2

MASTER

DP-MS-77-74

Conf-771208--2

DEVELOPMENT OF AN INTEGRATED FACILITY FOR PROCESSING TRU WASTES AT THE SAVANNAH RIVER PLANT

solid

by

M. D. Boersma
H. E. Hootman
P. H. Permar

Savannah River Laboratory
E. I. du Pont de Nemours & Co.
Aiken, SC 29801

A paper accepted for presentation at the
NEA-IAEA Technical Seminar on the Treatment, Conditioning,
and Storage of Solid Alpha-Bearing Wastes and Cladding Hulls
Paris, France, December 5-7, 1977
and for publication in the proceedings.

This paper was prepared in connection with work under Contract No. AT(07-2)-1 with the U. S. Department of Energy. By acceptance of this paper, the publisher and/or recipient acknowledges the U. S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper, along with the right to reproduce and to authorize others to reproduce all or part of the copyrighted paper.

EB

DISCLAIMER

DEVELOPMENT OF AN INTEGRATED FACILITY FOR PROCESSING TRU SOLID WASTES AT THE SAVANNAH RIVER PLANT*

M. D. Boersma, H. E. Hootman, and P. H. Permar

Savannah River Laboratory
E. I. du Pont de Nemours and Co.
Aiken, SC 29801

Abstract

An integrated facility is being designed for processing solid wastes contaminated with long-lived alpha emitting (TRU) nuclides; this waste has been stored retrievably at the Savannah River Plant since 1965. The stored waste, having a volume of 10^4 m^3 and containing 3×10^5 Ci of transuranics, consists of both mixed combustible trash and failed and obsolete equipment primarily from transuranic production and associated laboratory operations. The facility for processing solid transuranic waste will consist of five processing modules: 1) unpackaging, sorting, and assaying; 2) treatment of combustibles by controlled air incineration; 3) size reduction of noncombustibles by plasma-arc cutting followed by decontamination by electropolishing; 4) fixation of the processed waste in cement; and 5) packaging for shipment to a federal repository. The facility is projected for construction in the mid-1980's. Pilot facilities, sized to manage currently generated wastes, will also demonstrate the key process steps of incineration of combustibles and size reduction/decontamination of noncombustibles; these facilities are projected for 1980-81. Development programs leading to these extensive new facilities are described.

---

* The information contained in this article was developed during the course of work under Contract No. AT(07-2)-1 with the U. S. Department of Energy.

Introduction

The United States has stopped the practice of unconfined burial of solid wastes containing even small amounts of long-lived alpha-emitting (TRU) nuclides. These isotopes, and wastes containing them, are commonly called transuranics (TRU), although ^{233}U is included and some transuranics with relatively short half-lives are excluded. TRU wastes are now being stored in containers that can be retrieved with no external contamination for a period of at least 20 years. Final disposal policy has not been established, but geologic storage is being developed. A Waste-Isolation Pilot Plant in bedded salt is being considered for TRU wastes generated in government-owned facilities. The United States' policy requires (1) retrievable storage of TRU solid waste and (2) reduction of volume of all solid wastes generated at government-owned nuclear facilities, where practical.

At the Savannah River Plant (SRP) in South Carolina, where nuclear materials are produced for national defense, retrievable storage was begun in 1965. Solid waste with more than 1.8 Ci TRU/m^3 was placed in retrievable concrete containers for shallow land burial. Since June 30, 1974, solid waste with more than 10^{-8} Ci TRU/g has been retrievably stored in containers that are placed on ground-level concrete pads and then covered with earth.

At the previous seminar (Marcoule, 1974), we reported on studies of options for management of TRU wastes at SRP. [1]. Alternatives are still being studied, on an increasingly quantitative basis. Concurrently, we have begun intensive studies of a plan believed to be the most prudent. Planning, engineering, and research are in progress to retrieve the TRU solid wastes accumulated at SRP since 1965, and process them to reduce their volume and hazard for permanent disposal, in the decade 1987-1996. The total projected volume of retrievable TRU waste is $\sim 10^4$ m^3. A processing plant, called the TRU Solid Waste Facility (TSWF), has been designed in considerable detail to obtain a planning cost estimate and identify technology gaps.

In addition to the TSWF study, SRP is designing two earlier TRU waste processing facilities to gain experience in key process areas: incineration of combustibles and decontamination of metals. These relatively small facilities will process most of the TRU solid waste currently generated at SRP after their completion in the early 1980's. Supporting research and development work is being done at the Savannah River Laboratory (SRL) in the areas of incineration, size reduction, decontamination, and waste fixation. This report describes the TRU Solid Waste Facility (TSWF) and key supporting facilities and research programs.

The Task

The task of the TSWF is to process the TRU solid waste retrievably stored at SRP (Table I), reduce its volume and hazard potential, and prepare it for long-term disposal in a safe and efficient manner. No recovery of isotopes or other values is planned.

Most SRP TRU waste is stored in 210-L galvanized steel drums. Waste with activity levels >0.5 Ci/drum is overpacked in 2-m diameter x 2-m high reinforced concrete tanks (Figure 1). Concrete, steel, fiberglass, and plastic containers of various designs are also used. These containers are placed on a concrete surface and mounded over with a minimum of 1.2 m of earth cover (Figure 2). In addition, there are about 150 concrete tanks containing TRU waste >1.8 Ci/m^3, buried about 5 m underground.

The distinguishing and design-limiting characteristic of these wastes is high specific activity, 10-500 Ci/m^3, principally from ^{238}Pu and ^{244}Cm. Process and storage areas with large waste inventories must be designed for maximum confinement including protection from design-basis earthquakes and tornadoes.

Neutron (α, n) and photon radiation must be considered in facility design. Many of the packages will contain gases including H_2 from the alpha-radiolysis of organics and water. Positive gas pressures and high H_2 concentrations have been measured in each of four drums of actual combustible TRU waste chosen for observation (Figure 3).

The organic, combustible fraction of the waste has the most potential for reduction of volume and hazard. Over 70% of the waste volume and radioactivity will be in combustible form. The stored waste containers are generally sorted and labeled "combustible" or "noncombustible," but most of the noncombustible containers include combustible wrapping and packing. Bulky equipment wastes such as glove boxes also offer a significant volume-reduction potential, first by collapsing (cutting) and ultimately by complete decontamination to reclassify the metal as non-TRU waste.

Processes and Equipment

A schematic diagram of an integrated system to process all the retrievable TRU solid wastes at SRP is given in Figure 4.

Retrieval and Transport

Waste containers will be retrieved from mound and underground interim storage locations and transported ∿1 km to the TSWF, using conventional mobile equipment such as power shovels, cranes, and trucks. If external contamination or significant gamma-neutron radiation is encountered, containers will be overpacked or shielded.

Container Opening and Emptying

The most laborious, potentially hazardous, space-consuming, and expensive step is that of opening and emptying the waste containers. The concrete tanks, which have been closed with high-strength adhesive, will first be drilled to relieve any internal pressure. The tanks will then be circumferentially sawed to within ∿2 cm of the inside, and cracked open. Some of the concrete tanks may contain free water due to long burial in intermittently-saturated soil. These tanks will be dried with hot air in a hood.

Primary containers (mostly 210-L drums) will be removed from the concrete tanks, assayed by photon counting, and opened. This assay is for criticality and inventory control. Low-level waste drums (not stored in concrete tanks) will also be photon-assayed and opened. Large bulky equipment will be transferred to a disassembly room.

Sorting

210-L storage drums are lined with 0.23-cm-thick rigid polyethylene containers, which will be removed and opened. Drum contents, consisting of waste in plastic bags, cardboard boxes, etc., will be sorted into several categories: combustibles, cleanable metals, uncleanable noncombustibles (such as glass, ceramic, and cable), and sorbents and resins. Complex items such as filters will be mechanically separated into these categories. Frangible materials will be condensed in a hammerhill. These fragments, together with resins and chemical sorbents, will be promptly immobilized with cement in small batches.

Incineration

Combustible waste including polyethylene containers will be shredded, repackaged, and fed to a two-stage controlled-air incinerator. The incinerator system is specifically designed for burning high-level alpha waste at the relatively low maximum rate of 10 kg/hr. The theoretical ratio of radioactivity in solids to radioactivity in effluent gases is $>10^{10}$. Many of the basic incinerator concepts are derived from the Windscale, England incinerator.

The distinguishing features of the proposed SRP incinerator are:

- All-electric. Auxiliary fuel such as gas or oil are excluded from the initial design for intrinsic safety. The pyrolysis (primary) chamber is heated through a nickel-alloy roof plate. Ceramic-sheathed heaters are strategically located in the combustion (secondary) chamber.

- All-ceramic firebox, except primary roof. The primary chamber hearth will be a hemicylindrical trough, either a casting or brickwork. The basic structure will be refractory and insulating brickwork.

- Capable of flameless operation. Because of batch feeding, waste variability, and no auxiliary flame, a live flame in the combustion (secondary) chamber may be unstable and intermittent. The combustion chamber is designed for complete oxidation even without a live flame. This is accomplished with long residence time, turbulence (baffles and turns), and temperature ($\geq$1000°C). The catalytic effect of ceramic surfaces is another factor but the effect is not yet quantitatively understood.

- Compact design for space and energy conservation. The primary and the multiple secondary channels are all horizontal, with several common walls. The primary chamber, where endothermic pyrolysis takes place, is located just above the first secondary channel, where exothermic combustion takes place. The entire incinerator is an orthogonal parallelepiped.

A pilot-scale ($\sim$1/20 volume) incinerator of the type described above is operating at SRL (Figure 5). Nonradioactive waste components such as paper, rubber, and various plastics are being burned individually to determine operating ranges for the control parameters--feed batch size and frequency, temperatures, and air flows--and to measure performance in terms of ash and off-gas quality. Corrosion tests are also being made. Successful flameless incineration has been demonstrated for all materials tested to date. Final design of the Plant incinerators will be based in part on these pilot tests.

A 5 kg/hr incinerator (1/2 capacity of TSWF incinerator) of the same basic design is planned to promptly process all combustible solid alpha-bearing wastes generated at SRP after 1981. A nonradioactive R&D incinerator of this same size and basic design will be built in 1978 and will be used to characterize combustion performance, develop Plant standards and procedures, and pre-test actual Plant off-gas system components.

Main features of incinerator off-gas processing include cooling, scrubbing, deacidification, and dual filtration with fiber filters that remove 99.99% of particles above 0.1 μm; a final feature, added for safety, is filtration through a fireproof, windproof, and earthquake-resistant sand filter. Acid, mainly HCl from the incineration of chlorinated plastics, will be neutralized with Na_2CO_3 solution in a gas-liquid adsorber. The resultant NaCl solution will be periodically replaced and evaporated to dryness, and the salt will be canned for disposal as TRU waste. The off-gas filters also become waste so the calculated net volume reduction for the incineration operation is 30:1.

Size Reduction

Large items of alpha-contaminated equipment such as glove box shells, process vessels, and drums will be cut into smaller, simple pieces. High-efficiency air filters up to 60 cm x 60 cm x 30 cm will be disassembled and compressed. In general, conventional tools will be used. A plasma-arc torch will be provided for cutting thick stainless steel components.

Electrodecontamination

Electropolishing has been used extensively in industry to produce a smooth, polished surface on a variety of metals and alloys, and has recently been shown to be an effective metal-decontamination technique [2]. A wide interest in electrodecontamination has developed in the United States in the last two years, largely because of pioneering development work at the Battelle Pacific Northwest Laboratories. Besides R&D facilities, several small electrodecontamination facilities are in routine use for cleaning tools, hot sample carriers, etc., for reuse.

Polishing is achieved by the removal of a thin layer of metal, particularly from the crests of microscopic ridges. The metal to be polished (or decontamiated) serves as the anode in an electrolytic cell. Typical operating conditions are 9 to 24 volts DC at current densities of 1000-2000 A/m^2 of the workpiece, with bath temperatures of 50-60°C. Solid-state rectifiers of suitable size are available commercially. Any radioactive contamination that is either on the surface or entrapped within scratches is transferred into the electrolyte by the surface dissolution process. After the surface is electropolished, an acid dip followed by a water rinse removes the electrolyte and leaves a contamination-free surface. Phosphoric acid is the common electrolyte, and may be used over a wide range of concentrations (12 to 75%).

For complex shapes such as pipe, specially shaped cathodes are required to achieve the desired current distribution. Cathodes are reusable and will be stored between runs. Metals to be electropolished must be free of paint and heavy grease films. A hot alkali dip will be used to remove these materials.

Electropolishing will be performed in a computer-controlled, automated polishing line, similar in design to commercial automated electroplating systems. Material to be decontaminated will be hung on racks using manipulators. The racks will travel to specific tanks in the polishing line in any desired sequence, and return to the starting point for reloading.

Complete decontamination can be achieved even when the dissolved metal and radionuclide content of the electrolyte becomes significant. One liter of electrolyte (75% H_3PO_4) can typically clean 2 m^2 of metal before it must be replaced or reclaimed. Spent electrolyte will be treated to remove most of the radioactivity and dissolved metal as a solid suitable for immobilization in concrete, and possibly to recover the acid. The exact process has not yet been selected. The net volume reduction ratio for disassembly and decontamination of bulky equipment waste is expected to be $\sim$15:1, counting only the solid content of liquid wastes and counting clean metals ($<2d/(m)(cm^2)$) as zero.

As in the case of incineration, SRP and SRL have a research program and a graduated series of facilities planned for equipment size reduction and decontamination. A Plant facility for decontaminating failed or obsolete alpha-contaminated equipment at the anticipated generation rate of $\sim$75 m^3/yr is planned for 1983 startup. This facility (Figure 6) will provide design, construction, and operating experience for the decontamination section of the TSWF. Savannah River Laboratory has a small experimental electropolishing system in operation. A demonstration consisting of decommissioning an obsolete alpha-contaminated research facility or decontaminating selected equipment is now being planned.

Immobilization and Encapsulation

All solid TRU wastes leaving the TSWF will be fixed in concrete. The final waste container as presently designed is a double-wall steel cylinder, 1.5 m in diameter x 1.5 m high (Figure 7). Portland cement grout will be poured around processed waste items in the inner, carbon steel container. The outer, stainless steel shell is provided for protection from conceivable surface storage environments (including earth cover) for ≥100 years. If the wastes can be promptly sent to permanent geologic storage, the outer shell might be omitted. The package (filled containers) is designed to be large enough for intrinsic stability in surface storage, but small enough for mine elevator size and weight limits. For the TSWF design basis waste feed rates, 70 of these containers will be produced annually for 10 years. The overall volume reduction, from incoming waste (including containers) to final waste packages will be 6:1.

Incinerator ash and salt will be canned in small containers before grouting in the large storage container. This is done for operating convenience, but may also serve an important purpose of isolating nearly all of the alpha radioactivity from direct contact with the concrete. Alpha radiolysis of concrete (water) can produce high hydrogen pressure [3].

Vitrification of the incinerator ash, containing up to 90% of the TRU radioactivity, is also being studied as an alternative to canning and grouting. A possibility at SRP may be to incorporate this ash in the glass product of a planned high-level liquid waste vitrification facility.

Facility

A plan of the proposed TSWF is given in Figure 8. The process areas described above are marked on the building plan.

As indicated previously, container opening and emptying requires the largest area. These operations will be performed remotely, using cranes and electromechanical manipulators. The opening of high-level containers will be done within a containment room designed for maximum resistance to design-basis tornadoes and earthquakes. Waste will be metered from this room to the subsequent processing lines (sorting, incineration, etc.) which will be operated with carefully controlled radionuclide inventories. This will allow use of containment structures that do not require maximum tornado/earthquake resistance, and thereby will allow more-direct access to relatively-sophisticated processes.

In the size reduction-disassembly area, routine and time-consuming operations such as metal cutting and filter compaction will be done remotely using electromechanical manipulators and special tool adapters. Nonroutine work such as tool setup and maintenance will be done directly by operators wearing plastic airsuits.

As discussed previously, electropolishing will be highly automated. The polishing line will be enclosed in a hood, with suitable access for manual operations and maintenance. Because of the extensive commercial development of automated electroplating equipment, a minimum of maintenance is expected.

The incineration and general sorting lines will be enclosed in glove boxes and hoods, with local shielding as required. The incinerator will be in a walk-in hood, with a small glove box for feed charging. Encapsulation will be done with cranes, manipulators, and automatic equipment.

Rigid polyethylene containers (210-L drum liners) will be used for transfers between the main process lines. A conveyer system in a tunnel crosses and connects the process lines.

Waste containers with a radiation level of more than 0.5 rem/hr at one meter will be shunted directly to encapsulation, without other handling.

Summary

TRU-contaminated solid wastes are being accumulated at the Savannah River Plant in storage containers that can be retrieved intact for at least 20 years. These wastes are characteristically high-level in alpha radioactivity, 10-300 Ci/m^3, because of ^{238}Pu and ^{244}Cm contamination. Through 1990, the projected waste volume is $\sim 10^4$ m^3, containing 3×10^5 Ci alpha activity. An integrated facility to process these wastes for permanent disposal has been designed in sufficient detail for project planning and research guidance. The facility will incinerate combustibles, decontaminate metals, and immobilize and double-encapsulate all final waste forms. The overall volume reduction from interim storage containers to final storage containers is 6:1. The plan to build and operate such a facility is technically supported by research and by near-term incineration and decontamination facilities.

Table I

Waste to be Processed in Savannah River Plant
Transuranic Solid Waste Facility (Design Basis), 1987-1996

Uncompacted waste volume	7,200 m^3
Container solid volume (potential waste)	3,400 m^3
Combustible waste volume	5,300 m^3
Combustible waste mass	1,000 tonne
Isotopes (corrected for decay to 1989)	
^{238}Pu	280,000 Ci
^{244}Cm	16,000 Ci
^{239}Pu	4,500 Ci
^{252}Cf	<1 Ci
Containers	
210-L drums	26,000[a]
2-m dia x 2-m high concrete tanks	760[a]
Concrete boxes, ~1/2 m^3	500
Other boxes (plastic, metal, fiberglass)	400

---

[a] Includes 8000 drums in 575 concrete tanks.

References

1. Albenesius, E. L., and Reinig, W. C., "Long Range Management of Transuranium-Contaminated Solid Wastes at Savannah River." Proceedings of the *Seminar on the Management of Plutonium-Contaminated Solid Wastes*, Marcoule, France, 1974. OECD, 1975.

2. Allen, R. P., Arrowsmith, H. W., and Budke, W. C., "Electropolishing as a Large Scale Decontamination Technique." Proceedings of the 70th Annual A.I.Ch.E. Meeting, New York City, November 13-17, 1977 (to be published by American Institute of Chemical Engineers, New York).

3. Bibler, N. E., and Orebaugh, E. G., *Radiolytic Gas Production from Tritiated Waste Forms — Gamma and Alpha Radiolysis Studies*. USERDA Report DP-1459, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, SC (1977).

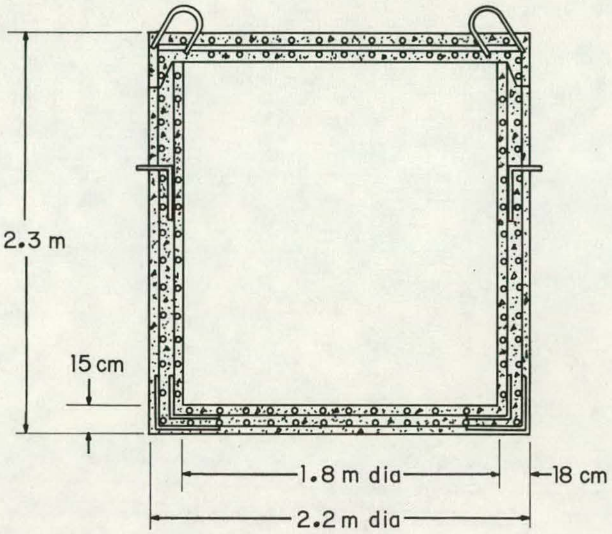


FIGURE 1. Reinforced Concrete Tank for Interim Storage of High-Level TRU Solid Waste

FIGURE 2. Retrievable Storage of TRU Solid Waste at the Savannah River Plant

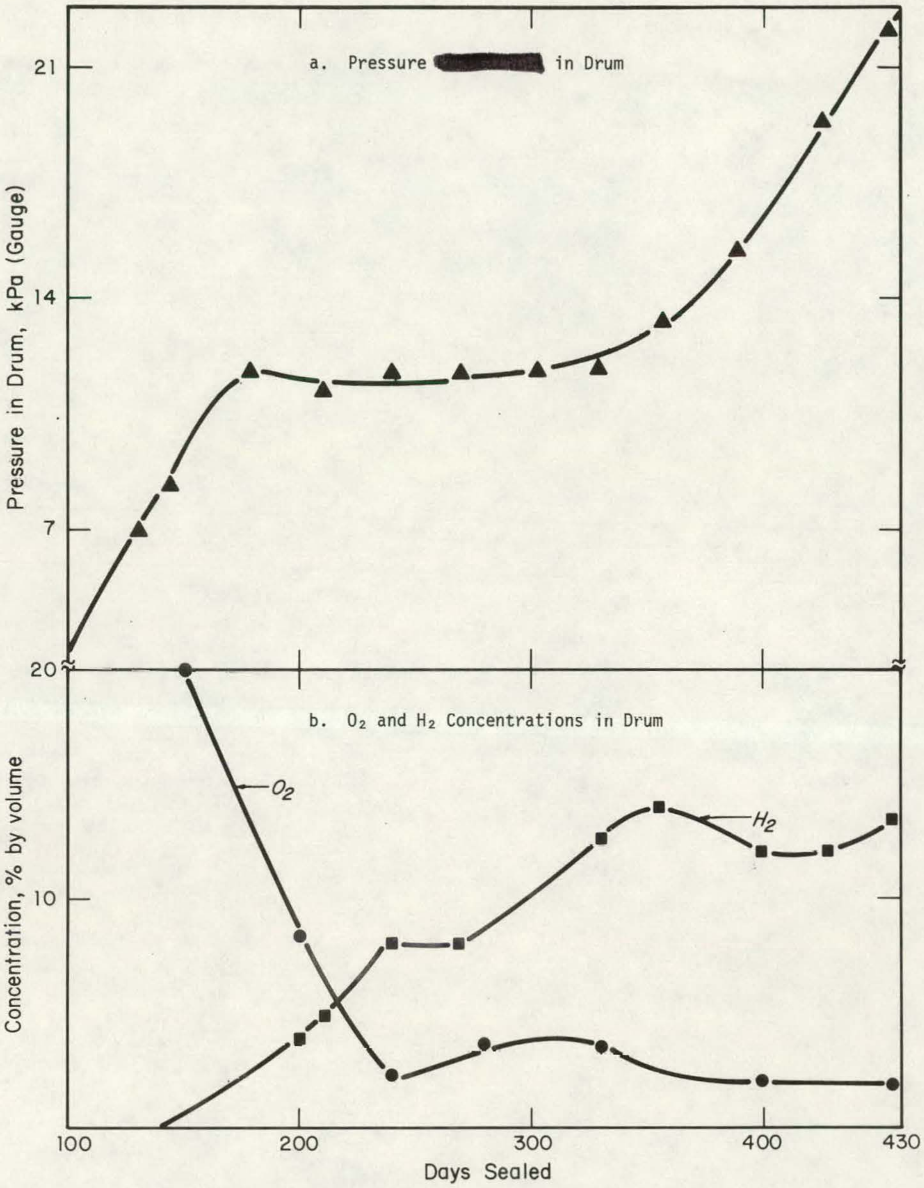


FIGURE 3. Gas Pressure and H_2-O_2 Concentrations in 210-L Drum of Combustible Solid Waste Containing 8.4 g (140 Ci) of ^{238}Pu

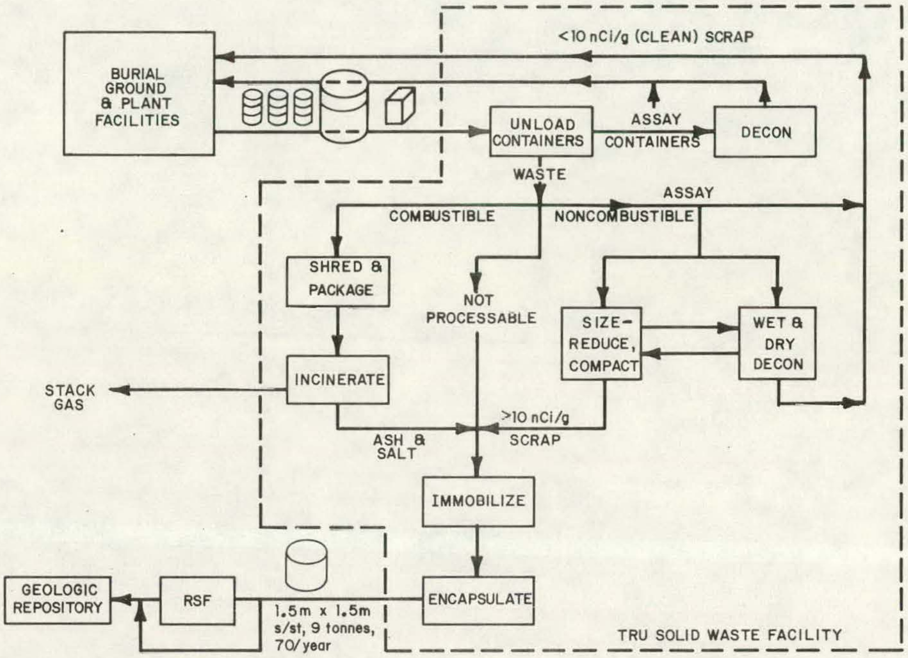
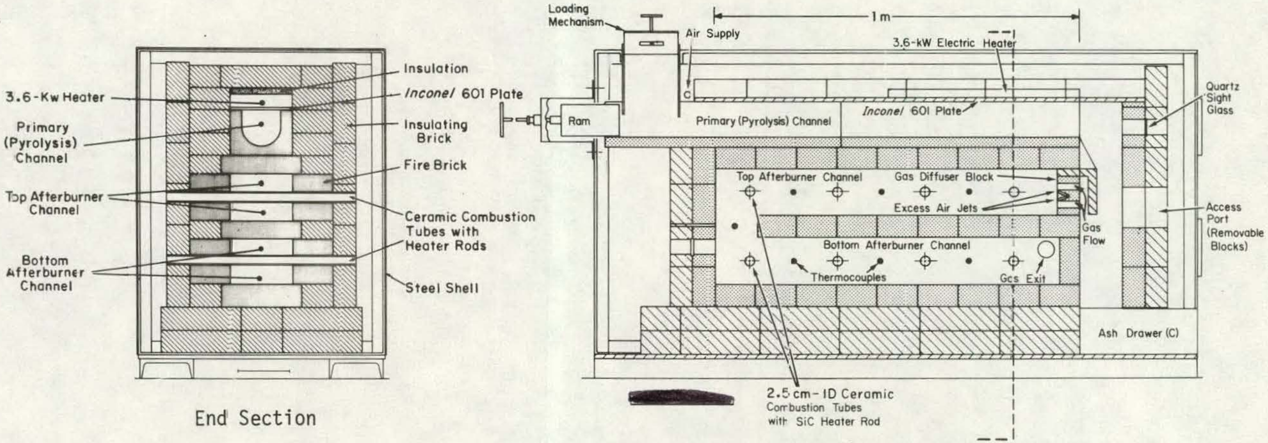


FIGURE 4. TRU Solid-Waste Processing Scheme



[redacted]

End Section

Side View

End Section Taken at This Point

FIGURE 5. Pilot-Scale SRL Incinerator

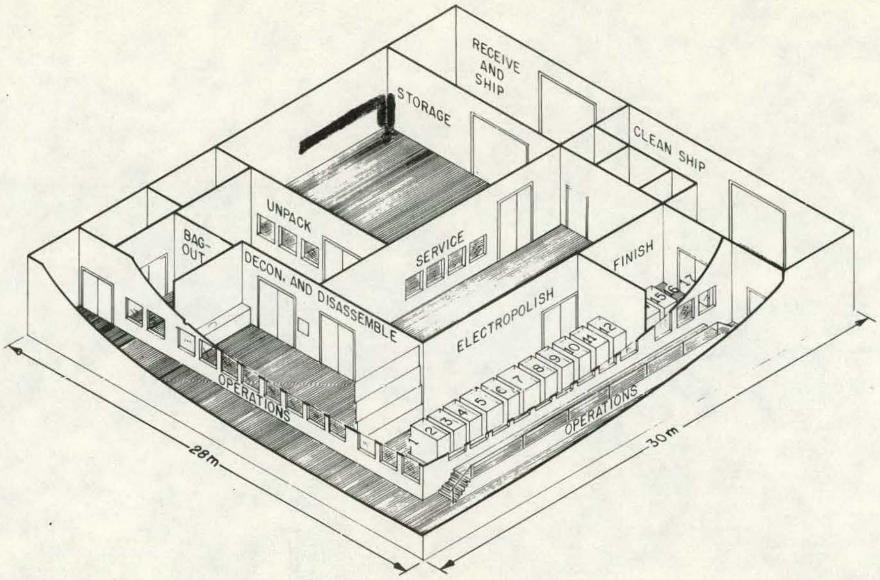


FIGURE 6. Disassembly & Decontamination Facility for Current TRU Waste Only

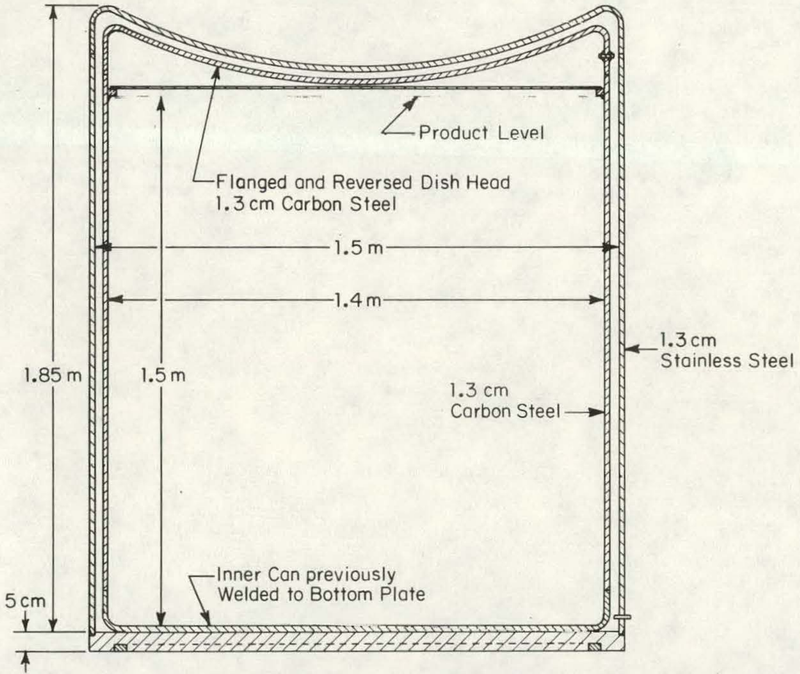


FIGURE 7. Conceptual Long-Term TRU Solid-Waste Storage Container

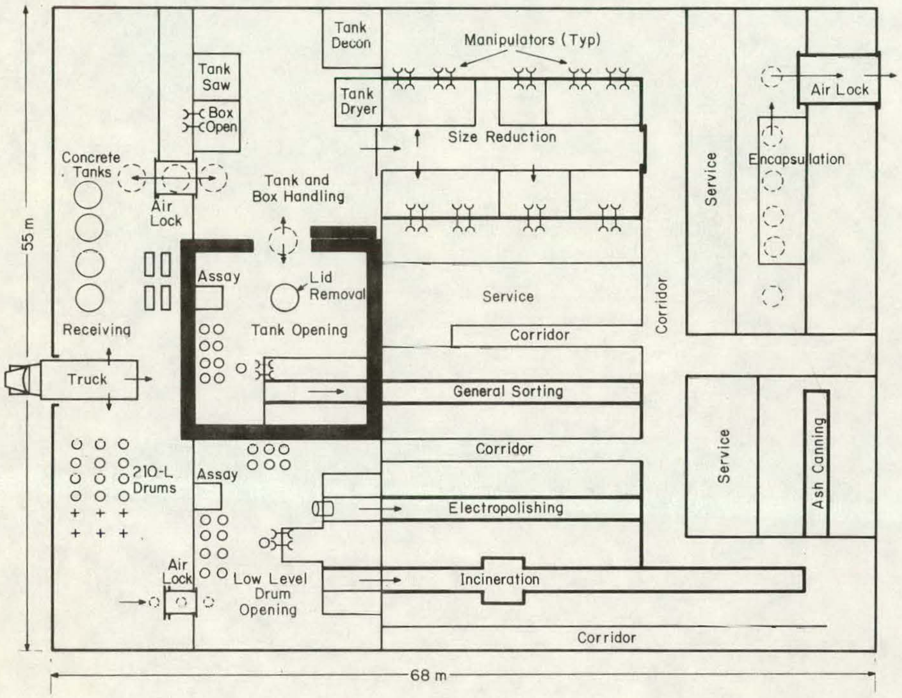


FIGURE 8. Plan of TRU Solid-Waste Facility Proposed for Savannah River Plant