MASTER

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UC-70

ECONOMIC EVALUATION OF VOLUME REDUCTION FOR DEFENSE TRANSURANIC WASTE

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DISCLAIMER

SYNOPSIS OF MEETING ON ECONOMIC EVALUATION

1 September 1981

($\$/m^3$)

Newly Generated Waste - Values Based on RFP & INEL

$3,300		Total Cost for Placing Waste in WIPP.
$2,330		Total Savings for Not Placing Waste in WIPP
	$260	Handling and Packaging; Includes Labor and Materials
	$200	Interim Storage; Includes Cost of Preparing Storage Facility and Emplacement
	$600	Retrieval; Includes Cost of Retrieval Structure, Machinery, and Labor
	$630	Transportation: RFP — INEL ($120) by ATMX INEL — WIPP ($510) by TRUPAC
	$640	Final WIPP Storage: Includes Labor, Operating Cost, Surveillance

EXECUTIVE SUMMARY

This study evaluates the economics of volume reduction of retrievably stored and newly generated DOE transuranic waste by comparing the costs of reduction of the waste with the savings possible in transportation and disposal of the waste. The report develops a general approach to the comparison of TRU waste volume reduction costs and cost savings, establishes an initial set of cost data, and develops conclusions to support selecting technologies and facilities for the disposal of DOE transuranic waste.

Section I outlines the analysis which considers seven types of volume reduction from incineration and compaction of combustibles to compaction, size reduction, shredding, melting, and decontamination of metals. The study considers the volume reduction of contact-handled newly generated, and retrievably stored DOE transuranic waste. Section II of this report describes the analytical approach, assumptions, and flow of waste material through sites. Section III presents the waste inventories, disposal, and transportation savings with volume reduction and the volume reduction techniques and savings.

Section IV contains the results and conclusions of the study. The following summarizes the major conclusions drawn from the study.

1) For a site with a small amount of waste requiring disposal (less than 1000 m^3/year) the cost of volume reduction is greater than the transportation and disposal savings from volume reduction. All sites except INEL fall into this category.
2) For INEL incineration and metal shredding come closest to being cost-effective, provided a facility is to be constructed as a consequence of repackaging the fraction of stored waste which may require repackaging and immobilizing chemical process waste to meet WIPP criteria. In addition, no costly changes to the facility must be required other than the additional floor space to add the volume reduction processes.

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INTRODUCTION

1.1 Background

This topical report is an economic evaluation comparing the costs of volume reduction of stored and newly generated DOE transuranic waste with the savings possible in transportation and disposal of the waste. The study is intended to provide information to help determine the strategy, technology develpment, and facility plans for the disposal of DOE TRU waste in the WIPP facility.

This study was performed in support of the Transuranic Waste Management Program. The program is to provide technology for management of TRU waste from the point of generation through readiness for delivery to a permanent repository. Part of the program includes a system analysis effort to provide comprehensive, systematic methodology and support to understand the options for national long-term management of TRU waste. The analysis effort supports two program responsibilities which include identifying and integrating technical issues into a national program strategy and providing cost/benefit analysis for alternate strategies, technologies, and facility plans.

1.2 Approach

This study develops a general, parametric approach to the economic comparison of TRU waste volume reduction costs and cost savings, establishes an initial set of cost data, and develops conclusions to support selecting technologies and facilities for the disposal of DOE transuranic waste. The study develops insight to waste disposal economics by evaluating the following:

1) The savings associated with reducing the volume of transuranics requiring transportation and disposal.
2) The volume reduction techniques applicable to TRU waste.
3) The capital and operating cost of each technique.

METHOD OF ANALYSIS

2.1 Description

The analysis evaluates cost savings from volume reduction for two areas: reduced full operation time for waste disposal at WIPP and more efficient waste transportation (higher ratio of waste to container tonnage). Balanced against these possible savings is the cost of volume reducing the TRU waste. The study considers the incremental cost of volume reduction, that is, the cost to install and operate the technique by adding floorspace, equipment, and personnel to a facility which is to be constructed and operated as a consequence of repackaging the fraction of stored waste which may require repackaging and immobilizing chemical process waste to meet WIPP criteria. The following possible volume reduction techniques are addressed in the report.

1) Incineration of Combustibles
2) Compaction of Combustibles
3) Compaction of Metals
4) Size Reduction of Metals
5) Metal Shredding
6) Metal Melting
7) Metal Decontamination

Only the volume reduction and disposal of the contact-handled, newly generated and retrievably stored DOE transuranics waste are considered. The management of buried TRU waste is outside the scope of this study. The study considers only newly generated and stored waste.

2.2 Assumptions

The following assumptions limit the analysis, but still allow the objectives of the study to be fully met. First, the sites used in the study are listed below:

1) Hanford Site
2) Savannah River Plant (SR)
3) Los Alamos National Laboratory (LANL)
4) Idaho National Engineering Laboratory (INEL)
5) Rocky Flats Plant (RF)

Second, waste management operations in this analysis start in 1990. Repository construction is complete in 1988 with equivalent full level of operation begun in 1990. Processing facilities are started as necessary to maintain full level of disposal operations until the stored waste is worked off. Third, the waste is divided into only three general categories; combustibles, metals, and chemical process wastes (sludges). It is assumed that combustibles and metals will meet WIPP acceptance criteria without processing. Chemical process waste will require immobilization for acceptance.

2.3 Material Flow at a Site

The flow of material through a DOE facility is shown in Figures 1-3. Three generalized cases are considered:

1) No volume reduction.
2) Volume reduction of combustibles.
3) Volume reduction of metals.

Figure 1 shows the minimum handling required at a site with stored waste. Figures 2 and 3 show the increased handing from volume reduction. Major retrieval sites will require a facility for some of the stored waste.

FIGURE 1

Material Flow With No Volume Reduction

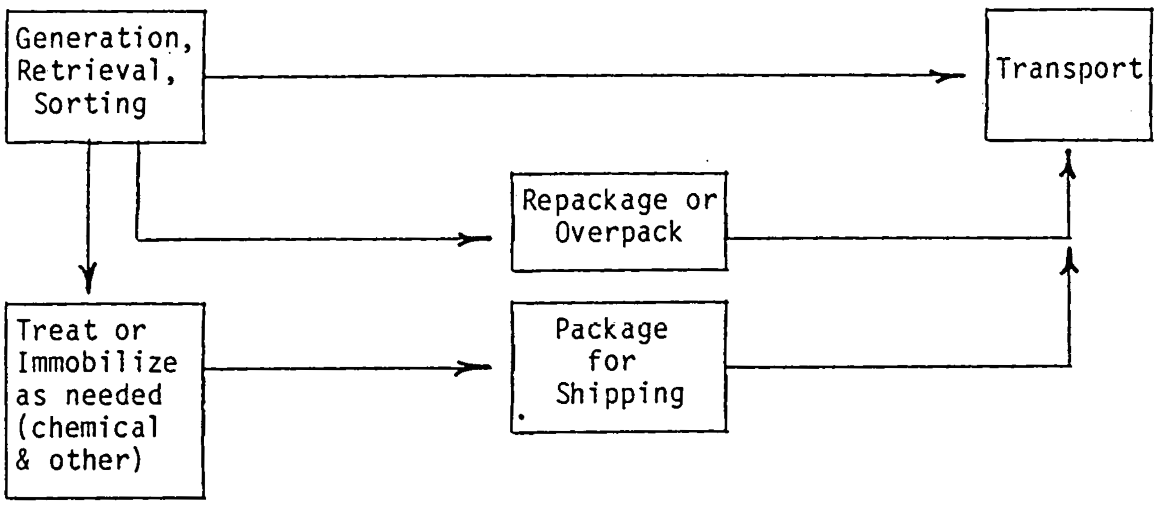


FIGURE 2

Material Flow - Volume Reduction of Combustibles

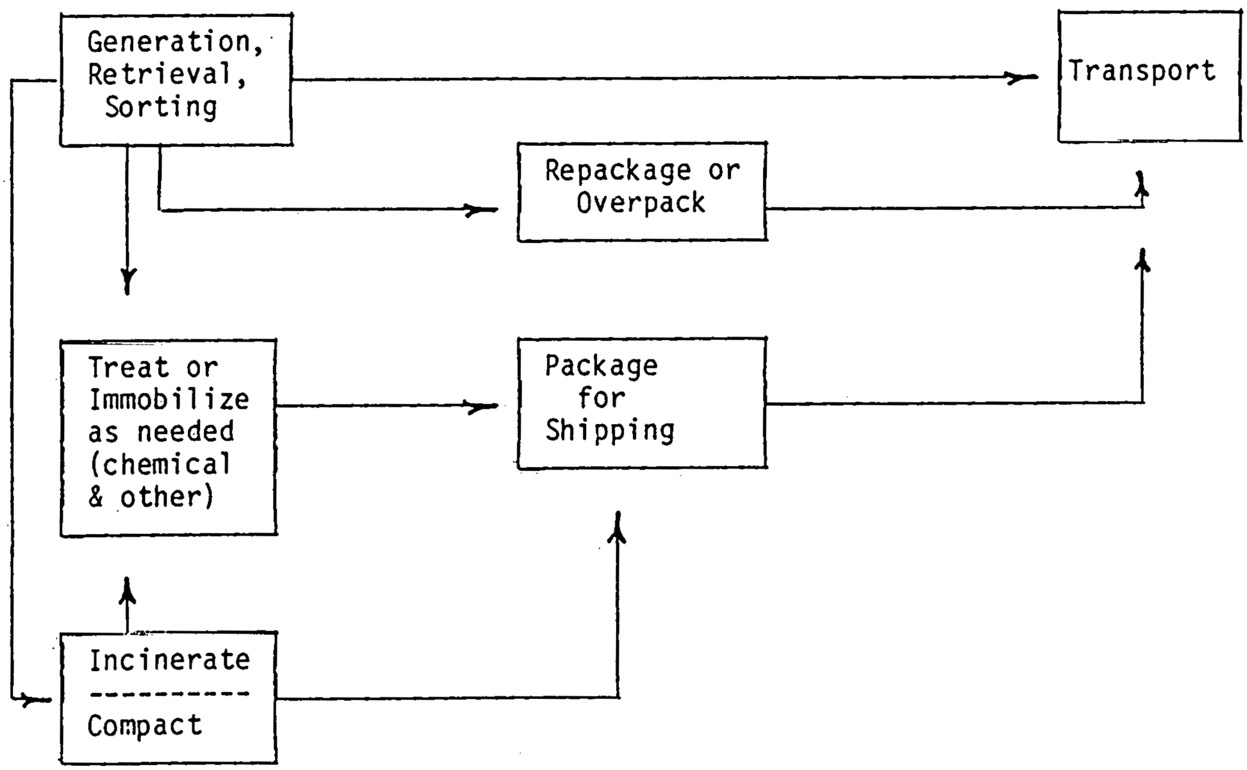
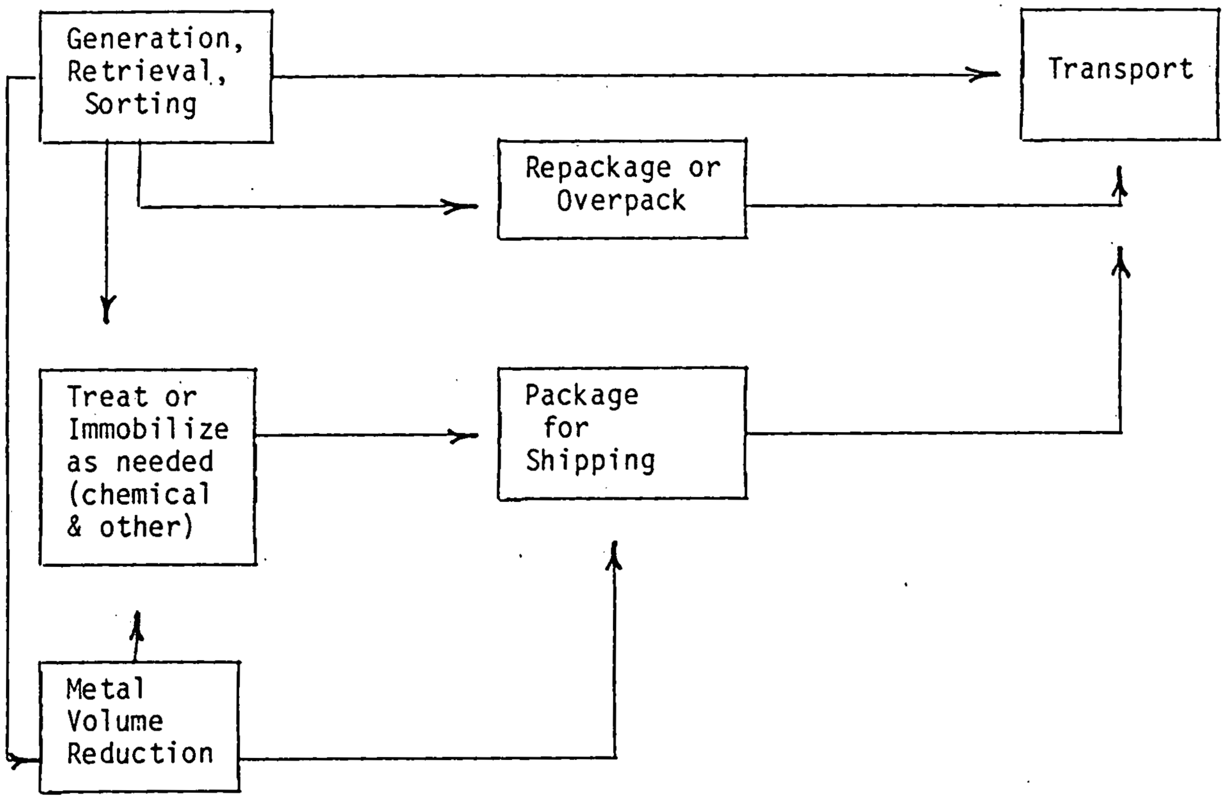


FIGURE 3

Material Flow - Volume Reduction of Metals



DATA

3.1 Waste Inventories

Tables 1 and 2 give the waste inventories used in this study.[1] The tables present projected inventories in cubic meters with new waste generation given in cubic meters per year. Estimates of retrievably stored waste for dates other than 1990 are made by linear extrapolation of newly generated waste rates, assuming current interim waste management practices continue until processing and disposal begins. Beginning in 1983 for Rocky Flats and in 1985 for other sites, it is assumed that as much waste as possible will be packaged to meet WIPP acceptance criteria (WIPP certified) and will be stored separately from other retrievably stored waste. The amount of waste immediately ready for WIPP in 1990 is assumed to be 5 years of average new generation for all sites. Current interim practices are discontinued and waste transfers made according to the scenario under consideration when processing and disposal begin. The newly generated waste rates given in Table 2 continue through the work-off period.

TABLE 1

Contact-Handled Stored TRU Wastes (m^3)[1,2]
(1990)

	Metals	Chem Process	Combustibles	Other	Total
Hanford	4,500(900)	600(100)	11,100(2200)	200(50)	16,400(3250)
SR	1,900(550)	--	3,400(950)	--	5,300(1500)
LANL	3,800(750)	3,800(1400)	1,000(250)	--	8,600(2400)
INEL	22,700(3500)	11,900(1950)	24,000(5600)	4,800(850)	63,400(11,900)
TOTAL	32,900(5700)	16,300(3450)	39,500(9000)	5,000(900)	93,700(19,050)

[1] Total volume (WIPP certified volume).

[2] Assumes no volume reduction; WIPP certified waste assumes 5 years average new generation for all sites.

TABLE 2

Contact-Handled New Waste Generation (m^3/yr)

	Metals	Chem Process	Combustibles	Other	Total
Hanford	180	20	440	10	650
SR	110	--	190	--	300
LANL	150	280	50	--	480
RFP	470	270	930	130	1,800
TOTAL	910	570	1,610	140	3,230

3.2 Waste Disposal Savings

Currently it is planned to place the retrievably stored DOE TRU waste at INEL and all newly generated TRU waste beginning about 1990 in the Waste Isolation Pilot Plant (WIPP). Stored waste at other sites may be placed in WIPP although no decision has been made to do so. The benchmark design capacity (170,000 m^3) is adequate for these wastes for WIPP. Cost given below are based on reference 2.

Yearly waste handling capacity with one-shift operation is 14,200 m^3/year. Waste disposal during the period of stored waste work-off would not require more than one-shift operation. Operating and maintenance costs at this rate are approximately 29 million 1981 dollars per year. This study assumes that retrieval, processing, and shipping at the various DOE sites will be coordinated to keep WIPP at full one-shift capacity until the stored waste is worked off. At the end of this period it is assumed WIPP will continue to receive newly generated waste and operate at a reduced level. Cost savings from volume reduction are then calculated from operations' cost saved by working off stored waste sooner. Operating and maintenance cost to handle only the newly generated waste (~3,500 m^3/year) is $22 million per year.

Waste disposal savings for each cubic meter not emplaced in WIPP is found by subtracting the yearly operating cost at the reduced (newly generated waste only) level from the yearly operating cost at the full one-shift level and dividing this by the yearly storage volume at the full one-shift level. Cost savings per cubic meter not emplaced in WIPP is found to be \$500/m^3 (\$14/ft^3). For each of the volume reduction processes given in section 3.4, the cost savings per cubic meter of unprocessed waste is given by the equation:

$$\text{Cost per } m^3 \text{ unprocessed waste} = (1 - K) \times \text{Cost per } m^3 \text{ not emplaced}$$

where K = the fraction of waste volume remaining after volume reduction and immobilization. Table 3 gives the cost savings per cubic meter of unprocessed waste for each of the processes.

TABLE 3

Waste Disposal Savings for Each Reduction Process[1]

	Incineration	Compaction	Size Reduction	Metal Shredding	Metal Melting	Metal Decontamination
K	.037	.68	.50	.20	.10	.17
Savings	480	160	250	400	450	420

[1] Savings in dollars/m^3 of unprocessed waste

3.3 Transportation Savings

Transportation of DOE transuranic waste to WIPP is expected to require a Class B type of shipping container. The Transportation Technology Center (TTC) at Sandia Laboratories in Albuquerque is developing preliminary designs for these containers (currently referred to as a TRUPACT). Two designs are considered in this study; the initial TRUPACT design which is most economical if the waste is packaged in drums or sized packages

(3' x 4' x 6') and a modified TRUPACT design which is heavier and larger, but is the best compromise for shipping stored waste without repackaging. Table 4 gives the description of each type of container.

TABLE 4

Waste Container Design Description

	Initial TRUPACT	Modified TRUPACT
Cavity	29.7 m^3	32.3 m^3
Empty Weight	12 tons	17 tons
Payload Limit[1]	21 tons	18 tons
Waste Volume (% Loading)		
With Sized Containers (3' x 4' x 6')	22.4 m^3 (75%)	22.4 m^3 (70%)
With 8 Six-Packs[2] (48 drums)	10.2 m^3 (35%)	10.2 m^3 (32%)
With 4 Six-Packs and 4 RFP Boxes (4' x 4' x 7')	Too Large	17.8 m^3 (55%)

[1] When shipped by rail.

[2] Six 55-gallon drums held as a single unit by a frame.

The following assumptions are made in calculating the savings from waste volume reduction due to transportation.

1) Consider only rail transportation of waste.
2) Shipping cost by rail is 11 cents/ton/mile, including 10% for capital cost for the waste package. This is the approximate current TRU waste shipment cost.
3) For newly generated waste use the initial TRUPACT design.

4) For stored waste use modified TRUPACT for unprocessed waste and the initial TRUPACT for volume reduced waste.

5) Stored metals are assumed shipped with immobilized sludges.

6) Combustibles are assumed shipped on their own.

Tables 5 and 6 present the waste description and packaging description, respectively, used in the study.[3] Packaging costs for new packaging or overpacks average \$175/m^3 and are added to shipping cost given in the tables.

TABLE 5

Unprocessed Waste Description

	Density[1]	Packaging
Metals	26 lb/ft^3 (.46 ton/m^3)	RFP boxes
Combustibles	22 lb/ft^3 (.39 ton/m^3)	50% drums 50% boxes
Sludges	68 lb/ft^3 (1.20 ton/m^3)	100% drums

[1] Including original containers, add 12% for wood box overpack and/or drum bracing.

TABLE 6

Waste Package Description

Container	Size	Volume (ft^3)	Container Weight (lb)	Cost ($)
RFP Box	4' x 4' x 7'	112	--	--
55-Gallon Drum	--	7.4	55	25
TRUPACT Container	3' x 4' x 6'	72	325	400
Six-Pack Bracing	3' x 4' x 6'	--	200	45

The shipping cost for each cubic meter of waste shipped equals the product of the number of containers shipped per year times the weight of the waste plus twice the container weight times the one-way shipping distance times the shipping rate divided by the volume of waste shipped per year. This reduces to the following equation.

$$\text{Shipping Cost/m}^3 \text{ of Waste Shipped} = \text{One-Way distance} \times \text{rate} \times (\text{waste density} + 2 \times \text{container weight/container waste volume})$$

For unprocessed waste the shipping cost per m^3 of waste retrieved or generated equals the shipping cost per m^3 of waste shipped. For each process which volume reduces waste, the shipping cost per m^3 of waste retrieved or generated equals the shipping cost per m^3 of waste shipped times K. Where K equals the fraction of the unprocessed volume remaining after reduction and immobilization. The cost savings per m^3 of waste stored or generated equals the unprocessed cost minus the processed cost. Unprocessed waste shipping costs from various sites are given in Table 7. Costs are given in 1981 dollars per cubic meter stored or generated. Processed waste shipping cost from various sites is given in Table 8. Shipping cost savings from volume reduction is summarized in Table 9.

TABLE 7

Unprocessed Waste Shipping Costs from Various Sites

	Newly Generated		Stored Waste		
				Combustibles	
	Metals	Combustibles	Metals	Drums & Boxes	Drums Only
Container weight (tons)	12	12	12[1]	17	12
Container waste volume (m^3)	22.4	22.4	12.7[1]	17.8	10.2
Waste density (Ton/m^3)[2]	.46	.39	.52	.44	.44
Cost/mile/m^3	.17	.16	.26	.26	.31
					Avg. .28
Cost/m^3 (container, overpack, or bracing cost)					
Hanford	390 (175)	370 (175)	600 (175)		640 (105)[3]
SR	260 (175)	240 (175)	390 (175)		420 (105)
LANL	82 (175)	77 (175)	120 (175)		130 (105)
INEL	300 (175)	280 (175)	460 (175)		490 (105)
RF	120 (175)	110 (175)	---		---

[1] Fraction of container proportioned to boxes with metal, rest assumed to be chemical process waste in drums.

[2] Includes overpack and/or bracing.

[3] Fifty percent boxes at \$175/m^3, 50% drums at \$35/m^3 for bracing.

TABLE 8

Processed Waste Shipping Costs from Various Sites

	Incineration	Compaction Combustibles	Compaction Metals	Size Reduction	Metal Shredding	Metal Melting	Metal Decontamination
Container weight (tons)	12	12	12	12	12	12	12
Container waste volume (m^3)	7.8[2]	22.4	22.4	19.1[2]	8.1[2]	3.9[2]	15.0[2]
Waste density (ton/m^3)[1]	2.7	.60	.81	1.1	2.6	5.4	1.4
K	.037	.68	.68	.50	.20	.10	.17
Cost/mile/m^3	.024	.12	.14	.13	.13	.13	.056
Cost/m^3 (container and bracing cost)[3]							
Hanford	55 (6)	280 (120)	320 (120)	300 (88)	300 (53)	300 (18)	130 (30)
SR	36 (6)	180 (120)	210 (120)	195 (88)	195 (53)	195 (18)	84 (30)
LANL	12 (6)	58 (120)	67 (120)	62 (88)	62 (53)	62 (18)	27 (30)
INEL	42 (6)	210 (120)	245 (120)	230 (88)	230 (53)	230 (18)	98 (30)
RF	17 (6)	84 (120)	98 (120)	91 (88)	91 (53)	91 (18)	39 (30)

[1] Includes containers.

[2] Weight limited at 0.94 $tons/m^3$ = 21 tons in 22.4 m^3.

[3] K x $175/$m^3$.

TABLE 9

Shipping Cost Savings at Various Sites ($\$/m^3$)

Site	Incineration	Compaction Combustibles	Compaction Metals	Size Reduction	Metal Shredding	Metal Melting	Metal Decontamination
Newly Generated Waste							
Hanford	480	145	125	180	215	250	405
SR	370	115	105	150	185	220	320
LANL	230	74	70	110	145	180	200
INEL	410	125	110	160	195	230	350
RF	260	81	77	120	155	190	230
Stored Waste							
Hanford	680	345	335	390	425	460	615
SR	480	225	235	280	315	350	450
LANL	220	57	110	145	180	215	240
INEL	550	265	270	320	355	390	510

3.4 Volume Reduction Techniques

There are several volume reduction processes which could be applied to TRU wastes. These processes fit in the broad categories of incineration, size reduction, compaction, melting, and decontamination. These are all post-generation waste treatments; pre-generation treatments are being addressed under a separate task of the TRU Waste Management Program. This document addresses volume reduction techniques to be used at a TRU waste treatment facility, and deals with contact-handled waste from the major source locations.

Cost estimates for these processes are based on a stored waste facility and a facility for newly generated wastes sized to treat the waste streams given in Table 10. Details of these estimates are given in Appendix A. These are yearly processing rates for wastes at INEL and RFP respectively. These sites are used to demonstrate the cost effectiveness of volume reduction.

TABLE 10

Waste Processing Rates for Cost Estimates

Waste Type	Large Facility (m^3/yr)	Small Facility (m^3/yr)
Combustibles	2500	930
Metals	2350	500
Chemical Process Wastes	1500	300

All cost estimates in this section are given in constant 1981 dollars. Capital costs are assigned to a cubic meter of waste based on a 15-year facility lifetime. All costs are incremental costs, that is, the cost to add the floor space and equipment to a facility which must be built anyway or to a facility which already exists. Cost estimates in this study assume that the type of facility which is required to repackage the fraction of stored waste which may require repackaging and to immobilize chemical process waste to meet WIPP criteria would only need additional floor space to add the volume reduction facilities discussed in this section. If a more complicated (i.e., more containment) facility is required, then the incremental cost estimates would be larger. The estimates assume a minimum of remote handling of waste.

Initial waste densities given in the material flow diagrams in this section are the packaged densities in stored waste and represent roughly a 2 to 1 reduction over "loose" density. Newly generated waste is assumed to be packed as it is generated to this density before volume reduction. Reduction factors in the diagrams represent reduction from this packaged density.

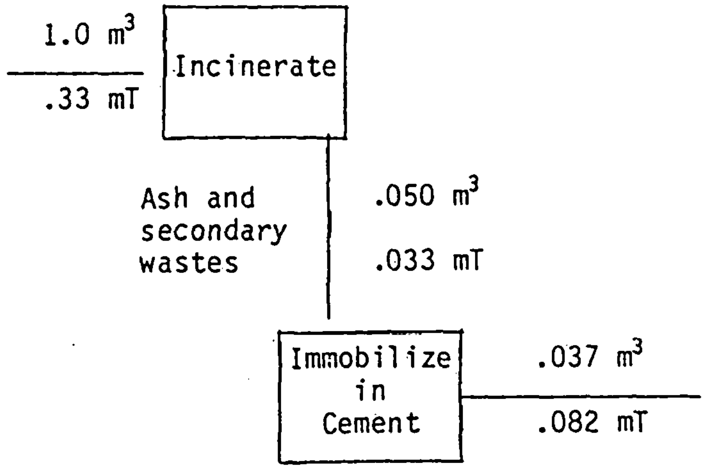
3.4.1 Incineration of Combustibles

The term "incineration" is used to describe several processes which effect a volume reduction by chemical oxidation. Therefore, incineration processes include wet and pyrochemical processes. A significant amount of the TRU waste is converted to nonradioactive gases and released to the atmosphere. An incineration process for TRU waste treatment will reduce both weight and volume. Typical volume reductions are 20:1 to 40:1 (95-98%).

The Rocky Flats Fluid Bed Incinerator is used as a basis for calculations. The assumed volume reduction is 20:1 and weight reduction is 10:1 with ash and secondary waste streams. A generalized material flow diagram is shown in Figure 4 for an unprocessed combustible waste input of 1.0 m^3. Immobilization is included in the incineration block diagram, since it is expected that ash and secondary waste streams must be immobilized to be emplaced in WIPP. It is assumed that cements with 40% by weight waste loading will meet WIPP acceptance criteria. Final density of this waste form is 140 lb/ft^3 or 2.2 metric $tons/m^3$.

FIGURE 4

Material Flow - Incineration



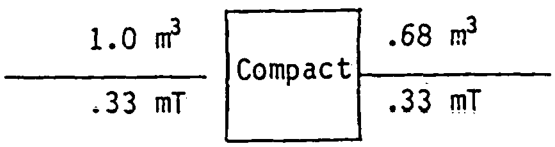
Final waste density = 2.2 mT/m^3

3.4.2 Compaction of Combustibles and Metals

The compaction process considered is a hydraulic or air operated ram which forces bulk waste into its final container. Volume reductions using this method are about 30-35%, although reductions of over 80% have been demonstrated with HEPA filters. A value of 32% volume reduction is used in this analysis. The same type of equipment is envisioned for both combustibles and metals. The material flow diagrams are given in Figures 5 and 6.

FIGURE 5

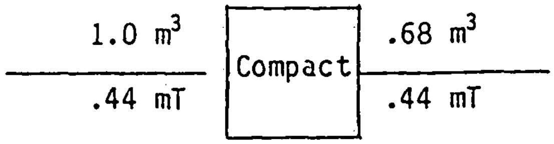
Material Flow - Combustible Compaction



Final waste density = 0.49 mT/m^3

FIGURE 6

Material Flow - Metal Compaction



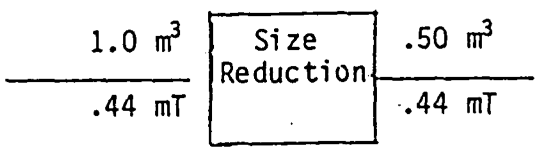
Final waste density = 0.65 mT/m^3

3.4.3 Size Reduction of Metals

There are several methods of size reduction in use in the nuclear industry. Sawing and torch cutting are the most common size reduction techniques. The process consists of separating pieces of metal from each other by removing a narrow kerf of material between the two. Equipment used for this operation includes, but is not limited to, hand hacksaws, power hacksaws, handsaws, oxyacetylene torches, and plasma arc torches. The volume reduction accomplished by this technique is about 50% on bulky items. Material flow is given in Figure 7.

FIGURE 7

Material Flow - Size Reduction



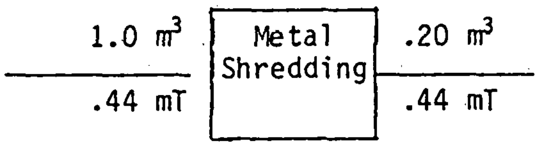
Final waste density = 0.88 mT/m^3

3.4.4 Metal Shredding

The cutting or shearing processes can be used for a wide variety of materials found in current and stored TRU wastes. Most shredding equipment uses the same type of action as a reel lawn mower; that is, the material to be processed is fed between two sets of blades; one blade (usually called the anvil) is stationary, and the moving blade is one of several mounted on a rotating drum or axle. This process is expected to reduce the bulk volume of TRU waste metals by about 80%. The material flow is given in Figure 8.

FIGURE 8

Material Flow - Metal Shredding



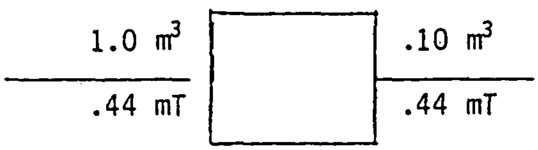
Final waste density = 2.2 mT/m^3

3.4.5 Metal Melting

This process as applied to TRU wastes is a consolidation of metal waste into buttons or ingots by melting and pouring. Electric melters are widely used in the nuclear industry. The electric melting furnaces can be of the resistance, induction, or arc types. For the amount of waste considered, the arc furnace is probably the best choice. For this analysis a volume reduction of 90% is assumed. Material flow is shown in Figure 9.

FIGURE 9

Material Flow - Metal Melting



Final waste density = 4.4 mT/m^3

3.4.6 Metal Decontamination

Metal can be decontaminated by several methods, including washing, leaching, vibratory finishing, chemical milling, and electropolishing. Most of these methods remove the contamination by removing a thin layer of the metal surface by mechanical or chemical action. The contamination and removed metal are carried away as sludge by the cleaning solution.

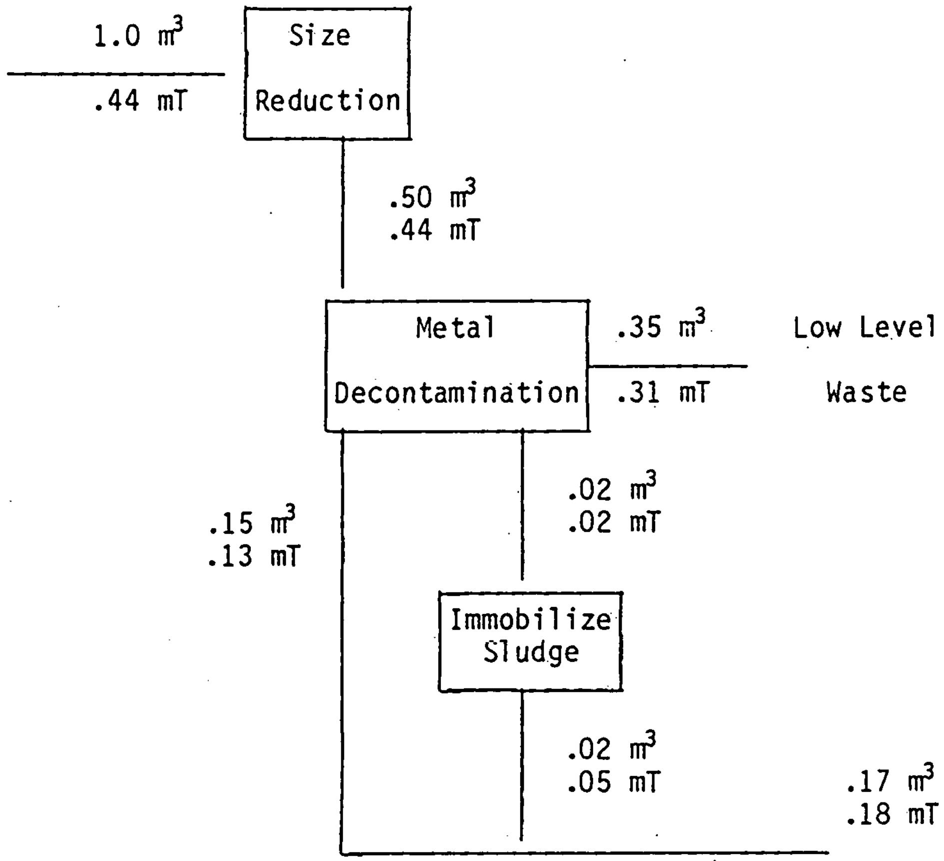
The purpose of decontamination is to reduce costs by removing metal to a low-level waste stream for shallow land burial. In most cases about 70% of the original metal waste can be removed from the TRU waste category. This analysis assumes that the remaining metal goes to WIPP. A side waste stream of TRU sludge is generated which is assumed to be about 4% of the incoming waste volume. This stream is immobilized before shipment to WIPP. Material flow is given in Figure 10.

3.4.7 Summary of Costs for Volume Reduction

Table 11 summarizes costs for each of the volume reduction techniques discussed in this document. All costs are given in 1981 dollars per cubic meter of unprocessed waste. For each process, two estimates are given. The first estimate is for processes of the approximate size to volume reduce metals or combustibles retrievably stored at INEL (10-year work-off period). The second is for processes of the approximate size to volume reduce wastes newly generated at RFP. Details of cost estimates for each process is given in Appendix A.

FIGURE 10

Material Flow - Metal Decontamination



Final waste density = 1.1 mT/m^3

TABLE 11

Costs for Volume Reduction of TRU Waste[1]

	Incineration	Compaction Combustibles	Compaction Metals	Size Reduction	Metal Shredding	Metal Melting[2]	Metal Decontamination[2]
Processing Stored Waste (INEL)	1,300	830	860	1,000	800	2,200	1,600
Processing Newly Generated Waste (RFP)	1,900	1,200	1,600	1,900	1,500	4,000	2,900

[1] Costs are given in 1981 dollars per cubic meter of unprocessed waste.
[2] Includes size reduction costs.

RESULTS AND CONCLUSIONS

Conclusions in this study are based on representative costs and savings comparisons at a DOE stored waste site and a new waste generation site. Costs for processes are based on equipment and staff sized to treat the waste streams given in section 3.4. These are approximate projected yearly processing rates for waste at INEL and RFP respectively. These sites are used to demonstrate the cost effectiveness of volume reduction. Table 12 compares processing costs against disposal and transportation cost savings for volume reduction at these sites and subsequent transportation to WIPP. Costs are given in 1981 dollars per cubic meter. The following conclusions are drawn from the table.

1) For a site with a small amount of waste requiring disposal (less than 1000 m^3/year) the cost of volume reduction is greater than the transportation and disposal savings from volume reduction. All sites except INEL fall into this category.
2) For INEL incineration and metal shredding come closest to being cost-effective, provided a facility to repackage the fraction of stored waste which may require repackaging and to immobilize chemical process waste to meet WIPP criteria must be constructed anyway. In addition, no costly changes to the facility must be required other than the additional floor space to add the volume reduction processes.

TABLE 12

Savings Versus Cost Comparison for Volume Reduction[1]

	Incineration	Compaction Combustibles	Compaction Metals	Size Reduction	Metal Shredding	Metal Melting[2]	Metal Decontamination[2]
Newly Generated Waste at RFP[3]	1,900(740)	1,200(240)	1,600(240)	1,900(370)	1,500(550)	4,000(640)	2,900(650)
Stored Waste at INEL[4]	1,300(1,030)	830(425)	860(430)	1,000(570)	800(750)	2,200(840)	1,600(930)

[1] Process cost (disposal and transportation savings) in dollars/m^3.

[2] Includes size reduction costs.

[3] Also represents approximate costs for sites with less than 1,000 m^3/yr requiring disposal and approximate savings for sites 700 miles from WIPP.

[4] Also represents approximate costs for sites with 2,500 m^3/yr requiring disposal and approximate savings for sites roughly 2,000 miles from WIPP.

REFERENCES

1. Communication, L. J. Smith, Transuranic Waste Systems Office, Rocky Flats, Colorado. Updated estimates to appear in revision to ORO-778, Spent Fuel and Waste Inventories and Projections.

2. Communication, WIPP Project Office, Department of Energy, Albuquerque, New Mexico.

3. H. C. Shefelbine, Preliminary Evaluation of the Characteristics of Defense Transuranic Waste, SAND 78-1850 (November 1978).

4. F. C. Jelen, Cost and Optimization Engineering, McGraw-Hill, New York, 1970.

APPENDIX A

INCREMENTAL COST ESTIMATES FOR WASTE VOLUME REDUCTION PROCESSES

All cost estimates in this section are given in constant 1981 dollars. All costs are incremental costs, that is, the cost to add floor space, equipment, and personnel to a facility which must be built anyway or to a facility which already exists. Cost estimates in this study assume that the type of facility which is required to repackage the fraction of stored waste which may require repackaging and to immobilize chemical process waste to meet WIPP acceptance criteria would only need additional floor space to add the volume reduction facilities discussed in this section. If a more complicated (i.e., more containment) facility is required, then the incremental cost estimates would be much larger.

For each type of volume reduction, first, the basis and assumption for the cost estimate is presented. Second, the yearly fixed and variable cost estimates are scaled from the base design for the waste processing rates given in Table 10 in section 3.4. This results in two costs for each process; one for processes of the approximate size to work-off the stored waste at INEL and one for processes of the approximate size to reduce the newly generated waste at RFP. Costs are scaled using the following equation:[4]

$$C_2 = C_1 \cdot (Q_2/Q_1)^{0.6}$$

where C_2 = cost with capacity Q_2

C_1 = cost with capacity Q_1

The following assumptions apply to all cost estimates:

1) Capacities (in cubic meters per year) assume waste densities given in Section 3 of this report. These densities are the packaged density in stored waste and represent roughly a 2 to 1 reduction over "loose" density. Newly generated waste is assumed

to be packed to this density before volume reduction. Reduction factors given in this report represent reduction from this packaged density.

2) Capital costs for processes are divided over a 15-year lifetime.
3) Process costs are estimated with minimum remote handling equipment. Reduced worker exposure guides would make all alternatives less cost effective.
4) Floor space cost is derived from the cost of the new plutonium facility at Rocky Flats and is $500/ft^2$.
5) Labor costs are assumed to be $75,000/man-year.
6) Six percent is added to capital equipment cost to cover research and development.
7) Ten percent is added to capital equipment cost to cover D&D of the process at the end of its life.
8) All costs are given in millions of 1981 dollars (M)

1.1 Incineration of Combustibles

The incinerator cost estimate is based on the installed cost of the Rocky Flats fluid bed incinerator. The cost for immobilization of ash is estimated as an incremental cost to an immobilization facility which will be required for chemical process wastes. Capacity of the FBI is 82 kg/hr or approximately 1200 m^3/year. Costs are given in Table A-1.

TABLE A-1

Incineration Cost Basis

Fixed Cost	
Equipment, as installed	2.71 M
Floorspace (3200 ft^2)	1.60 M
R&D and D&D	.70 M
	5.0 M
Over 15 year lifetime	.33 M/yr
Variable Cost	
Labor	
5 man crew, 4 shifts	1.50 M/yr
2 average maintenance	.15 M/yr
Materials	.08 M/yr
	1.70 M/yr

Fixed and variable costs scaled to the process rates for stored waste at INEL and newly generated rates at RFP are given in Table A-2.

TABLE A-2

Incineration Process Costs (Million $/yr)

	Fixed Cost	Variable Cost	TOTAL
Stored waste at INEL	.51 (.13)	2.64 (.013)	3.29
New waste at RFP	.28 (.06)	1.46 (.012)	1.81

* Numbers in parenthesis are immobilization costs to expand an existing immobilization facility.

1.2 Compaction

Cost estimates for compaction are based on processes for the Rocky Flats Advanced Size Reduction Facility (ASRF). The cost estimate given in Table A-3 is for a capacity of 1,000 m^3/year.

TABLE A-3

Compaction Cost Basis

Fixed Cost	
Equipment and controls	.10 M
Containment (Glovebox)	.50 M
Floorspace (1,400 ft^2)	.70 M
R&D and D&D	.21 M
	1.5 M
Over 15 year lifetime	.10 M/yr
Variable Cost	
Labor	
3 man crew, 4 shift	.9 M/yr
2 average maintenance	.15 M/yr
Materials	.01 M/yr
	1.1 M/yr

Fixed and variable costs scaled to the process rates in section 3.4 are given in Table A-4.

TABLE A-4

Compaction Process Costs (Million $/yr)

	Fixed Cost	Variable Cost	TOTAL
Stored waste at INEL			
Combustibles	.17	1.91	2.08
Metals	.17	1.84	2.01
New waste at RFP			
Combustibles	.10	1.05	1.15
Metals	.07	.73	.80

1.3 Size Reduction of Metals

Cost estimates for size reduction are based on processes for the Rocky Flats ASRF without remote handling manipulators. The cost estimate given in Table A-5 is for a capacity of 2,700 m^3/year.

TABLE A-5

Size Reduction Cost Basis

Fixed Cost	
Equipment and installation	5.0 M
Floorspace (9,600 ft^2)	4.8 M
O&M and D&D	1.6 M
	11.4 M
Over 15 year lifetime	.76 M/yr
Variable Cost	
Labor	
5 man crew, 4 shift	1.50 M/yr
4 average maintenance	.30 M/yr
Material	.05 M/yr
	1.9 M/yr

Fixed and variable costs scaled to the process rates in section 3.4 are given in Table A-6.

TABLE A-6

Size Reduction Process Costs (Million $/yr)

	Fixed Cost	Variable Cost	TOTAL
Stored waste at INEL	.70	1.75	2.45
New waste at RFP	.28	.69	.97

1.4 Metal Shredding

Cost estimates for metal shredding are based on processes for the Rocky Flats ASRF. The cost estimate given in Table A-7 is for a capacity of 2,000 m^3/year.

TABLE A-7

Metal Shredding Cost Basis

Fixed Cost	
Equipment and controls	1.0 M
Containment (Glovebox)	.5 M
Floorspace (2,000 ft^2)	1.0 M
R&D and D&D	.4 M
	2.9 M
Over 15 year lifetime	.19 M/yr
Variable Cost	
Labor	
4 man crew, 4 shift	1.2 M/yr
4 average maintenance	.3 M/yr
Materials	.01 M/yr
	1.5 M/yr

Fixed and variable costs scaled to the process rates in section 3.4 are given in Table A-8.

TABLE A-8

Metal Shredding Process Cost (Million $/yr)

	Fixed Cost	Variable Cost	TOTAL
Stored waste at INEL	.21	1.65	1.86
New waste at RFP	.08	.65	.73

1.5 Metal Melting

Cost estimates are derived from estimates of installed costs of a large arc melt vacuum furnace to melt large metal items at the Hanford facility. The cost estimate given in Table A-9 is for a capacity of 2,500 m^3/year.

TABLE A-9

Metal Melting Cost Basis

Fixed Cost	
Equipment and installation	
5 arc furnaces	2.5 M
Installation, electrical	4.0 M
Floorspace (5000 ft^2)	2.5 M
R&D and D&D	1.4 M
	10.4 M
Over 15 year lifetime	.69 M/yr
Variable Cost	
Labor	
6 man crew, 4 shift	1.80 M/yr
4 average maintenance	.30 M/yr
Material	.02 M/yr
	2.1 M/yr

Fixed and variable costs scaled to the process rates in section 3.4 are given in Table A-10.

TABLE A-10

Metal Melting Process Cost (Million $/yr)

	Fixed Cost	Variable Cost	TOTAL
Stored waste at INEL	.66 (.70)	2.0 (1.75)	5.1
New waste at RFP	.26 (.28)	.80 (.69)	2.0

*Numbers in parenthesis are size reducton costs required pior to decontamination.

1.6 Metal Decontamination

Cost estimates for metal decontamination are based on processes for the Rocky Flats ASRF. The cost estimate given in Table A-11 is for a capacity of 2,700 m^3/year.

TABLE A-11

Metal Decontamination Cost Basis

Fixed Cost	
Equipment and installation	3.0 M
Floorspace (1,000 ft^2)	.5 M
R&D and D&D	.5 M
	4.0 M
Over 15 year lifetime	.27 M/yr
Variable Cost	
Labor	
3 man crew, 4 shift	.9 M/yr
1 maintenance	.08 M/yr
Material	.05 M/yr
	1.0 M/yr

Fixed and variable costs scaled to the process rates in section 3.4 are given in Table A-12.

TABLE A-12

Metal Decontamination Process Costs (Million $/yr)

	Fixed Cost	Variable Cost	LLW Disposal	TOTAL
Stored waste at INEL	.25 (.70)	.92 (1.75)	.12	3.74
New waste at RFP	.10 (.28)	.36 (.69)	.04	1.47

* Numbers in parenthesis are size reduction costs required prior to decontamination.

APPENDIX B
VOLUME REDUCTION PROCESSES

There are several volume reduction processes which could be applied to TRU wastes. These processes fit in the broad categories of incineration, size reduction, compaction, melting, and decontamination. The TRU waste to be treated includes both stored and recently generated wastes.

A. Incineration

The term 'incineration' is here used to describe several processes which effect a volume reduction by chemical oxidation, and hence incineration processes include wet and pyrochemical processes.

An incineration process for TRU waste treatment must reduce weight and volume, and produce a product suitable for repository emplacement. Feedstocks will include plastics, cellulosics, charcoal, and other combustibles.

Low Temperature Combustion (<600°C)

- Fluidized Bed Incinerator (RFP)
- Acid Digestion (HEDL)

High Temperature Combustion (>600°C)

- Firebox (RFP)
- Agitated Hearth (RFP)
- Rotary Kiln (RFP)
- Controlled-Air (LASL, SRL)
- Cyclone Drum (Mound)
- Molten Salt (AI)
- Slagging Incinerator (INEL)

Several of these processes are still under development. Four of the processes are briefly described below.

The SRL controlled air incinerator is comprised of two adjoining chambers. The primary chamber is operated with substoichiometric air. Regulation of the point and quantity of air flow injection fosters fly ash entrainment and effective combustion. Positive ash removal is provided by gravity displacement as new material is introduced.

The rotary kiln was developed for combustion of contaminated residues at RFP. It is a horizontal cylindrical chamber rotating on its longitudinal axis. Operation is in an excess air, continuous mode. Potential advantages include thorough mixing of waste media, distribution of residues in a thin layer, and positive ash removal. Residence time is about 1 hour. The principle disadvantage is the mechanical complexity of the rotating primary chamber.

Wastes could be accepted in an unshredded form for these two types of incinerators. Introduction may be effected with a ram package feed system. No problems are anticipated in processing the solid combustibles and charcoal. Only the rotary kiln, however, has been developed for use with liquid combustibles. The SRL controlled air unit would need development in this area.

Fluidized bed incineration effects flameless combustion in a primary bed of sodium carbonate granules succeeded by an afterburner with oxidation catalyst bed. It was developed and demonstrated with contaminated waste at RFP. Vessel temperatures at 550 and 600°C, respectively. No refractories are required, construction is stainless steel. Product removal is through elutriation and it is both positive and continuous. Residence time is short, providing minimal ash hold-up and increased inventory accuracy. Factors inherent to fluidized beds include small facility size and thorough agitation of waste media. The presence of basic salts in the primary bed neutralizes acidic constituents, and permits use of a dry off-gas system.

Acid digestion effects combustion through chemical oxidation in a sulfuric/nitric acid bath. Development work was performed at Hanford Engineering Development Laboratory (HEDL). It is a low temperature process, operating at about 250°C. Construction is of glass and glass-lined steel. The primary safety concern is the presence of moderating liquids in contact with fissile material. Aqueous off-gas scrubbing is necessitated by acid recovery and cleansing requirements. A fractionation column for recovery and recycle of acids is included.

The four processes described above are all well developed. Only the fluidized bed and acid digestion processes have been demonstrated with contaminated waste on a commercial scale, however. All processes could be remotely operated if desired. Additional investigation would be needed for combusting liquids in the controlled air unit and incinerating charcoal in the fluidized bed. Alternative disposal must be identified for the charcoal and NPH liquids if acid digestion is selected.

B. Size Reduction

There are several methods of size reduction in use in the nuclear industry, and several others in use in other industries. Size reduction of some type is usually a necessary pretreatment to other volume reduction or immobilization processes, and has also been used in the past to facilitate the disposal or retrievable storage of large TRU contaminated equipment.

Size reduction processes can be divided into four broad categories as follows:

1) Crushing and grinding;
2) cutting or shearing;
3) sawing or torch cutting; and
4) other.

The other category includes such processes as thermal shock, explosive disintegration, flash pulverization, etc. These are applicable to some product streams in the chemical industry, but not to large-size TRU wastes.

1. Crushing and Grinding

Crushing and grinding processes are applicable to friable material such as glass and ceramics, and to metals to a lesser extent. Crushing and grinding achieves its effect by imparting enough energy (in mechanical form) to the process material to cause fracturing of the material. This is usually accomplished by forcing the material between two hard surfaces. There are a number of equipment types which accomplish this phenomena; it is the operating principle of roll mills, ball and rod mills, hammer mills, disc mills, and jaw crushers.

Another process which utilizes impact force for size reduction is the fluid energy or jet mill. These are commonly used inside other process equipment (such as fluid beds) and for grinding pneumatically conveyed solids. This is not considered of useful process for TRU waste volume reduction.

2. Cutting and Shearing

The cutting and shearing processes can be used for a wide variety of materials found in current and stored TRU wastes, from rags, paper, and plastics to light metals. Most cutting or shearing equipment uses the same type of action as a reel lawn mower; that is, the material to be processed is fed between two sets of blades; one blade (usually called the anvil) is stationary, and the moving blade is one of several mounted on a rotating drum or axle. Material flow can be transverse or normal to the axle, as is usually the case in heavy duty applications (such as the shredding of junk car bodies for steel remelt) or parallel to the axle (used in the slicing of bread).

3. Sawing and Torch Cutting

These are the most common size reduction techniques used in nuclear waste management. The process consists of separating pieces of metal from each other by removing a narrow kerf of material between the two. Equipment used for this operation includes, but is not limited to, hand hacksaws, power hacksaws, handsaws, oxyacetylene torches, and plasma arc torches.

C. Decontamination

Several types of noncombustible solid TRU wastes are produced or in storage. These include metals, glass, insulation, and ceramic materials. The only waste to be dealt with in this section will be metal; however, washing and leaching operations can be used to decontaminate combustible materials. The purpose of decontaminating metal is to reduce costs by removing metal to a low-level metal waste stream for LLW burial instead of TRU waste to be interred in WIPP.

1. Metal Decontamination Processes

Process options are:

- Electrodecontamination with phosphoric acid.
- Basic electrodecontamination.
- Electrodecontamination with the ceric-nitric acid system.
- Vibrafinish (vibratory finishing).
- Steam cleaning.
- Chemical decontamination.
- Melt-slagging.
- Miscellaneous

These processes will be described and evaluated individually.

a. Description of Processes

(1) Electrodecontamination with Phosphoric Acid

The use of phosphoric acid as an electrodecontaminating agent has been extensively investigated and reported. Two problem areas with phosphoric acid are the difficulty in recovering actinides from the solution and the difficulty of processing the spent electrolyte to obtain a solid waste form. Cadmium must also be processed since it is added as a neutron absorber. Phosphoric acid is an effective decontaminating agent, however, and the rate of decontamination is faster with phosphoric acid than with other systems.

(2) Basic Electrodecontamination

This electrodecontamination method uses a solution of pH 8.5 containing 200 g/l $NaNO_3$, 20 g/l $Na_2B_4O_7 \cdot H_2O$ (added to serve as a neutron poison) and 2 g/l $Na_2C_2O_4$ (to aid in filtering the sludge). The metal being decontaminated serves as the anode. Samples of stainless steel contaminated to 10^6 dpm/cm^2 were decontaminated to background (0.16 dpm/cm^2) by electrolysis at 25°C for 4 minutes; this resulted in the removal of ~30 mg/cm^2 of metal. The actinide, nickel, and iron dissolved from the stainless steel form a sludge in the bottom of the container. One disadvantage of this system is that chromium remains in the electrolyte, increasing to a concentration of 20 g/l. The actinide-containing sludge can be solubilized with nitric acid and this waste stream can be recovered by conventional methods.

(3) Electrodecontamination with the Ceric-Nitric Acid System

Cerium(IV) in nitric acid is a good dissolution agent for plutonium oxide and can be used for decontaminating metal surfaces. Studies have shown that 0.2M Ce(IV) in 2M HNO_3 at 90°C can reduce <10^6 dpm/cm^2 on stainless steel to background levels (<1 dpm/cm^2) in about 1 hour. Although this process is slower than the methods discussed above even at the higher temperature, the ceric-nitric acid system does possess some advantages. First, the system is not a high salt system; therefore, there is potentially less waste generation. Secondly, the cerium can be recovered and recycled (as described in the Actinide Recovery section). Third, the process does not require immersion of the equipment being decontaminated, so it can be used as a spray or as a flow-through system.

(4) Vibrafinish

Although vibratory finishing has been used for years in metal finishing, it has been tested only recently for decontamination. It has a longer process time (1/2 to 1 hour versus 1 to 2 minutes for electrodecontamination or electropolish) and the recovery process has not been well defined. It is usually considered as a preliminary decontamination step and preliminary tests show decontamination factors (the ratio of initial count to final count) of up to 100.

One real advantage is that materials other than metals can be decontaminated. The inability of the decontamination medium to reach areas accessible to liquid decontaminants is a disadvantage.

(5) Steam Cleaning

This method appears to be attractive in several ways: (1) about 95% of the actinide can be recovered from the steam condensate by filtration alone; (2) epoxy adhesive, a common contaminant, is quickly and completely removed; and (3) it is easy to remote.

Disadvantages include: (1) the decontamination factor is only about 10, so subsequent treatment by a more effective method is necessary; (2) a lot of aqueous waste (7 gal/ft^2 of contaminated surface) is generated; and (3) the containment area is subject to material (maintenance) problems because of the high humidity. The most serious disadvantage is the poor decontamination.

Vibratory Finishing

Process Description. Vibratory finishing is a process that uses the scouring action of vibrating abrasive media for cleaning the surface of materials. Energy in the form of vibratory forces is transferred from mechanical drive systems into a mass of loose media and then into the part. The entire load is in motion at the same time so that the media acts against the parts throughout the complete mass. During the process, an aqueous solution is percolated down through the media and parts to remove the metal fines, impurities, and contamination.

The basic elements of the process are the machine, abrasive media, aqueous solution, possibly a finishing compound, and the part being processed.

Abrasive Blasting

Process Description. Abrasive blasting is a process used for cleaning and finishing of materials by forceful direction of an abrasive grain, applied either dry or suspended in a liquid medium against the surface of the workpiece. The process is considered an economical operation because of a reduction in man-hour requirements as compared to other processes, the need for expensive equipment, and its application to surface areas without extensive preliminary sectioning or cutting of parts into specific sizes and shapes.

Abrasive blasting may be applied by either mechanical or air pressure means. When automation is a factor, mechanical dry blasting is generally used for removing surface contamination. Dry pressure blasting is used when relatively small to medium parts with intricate designs are being cleaned. Wet blasting, which is generally used with suspended fine abrasives in chemically treated water, is used with air pressure for the precision finishing of parts.

Chemical Milling

Chemical milling is a process that has considerable potential for decontamination processing. One of the processes being investigated uses cerium(IV) to accelerate the surface dissolution of stainless steel in nitric acid. The cerium(IV) oxidizes the metal surface, effecting its dissolution in the nitric acid. The cerium(IV) that is reduced to cerium(III) by the reaction is regenerated electrolytically at an anode. Electrical contact with the part to be decontaminated is not required, and the dissolution process is not sensitive to the location of the regeneration electrode. This makes the process well suited for spray or flow-through, in situ decontamination applications. The process is expected to produce low secondary volumes of waste, which are compatible with existing liquid waste processing and disposal systems.

Melting Slagging

Melting slagging is a melt-refining process being considered for separating transuranic contaminants from waste metals and for reducing the volume of waste metal. The process is based on a metallurgical smelting operation that separates the metal from impurities by chemical or physical fusion. To facilitate the fusion, and thereby increase impurity removal, flux substances are added. The mechanism for removal is that some impurities are dissolved in the flux, whereas others are chemically combined. The fused product formed by the action of the flux on the oxidized impurities is called the slag.

The contamination can be separated from the metal into the formed slag because of fusibility, chemical activity, dissolving power, and low density. Other functions of slag are protection of the melt from hot gases, heat stabilizers, and conservation of heat.