an inert (i.e., argon)

¹³ *"Building Histories, Historical Release Report, Building 447", DOE 1994*

atmosphere A HEPA ventilated negative pressure enclosure was used to contain the operation This project was performed in 1996 ¹⁴

4.2 STABILIZATION EVALUATION

Stabilization has historically been used at many locations in the DOE complex and other industries for treatment of uranium metal chips prior to disposal. The principal advantage for stabilization is that the hazards and additional steps associated with oxidation are removed. If the uranium oxide produced using thermal or chemical oxidation requires stabilization for disposal, oxidation would essentially be an unnecessary treatment step. Stabilization encases the uranium and renders it nonreactive as long as the monolith is competent. Additionally, underlying contaminated soils associated with the T-1 trench could be treated with the chips without separation.

The disadvantages of stabilization is that sizing or sorting would likely be required to render the waste material in a form which could be mechanically mixed with the grout. The Los Alamos project encountered turnings which were described as "steel wool-like" material too large to fit in a drum. Material such as this would need chopping or shredding to be of a size which could be handled by a mixing system.

Cement-based stabilization can be sensitive to the presence of oils or solvents. Particular attention must be paid to the proper proportion of ingredients determined during waste stream testing.

¹⁴ Robert Murphy, personal communication, January 28, 1997

5 0 SUMMARY AND COMPARATIVE ANALYSIS

Table 5 1 presents a summary of the historical technology experience. The thermal oxidation and stabilization technologies have been successfully utilized for treatment of similar wastes at many DOE and commercial facilities. Chemical oxidation has only been evaluated at the pilot scale. The differences in the technologies include the final waste form and volume, cost, and personnel safety issues.

Table 5 2 presents a comparative evaluation of each of the treatment technologies. This table can be used in the selection of the optimal treatment technology for the DU chips and associated material excavated from Trench T-1.

TABLE 5 2

Summary of Historical Treatment Methodologies for Depleted Uranium Chips

Treatment Method	Historical Site Use		Experience
	Location	Time Period	
Thermal Oxidation	Hanford		Thermal oxidation of chips and fines of uranium, Zircaloy, and copper-silicon alloy in 300 Area in facility designed for 120 lb/hr production. Process involved chip chopping, ignition in drum contained in water-filled chamber. Off gas controlled by ventilation systems. ¹
	Oak Ridge	1986-1989	Thermal oxidation of chips only in oxidizer controlled with a continuously recirculating spray system. Off gas controlled by ventilation systems. ²
	Fernald	1953-1984	Machining chips and turnings oxidized in rabble-arm furnaces. Material was returned as feed to digestion/denitrification plant. ³
	Rocky Flats	1956 - 94	Chip roaster used for depleted uranium chips in Building 447 for treatment of chips prior to disposal. Chips were most recently steam cleaned to remove coolant prior to oxidation. ⁴
	AMTL, Watertown Mass	1992-1994	Chemical oxidation of depleted uranium powder using hypochlorite under a laboratory hood.
Chemical Oxidation	Los Alamos		Pilot scale testing performed on chemical oxidation using hypochlorite (bleach). Production unit was built but not used. ⁵
	Hanford	Late 1970's - Early 1980's	Cement-based method mixing chips with grout in portable mixer and pouring into drums. ⁶
Stabilization	Hanford	1993	Masonry cement-based process involving stabilization directly in 30 gallon drums modified with paddles on interior and using a drum roller for mixing. ⁶
	NFS (Erwin, TN)		Concrete-based process involving mixing chips in drums with a lid-mounted mixer. Drums were accepted for commercial disposal at Barnwell, SC. ⁷
	AMTL, Watertown Mass	1992-1994	Stabilization of chips and chemically-oxidized powder mixing in portable mixer with cement. Mixture poured in ten-inch lifts in B25 boxes and disposed at Barnwell, SC. System had HEPA filtered enclosure.
	Los Alamos	1996	Depleted uranium chips in diesel, stabilized in drums with Petroset. Individual drums stabilized under inert (argon) atmosphere. HEPA filtered enclosure for operation.
	Rocky Flats	? - 1993	Cement-based process involving mixing chips with grout and pouring into 55-gallon drums in Building 447. ⁸
	Los Alamos	1996	Cement-based process involving mixing chips with grout in drums. ⁹
	GE (Ewendale, OH)	Early 1990's	Cement-based process involving mixing chips in drum using lid-mounted mixer. Processor had difficulties with generation of hydrogen gas during curing which deformed drums. ¹⁰

TABLE 5 2

Summary of Historical Treatment Methodologies for Depleted Uranium Chips

- 1 *Safety Analysis Report Fuels Manufacturing Uranium Oxide Facility, Document No UNI-M-157 DOE 1983*
- 2 *Final Safety Analysis Report For Uranium Chip Oxidation Facility (Y-12 Building 9401-5) DOE 1987*
- 3 *Addendum to FMPC-2082, History of FMPC Radionuclide Discharges, DOE 1988*
- 4 *Historical Release Report, Building Histories, Building 447, DOE 1994*
- 5 *Hypochlorite Oxidation of Uranium Metal Scrap, DOE*
- 6 *John Ramaize, Private Communication, January, 1997*
- 6 *John Ramaize, Private Communication, January, 1997*
- 7 *Alan Vaughn, Private Communication, January 1997*
- 8 *Historical Release Report Building Histories, Building 447, DOE 1994*
- 9 *George Jobson, Private Communication, January 1997*
- 10 *James Staehr, Private Communication January 1997*

TABLE 5 2

Comparative for Depleted Uranium Treatment Technologies

Waste Stream	Treatment Option	Disadvantages	Advantages
<p>Uranium chips in machining coolant (Waste classified as characteristic due to potential for being pyrophoric or reactive)</p>	<p>Thermal Oxidization</p>	<p>Expensive, capital intensive (120 LB/hr unit with bag house, HEPA, stack monitor cost \$950K (1982 dollars), probably \$2M today) May incinerate solvents raising air emissions control issues, hard to get public acceptance or permit/waiver (1% of U may end up in stack, HCl emissions from organics would require scrubber) May require stabilization to be acceptable for land disposal Safety is a concern due reactive metals and organics with potential for uncontrolled oxidation or explosion"</p>	<p>Stabilizes Uranium to non-pyrophoric oxide form Eliminates solvents and oils Extensive experience within DOE complex with thermal oxidation Safety Analysis Reports available from previous projects</p>
<p>Uranium chips in machining coolant (Waste classified as characteristic due to potential for being pyrophoric or reactive)</p>	<p>Chemical Oxidation</p>	<p>Uranium precipitate and soils may have to be stabilized Would not address oils, solvents Pre-treatment may be necessary to address oils and solvents Capital intensive (LANL system cost > \$1M) Never used in the DOE complex on a full scale May still need stabilization to be acceptable for land disposal May require air scrubbing for chemicals (chlorine) Secondary waste stream (spent solution) requiring handling and treatment</p>	<p>Chemically transforms Uranium into uranyl hydroxide or other uranyl hydrated form, non pyrophoric Will also address cyanide waste stream Solvent is common material (bleach), easily acceptable by public Safe process at low temperature with no potential for airborne radionuclide release, explosion, or uncontrolled oxidation</p>

TABLE 5 3
Comparative for Depleted Uranium Treatment Technologies

Waste Stream	Treatment Option	Disadvantages	Advantages
Uranium chips in machining coolant (Waste classified as characteristic due to potential for being pyrophoric or reactive)	Direct encapsulation or stabilization in grout type mix	Likely to require sizing/sorting step prior to mixing Presence of oils and solvents may affect grout mix May require an inert atmosphere to process	Used at a number of other DOE sites Simplifies the number of processing steps, eliminates the need for pre-oxidation of U chips Stabilizes U fines and chips to non-pyrophoric, non-reactive Could also be used on highly contaminated soils underlying drums May also address cyanide waste stream

1 DOE, *Safety Analysis Report, Fuels Manufacturing Uranium Oxide Facility - Hanford*, Document No UNI-M-157, May 7, 1983

" DOE, *Hypochlorite Oxidation of Uranium Metal Scrap - Los Alamos National Laboratory*