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Interim Report: Waste Management Facilities Cost Information for Mixed Low-Level Waste

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**Interim Report:
Waste Management Facilities
Cost Information for
Mixed Low-Level Waste**

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ABSTRACT

This report contains preconceptual designs and planning level life-cycle cost estimates for treating alpha and nonalpha mixed low-level radioactive waste. This report contains information on twenty-seven treatment, storage, and disposal modules that can be integrated to develop total life cycle costs for various waste management options. A procedure to guide the U.S. Department of Energy and its contractor personnel in the use of estimating data is also summarized in this report.

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ACRONYMS

AEA	Atomic Energy Act
C	Celsius
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DOEHQ	U.S. Department of Energy, Headquarters
EG&G	EG&G Idaho, Inc.
EPA	U.S. Environmental Protection Agency
F	Fahrenheit
ft	foot or feet
FAST	Freiman Analysis of Systems Technique
FTE	full-time equivalent
gal	gallon
HEPA	high-efficiency particulate air
hr	hour
lb	pound
kg	kilogram
m	meter
MK	Morrison Knudsen Corporation, Environmental Services Division
MWIR	Mixed Waste Inventory Report
NEPA	National Environmental Policy Act of 1969
O&M	operations and maintenance
PAN	passive/active neutron
PEIS	programmatic environmental impact statement

PFD	process functional diagram
PLCC	planning life-cycle cost
ppm	parts per million
PTM	portable treatment module
RCRA	Resource Conservation and Recovery Act
RTR	real-time radiography
SGS	segmented gamma scanning
SUI	special, unknown, and inherently hazardous waste
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TOC	total organic carbon
TRU	transuranic
TSD	treatment, storage, and disposal
VIM	volume input model
VOC	volatile organic compound
WMEP	waste management estimating program
WMFCI	Waste Management Facility Cost Information
WOX	wet-air oxidation
yr	year

PREFACE

This is an interim report prepared for use in the Programmatic Environmental Impact Statement project (PEIS), and Site Treatment Plans in compliance with the Federal Facilities Compliance Act (FFCA), and is meant to provide a readily useable catalog of developed cost information. A complete set of assumptions and bases for the cost data in this report will be included as part of the final report to be issued simultaneous with the draft PEIS. The assumptions and bases used in this report are essentially the same as those stated in *Waste Management Facilities Cost Information*, EGG-WM-10443.

The method presented in this report is for planning level life cycle cost estimates (accuracy of plus or minus 30%). Estimates based on this report are good for comparative alternative evaluations. The cost information is non-site specific, and any alternative selection based on the estimates derived from this method would warrant further study. These estimates should not be used to determine funding.

This report is organized according to distinct modules that can be assembled in various ways to create different types of treatment, storage, and disposal facilities. Discussions of the modules are contained in Section 2 through Section 29. Each module is represented by an abbreviation that is used repeatedly throughout the discussion of the module. For convenience, the abbreviations are used on the tab pages that separate the sections of the report that discuss the modules.

Interim Report: Waste Management Facilities Cost Information for Mixed Low-Level Waste

1. INTRODUCTION AND SUMMARY

1.1 Background

The Waste Management Facility Cost Information (WMFCI) for mixed low-level waste report contains cost information on the U.S. Department of Energy (DOE) Complex waste streams that will be addressed by the DOE in a Programmatic Environmental Impact Statement (PEIS) project. This report covers treatment, storage, and disposal (TSD) facilities that will be needed for the management of alpha^a and nonalpha mixed low-level radioactive waste streams.

This report describes the cost information for the alternatives involving TSD modules needed for managing alpha and nonalpha mixed low-level waste. These modules are designed to be part of an integrated treatment facility.^b The report contains cost information for four different applications: (1) large waste generator modules; (2) small waste generator modules using new buildings and equipment; (3) small waste generator modules placing new equipment in existing buildings; and (4) portable treatment equipment.

1.2 WMFCI Task Participants

The WMFCI task was performed by a project team from EG&G Idaho, Inc. and the Environmental Services Division of Morrison Knudsen Corporation (MK). EG&G Idaho and MK were selected for this task because of their combined expertise in design, construction, and operation of waste management TSD facilities for DOE sites and for the nuclear industry.

1.3 Modules and Unit Operations

For cost estimating flexibility, the TSD facility has been divided into several distinct modules. Figure 1-1 shows the TSD facilities as a whole. The modules can be assembled in various ways to create different types of integrated TSD facilities. In addition, each TSD module is broken down

a. Alpha MLLW is MLLW containing transuranic nuclides at concentrations ranging from 10-100 nCi/gm.

b. Technologies used in the treatment modules presented in this report are based on commercially available equipment selected for the purpose of developing typical costs of treating various waste streams analyzed by the PEIS. This is not to be construed as adoption of a given technology for DOE installations. Others will select the technology for treating alpha and nonalpha waste stored at, or generated by, various DOE installations as part of the current DOE efforts pursuant to the Federal Facility Compliance Act.

into several distinct functions, referred to as unit operations. Each unit operation consists of all buildings, equipment, and accessories needed to accomplish a given function.

The estimator must know the appropriate modules for the particular waste stream. The selection of the modules may be determined by use of the FFCA Treatment Technology Selection Guide or by knowledge of the site-specific processing requirements. Recommended treatment modules are also provided in Section 29 of this report.

1.4 Technical and Cost Estimate Basis and Assumptions

For larger production-oriented waste generator facilities, modules with at least three different capacities were cost estimated to generate a cost versus capacity curve. In addition, small generator modules were configured for installation at typical DOE research and development (non-production oriented) laboratories. Modules for small generator sites can be constructed in three different ways:

- As a module enclosed within a new building
- As a module constructed within an existing building
- As portable modules.

Modules for small generator sites are provided only for selected treatment options (see Table 1-1). Costs have been estimated for the modules indicated in the table. Modules are stationary (fixed) unless stated as portable.

Costs have not been provided for commercial treatment or low-volume treatment (R&D scale, treatability studies). Costs are not applicable to high level waste or remote handled wastes.

1.4.1 General Assumptions

Facility construction and ownership: It is assumed that all facility equipment will be new and placed within either totally new structures or modified existing structures. Modified structures will be upgraded to house equipment required for processing alpha and nonalpha waste. The upgrades will include construction of interior walls, roof modifications, secondary containment, and other improvements that are necessary to meet all technical and regulatory standards applicable to each treatment facility. Site development costs such as utilities and road work are included within 100 feet of the facility only. Site infrastructure costs are not included. All facilities are assumed to be government owned and contractor operated.

Throughput: For large generator facilities, a broad capacity range is selected to cover the requirements of the PEIS alternatives. For small generator facilities, data from the DOE Mixed Waste Inventory Report (MWIR) indicates that the capacity needs of representative small generator DOE research-and-development laboratory installations typically range from 176-704 ft³/yr (5 to 20 m³/yr). This capacity, which ranges from twenty-five to one hundred 55-gallon drums per year, is much less than the smallest throughput offered by most commercially

Table 1-1. Sizes, types, and capacity ranges of modules developed.

Module	Module abbreviations	Units	Small Generator Module		Portable	Large Generator Module	
			in new building	in existing building		Alpha	Nonalpha
			Alpha	Nonalpha			
Front-end support	TADMD	kg/hr	-	-	-	-	90.7-5670
Receiving and inspection	RCINS	kg/hr	-	-	-	680.4-5670	680.4-5670
Front-end and back-end support	FBSPT	kg/hr	36.3	36.3	-	-	-
Open, dump, and sort	OSORT	kg/hr	-	-	-	408.2-5670	90.7-5670
Maintenance	MAINT	kg/hr	-	-	-	204.1-8255.5	204.1-8255.5
Incineration	INCIN	kg/hr	18.1	18.1	-	45.4-907.2	45.4-907.2
Organic-solids wet-air oxidation	WETOX	kg/hr	18.1	18.1	18.1	18.1-304.2	18.1-226.8
Thermal desorption	THDRB	kg/hr	18.1	18.1	18.1	18.1-226.8	18.1-226.8
Lead recovery	PBRCR	kg/hr	9.1	9.1	-	27.2-90.7	27.2-90.7
Mercury separation	RMERC	kg/hr	9.1	9.1	-	27.2-90.7	27.2-90.7
Déactivation module	DEACT	kg/hr	2.3	2.3	-	9.1	9.1
Shredding and compaction	CMPCT	kg/hr	-	-	-	136.1-1814.4	136.1-1814.4
Sludge washing	SWASH	kg/hr	-	-	-	226.8-3628.8	226.8-3628.8
Soil washing	EWASH	kg/hr	-	-	-	226.8-3628.8	226.8-3628.8
Debris washing	DWASH	kg/hr	-	-	-	226.8-3628.8	226.8-3628.8
Aqueous waste treatment	AQWTR	kg/hr	9.1	9.1	9.1 ^a	45.4-1360.8	45.4-1360.8
Grout stabilization	GROUT	kg/hr	9.1 ^a	9.1 ^a	9.1 ^a	181.4-1814.3	181.4-1814.3
Polymer stabilization	PLYMR	kg/hr	9.1 ^a	9.1 ^a	9.1 ^a	22.7-272.2	18.1-113.4
Vitrification	VITRF	kg/hr	-	-	-	18.1-453.6	22.7-453.6
Certification and shipping	CSHIP	kg/hr	-	-	-	-	204.1-8255.5
Storage front-end and back-end support	SADMN	m ³ /hr	-	-	-	0.14-2.46	0.14-2.46
Storage	STORE	m ³	-	-	-	11,419-198,688	11,419-198,688
Disposal front-end support	DADMN	m ³ /hr	-	-	-	0.51-3.57	0.51-3.57
Engineered disposal	AGDSP	m ³	-	-	-	41,108-287,754	41,108-287,754
Shallow land disposal	SLDSP	m ³	-	-	-	-	41,108-287,754
Silo disposal	SIDSP	m ³	27-3,288	27-3,288	-	3,288-13,474	3,288-13,474
Bore hole disposal	BHDSP	m ³	1.0	1.0	-	-	-

a. For small generator modules, grout and polymer stabilization unit operations are combined into a single module.

available processing equipment. Therefore, the equipment included in the small generator waste treatment modules could have the potential to process larger capacities than are actually needed.

Modular facility: The planning level life-cycle cost (PLCC) estimates in the WMFCI reports are based on a set of facility modules, each of which may be used alone or combined.

Technology availability: Cost information in this report is based on available technologies. The basic rule employed in using the technologies is that at least one vendor must commercially offer the given technology without incurring upfront basic research and developmental costs. Information and data used in this report are based on the best available knowledge about waste processing requirements, technology availability, and cost data. The information in this report may require updating when additional information is obtained.

Cost Basis: Estimates for new facility construction are based on the conditions for the Idaho National Engineering Laboratory (INEL) site including utility, labor and the related design, construction, operation, and management factors. The INEL costs are considered to represent the mid range costs within the DOE complex. Site specific evaluations should be performed to improve the cost estimating accuracy.

Escalation Rates: The Planning Life Cycle Cost Estimates are developed based on 1994 dollars. The time value of money or escalation for expenditures occurring at different time frames has not been considered in the estimates. The costs have been summarized by major program elements (i.e. Pre-Operation, Construction, O&M, and D&D) so that the user could apply appropriate escalation rates to represent the specific schedule requirements.

1.4.2 Facility Operation Assumptions

For large generator facilities, the PLCC estimates are based on the assumption that the operating period of the facility is 10 years. New facilities would have a total operational life of 30 years. During this period, the facility may operate a maximum of 24 hours/day, 240 days/year, and at 70% availability during operation. This is equivalent to 168 days/year or 4,032 hours/year of operation. To compensate for the over-capacity of the small generator alpha and nonalpha waste treatment modules, it is assumed that the operations will be done on a batch basis. Batch operation provides flexibility to handle variations in capacity and waste characteristics.

In this report, it is assumed that alpha contaminated wastes are handled only at large generator facilities. This is due to the complex, and hence expensive, handling techniques and equipment required. All modules applicable to small generators or portable equipment are designed and costed assuming they will process only nonalpha contaminated wastes.

1.4.3 Mass Flow Rate Calculations

In order to facilitate variations in the waste type and quantities, all processing mass flow rates given in this report are uniformly calculated based on 100 lbs of input waste. This information, which is presented in the process functional diagrams (PFDs), may be used to calculate the site-specific mass-flow rates.

1.4.4 Cost Basis

Figure 1-2 shows a block diagram of the steps used in the estimating process. Whenever possible, the baseline capacities were selected to be the same as those of an existing facility or one estimated earlier in the WMFCI task. This approach, referred to as *anchoring*,^c provided a reference point that could be used as the basis for estimating the various cost components. Furthermore, anchoring provides a comparison of the estimates in this report with either the actual costs incurred by an operating facility or estimates of facilities that are in an advanced state of design and construction. Data from the study was based on "bottoms-up" cost estimates of three different facility sizes: small, medium, and large. Whenever possible, the baseline capacities were selected to be the same as an existing facility.

Using the given capacities, a preconceptual design package for each facility was developed and used as the basis for the PLCC estimates. Each preconceptual design package included a PFD with mass flow rates, a layout, and a summary of functional and operational requirements. The PFD and layout drawings were developed to identify necessary unit operations. After unit operations were defined, major equipment lists and building configurations were developed for each of these operations. The design packages used as much data from existing or planned commercial and DOE (anchor) facilities as possible. New designs were generated only when existing data were not available.

The PLCC estimate for each facility was divided into six components (see Figure 1-2). Costs for the first and second components (studies, bench-scale tests, and demonstration) were obtained by estimating research manpower and equipment needs.

The third cost component (facility construction costs) consists of two key subcomponents: major equipment costs and building costs. Cost estimates for major equipment were obtained either from a similar facility, from an anchor facility, by soliciting budgetary costs from the suppliers, or by making engineering judgments. Building costs were estimated either by multiplying building unit costs by the square footage allocated to each unit operation in the layouts, or by developing building material and labor requirements and multiplying them by the appropriate unit rates. Building costs for modifications to existing structures were estimated by developing material and labor requirements for building cost components. It is assumed that modifying an existing facility will not require site preparation and superstructure construction necessary for a new facility. All other building cost components will be identical to that of a new facility.

Once the equipment and building costs were estimated for each facility, they were totalled and multiplied by a factor to allow for the construction contractor's indirect costs. The sum of

c. In this report, the term *anchor facility* denotes reference facilities that are either operating or are in advanced stages of design and construction. *Anchoring* denotes using technical data and capital, operating and maintenance costs incurred by an anchor facility as a yardstick in the development of the PLCC estimates. Before comparing costs from an anchor facility, they were adjusted to account for any differences in technical requirements and cost escalation. The manual *Construction Cost Trends*, published by the Bureau of Reclamation, United States Department of Interior, was used as the basis for escalation data.

the equipment, building, and indirect costs were then multiplied by applicable factors to allow for design, inspection, construction management, and project management costs. Allowances were also included for management reserve and contingencies.

The fourth cost component (operations-budget funded activities) includes conceptual design, safety assurance, National Environmental Policy Act of 1969 (NEPA) compliance efforts, permitting, preparation for operation, and project management costs.^d All other subcomponents of the cost of operations-budget funded activities were estimated as a percentage of the construction cost.

The fifth cost component (operations and maintenance [O&M]) consists of five subcomponents: operating labor, utilities, consumable material, and maintenance (parts, equipment, and labor). The first three subcomponents were estimated by analyzing the requirements of each facility at the unit-operations level. The maintenance costs were estimated as a percentage of the original equipment installed at the facility. Allowances were also included for management reserve and contingencies.

The sixth cost component (decontamination and decommissioning [D&D] at facility closure) was estimated by multiplying a D&D unit rate by the facility square footage.

The total facility PLCC estimates were obtained by taking the sum of the six cost components.

Cost estimating backup data for the modules will be provided in a supplemental report that will be prepared with the final version of this report.

1.4.4.1 Cost Curve Development Approach. For large generator facilities, unique parametric cost equations were developed for the Pre-Operations, Facility Construction, Operations and Maintenance, and D&D cost elements of each module. These equations were developed based on the baseline WMFCI bottoms-up estimates regressed over a range of facility capacities for each cost module. There are approximately 400 equations that describe MLLW/LLW costs, alpha MLLW/LLW costs, MLLW Full Time Equivalents (FTE's), and alpha MLLW FTE's.

Linear and non-linear approaches were used to provide the best fit cost curves. The curves were developed to represent the full range of facility costs over the estimated capacity. Costs should not be extrapolated for facility capacities outside the defined range of capacities.

1.4.4.2 Cost Curve Applications. Cost curves have been provided for the majority of cost modules to describe the major manpower (FTE) components, cost components, total life cycle

d. Please note that NEPA costs of \$6 million are included in only the Receiving and Inspection Module (RCINS) for the large facility cost estimates. The NEPA and safety assurance costs for the small generator are included in only the front end and back end support module (FBSPT). Additionally, the MLLW and LLW module costs have been defined as equivalent. Although differences in handling regulations and permitting may create small differences in the cost estimates.

costs, and total life cycle unit costs. Separate FTE and cost curves are provided for alpha and non-alpha facilities (as applicable).^e

A total of five FTE and cost figures may be presented for each module:

1. FTE workers versus capacity for MLLW/LLW
2. PLCC versus capacity for MLLW/LLW
3. FTE workers versus capacity for alpha MLLW/LLW (as applicable)
4. PLCC versus capacity for alpha MLLW/LLW (as applicable)
5. PLCC versus capacity including unit rates for MLLW/LLW and alpha MLLW/LLW.

The curves in Figures 1, 2, 3, and 4 were developed to represent only the major FTE and cost components. These cost figures can be used to derive the four primary costs required to estimate the individual module costs. The six estimated cost components listed in Section 1.4.4. were simplified by reducing to the following four elements:

1. *Pre-Operations.* The Pre-Operations costs include the first (Studies and bench scale test costs), second (Demonstration costs), and fourth (Operation budget funded activities) cost components listed in Section 1.4.4. These costs were combined because the first and second cost components are relatively small and would be completed at approximately on the same schedule as the fourth cost component. Graphically, the small FTE and cost values for the first and second cost components do not fall on a common scale with the other cost elements.
2. *Facility Construction.* The Facility Construction costs would be identical to the third cost element (Production facility Construction cost). This cost element would require capital equipment and line item funding.
3. *Operations and Maintenance.* The Operations and Maintenance would be equivalent to the fifth cost element (Operations and Maintenance). The estimated FTE figures are based on 1 year of O&M, and the estimated cost figures have been based on 10 years of O&M. This was done in order to keep the numbers on a common scale on the figure. The estimator may need to multiply the number of FTE's or costs from the curves by the appropriate number of years of O&M for their specific estimate.
4. *D&D.* The D&D costs would be identical to the sixth cost element (Decontamination and Decommissioning).

e. Separate cost figures are only provided for MLLW/LLW and alpha MLLW/LLW when there is a significant difference in FTE's or cost for alpha versus non-alpha facilities. When no significant difference is noted, the cost figures are combined for the alpha and non-alpha MLLW/LLW.

These four cost elements should be used to determine the required module costs. Existing facility costs would only require the O&M and D&D costs. New facilities will include all Pre-Operation costs, Facility Construction and Equipment, O&M, and D&D. The O&M costs can be factored from the cost curves to obtain operating costs for periods other than 10 years.

The fifth cost figure (i.e., PLCC versus capacity including unit rates for MLLW/LLW and alpha MLLW/LLW) provides the total life cycle cost curve including: Pre-Operation, Facility Construction, Operations and Maintenance, and D&D. The total life cycle unit cost curve is also provided in metric (e.g., \$/Kg, \$/m³) and english units (e.g. \$/lb, \$/ft³) for maximum utility. These summary level curves should only be used when the operation and maintenance period of 10 years is required.

The capacity units of measure for the WMFCI modules have been provided in terms of processing rates (kg/hr, m³/hr) for administrative, treatment, and shipping and receiving modules. The capacity units of measure for the storage and disposal modules have been provided in terms of total capacity (total m³). Table 1-2 shows an example of a module cost estimate data sheet and top level components of a typical estimate. This table illustrates the major WBS cost elements including the simplification of the six estimated cost components collapsed into four elements.

1.4.5 Portable Facilities

1.4.5.1 General Assumptions. The portable facility will consist of one or more trailer-mounted treatment modules that can be dispatched to the DOE laboratory installations to treat their waste.

Facility and waste type: The portable small sized facility is designed to treat minimal quantities of waste generated at DOE laboratory installations. The portable treatment modules (PTMs) are most suitable for treatment of waste streams that are not generated on a regular basis. They can also be used to augment available existing treatment processes. High temperature portable thermal treatment processes were excluded due to inherent technical difficulties in licensing such PTMs for treating radioactive contaminated waste.

Facility construction and ownership: The PTMs are for nonalpha waste only. They consist of equipment mounted in enclosed 8- by 40-foot trailers. These modules will be stored at a central location and moved to a DOE installation to treat stored waste. Once on site, PTMs will be set up on existing pads that are equipped with secondary containment. It is assumed that the PTMs will be government owned and contractor operated.

Throughput: PTM use is on a campaign basis. Campaigns are planned activities necessary to treat an accumulated quantity set at 88.3 ft³ (2½ m³) of waste. It is estimated that each campaign will require a total of 14 days to transport, mobilize, set up, process the waste, decontaminate, disassemble, and demobilize. Each PTM is assumed to complete twelve campaigns per year.

Mobilization and Startup: The PTM will be dispatched from the storage site to the desired DOE installation by a licensed commercial firm with drivers certified for interstate travel. The

Table 1-2. Sample PLCC estimate summary for small generator incineration module.

Module Name: Incinerator Option Name: Example

Waste Type: ☒ MLLW ☐ HLW ☐ M-TRU
☐ alpha ☒ non-alpha ☒ contact handled ☐ remote handled

Module Location: Example

Module Status: ☐ Existing ☒ New ☒ Small generator ☐ Large generator
☒ On-Site ☐ Off-Site ☐ Portable ☐ Commercial ☐ R&D

Reference Capacity Requirement: 1.81 kg/hr (kg/hr, m³/hr, m³)

<u>WBS ELEMENT</u>	<u>(\$ x 1000)</u> <u>SUB \$</u>	<u>(\$ x 1000)</u> <u>ELEMENT \$</u>
1.0 Pre-Operations		
1.1 Studies and bench scale Test Costs	<u>\$ 206</u>	
1.2 Demonstration Costs	<u>\$ 588</u>	
1.3 Operations Budget Funded Activities		
1.3.1 Conceptual Design	<u>\$ 311</u>	
1.3.2 Safety Assurance Documentation	<u>\$ 0</u>	
1.3.3 Permitting	<u>\$ 0</u>	
1.3.4 Preparation for Operations	<u>\$ 759</u>	
1.3.5 Project Management	<u>\$ 107</u>	
TOTAL PRE-OPERATIONS		<u>\$ 1,971</u>
2.0 Facility Construction Costs		
2.1 Design (Title I and II)	<u>\$ 1,293</u>	
2.2 Inspection	<u>\$ 754</u>	
2.3 Project Management	<u>\$ 1,078</u>	
2.4 Building Construction (inc. indirect)	<u>\$ 1,843</u>	
2.5 Equipment (inc. indirect)	<u>\$ 4,008</u>	
2.6 Construction Management	<u>\$ 6,767</u>	
2.7 Other (inc. reserve and contingency)	<u>\$ 5,219</u>	
TOTAL FACILITY CONSTRUCTION COSTS		<u>\$ 20,962</u>
3.0 Operations and Maintenance		
3.1 Annual Operating Labor	<u>\$ 171</u>	
3.2 Annual Utilities	<u>\$ 5</u>	
3.3 Annual Materials	<u>\$ 24</u>	
3.4 Annual Maintenance	<u>\$ 408</u>	
3.5 Annual Other (inc. reserve and contingency)	<u>\$ 152</u>	
TOTAL ANNUAL O&M	<u>\$ 759</u>	
x NUMBER OF YEARS OF OPERATION	<u>x 10 years</u>	
TOTAL OPERATIONS AND MAINTENANCE		<u>\$ 7,590</u>
4.0 Decontamination and Decommissioning		
4.1 Facility D&D	<u>\$ 2,167</u>	
4.2 Closure, Post-Closure, Monitoring	<u>\$ 0</u>	
TOTAL DECONTAMINATION AND DECOMMISSIONING		<u>\$ 2,167</u>
TOTAL COST FOR <u>INCINERATOR</u> MODULE (1994 Dollars)		<u>\$ 32,690</u>

total loaded trailer weight will not exceed the legal highway weight limit of 65,000 lbs (29,500 kg). Once at a treatment site, PTMs will be interconnected to form an integrated treatment facility, and utilities such as service water and electrical power will be hooked up. Preoperational check out and safety checks will then be performed to ensure operation readiness of the integrated treatment facility.

Interface availability: It is assumed that the host site will provide the space, utilities (water, electrical power) and other services (i.e., a paved operating pad with secondary containment) needed for operating the PTMs.

Decontamination: At the end of each campaign, the module will be decontaminated by treating all waste through the facility, and completely flushing and draining each piece of equipment that has been in contact with waste. Waste generated during decontamination will be treated and disposed as required. After decontamination, the interior and exterior of PTMs will be assayed and inspected before disassembly and removal from the treatment site.

Demobilization: After decontamination, the trailers will be disassembled, all flexible lines will be disconnected, loose components will be tied down, and the trailer doors will be locked. A radiological survey of the trailers will be performed, and the shipment certification and manifest documents will be prepared. Truck tractors will be connected to the trailers, and the modules will be shipped back to their storage locations. A one-way distance of 500 miles is assumed between the treatment site and the module storage location.

Maintenance: General maintenance will be performed at the storage location on a routine basis.

1.4.5.2 Facility Operation Assumptions. All operations will be done on a batch basis to compensate for the over-capacity of the PTMs and to accommodate differences in treatment capacity requirements at each treatment site. The PLCC estimates are based on the assumption that the operating life of all PTMs and control trailers is 5 years. The PTMs are assumed to complete twelve campaigns per year or 60 campaigns during the total life of the facility. Safety assurance, NEPA compliance efforts, and permitting are assumed to be part of the location activities and have not been included in the cost estimates.

1.4.5.3 Cost Estimating Method. The general technical and cost estimate assumptions and the PLCC estimates methods used for the portable minimum modules are the same as for the new minimum facility described in the previous section. The methods for estimating the first and second components also remain the same.

The third component (production facility construction costs) consists of only one key subcomponent: major equipment. Buildings are not required since the equipment is mounted on fully enclosed trailers. Budgetary cost estimates for major equipment were obtained from vendors that supplied PTMs and obtained by making engineering judgments. Trailer costs were obtained from suppliers and were adjusted to account for special process requirements.

Once the equipment costs (including trailers) were estimated for each facility, they were totalled and multiplied by a percentage to allow for the construction contractor's indirect costs.

The sum of the equipment, trailer, and indirect costs were further multiplied by appropriate factors to allow for design, inspection, construction management, and project management costs. Allowances were also included for management reserve and contingencies.

The fourth cost component (operation-budget-funded activities) includes conceptual design, preparation for operation, and project cost. NEPA compliance and permitting costs are not included.

The fifth cost component (O&M) is the same as for the new small facility (except for front-end and back-end support, which is part of normal installation operation), plus the cost for transporting the trailers to and from a location, and decontaminating the module before leaving the treatment location. It is also assumed that utilities are available at the installation and only tie-ins are necessary, a parking pad within a secondary containment area is available, and administration support is provided by the host DOE installation.

The sixth cost component (D&D at the end of module life) was estimated by multiplying a D&D unit rate by the total trailer square footage.

The total facility PLCC estimates for the portable minimum-sized facility were obtained by adding the six components. Campaign costs were determined based upon five years of operation divided by 60 (12 campaigns per year for 5 years).

1.5 Cost Estimating Procedure

A detailed cost estimating procedure along with waste load data sheets are presented in Section 29 of this report. Applying estimates in this report requires the following basic steps:

1. Define the treatment process selection based on the waste stream requirements (waste type), TSD requirements, final waste form, operating parameters. Utilize integrated flow sheets containing modules. Define required support module requirements.
2. Define the total capacity requirements for each module (define if new or existing facility). (Refer to Figures 29-4, 29-5, and 29-6.)
3. Prepare cost estimates for each module required to provide TSD for the waste stream utilizing the module cost curves.
4. Add the individual module costs to obtain a total waste stream cost.
5. Add transportation costs for off-site shipments to obtain the total option cost.

Estimators preparing costs for the FFCA Draft Site Treatment Plans (DSTP's) should refer to the specific FFCA DSTP cost guidance instructions and worksheets.

1.6 Cost Assessment Activities

To the extent possible, equipment costs for each module were compared with data from anchor facilities to establish a cost confidence level within the boundaries established for the PLCC estimates. Both the DOE and the commercial nuclear industry are now planning or operating similar facilities. These facilities were surveyed to obtain capacity, cost data, and other information needed to support the WMFCI data. Before using these costs, the data were adjusted to account for capacity differences and escalation.

Additional assessment activities have included a review of existing DOE facility capital and operating costs for comparison with the WMFCI. Existing DOE facilities that have evaluated include: Waste Experimental Reduction Facility (incineration, shredding, and compaction) at the Idaho National Engineering Laboratory (INEL), the Controlled Air Incinerator at Los Alamos National Laboratory, the Toxic Substances Control Act Incinerator at Oak Ridge National Laboratory, the Supercompactor and Repackaging Facility (SARF) at Rocky Flats, Radioactive Waste Management Complex Low-Level Waste Disposal at the INEL, and the Transportable Waste Water Treatment Unit from the Uranium Mill Tailings Remedial Action Project (UMTRA). Planned DOE facility costs at the INEL were also evaluated for the Radioactive Waste Storage Facility, the Waste Characterization Facility, the Idaho Waste Processing Facility, and the Mixed Low-Level Waste Treatment Facility.

Other facilities evaluated include: the Illinois Compact Low-Level Waste Engineered Disposal facility, and the Commonwealth of Massachusetts Low-Level Radioactive Waste Disposal.

1.7 Limitations

Section 1.6 of this report and Appendix A of the WMFCI report (EGG-WTD-10443) must be consulted regarding limitations and qualifications that apply to development of PLCC estimates. To apply cost data from this report, the reader must ensure that the front-end and back-end support module and any linked treatment modules (e.g., stabilization and aqueous waste treatment modules required for secondary waste) are currently available at the installation. If not available, the PLCC estimates for a new module, as given in this report, must be incorporated in the overall facility estimates. When using existing facilities, the appropriate operating and maintenance costs must be added to the overall facility costs.

Figure 1-1. Integrated waste management facility.

Figure 1-2. PLCC cost estimating steps

2. TREATMENT FRONT-END SUPPORT (MODULE TADMN)

2.1 Basic Information

The treatment front-end support module includes all administrative and laboratory buildings required for large generator waste management support functions. The treatment front-end support module is essentially the same for all treatment facilities regardless of their capacity. Treatment front-end support should be used whenever a new treatment facility is planned.

2.2 Technical Bases and Assumptions

2.2.1 Function and Operation of Large Generator Modules

The treatment front-end support module incorporates all technical and administrative support functions needed to manage the operation of a waste management facility. These functions include security, access control including personnel decontamination (radioactive and hazardous), maintenance of uncontaminated areas and equipment, health physics and radiation badges, facility access control, sanitary facilities, work control and personnel support, internal and external (public relations) communications, spill or emergency response provisions (hazardous and radioactive), analytical laboratory, environmental field sampling, environmental regulatory reporting, and records management.

2.2.2 Integration of Large Generator Modules

The treatment front-end support module maintains general interfaces with all treatment modules. O&M consumables include analytical supplies, office supplies, sanitary supplies, and personal protective equipment, which all must be purchased.

2.2.3 Small Generator and Portable Modules

No separate fixed small generator module has been developed. The treatment front-end support functions for such a facility has been combined with the back-end support functions into a front-end/back-end support module in module FBSPT (Section 4).

2.3 Cost Bases, Assumptions, and Results

The treatment front-end support module is the same for alpha and nonalpha waste. Major equipment capital cost items are laboratory analytical equipment. A \$1 million allowance is made for analytical instruments and components needed for a mixed waste laboratory.^f Table 2-1 lists the plan dimensions of the module. Figure 2-1 shows the relationship between estimated FTE workers and capacity of the module. Figures 2-2 and 2-3 show the relationship between PLCC and capacity.

f. The mixed waste laboratory has been sized to support a 10% sampling and analysis capability. These costs should be modified if less or more sampling is expected to be required.

The treatment front-end support should be sized based on the total waste capacities to be treated in all treatment modules.

Table 2-1. Plan dimensions of treatment front-end support module (TADMN).

Module size	Dimensions (feet)		Dimensions (meters)	
	Width	Length	Width	Length
Large generator				
Small	100	92.5	30.5	28.2
Medium	100	172.5	30.5	52.6
Large	100	265.0	30.5	80.8
Small generator	—	—	—	—

Figure 2-1. FTE workers versus capacity for treatment front-end support module (module TADMN).

Figure 2-2. PLCC versus capacity for treatment front-end support module (module TADMN).

Note: Basis includes 10 years O&M

Note: Basis Includes 10 years O&M

Figure 2-3. PLCC versus capacity including unit rates for treatment front-end support module (module TADMN).

3. RECEIVING AND INSPECTION (MODULE RCINS)

3.1 Basic Information

The receiving and inspection module, shown in Figure 3-1, is effectively the same for alpha and nonalpha waste. There are minor differences in the assay and inspection equipment that are negligible at a PLCC estimate level. Unit operations are shown in the PFD in Figure 3-2.

The receiving and inspection module is intended to be contiguous with the open, dump, sort module and the waste treatment modules. It consists of two unit operations: (1) unload and stage and (2) inspect and assay. The containers of waste (in drums, boxes, and metal bins) arrive at the receiving and inspection module on a transport vehicle. Containers are removed from the transport vehicle and placed in a staging or storage area. The containers are visually examined, labeled, logged, recorded, and sent to inspection and assay.

The purpose of the inspect and assay unit operation is to physically and radiologically characterize the waste to allow segregation of the containers. Based on the inspection and assay results, the waste containers are grouped according to their processing needs. The inspection and assay unit operation also identifies a special waste category that applies to any containerized waste requiring special processing operations.

The receiving and unloading area is equipped with a bridge crane and a forklift truck. It is designed to receive and unload containers from flat-bed trailers or van trucks. Containers brought in large overpacks, for example transportation (TRUPAC II) type containers, can also be unloaded.

3.2 Technical Bases and Assumptions

3.2.1 Function and Operation of Large Generator Modules

Transportation vehicles are used to ship the containers (in overpacks, if necessary) from the generators to the receiving and inspection module. These vehicles are not included in the module. In the unloading and staging unit operation, the transportation vehicles are unloaded, and containers are placed in the staging area. Surge storage is also provided. Containers may be moved within the unloading, staging, and surge storage areas and transported to and from the various interfacing unit operations.

Containers are unloaded in an enclosed truck bay and placed in an indoor staging area. The area is large enough to maneuver the containers and provide sufficient surge storage capacity to meet the desired operational reliability.

The assay and inspect unit operation determines the radioactivity, physical properties, and other parameters needed to categorize the containerized waste before processing, and in accordance with the criteria established for the processing unit operations. Various devices, such as passive/active neutron (PAN) counting instruments, may be used. Containers holding waste classified as other than alpha and nonalpha MLLW are returned to the generator.

Waste containers are also examined to allow classification by gamma radioactivity (in accordance with the criteria established for the processing unit operations) and to ensure that they are suitable for contact handling (less than 200 milliRems per hour on surface) and for treatment by the given process units. Various devices, such as segmented gamma scan (SGS) instruments, could be used. Containerized waste that does not meet the criteria is either handled as special waste or returned to the generator.

After the containers are examined, they are weighed and measured to determine waste density. Contents (categorized as metal, paper, glass, sludge, gas cylinders, and liquids) are determined by nondestructive examination. At a minimum, each container is examined using a nondestructive assay unit equipped with a real-time radiography (RTR) device. Ultrasonic devices are also used. After examination, each container is labelled, and the properties of its contents are logged and entered into a computerized database.

To allow year-round operations and to minimize the effects of a potential spill, it is assumed that the unloading and staging operations will take place indoors.

3.2.2 Integration of Large Generator Modules

In addition to general interfaces typical for all modules, waste from generator facilities becomes input to the receiving and inspection module. O&M consumables, including personal protective equipment, must be purchased. Module output consists of containers of alpha and nonalpha waste that are moved to the open, dump, and sort module or to treatment modules.

3.2.3 Small Generator Fixed Module

The receiving and inspection functions for a portable or small generator fixed module are performed by the back-end support module (module FBSPT).

3.3 Cost Bases, Assumptions, and Results

Cost bases and assumptions were derived from a variety of sources. Major equipment capital cost items for this module include alpha assay, gamma assay, 20-ton bridge crane, and RTR units. The crane cost is based on vendor quotations. The inspection and assay units are based on conceptual designs and cost estimates for a radiological and hazardous material measurement system provided by EG&G Idaho, Inc. (EG&G). Budget estimate for an inspection and assay system is \$2.0 million. Figures 3-3 and 3-4 show the relationships between estimated FTE workers and capacity of the module. Figures 3-5, 3-6, and 3-7 show the relationship between PLCC and capacity.

Figure 3-1. Equipment layout for receiving and inspection module (module RCINS).

Figure 3-2. Process flow diagram for receiving and inspection module (module RCINS).

Figure 3-3. FTE workers versus capacity for nonalpha waste for receiving and inspection module (module RCINS).

Figure 3-4. FTE workers versus capacity for alpha waste for receiving and inspection module (module RCINS).

Figure 3-5. PLCC versus capacity for nonalpha waste for receiving and inspection module (module RCINS).

Figure 3-6. PLCC versus capacity for alpha waste for receiving and inspection module (module RCINS).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 3-7. PLCC versus capacity including unit rates for receiving and inspection module (module RCINS).

4. SMALL GENERATOR FRONT-END AND BACK-END SUPPORT (MODULE FBSPT)

4.1 Basic Information

The front-end and back-end support module, shown in Figure 4-1, is the first part of the overall facility needed for treatment of alpha and nonalpha waste at a small generator facility. This module can be used in either a new building or within an existing building at a small generator facility. It is intended only for a small generator, combining the functions of front-end technical and administrative support, receiving and inspection, open, dump, and sort, maintenance, and certification and shipping. For a large generator facility, these functions are distributed among five separate modules (ADMIN, RCINS, OSORT, MAINT, and CSHIP). The small generator front-end and back-end support module is intended to be contiguous with the waste-treatment modules. Figure 4-2 shows a PFD of the front-end and back-end support module.

4.2 Technical Basis and Assumptions

4.2.1 Function and Operation of the Module

The front-end and back-end support module receives incoming untreated waste, which is in the form of liquid, solid, or sludge. Untreated waste arrives in drums, metal bins, and cardboard boxes shipped to the treatment facility by transport vehicles. Liquid waste is shipped by tank trucks or in special containers carried by transport vehicles. The incoming waste is contact handled (no shipping casks are anticipated) and is transported in enclosed vehicles. A loading-and-unloading unit operation equipped with an unloading device removes waste containers from the incoming vehicles and places them in a staging and interim (surge) storage area. The storage area is large enough to allow maneuvering the containers during staging operations and provides sufficient surge storage capacity to achieve the desired operational reliability.

An inspect-and-assay unit operation determines radioactive properties of the waste as needed for safe handling and processing. This unit operation also categorizes the waste by its chemical and physical properties using criteria established for various treatment modules. Radioassay functions may be accomplished by segmented gamma scanning instruments. Chemical characterization may be performed by sampling and analysis. Physical properties may be determined by appropriate instrumentation (e.g., weigh scales may be used to determine waste density). After examination, each container is labeled, and the properties are logged and entered into a computer database.

Organic liquid waste is sent for processing by an organic destruction unit (either the organic-solids wet-air oxidation module or incinerator module). Aqueous waste is sent to the aqueous waste treatment module.

Containers holding solid waste acceptable by the alpha and nonalpha waste treatment modules are sent to an opening-and-emptying unit operation, where the containers are uncapped and the contents are emptied onto a sorting device. There the waste is segregated and placed in transfer bins. Solid process residues are sent for organic destruction (incineration or organic-

solids wet-air oxidation), heterogeneous and organic debris are sent for organic destruction (incineration, organic-solids wet-air oxidation, or thermal desorption), inorganic debris is sent for stabilization (grouting), metal debris is sent for decontamination, and special, unknown and inherently hazardous (SUI) waste is sent for special waste treatment. Some of the bins containing solid waste may be sent first to a size-reduction unit operation as needed by the treatment step. For example, inorganic debris may be shredded to small particles to facilitate the stabilization process. Opening, emptying, sorting, size reduction, and transferring may be accomplished manually using appropriate material handling equipment. All unit operations have vent hoods to minimize the spread of dust and contamination.

The module also includes a discarded container packaging unit operation. In this unit operation, containers are either rinsed for reuse or are compacted and sent for disposal.

Another function of the front-end and back-end support module is certification and shipping of waste packaged by the treatment facility. The packaged waste containers brought from the treatment modules are placed in an inspect, assay, and certify unit operation. At this unit operation, the containers are weighed, visually examined, tagged, logged, recorded, and sent to the assay device for classification with regard to gamma radioactivity, in accordance with transportation, storage, and disposal criteria. The presence of material restricted by these criteria is determined using process knowledge. The radioactivity properties are also logged and recorded into the computerized database. The containers are then moved to a temporary storage area until they are ready for shipment to a long-term storage or disposal facility. When ready, the loading and unloading unit operation transfers the container onto enclosed vehicles. Before leaving the module, the vehicles are inspected and certified in accordance with DOE and U.S. Department of Transportation regulations. The testing laboratory provides the capability to sample and analyze to certify that the hazardous component of the waste has been removed, as required for disposal or recycling.

Existing building space required for installation of this module is 5,450 ft² (506 m²). The required ceiling height is 25 ft (7.6 m). The area required for the new building is the same.

4.2.2 Integration of the Fixed Module

Input to the front-end and back-end support module consists of containers of untreated waste from storage or generator facilities, and packages of treated waste from the treatment modules. Output from the front-end and back-end support module includes waste that is sorted according to treatment requirements; empty containers, which are recycled or packaged for disposal; and treated waste, which is placed in shipping vehicles going to disposal or long-term storage facilities. Secondary waste generated in this module consists of treated air discharged from high-efficiency particulate air (HEPA) filters and spent rinse water from the washing of empty containers. This module is linked with site communication and alarm systems, including telephone, evacuation, security alarm, and public address systems. This module also serves as the support center for the waste management facility. Consumables, including personal protective equipment, are purchased.

4.3 Cost Bases and Results

Major equipment capital cost items for this module include a testing laboratory, SGS assay system, forklift, shredder, container rinse booth, drum baler, and sorting glove box. All waste is contact handled, and O&M activities are manual. Sorting will be manual, using glove boxes. Emergency showers, personnel decontamination, breathing air, and maintenance, mechanical, and instrument shop equipment are included in the module. Estimated operating staff is based on handling 4.5 drums per day or 36.3 kg/hr. Estimated FTE workers versus capacity is shown in Table 4-1.

Laboratory analytical equipment for environmental and alpha and nonalpha waste analysis is estimated to be \$1 million; this estimate is based on quotes obtained by Eberline Corporation, of Santa Fe, New Mexico. The cost to furnish size-reduction equipment is based on prices obtained from a stock equipment company of Groveport, Ohio. The cost to furnish the SGS assay system, rinse booth, and personnel portal monitor is based on a quotation from Atlan-Tech Corporation, Inc., of Roswell, Georgia. The cost to furnish the drum baler is based on a quotation from the Stock Equipment Company, of Cleveland, Ohio. Cost for the front-end and back-end support module is shown in Table 4-2.

The difference in the columns in Tables 4-1 and 4-2 reflect the cost of a new building versus building modification costs.

Table 4-1. FTE workers for the front-end and back-end support module.

Cost component	Type of module	
	Fixed, in new building(s)	Fixed, in existing building(s)
(1.0) Studies and bench-scale tests	127	109
(2.0) Demonstration		
(3.0) Production facility		
(4.0) Operations-budget-funded activities		
(5.0) O&M	160	160
(6.0) D&D		
All cost components (total for 10 years O&M)	287	269

Table 4-2. PLCC (\$1,000) for the front-end and back-end support module.

Cost component	Type of module	
	Fixed, in new building(s)	Fixed, in existing building(s)
(1.0) Studies and bench-scale tests	27,667	23,356
(2.0) Demonstration		
(3.0) Production facility		
(4.0) Operations-budget-funded activities		
(5.0) O&M	29,054	29,054
(6.0) D&D		
All cost components (total for 10 years O&M)	56,722	52,410

EQUIPMENT LIST

- ① GAMMA SPECTROSCOPE
- ② SORTING TABLE
- ③ GLOVE BOX
- ④ TRANSFER CART (TYP)
- ⑤ SIZE REDUCTION DEVICE
- ⑥ BALER
- ⑦ PORTABLE CRANE
- ⑧ DISCARDED CONTAINERS DECON RINSE BOOTH
- ⑨ MAINTENANCE TOOLS
- ⑩ FORKLIFT

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	-	-	-	-
	MEDIUM	-	-	-	-
	LARGE	-	-	-	-
SMALL GENERATOR	MINIMUM	110	60	33.5	18.3

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Figure 4-1. Equipment layout for front-end and back-end support module (module FBSPT).

Figure 4-2. Process functional diagram for front-end and back-end support module (module FBSPT).

5. OPEN, DUMP, AND SORT (MODULE OSORT)

5.1 Basic Information

The open, dump, and sort module, shown in Figure 5-1, is designed to be contiguous with the treatment facilities and is ideal for use with an integrated waste management facility that handles multiple waste streams. The module opens and dumps the incoming waste containers and segregates the waste so it can be fed to a combination of treatment processes. The module handles the waste in drums, boxes, or metal bins that are assumed to be properly characterized before they are opened. The module is not needed if the waste arrives presorted. Module SORT is applicable to both nonalpha and alpha waste. Unit operations are given in the PFD in Figure 5-2.

The module also has the capability to reduce the size of empty nonmetal containers. Metal containers, however, must be transported to other modules for handling, such as a decontamination module for washdown and reuse or a metal melting module for processing.

5.2 Technical Bases and Assumptions

5.2.1 Function and Operation of Large Generator Modules

At the open, dump, and sort module the waste containers are decapped, and the waste is dumped either onto sorting devices or into transport bins that carry the waste to the treatment operations.

Containers of nonalpha waste are opened manually, while containers of alpha waste are opened by remote means. Containers of both waste types are dumped and sorted remotely by manipulators and robots housed in a cubicle. The cubicle has a controlled environment and multiple barriers. Adequate hoods and supporting ventilation are provided to minimize the spread of dust and contamination. Operations on alpha waste are accomplished in an alpha cell where containers enter the cell through airlock doors. Equipment maintenance is accomplished manually in a controlled environment. In addition, the equipment can be pulled out and decontaminated before performing maintenance.

After the waste containers enter the controlled cubicle environment through airlock doors, they are grouped into two categories: homogeneous waste and heterogeneous waste. Containers of homogeneous waste are opened, dumped, sorted, and sent to treatment modules. Containers of heterogeneous waste are opened, dumped, robot sorted, manually sorted, packaged, and sent to treatment modules.

The waste in containers that are designated for segregation is dumped onto a sorting station, which removes bulk metal, noncombustibles, semicomcombustibles, combustibles, special waste,^g and

g. Special wastes are those materials that are incompatible with the treatment techniques provided in the facility (e.g., mercury). After identification and segregation, special wastes are treated by mobile units provided on a case-by-case basis.

gas cylinders. Various sorting technologies, such as robotic assisted sort tables, vibratory screens, and air classifiers, may be used in the sorting station. Any spilled liquid is collected and sent to other unit operations for treatment. The sorted waste material is placed in transfer bins and moved to the treatment modules. Nonmetallic containers are cut into smaller pieces as required for processing.

5.2.2 Integration of Large Generator Modules

In addition to general interfaces for all modules, input interfaces to the open, dump, and sort module are waste containers from the receiving and inspection module. O&M consumables including personal protective equipment are purchased. Output interfaces include sending solid sorted alpha and nonalpha waste to treatment. Reusable empty metal drums and boxes are sent to a decontamination module for cleaning and recycle. Other empty metal containers are sent to the metal melting module. Empty wood and fiberglass boxes are shredded and sent to treatment modules.

5.2.3 Small Generator Fixed and Portable Module

For small generator (non-alpha) modules, the open, dump, and sort functions are performed by the front-end and back-end support module (module FBSPT).

5.3 Cost Bases, Assumptions, and Results

Major equipment capital cost items for this module are container open, dump, and sort devices and robotics arms. The costs for these items are developed based on consultation with personnel from DOE contractors involved in the Office of Technology Development, Robotic Technology Development Program. Figures 5-3 and 5-4 show the relationship between estimated FTE workers and capacity of the module. Figures 5-5, 5-6, and 5-7 show the relationship between PLCC and capacity.

Input capacities for the open, dump, and sort modules should be based on the amount of uncharacterized waste to be treated. Pre-sorted and newly generated wastes may already be sufficiently characterized to go directly to treatment. Uncharacterized and new "unknown" wastes would need to utilize this module.

EQUIPMENT LIST

- ① SELF GUIDED VEHICLE
- ② DE-CAP DEVICE
- ③ SORT HOPPER
- ④ SORT TABLE/ROTATING TABLE
- ⑤ SPECIAL WASTE GLOVEBOX
- ⑥ DUMP HOPPER
- ⑦ MAINTENANCE CRANE
- ⑧ BINS 4 (4'X4'X6')
- ⑨ BIN CONVEYORS 8' LONG
- ⑩ BIN CONVEYOR 20' LONG
- ⑪ BIN PUSHER
- ⑫ MAIN CELL GANTRY ROBOT
- ⑬ SORTING TABLE HYDRAULIC MANIPULATOR
- ⑭ SORTING MASTER SLAVE MANIPULATOR
- ⑮ BOX SIZE REDUCTION UNIT
- ⑯ DRUM OPENING GANTRY ROBOT
- ⑰ GLOVEBOX HYDRAULIC MANIPULATOR
- ⑱ CONTAINER GRAPPLER
- ⑲ DECAP ENCLOSURE
- ⑳ GLOVEBOX MASTER SLAVE MANIPULATOR

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	100	80	30.5	24.4
	MEDIUM	200	153	60.9	46.7
	LARGE	300	204	91.5	62.2
SMALL GENERATOR	MINIMUM	-	-	-	-

Figure 5-1. Equipment layout for open, dump, and sort module (module OSORT).

Figure 5-2. Process functional diagram for open, dump, and sort module (module OSORT).

Figure 5-3. FTE workers versus capacity for nonalpha waste for open, dump, and sort module (module OSORT).

Figure 5-4. FTE workers versus capacity for alpha waste for open, dump, and sort module (module OSORT).

Figure 5-5. PLCC versus capacity for nonalpha waste for open, dump, and sort module (module OSORT).

Figure 5-6. PLCC versus capacity for alpha waste for open, dump, and sort module (module OSORT).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 5-7. PLCC versus capacity including unit rates for open, dump, and sort module (module OSORT).

6. MAINTENANCE (MODULE MAINT)

The maintenance shop is the same for nonalpha and alpha modules except that the alpha waste module includes a mock-up shop. Module B-MAINT is for nonalpha waste and A-MAINT is for alpha waste.

6.1 Basic Information

The maintenance module is equipped with a building for receiving and repairing failed equipment. This module is used in conjunction with the treatment modules when such a function is not available at the existing modules. The maintenance shop costs assume that the module will repair components contaminated with low-level radioactivity but not alpha emitters. Components contaminated with alpha particles must be decontaminated in the alpha maintenance galleries before they are brought into the maintenance shop. Module A-MAINT has a remote component mock-up area.

6.2 Technical Bases and Assumptions

6.2.1 Function and Operation of Large Generator Modules

Contaminated failed equipment and parts arrive at the shop in transfer carts. Parts are removed from the transport carts and placed in a decontamination area where high-pressure spraying or other techniques are used to remove any loose contamination. After cleaning and decontamination, components are moved to maintenance tables. Maintenance machinery and tools are used as needed. The shop includes an overhead crane and a jib crane for material handling. A paint booth is also included.

6.2.2 Integration of Large Generator Modules

The module receives failed equipment from the treatment module. The output is repaired equipment. The module has secondary waste containing decontamination solutions, spent oil and solvent. O&M material includes parts, materials and consumables which are assumed to be purchased items.

6.2.3 Small Generator Module

The maintenance functions for the small generator module are performed by the front-end and back-end support module.

6.3 Cost Bases, Assumptions and Results

Major equipment capital cost items are cranes, milling, sanding, and lathe machinery and tools. Costs for all machinery and equipment including the cranes are based on industrial (nonradioactive) applications. Figure 6-1 and 6-2 show the relationship between estimated FTE workers and capacity of the module. Figures 6-3, 6-4, and 6-5 show the relationship between PLCC and capacity. Table 6-1 lists plan dimensions of the module.

Table 6-1. Plan dimensions of maintenance module (MAINT).

Module size	Dimensions (feet)		Dimensions (meters)	
	Width	Length	Width	Length
Large generator				
Small	30	87	9.1	26.5
Medium	30	250	9.1	76.2
Large	30	334	9.1	101.8
Small generator	—	—	—	—

Figure 6-1. FTE workers versus capacity for nonalpha waste for maintenance module (module MAINT).

Figure 6-2. FTE workers versus capacity for alpha waste for maintenance module (module MAINT).

Figure 6-3. PLCC versus capacity for nonalpha waste for maintenance module (module MAINT).

Figure 6-4. PLCC versus capacity for alpha waste for maintenance module (module MAINT).

Note: Basis includes 10 year O&M

Note: Basis includes 10 years O&M

Figure 6-5. PLCC versus capacity including unit rates for maintenance module (module MAINT).

7. INCINERATION (MODULE INCIN)

7.1 Basic Information

This module is a thermal (flame) organic destruction unit. Module INCIN is applicable to both alpha waste and nonalpha waste. The incineration module, shown in Figure 7-1, must be either used in conjunction with the receiving and inspection module (module RCINS) and stabilization module (module PLYMR) or installed at a location where similar functions are available in existing facilities. For a small generator facility, the incineration module should be used with the front-end and back-end module devised for small generators (module FBSPT).

The incinerator module receives and treats input organic solid waste, including process solid residues and organic and heterogeneous (i.e., combustibles commingled with noncombustibles) debris. Other material, such as organic liquids and lab packs, may also be processed by the incinerator. Extensive sorting of the organic and inorganic material is not necessary, as the incinerator can tolerate a high percentage of inorganic material in the feed. It is assumed that the input organic solids may contain up to 15% inorganic material.

The Controlled Air Incineration facility at the Los Alamos National Laboratory has been used as the basis for the small generator module. The incineration concept is similar to this existing facility except that the concept uses the smallest available unit. The TSCA incinerator at Oak Ridge National laboratories and the Consolidated Incineration Facility at Savannah River Site have been used as a basis for the large generator modules.

The waste is sorted at the receiving and inspection module (module RCINS or FBSPT) and transferred to the module in transport bins (or combustible boxes). The input waste generally consists of discarded paper, plastics, clothing (textile fabrics), wood, organic sludges, spent ion-exchange resins, spent activated carbon, and other solids produced by typical operations at DOE production or research and development installations.

Treatment units are provided assuming that the incoming waste contains radioactive constituents regulated under the Atomic Energy Act (AEA) and toxic metal and organics regulated under the Resource Conservation and Recovery Act (RCRA). In addition to the input waste, the incinerator module treats the secondary organic solid waste from other modules of the alpha and nonalpha waste treatment facility. The module has a number of unit operations that accomplish the required functions. These unit operations are shown in the PFD in Figure 7-2.

7.2 Technical Basis and Assumptions

7.2.1 Function and Operation of Large Generator Modules

The incinerator module has all the unit operations needed for treating the incoming organic liquid and solid waste, which has a broad range of RCRA-regulated organic contaminants. Organic contaminants can include volatile organic compounds (VOCs), aromatics, alcohols, ketones, glycols, and petroleum compounds. The unit operations also have the capability to treat

the alpha and nonalpha secondary waste, which consists of organic solids and organic liquids. The incoming solid waste is presorted before it is brought to the incineration module.

The incoming waste is brought to the module in transfer bins (or cardboard boxes) mounted on transport devices. The contents are sorted and thoroughly characterized at the receiving and inspection module. Therefore, the function of the preparation-and-feed unit operation in the incineration module is merely to convey the solid waste to the incineration chamber. The preparation-and-feed unit operation has a second feed device that batches and feeds organic liquids or slurries to the incinerator.

The incinerator oxidizes the organic and other combustible material contained in the feed. When sufficient solid waste is accumulated, the incinerator temperature is raised from the idle temperature (approximately 700-900°F) to the combustion temperature (approximately 1,600-1,800°F). The process begins by gradually charging the incinerator chamber with input waste in solid form. Concentrated organic liquids are injected to the chamber as a fuel supplement, when needed. Low concentration organic liquids are added to cool the incinerator, when needed.

After oxidizing the organic liquids and solids, the resulting ash is discharged from the incinerator and placed in containers, which are sent to the stabilization module. The incinerator is designed to completely burn the feed and minimize the amount of carbon in the ash.

Gas generated during the incineration process is the module's first secondary waste stream. To ensure complete destruction of organic material, the gas is first heated in a secondary combustion chamber to a temperature of 2,000°F with a residence time of at least 2 seconds. This gas is then sent to an offgas treatment unit operation (or air pollution control unit) that cools and treats the gas to remove particulates, toxic metals and acidic gases and other regulated elements and compounds before it is released to the atmosphere. This unit operation ensures that the offgas discharged to the atmosphere meets emission standards.

The offgas treatment unit operation has three major phases: dry filtration, wet scrubbing, and monitoring and discharge.

The dry filtration phase removes as much of the particulates (e.g., fly-ash, and particulates of vaporized toxic metal compounds) as possible to minimize the amount of radioactive particles and toxic metal particles that pass to the wet scrubbing phase. This is done by first cooling the gas using a water quench and then dry filtering the gas using a bag or ceramic candle filters. The filtered gas is then sent to a filter of sulfur-impregnated activated carbon to remove mercury, lead, and other compounds. The final step in the dry phase consists of polishing the gas using a HEPA filter unit. Solid waste from this phase (fly ash, spent activated carbon, and spent HEPA filters) is sent to the stabilization module. If the incinerator input waste has a high mercury content, the spent activated carbon may be sent to a retort unit operation (to be included in the special waste module) for mercury recovery and amalgamation.^h

h. The overall fate of mercury in the system is as follows. Mercury vaporized during the incineration process is partially removed from the flue gas by the dry offgas filters and by carbon adsorption. The remainder is removed in the wet-gas primary scrubber using an aqueous acidic scrubbing medium. The

The wet scrubbing phase further removes toxic metal, vapor, and acidic and alkaline gases (including hydrogen chloride and sulfur dioxide) and their salts. A series of wet scrubbing devices using caustic (or lime) solutions accomplishes this function. After scrubbing, the gas is sent to a moisture remover, a reheater, and to the emissions monitoring and discharge unit. Secondary waste from the scrubbing process, which consists of spent slurry, is neutralized and sent to a concentrator unit. The concentrator uses low-temperature evaporation to avoid revaporizing the captured mercury salts. Bottom sludge from the concentrator is sent to the polymer stabilization module. The concentrator distillate is treated and reused.

The monitoring and discharge phase continuously samples the gas and measures the concentration of the elements and compounds as specified by the facility emission control standards. The treated offgas meets the emissions standards as specified by the permit. The module minimizes as much as possible the volume of waste requiring disposal.

7.2.2 Integration of Large Generator Modules

Input waste to the incineration module comes from the container open, dump, and sort, receiving and inspection, thermal desorption, and aqueous waste treatment modules. Incinerator output consists of bottom ash and flyash, spent activated carbon, spent HEPA filters, and wet scrubber sludge, which are sent to the grout stabilization module. Treated water is reused. Materials purchased for O&M include such consumables as personal protective equipment, fuel, activated carbon, chemicals, and containers.

7.2.3 Function and Operation of Small Generator Fixed Module in a New or Existing Building

Function and operation of a fixed small incineration module are essentially the same as that described above in "Function and Operation of Large Generator Module." The operation can be performed in a new building or within an existing facility of the same area. Costs have been calculated for both, the difference being the cost of a new building versus building modification costs.

Existing building space required for installation of this module is 4,790 ft² (445 m²). The required ceiling height is 25 ft (7.6 m). The area required for a new building is the same.

7.2.4 Integration of Small Generator Fixed Module in a New or Existing Building

Input waste to the incineration module comes from the front-end and back-end support module and aqueous waste treatment module. Incinerator output consists of bottom ash and flyash, spent activated carbon, spent HEPA filters, and wet scrubber sludge, which are sent to the grout stabilization module. Treated water is reused. Materials purchased for O&M include such consumables as personal protective equipment, fuel, activated carbon, chemicals, and containers.

mercury removed in the dry-gas filters accumulates in the ash and beds of activated carbon. This waste is eventually solidified by the stabilization module. The mercury removed during the wet scrubbing accumulates in the concentrated bottom sludge. This waste is also solidified by the stabilization module.

7.2.5 Function and Operation of Portable Module

A portable small incineration module has not been developed.

7.3 Cost Basis, Assumptions and Results

The feed preparation, incinerator, secondary combustion chamber, dry offgas filtration, wet scrubber, stack monitors, and concentrator constitute the major equipment capital cost items. The estimate for operating and maintenance manpower of a small generator module is based on the assumption of operating in batch mode and processing about 18.1 kg/hr. Table 7-1, and Figures 7-3, and 7-4 show the relationship between estimated FTE workers and capacity of the module.

The cost estimate for the incineration package is based on quotations by Joy Energy Systems, of Charlotte, North Carolina and of ABB of Chicago, Illinois. The cost estimate for the dry offgas filters is based on the use of a ceramic candle unit as quoted by Pall Advances Separation Systems of Cortland, New York. The cost estimate for the wet scrubbing unit is based on the use of a quencher-and-scrubbing unit as quoted by Croll-Reynolds Company of Westfield, New Jersey. The cost estimate for the concentrator unit is based on the use of a thin-film evaporator unit as quoted by LCI Corporation of Charlotte, North Carolina. The cost estimate for the air- and area-monitoring unit is based on a quote by Eberline of Santa Fe, New Mexico. The estimate for the stack-monitoring unit is based on information received from the Eberline Corporation of Santa Fe, New Mexico. Cost versus capacity for the incineration module for either a new or existing building is shown in Table 7-2 and cost versus capacity is presented in Figures 7-5, 7-6, and 7-7.

Table 7-1. FTE workers for the small generator incineration module.

Cost component	Type of module	
	Fixed, in new building(s)	Fixed, in existing building(s)
(1.0) Studies and bench-scale tests	89	73
(2.0) Demonstration,		
(3.0) Production facility		
(4.0) Operations-budget-funded activities		
(5.0) O&M	60	60
(6.0) D&D		
All cost components (total for 10 years O&M)	150	133

Table 7-2. PLCC (\$1,000) for the small generator incineration module.

Cost component	Type of module	
	Fixed, in new building(s)	Fixed, in existing building(s)
(1.0) Studies and bench-scale tests	22,933	19,417
(2.0) Demonstration,		
(3.0) Production facility, and		
(4.0) Operations-budget-funded activities		
(5.0) O&M	9,757	9,757
(6.0) D&D		
All cost components (total for 10 years O&M)	32,690	29,174

NOTE: WALLS NOT SHOWN FOR CLARITY

Figure 7-1. Equipment layout for incineration module (module INCIN).

Figure 7-2. Process functional diagram for incineration module (module INCIN).

Figure 7-3. FTE workers versus capacity for nonalpha waste for incineration module (module INCIN).

Figure 7-4. FTE workers versus capacity for alpha waste for incineration module (module INCIN).

Figure 7-5. PLCC versus capacity for nonalpha waste for incineration module (module INCIN).

Figure 7-6. PLCC versus capacity for alpha waste for incineration module (module INCIN).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 7-7. PLCC versus capacity including unit rates for incineration module (module INCIN).

8. ORGANIC-SOLIDS WET-AIR OXIDATION (MODULE WETOX)

8.1 Basic Information

The organic-solids wet-air oxidation (WETOX) module, shown in Figures 8-1 and 8-2, must be either used in conjunction with the receiving and inspection module (module RCINS) and stabilization module (module PLYMR) or installed at a location where similar functions are available in existing facilities. It is a flameless organic-destruction unit and has a function analogous to an incinerator. This module will not be needed if a treatment facility already is equipped with an incinerator.

This module collects and treats input solid waste, including solid process residues and organic and heterogeneous (i.e., combustibles commingled with noncombustibles) debris. Other material, such as organic liquids and lab packs, may also be processed by the organic-solids wet-air oxidation module. The wet-air oxidation (WOX) process has less tolerance for inorganic material in the feed. It is assumed that the input organic solids may contain up to only 5% inorganic material. The process is also sensitive to certain organic compounds and, therefore, thorough precharacterization of the feed and strict process control are necessary. Another stringent requirement of the WOX process is that the input solids must be shredded and ground to fine particles and mixed with water before they are slurried to the oxidation reactor.

The waste is sorted at the receiving and inspection module (module RCINS) and transferred to the module in transport bins. The general composition of the input waste is assumed to be discarded paper, plastics, clothing (textile fabrics), wood, organic sludges, spent ion-exchange resins, spent activated carbon, and other solids produced from typical operations at DOE research and development installations. These installations are typically involved in scientific and technology development projects encompassing bench-scale, prototype, mock-up and demonstration efforts.

Treatment units are provided assuming that the incoming waste contains radioactive constituents regulated under AEA and toxic metal and organics regulated under RCRA. In addition to the input waste, the organic-solids wet-air oxidation module treats the secondary organic solid waste from other modules of the alpha and nonalpha waste treatment facility. The module has a number of unit operations that accomplish the required functions. These unit operations are shown in the PFD in Figure 8-3.

8.2 Technical Basis and Assumptions

8.2.1 Function and Operation of Large Generator Modules

The organic-solids wet-air oxidation module has all the unit operations needed for treating the incoming organic solid waste, which has a broad range of RCRA-regulated organic contaminants. Organic contaminants may include VOCs, aromatics, alcohols, ketones, glycols, phenols, and petroleum compounds. The unit operations also have the capability to treat the secondary organic solids and liquid waste generated by the treatment modules. The incoming

solid waste is pre-sorted before it is brought to the organic-solids wet-air oxidation module. The key unit operation, oxidation, is a laboratory-scale unit and is based on batch operations.

The incoming waste is brought to the module in transfer bins mounted on transport devices. The bin contents are processed by a waste preparation and feed unit where the solid material is first shredded and reduced to particle sizes of approximately 3 mm. The shredded particles are collected in a batch feed device, where they are mixed with water to form a slurry with about 3% solids. The slurry is sent to the oxidation unit operation.

The oxidation unit operation oxidizes the organic and other combustible material contained in the feed slurry. The process begins by charging the reactor with a known mass of input waste in slurry form. The contents are then brought to the operating temperature and pressure, and oxygen is introduced to the reactor to start the oxidation reaction. During oxidation, the pH is controlled by adding caustic. A catalyst is used to enhance the reaction and to complete the destruction of certain organics. Nitrogen is also added to the reactor to control process parameters. The process typically operates at a temperature of 280°C and at a pressure of up to 1,800 pounds per square inch.

After oxidizing the organic solids (and liquids), the contents of the oxidation reactor are discharged as high-TDS aqueous waste. This waste, which contains salts (e.g., NaCl) and suspended solids, is sent to a concentration unit. After concentration, the bottom sludge is sent to the stabilization module. The distillate from the concentrator is sent to an aqueous waste module and is treated to remove any radioactivity or traces of low-molecular-weight organics. The treated water is sent to a sampling tank before recycling and reuse.

Gas generated during the oxidation process is the module's secondary waste stream. This gas is treated by an offgas unit to remove RCRA-regulated compounds before release to the atmosphere. The treatment consists of two steps. First, the gas is cooled to condense the water vapor, and then the gas is dried and passed through a bed of activated carbon to remove any mercury and organic vapors. After initial filtration, the gas is processed through a HEPA filter for final polishing. Water recovered from offgas condensation is sent to the concentration unit. Before discharge to the atmosphere, the gas is monitored to ensure compliance with the emission restrictions established by the facility permit.

The oxidation reactor is heated by a hot oil (or steam) skid. Also, since the oxidation batch processing requirements are highly dependent on the theoretical oxygen demand needed to oxidize the feed, frequent sampling and analysis of the process feed and the byproduct is needed. It is assumed that the administration module provides the required analytical services. Provisions are included for radiation monitoring throughout the facility.

The organic-solids wet-air oxidation module destroys organics to a level such that the stabilized sludge meets the TCLP requirements of the land disposal restrictions established by the EPA. The treated offgas meets the requirements of the facility emissions permit.

8.2.2 Integration of Large Generator Modules

Input waste to the organic-solids wet-air oxidation module comes from the receiving and inspection module, container open, dump, and sort module, and the aqueous waste treatment module. The WOX output is concentrated sludge and spent activated carbon, which are sent to the stabilization module. Treated water is reused. Materials purchased for O&M include such consumables such as personal protective equipment, activated carbon, chemicals, and containers.

8.2.3 Function and Operation of Small Generator Fixed Module in a New or Existing Building

A fixed small generator module to be installed in a new building or occupying the same area in an existing building has been cost estimated. Function and operation of the fixed small generator module is essentially the same as the large modules.

Existing building space required for installation of this module is 4,869 ft² (452 m²). The required ceiling height is 25 ft (7.6 m).

8.2.4 Integration of Small Generator Fixed Module in a New or Existing Building

Input waste to the organic-solids wet-air oxidation module comes from the front-end and back-end module (module FBSPT) and the aqueous waste treatment module. The output is concentrated sludge and spent activated carbon, which are sent to the stabilization module. Treated water is reused. Materials purchased for O&M include such consumables such as personal protective equipment, activated carbon, chemicals and containers.

8.2.5 Function and Operation of Portable Module

Function and operation description is the same as the large generator modules with the exception that all equipment is skid mounted on five trailers. Trailers A, B, C, and D contain treatment unit operations that are accompanied by a control trailer. Description of the control trailer is presented in Section 17 of this report. It is assumed that all feed preparation necessary to meet process feed specifications are performed by the host site. The only feed preparation performed by this module is to slurry waste so as to meet the solids-content specifications of the WOX process.

8.2.6 Integration of Portable Module

Input waste to the portable organic-solids wet-air oxidation module comes from the generators. The output is concentrated sludge and spent activated carbon, which are sent to stabilization (module PLYMR). Liquid waste generated in the process is sent to aqueous waste treatment (module AQWTR). The portable module will need to be accompanied by a portable stabilization module and portable aqueous waste treatment module when dispatched to sites without such capabilities.

8.3 Cost Bases, Assumptions and Results

The feed preparation unit, shredder, oxidation reactor, hot oil skid, air compressor package, and evaporator constitute the major equipment capital cost items. All unit cost estimates are based upon budgetary prices submitted by various vendors. The cost estimate for the WOX package is based on a quotation by Zimpro of Rothschild, Wisconsin. Cost of the shredder unit is based on a quotation by Komor Industries, Inc. of Groveport, Ohio. Equipment sizing is based upon a flow rate of about 18.1 kg/hr for the fixed small generator modules. For portable treatment modules, it is assumed that 26.9 ft³ (2.5 m³) of waste is to be treated during each campaign. The small generator and portable module FTEs and PLCC are shown in Tables 8-1 and 8-2. Data is given for placing the equipment in either a new building or existing facility. Figures 8-4 through 8-8 show estimated FTE workers and cost versus capacity for the large generator module.

Table 8-1. FTE workers for the small generator organic-solids wet-air oxidation module.

Cost component	Type of module		
	Fixed, in new building(s)	Fixed, in existing building(s)	Portable
(1.0) Studies and bench-scale tests	137	120	105
(2.0) Demonstration			
(3.0) Production facility			
(4.0) Operations-budget-funded activities			
(5.0) O&M	86	88	243
(6.0) D&D			
All cost components (total for 10 years O&M)	223	208	348

Table 8-2. PLCC (\$1,000) for the small generator organic-solids wet-air oxidation module.

Cost component	Type of module		
	Fixed, in new building(s)	Fixed, in existing building(s)	Portable
(1.0) Studies and bench-scale tests	34,582	30,793	26,976
(2.0) Demonstration			
(3.0) Production facility			
(4.0) Operations-budget-funded activities		-	
(5.0) O&M	11,322	13,817	18,716
(6.0) D&D			
All cost components (total for 10 years)	45,904	44,160	45,692
Cost per campaign	-	-	762

EQUIPMENT LIST

- ① PRIMARY SHREDDER
- ② SECONDARY SHREDDER
- ③ DRUM HOIST STRUCTURE
- ④ DRUM HOIST
- ⑤ ROLLER CONVEYOR
- ⑥ DUST COLLECTOR UNIT
- ⑦ WASTE SLURRY TANK
- ⑧ WASTE SLURRY PUMP
- ⑨ CHEMICAL FEED PUMP
- ⑩ CHEMICAL FEED TANK
- ⑪ DILLUTION WATER FEED PUMP
- ⑫ WASTE WATER FEED PUMP
- ⑬ HIGH PRESSURE PUMP
- ⑭ CAUSTIC METERING PUMP
- ⑮ MIX TANK
- ⑯ PROCESS AIR COMPRESSOR
- ⑰ EFFLUENT PUMP
- ⑱ HOT OIL HEAT EXCHANGER
- ⑲ FEED & EFFLUENT HEAT EXCHANGER
- ⑳ PROCESS COOLER
- ㉑ PROCESS REACTORS
- ㉒ HOT OIL SYSTEM
- ㉓ SEPARATOR
- ㉔ PRESSURE CONTROL VALVES
- ㉕ CONTROL PANEL
- ㉖ CONCENTRATOR & CONDENSER
- ㉗ HEPA FILTER
- ㉘ VAPOR PHASE ACTIVATED CARBON
- ㉙ BLOWER
- ㉚ STACK
- ㉛ CONTROL PANEL
- ㉜ 10 TON OVERHEAD CRANE

Figure 8-1. Equipment layout for organic-solids wet-air oxidation module (module WETOX).

EQUIPMENT LIST

- ① WASTE STORAGE TANK
- ② WASTE PUMP
- ③ WASTE FEED BLENDING TANK
- ④ WASTE PUMP
- ⑤ CHEMICAL STORAGE TANK
- ⑥ CHEMICAL PUMP
- ⑦ CHEMICAL BLENDING TANK
- ⑧ CHEMICAL PUMP
- ⑨ STACK
- ⑩ CONCENTRATOR & CONDENSER
- ⑪ DILLUTION WATER FEED PUMP
- ⑫ WASTE WATER FEED PUMP
- ⑬ HIGH PRESSURE PUMP
- ⑭ CAUSTIC METERING PUMP
- ⑮ MIX TANK
- ⑯ PROCESS AIR COMPRESSOR
- ⑰ EFFLUENT PUMP
- ⑱ HOT OIL HEAT EXCHANGE
- ⑲ FEED AND EFFLUENT HEAT EXCHANGER
- ⑳ PROCESS COOLER
- ㉑ PROCESS REACTORS
- ㉒ HOT OIL SYSTEM
- ㉓ SEPARATOR
- ㉔ PRESSURE CONTROL VALVES
- ㉕ CONTROL PANEL
- ㉖ HEPA FILTER
- ㉗ VAPOR PHASE ACTIVATED CARBON
- ㉘ INFLOWER

Figure 8-2. Equipment layout for portable organic-solids wet-air oxidation module (module WETOX).

Figure 8-3. Process functional diagram for large generator organic-solids wet-air oxidation module (module WETOX).

Figure 8-4. FTE workers versus capacity for nonalpha waste for organic-solids wet-air oxidation module (module WETOX).

Figure 8-5. FTE workers versus capacity for alpha waste for organic-solids wet-air oxidation module (module WETOX).

Figure 8-6. PLCC versus capacity for nonalpha waste for organic-solids wet-air oxidation module (module WETOX).

Figure 8-7. PLCC versus capacity for alpha waste for organic-solids wet-air oxidation module (module WETOX).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 8-8. PLCC versus capacity including unit rates for organic-solids wet-air oxidation module (module WETOX).

9. THERMAL DESORPTION (MODULE THDRB)

9.1 Basic Information

The thermal desorption module, shown in Figures 9-1 and 9-2, is used to remove VOCs from debris and soil. The module uses an indirectly heated low temperature kiln to volatilize the VOCs. The kiln is operated at temperatures high enough to volatilize VOCs but below the melting point of low temperature plastics and salts.

A large generator module must be used in conjunction with the receiving and inspection module (module RCINS), open, dump and sort module (module OSORT), incineration module (module INCIN), and stabilization module (module GROUT or VITRF), or installed at a location where similar functions are available in existing modules. The small generator module must be used in conjunction with front-end/back-end module (module FPSPT).

This module receives waste from the receiving and inspection module, where the waste has been sorted to remove material incompatible with the desorption process, and size reduced to meet process feed size specifications. Following the desorption process, treated material is sent to stabilization, Module GROUT. Offgas containing VOCs is condensed. Condensed organic liquids are temporarily stored, and later sent to an onsite or offsite incineration module for destruction. Treated offgas is then filtered, passed through a carbon adsorption unit and through a HEPA filter, and discharged to the atmosphere.

The module consists of nine unit operations that accomplish the required functions, as shown in the PFD in Figure 9-3.

9.2 Technical Basis and Assumptions

9.2.1 Function and Operation of Large Generator Modules

The desorption module has all the unit operations needed for desorbing VOCs from incoming solid waste streams of debris and soil. Incoming debris and soil waste is inspected at the receiving and inspection module. Material that is not compatible with the desorption process is removed from the feed. Material is incompatible to this process if it contains low melting point components such as low temperature plastics, salts or contain highly corrosive components such as fluorine. The sorted waste stream is also size reduced by shredding at the receiving and inspection module before being sent to the thermal desorption module.

The desorption kiln operates at an approximate temperature of 400°-600° F. Offgas from this unit is condensed in primary and secondary condensing units. The condensed organic liquids are sent off for incineration. Offgas from the condensing process is filtered by vapor phase activated carbon to remove remaining traces of organics. Treated offgas is then passed for a final polish through a HEPA filter before discharge to the atmosphere. Treated soils and debris, solid process waste, spent carbon, and spent HEPA filter elements generated in this process are sent to the stabilization module.

9.2.2 Integration of Large Generator Modules

This treatment module receives waste from receiving and inspection and from container open, dump, and sort (modules RCINS and OSORT). Output consists of treated soils, debris, and other solid process residue which are sent to a stabilization module. Liquid organic waste is sent to an incineration unit for destruction. Materials purchased for O&M include such consumables as personal protective equipment, gas fuel, activated carbon, and HEPA filters.

9.2.3 Function and Operation of Small Generator Fixed Module in a New or Existing Building

A small generator module suitable for installation in either a new or an existing building has been cost estimated. The function and operation of the module is essentially the same as that for the large generator module.

Existing building space required for installation of this module is 2,955 ft² (275 m²). The required ceiling height is 35 ft (10.7 m).

9.2.4 Integration of Small Generator Fixed Module in a New or Existing Building

This treatment module receives waste from the front-end and back-end support module (module FBSPT). Output consists of treated soils, debris, and other solid process residue which are sent to stabilization (module GROUT or VITRF). Liquid organic waste is sent to an incineration unit for destruction. Materials purchased for O&M include such consumables as personal protective equipment, gas fuel, activated carbon, and HEPA filters.

9.2.5 Function and Operation of Portable Module

Function and operation of the portable module is the same as for the large generator module with the exception that all equipment required is skid mounted on two trailers. Trailers A and B contain treatment unit operations which are accompanied by the control trailer. Description of the control trailer is presented in Section 17 of this report. It is assumed that all feed preparation necessary to meet process feed specifications are performed by the host site.

9.2.6 Integration of Portable Module

Input waste to the portable thermal desorption module comes from the generators. Output from the thermal desorption consists of treated soils and debris, concentrated sludge, spent activated carbon, and spent HEPA filters, all of which are sent to stabilization (modules GROUT or VITRF). The portable thermal desorption module will need to be accompanied with portable stabilization treatment module when dispatched to sites without stabilization capability.

9.3 Cost Basis, Assumptions and Results

The kiln or calciner, VOC condensers, and air pollution control constitute the major equipment capital cost items. The cost estimates for all equipment are based upon budgetary prices submitted by various vendors. The cost estimate for the calciner/kiln package is based on a

quotation by ABB Raymond Inc., of Lisle, Illinois. It is assumed that this module will handle only debris and soil predominantly contaminated with hydrocarbons and organochlorines. The estimated manpower for small generator module O&M is based on the assumption that batch operations will be used. Design capacities used for small generator modules are 18.1 kg/hr and design capacity of 26.9 ft³ (2.5 m³) per campaign is used for portable treatment modules. Estimated large generator modules FTEs and cost versus capacity are shown in Figures 9-4 to 9-8. Estimated FTE workers and PLCC for small generator and portable modules are shown in Tables 9-1 and 9-2.

Table 9-1. FTE workers for the small generator thermal desorption module.

Cost component	Type of small generator module		
	Fixed in new building(s)	Fixed, in existing building(s)	Portable
(1.0) Studies and bench-scale tests	35	22	19
(2.0) Demonstration			
(3.0) Production facility			
(4.0) Operations-budget-funded activities			
(5.0) O&M	38	28	68
(6.0) D&D			
All cost components (total for 10 years O&M)	73	50	87

Table 9-2. PLCC (\$1,000) for the small generator thermal desorption module.

Cost component	Type of small generator module		
	Fixed, in new building(s)	Fixed, in existing building(s)	Portable
(1.0) Studies and bench-scale tests	8,372	5,472	4,757
(2.0) Demonstration			
(3.0) Production facility			
(4.0) Operations-budget-funded activities			
(5.0) O&M	5,466	5,280	5,260
(6.0) D&D			
All cost components (total for 10 years O&M)	13,838	10,752	10,017
Cost per campaign	—	—	167

EQUIPMENT LIST

- ① PREPARE & FEED WASTE
- ② KILN
- ③ SOLIDS CONTAINER FOR COOLING
- ④ COOLING ROOM
- ⑤ PRIMARY CONDENSER
- ⑥ SECONDARY CONDENSER
- ⑦ VOC ADSORPTION
- ⑧ STORAGE TANK
- ⑨ HEPA FILTER

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	40	54	12.2	16.5
	MEDIUM	40	54	12.2	16.5
	LARGE	40	60	12.2	18.3
SMALL GENERATOR	MINIMUM	40	54	12.2	16.5

Figure 9-1. Equipment layout for large generator thermal desorption module (module THDRB).

EQUIPMENT LIST

- ① SORT & PREPARE FEED
- ② DESORPTION UNIT
- ③ SOLIDS COOLING CONTAINERIZATION
- ④ PRIMARY CONDENSER
- ⑤ SECONDARY CONDENSER
- ⑥ VOC ADSORPTION
- ⑦ STORAGE TANK
- ⑧ HEPA FILTER
- ⑨ CONTROL PANEL

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Figure 9-2. Equipment layout for small portable thermal desorption module (module THDRB).

Figure 9-3. Process functional diagram for thermal desorption module (module THDRB).

Figure 9-4. FTE workers versus capacity for nonalpha waste for thermal desorption module (module THDRB).

Figure 9-5. FTE workers versus capacity for alpha waste for thermal desorption module (module THDRB).

Figure 9-6. PLCC versus capacity for nonalpha waste for thermal desorption module (module THDRB).

Figure 9-7. PLCC versus capacity for alpha waste for thermal desorption module (module THDRB).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 9-8. PLCC versus capacity including unit rates for thermal desorption module (module THDRB).

10. LEAD RECOVERY SUBSYSTEM (MODULE PBRCR)

10.1 Basic Information

The lead recovery module, shown in Figure 10-1, is used as an addition to an existing facility where similar functions are already installed or in conjunction with treatment front-end and back-end support modules (modules FBSPT or OSORT).

The module involves nine major process unit operations that decontaminate solid lead waste material by wet abrasive blasting or by melting. Lead acid batteries are treated by neutralization and solidification. Products from this module are lead bricks and shielding, which can be recycled, and neutralized acidity which must be stabilized. Slag containing radioactive particles from the melting process will also be cast into ingots and macro-encapsulated for land disposal. Liquid effluent is recovered and processed in the aqueous waste treatment module. These unit operations are shown in the PFD in Figure 10-2.

10.2 Technical Basis and Assumptions

10.2.1 Function and Operations for Large Generator Modules

Presorted incoming waste will be received at the module in drums. These enter the processing building and will be opened for inspection. Each drum will be routed to decontamination or to lead melting depending on which type of waste the drum contains. Since the feed to the module will not be consistent, each processing line was sized to handle 7.5% of the process feed rate. Lead bricks and shielding material will be processed in the decontamination line. This process line will consist of a decontamination booth, where fixed contamination is removed using a liquid abrasive solution. In this process it was assumed that a 1/16-inch layer of lead material will be removed from the object being blasted.

Drums containing the waste material will be moved to the decontamination booth by powered roller conveyor. The material will be removed from the drum by a hydraulic drum dumper. Waste bricks or shielding will be manually placed onto the cleaning table by means of a glove box and will be moved into the booth for cleaning. After cleaning and drying, the table will be moved out of the opposite side of the booth for assaying. Articles proving to be decontaminated will be deposited into a clean drum. Articles not passing assay are placed in another drum and returned to the processing line. Drums containing cleaned material is taken by crane to the drum washer before exiting the building through an airlock.

Material such as lead blankets, lead shot, and leaded gloves are processed in the lead melter. This material, loaded in 55-gal drums, is dumped by drum dumper onto a sorting table for sorting and lead battery disassembly. The lead battery shell will be cut off by small stationary circular saw. Sulfuric acid will be collected in a 55-gal tank. Lead internal parts are collected in a stainless-steel 55-gal drum. The full drum containing 200 lbs of lead is then dumped into a shredder and reduced in size to minus 1/8 inch. Sodium carbonate is fed into the shredder during the shredding operation. Lead paste is collected under the shredder and dumped by drum dumper into the stirrer. The reaction for transforming lead sulphate (main paste component) into lead carbonate

under vigorous stirring takes about 1 hour. The paste is then dumped into the melter, where the melting will occur at a temperature less than 1,000°C.

The lead is melted in an induction melting furnace. Electric current penetrates the metal causing a stirring force in the melted lead separating the slag from the lead. Radioactive impurities in the form of slag are then separated from the surface of the melted lead before the lead is poured into a casting machine. The casting machine produces lead ingots measuring 4 x 4 x 12 inches. These ingots are collected in containers for cooling and moving them into the inspection area by overhead crane.

Smelter emissions are collected by overhead hood and treated in an offgas treatment facility. A secondary combustor rated at 40 ft³ (1.13 m³) per minute is used, followed by a quench elbow and high efficiency SO₂ absorption tower. An induction fan and HEPA filter are on the end of the treatment before the clean offgas is released to the atmosphere.

The unit operations produce three secondary waste streams: filter elements, liquid from abrasive blasting solution, and offgas. Filters in the abrasive blasting operation will be changed monthly. These waste elements will be placed in drums for disposal. Secondary liquid waste including acids from battery disposal and bleed from abrasive blasting will be treated in the aqueous waste treatment unit. The melter offgas system is equipped with a dry treatment train and a wet treatment train. The dry treatment train consists of high temperature HEPA filtration units with secondary combustion capabilities (such as ceramic filters). In this train any combustible constituents are thermally destroyed, and particulates are removed from the offgas stream. An induced air blower moves the conditioned effluent through the wet treatment train that is designed to remove SO₂, HCl, and NO_x.

10.2.2 Integration of Large Generator Modules

Input consists mainly of contaminated lead bricks, shielding material, and lead acid batteries received in drums or bins from open, dump and sort module (module OSORT or FBSPT). Major O&M purchased materials such as personal protective equipment, filter elements, abrasive media, flux, and disposable containers are assumed to be consumable supplies, and their respective costs are estimated accordingly.

Output consists mainly of lead bricks, shielding, and ingots for recycling. Drums are cleaned and recycled. Slag is cast into ingots and placed in drums for disposal as well as waste products from the abrasive blasting process. Waste acids and water are sent to aqueous waste treatment. Treated offgas is discharged to the atmosphere.

10.2.3 Function and Operation of Small Generator Fixed Module in a New or Existing Building

A fixed small generator module suitable for installation in a new or existing building space was cost estimated. The function and operation of the fixed small generator module is essentially the same as for the large generator modules.

Existing building space required for installation of this module is 5,099 ft² (474 m²). The required ceiling height is 25 ft (7.6 m). The area required for a new building is the same.

10.2.4 Integration of Small Generator Fixed Module in a New or Existing Building

Input consists mainly of contaminated lead bricks, shielding material, and lead acid batteries received in drums or bins from receiving and inspection (module FBSPT). Major O&M purchased materials, such as personal protective equipment, filter elements, abrasive media, fluxes and disposable containers, are assumed to be consumable supplies, and their costs are estimated accordingly.

Output consists mainly of lead ingots for recycling. Drums are cleaned and recycled. Slag is cast into ingots and placed in drums for disposal as well as waste products from the abrasive blasting process. Waste acids and water are sent to aqueous waste treatment. Treated offgas is discharged to the atmosphere.

10.3 Cost Bases, Assumptions and Results

Lead waste is received in drums. Lead bricks and sheets that can be decontaminated are separated from lead waste to be melted. The maximum size of any piece to be decontaminated or shredded is 12 x 12 x 12 inches. Containers will require washing for decontamination and recycling.

Since the quantities of lead waste to be decontaminated versus lead waste to be melted might not be consistent, both these sides of the lead recovery process should be designed for maximum capacity. Design capacities for the small generator modules are 9.1 kg/hr.

FTEs and cost for small generator module installed in existing building are shown in Tables 10-1 and 10-2. FTEs and cost versus capacity for the lead recovery module are shown in Figures 10-3 to 10-7.

Table 10-1. FTE workers for the small lead recovery module.

Cost component	Type of small module	
	Fixed, in new building(s)	Fixed, in existing building(s)
(1.0) Studies and bench-scale tests	54	33
(2.0) Demonstration		
(3.0) Production facility		
(4.0) Operations-budget-funded activities		
(5.0) O&M	34	38
(6.0) D&D		
All cost components (total for 10 years O&M)	88	71

Table 10-2. PLCC (\$1,000) for the small lead recovery module.

Cost component	Type of small module	
	Fixed, in new building(s)	Fixed, in existing building(s)
(1.0) Studies and bench-scale tests	12,854	8,003
(2.0) Demonstration		
(3.0) Production facility		
(4.0) Operations-budget-funded activities		
(5.0) O&M	6,645	6,645
(6.0) D&D		
All cost components (total for 10 years O&M)	19,499	14,648

NOTE: WALLS NOT SHOWN FOR CLARITY

EQUIPMENT LIST

- ① POWERED ROLLER CONVEYOR
- ② BARREL DECAPPING
- ③ AUTOMATIC DRUM DUMPER
- ④ DRUM PUSHER
- ⑤ SORT TABLE GLOVE BOX
- ⑥ DECONTAMINATION BOOTH
- ⑦ CLEAN METALS SORT TABLE
- ⑧ INGOT INSPECT SORT TABLE
- ⑨ BARREL CAPPING
- ⑩ ASSAY AND INSPECT STATION
- ⑪ BARREL DECONTAMINATION STATION
- ⑫ BATTERY SORT AND SIZING TABLE
- ⑬ SHREDDER
- ⑭ MIXER
- ⑮ MONORAIL
- ⑯ OVERHEAD CRANE
- ⑰ FURNACE WITH HOOD
- ⑱ LEAD CASTING MACHINE
- ⑲ SECONDARY COMBUSTOR

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	40	90	12.2	27.4
	MEDIUM	50	90	15.2	27.4
	LARGE	-	-	-	-
SMALL GENERATOR	MINIMUM	40	90	12.2	27.4

Figure 10-1. Equipment layout for lead recovery module (module PBRCR).

Figure 10-2. Process functional diagram for lead recovery module (module PBR CR).

Figure 10-3. FTE workers versus capacity for nonalpha waste for lead recovery module (module PBR CR).

Figure 10-4. FTE workers versus capacity for alpha waste for lead recovery module (module PBRCR).

Figure 10-5. PLCC versus capacity for nonalpha waste for lead recovery module (module PBR CR).

Figure 10-6. PLCC workers versus capacity for alpha waste for lead recovery module (module PBRCR).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 10-7. PLCC versus capacity including unit rates for lead recovery module (module PBR CR).

11. MERCURY SEPARATION (MODULE RMERC)

11.1 Basic Information

The mercury separation module, shown in Figure 11-1, is used for the removal of mercury from sludges as well as solids.ⁱ The module can also accept elemental (liquid) mercury. Aqueous waste contaminated with mercury and its salts would be processed by the aqueous waste treatment module (module AQWTR).

The module can be installed in the same building and used in conjunction with the open, dump and sort module (module FBSPT or OSORT), the aqueous waste treatment module (module AQWTR), and the stabilization module (modules VITRF, GROUT, or PLYMR), or installed in a new building with similar functions available in existing facilities.

The input waste is sorted at the receiving and inspection module (module FBSPT or RCINS), where waste containing mercury is segregated from other incoming waste. Treatment units are provided assuming that the incoming waste contains radioactive constituents regulated under AEA, and toxic metal and organics regulated under RCRA. In addition to the input waste, the mercury separation module could treat mercury contaminated ash or solids generated by other modules of the treatment facility. The module has a number of unit operations that accomplish the required functions. These unit operations are shown in the PFD in Figure 11-2.

11.2 Technical Basis and Assumptions

11.2.1 Function and Operations of Large Generator Modules

The mercury separation module has all the operations needed for treating sludge and solids containing or contaminated with elemental mercury or mercury compounds.

Incoming waste is brought to the module in transfer bins mounted on transfer devices. Elemental mercury is separated from other mercury contaminated waste. The elemental mercury is transferred to a liquid-mercury storage bottle, and other mercury waste is transferred to a waste preparation and feed bin. From the feed bin, the solid material is shredded, combined with sludges requiring no feed preparation, and transferred to an electrically heated vacuum retort. The retort thermally volatilizes (at approximately 1,000° F) the low boiling point constituents, including mercury and mercury compounds under high vacuum conditions. A small amount of nitrogen is admitted to the retort as an inert sweep gas. The retort is maintained at operating temperature for a predetermined heat soak period and then cooled. The solid residue, essentially inorganics and char, are removed from the retort, assayed and delivered either to a thermal treatment or to a stabilization module.

i. Detailed composition of the input waste is not available. Hence, it is assumed that organic sludges may include cutting and lubrication oils and mercuric acetates. Inorganic sludges may include those generated from acid leaching, thermal treatment, and mercury sulfide precipitates. Solids may include mercury-specific ion-exchange resin (e.g., Ionac SR-5), rags, wipes, and personal protective equipment.

The vapors from the retort pass through a heat exchanger, which reduces the vapor temperature enough to condense the mercury while allowing the other low boiling point constituents to remain volatilized. These remaining volatilized vapors (mainly water and organics) are burned in a secondary combustion chamber at a temperature of approximately 2,000°F. This gas is then sent to an offgas treatment unit operation that cools and treats the gas by quenching, dry filtration, carbon adsorption, and high efficiency filtration to remove regulated elements and compounds before the treated gas is released to the atmosphere. The unit operation ensures that the offgas discharged to the atmosphere meets the given emission standards.

The condensed mercury is separated from the uncondensed offgas and sent to the elemental mercury storage bottle. The liquid mercury is transferred to an amalgamation operation where the mercury is combined with copper (or zinc) powder, steel shot (for proper mixing), and nitric acid. This combination is mixed to form a copper-mercury amalgam, eliminating free mercury. The amalgam is packaged for assay and inspection to ensure that the amalgam meets toxicity characteristic leaching procedure (TCLP) standards.

11.2.2 Integration of Large Generator Modules

Input waste comes from the receiving and inspection module. Secondary waste received from other modules could include offgas mercury separation beds in the incinerator module and mercury separation sludges in the aqueous waste treatment modules.

Output from mercury separation consists of copper-mercury amalgam, spent HEPA filters, spent activated carbon, and solid debris, which are sent either to an incineration or to a stabilization module, or wet scrubber sludges, which are sent to the aqueous waste treatment module. Materials purchased for O&M include such consumables as personal protective equipment, fuel, activated carbon, copper powder, steel shot, and nitric acid.

11.2.3 Function and Operation of Small Generator Fixed Module in a New or Existing Building

A fixed small generator module suitable for installation in either a new or an existing building space was cost estimated. The function and operation of a fixed small generator module is essentially the same as for large generator modules.

Existing building space required for installation of this module is 2,028 ft² (188 m²). The required ceiling height is 25 ft (7.6 m). The area required for a new building is the same.

11.2.4 Integration of Small Generator Fixed Module in a New or Existing Building

Input waste comes from the receiving and inspection module. Secondary waste could also come from an incinerator module and aqueous waste treatment module.

Output from mercury separation consists of a copper-mercury amalgam, spent HEPA filters, spent activated carbon, and solid debris, which are sent to either an incineration or a stabilization module, or wet scrubber sludges, which are sent to the aqueous waste treatment module.

Materials purchased for O&M include such consumables as personal protective equipment, fuel, activated carbon, copper powder, steel shot, and nitric acid.

11.3 Cost Basis, Assumptions and Results

It is assumed that the module feed stream contains 5% elemental mercury and 95% other solid waste. Liquid elemental mercury can be readily segregated from the remaining solid waste. Mercury contaminated solid waste composition is approximately 5% mercury, 32% inorganics, 42% volatile organics, 4% non-volatile organics, and 17% moisture.

One retort batch can be completed per 8-hour shift. The estimate for the small generator module operating and maintenance manpower is based on the assumption of operating in a batch mode and processing about 9.1 kg/hr.

Cost estimates are based upon budgetary prices submitted by various vendors. The cost estimate for the feeder/shredder is based on a quote from System Service Solutions of Wilsonville, Ohio. The cost estimate for the retort is a quote from Denver Mineral Engineers, Inc., of Littleton, Colorado. The cost estimate for the amalgam mixer is based on a quote from Miracle Paint Rejuvenator of St. Paul, Minnesota. The cost estimate for the offgas treatment is based on the use of a dry filter as quoted by Pall Advanced Separation Systems of Cortland, New York, and a quencher and scrubbing unit as quoted by Croll-Reynolds Company of Westland, New Jersey.

FTE and cost versus capacity for the large generator mercury separation modules are shown in Figures 11-3 to 11-7. FTE and cost for the small generator mercury separation module for installation in either a new or existing building are shown in Tables 11-1 and 11-2.

Table 11-1. FTE workers for the small generator mercury separation module.

Cost component	Type of small generator module	
	Fixed, in new building(s)	Fixed, in existing building(s)
(1.0) Studies and bench-scale tests	31	24
(2.0) Demonstration		
(3.0) Production facility		
(4.0) Operations-budget-funded activities		
(5.0) O&M	44	47
(6.0) D&D		
All cost components (total for 10 years O&M)	74	71

Table 11-2. PLCC (\$1,000) for the small generator mercury separation module.

Cost component	Type of small generator module	
	Fixed, in new building(s)	Fixed, in existing building(s)
(1.0) Studies and bench-scale tests	7,599	6,170
(2.0) Demonstration		
(3.0) Production facility		
(4.0) Operations-budget-funded activities		
(5.0) O&M	7,327	7,239
(6.0) D&D		
All cost components (total for 10 years O&M)	14,926	13,409

NOTE: WALLS NOT SHOWN FOR CLARITY

Figure 11-1. Equipment layout for mercury separation module (module RMERC).

Figure 11-2. Process functional diagram for mercury separation module (module RMERC).

Figure 11-3. FTE workers versus capacity for nonalpha waste for mercury separation module (module RMERC).

Figure 11-4. FTE workers versus capacity for alpha waste for mercury separation module (module RMERC).

Figure 11-5. PLCC versus capacity for nonalpha waste for mercury separation module (module RMERC).

Figure 11-6. PLCC versus capacity for alpha waste for mercury separation module (module RMERC).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 11-7. PLCC versus capacity including unit rates for mercury separation module (module RMERC).

12. DEACTIVATION (MODULE DEACT)

12.1 Basic Information

The deactivation module, shown in Figure 12-1, must be either used in conjunction with the open, dump and sort module (module FBSPT or OSORT), or stabilization module (modules VITRF, GROUT, or PLYMR), and aqueous waste treatment module (module AQWTR), or installed at a location where similar functions are available in existing facilities.

The deactivation module collects and treats input reactive metal present as solids or as liquid solutions. The metal waste is shipped to the module in cans, drums, and special transport containers having several different capacities. Treatment units are provided based on the assumption that the incoming waste contains radioactive constituents regulated under AEA and toxic metal regulated under RCRA. The module has a number of unit operations that accomplish the required functions. These unit operations are shown in the PFD in Figure 12-2.

12.2 Technical Basis and Assumptions

12.2.1 Function and Operation of Large Generator Modules

The deactivation module has all the unit operations needed for treating incoming solid and liquid waste having a broad range of RCRA-controlled toxic, heavy-metal contaminants. Toxic metal contaminants can include arsenic, barium, beryllium, cadmium, chromium, cyanide, selenium, sodium, and uranium.

The incoming metal waste is segregated into solids and liquids before it is brought to the treatment module. Solids are brought to a metal preparation area for radioassay and sorting before treatment in the chemical treatment area as in the case of sodium and uranium, or in the metal classification area for recovery. Liquids are brought to a chemical treatment area.

The deactivation unit operations have maximum flexibility for batch operation. The waste is transferred from the incoming containers to the appropriate treatment operation.

Typical steps for treating bulk quantities of the liquid and solids waste categories are as follows (refer to PFD in this section):

Solid metal waste: Solid metal waste is processed through a metal preparation area where the waste is sorted into the various metal types and radioactivity. Sodium and uranium metal is segregated and sent to the sodium destruction and uranium removal areas respectively. All other metal is washed to remove tramp particles, is dried, and is again radioassayed. Large pieces are reduced in size by cutting before packaging. Metal determined not to be radioactively contaminated is sent to recycle. Radioactive metal is sent to the stabilization module. Metal particles collected by a filter in the washing operation, and dust particles collected by a HEPA filter in the air exhaust hood over the cutting operation, are eventually sent to the stabilization module. Liquids from the washing step are sent to the aqueous waste module.

Sodium waste: Metallic sodium (from the sorting step in the metal preparation area) is sent to the sodium destruction area and placed in the sodium reactor. Here it reacts with water to form sodium hydroxide. Small amounts of hydrogen from the reaction are destroyed in the offgas treatment step. Before the resultant sodium hydroxide solution is sent to the aqueous waste module, it can be neutralized by adding acid to the reactor.

Uranium waste: Metallic uranium from the sorting step in the metal preparation area is sent to the uranium removal area and placed in a reactor, where it is dissolved with nitric acid. The resulting liquid can be reacted with a solution of lime which precipitates most of the metal as a hydroxide, which is allowed to settle. Liquid in the reactor is decanted to the aqueous waste treatment module. Hydroxide sludge is sent to the solids removal area, where it passes through a filter press to remove large particles and through a pressure filter to remove fine particles. The sludge could also be sent to the chemical treatment area for additional processing in the precipitation unit. The liquid from filtration is then processed by ion exchange to remove trace amounts of uranium.

Liquid waste: Waste that contains a toxic metal in solution is sent to the chemical treatment area. Uranium solutions are sent to a reactor and processed with the solutions generated as described above. In the chemical treatment area, a single unit allows for pretreatment with hydrogen peroxide and sodium hypochlorite to oxidize the metal, and treatment with ferric sulfate, lime, and a polymer to coprecipitate metal in a hydroxide floc. The floc settles in a clarifier which is part of the same unit and is processed by the filter press in the solids removal area as described in the uranium waste section above. Clarifier liquid is again filtered in a pressure filter to remove fines and then goes to the ion-exchange system to remove traces of dissolved metal.

The unit operations remove radioactivity and RCRA-regulated metal to a level such that the treated water can be either recycled for reuse or discharged if allowed by the site discharge permits. Before release, the treated water out of the ion-exchange system is sampled and assayed for discharge or for further treatment in the aqueous waste module.

12.2.2 Integration of Large Generator Module

Input waste to the deactivation module comes from the open, sort and dump module. Output includes radioactive metal, spent resin, spent filter material, and concentrated sludge, which are sent to the stabilization modules. Secondary aqueous waste is sent to aqueous waste treatment. Materials purchased for O&M, such as personal protective equipment, ion-exchange resin, filter material, chemicals, and containers, are assumed to be consumable supplies, and their costs are estimated accordingly.

12.3.3 Function and Operation of Small Generator Fixed Module in an Existing Building

Function and operation of a fixed small generator module are essentially the same as for large generator modules.

12.3.4 Integration of Small Generator Fixed Module in an Existing Building

Input waste to the deactivation module comes from the receiving and inspection module. Output from the deactivation module includes radioactive metal, spent resin, spent filter material, and concentrated sludge, which are all sent to the grout stabilization module. Secondary aqueous waste is sent to aqueous waste treatment. Materials purchased for O&M, such as personal protective equipment, ion-exchange resin, filter material, chemicals, and containers, are assumed to be consumable supplies, and their costs are estimated accordingly. The existing building space needed for installing a small generator deactivation module is 2,800 ft² (260 m²) with a ceiling height of 25 ft (7.6 m). The area required for a new building is the same.

12.3 Cost Basis, Assumptions and Results

The mass balance summary presented in this section is based on the assumption that input waste consists of 75% solids by weight and 25% liquids. The solids are assumed to be 5% barium, 10% beryllium, 50% cadmium, 10% chromium, 10% selenium, 10% sodium, and 5% uranium. The liquids are assumed to be 25% arsenic, 20% barium, 25% cyanide, 20% selenium, and 10% uranium. For purposes of sizing equipment, each element in solution was assumed to be 500 mg/l. The pretreatment and precipitation unit, filter press and pressure filter, ion exchange system, sodium and uranium reactors, chemical and holding tanks and pumps, metal washing and sorting hoods or glove boxes, and offgas treatment equipment constitute the major equipment capital cost items. Their costs are based on budgetary prices submitted by various vendors. The small generator module PLCC and operating manpower staffing is based on an approximate metal waste treatment rate of 2.3 kg/hr for the small generator and 9.1 kg/hr for large generators. FTE and PLCC versus capacity for the small deactivation module are shown in Tables 12-1 and 12-2. Estimated FTE workers and PLCC versus capacity for large generator module is shown in Figures 12-3 to 12-7.

Table 12-1. FTE workers for the small deactivation module.

Cost component	Small generator 2.3 kg/hr	Large generator 9.1 kg/hr	
	Nonalpha	Nonalpha	Alpha
(1.0) Studies and bench-scale tests	42	44	178
(2.0) Demonstration			
(3.0) Production facility, and			
(4.0) Operations-budget-funded activities			
(5.0) O&M	17	37	159
(6.0) D&D			
All cost components (total for 10 years O&M)	59	81	337

Table 12-2. PLCC (\$1,000) for the small deactivation module.

Cost component	Small generator 2.3 kg/hr	Large generator 9.1 kg/hr	
	Nonalpha	Nonalpha	Alpha
(1.0) Studies and bench-scale tests	10,003	10,533	45,108
(2.0) Demonstration			
(3.0) Production facility			
(4.0) Operations-budget-funded activities			
(5.0) O&M	3,801	7,589	30,759
(6.0) D&D			
All cost components (total for 10 years O&M)	13,805	18,121	75,867
Total life cycle unit costs (\$)	\$149/kg	\$49/kg	\$207/kg

EQUIPMENT LIST

- ① METAL SORT STATION
- ② METAL WASH STATION
- ③ METAL DRYING STATION
- ④ HOLDING RACKS
- ⑤ CUT/SAW STATION
- ⑥ NON-RAD PACKAGING
- ⑦ ROLLING BIN
- ⑧ RAD PACKAGING
- ⑨ CONVEYOR
- ⑩ RAD UNLOAD TABLE (NON U & NA)
- ⑪ ROLLOUT PALLET
- ⑫ U AND NA UNLOAD TABLE
- ⑬ SODIUM REACTOR
- ⑭ ACID TANK & PUMP
- ⑮ URANIUM REACTOR
- ⑯ ACID TANK & PUMP
- ⑰ LIME PREPARATION TANK
- ⑱ FILTER PRESS (FP)
- ⑲ FP LIQUID HOLDING TANK & PUMP
- ⑳ BAG FILTER
- ㉑ CHEMICAL SOLUTIONS FEED TANKS AND PUMPS
- ㉒ PRE-TREATMENT & PRECIPITATION
- ㉓ ION EXCHANGE SKID
- ㉔ TREATED WATER TANK & PUMPS
- ㉕ AQUEOUS WASTE TANK & PUMPS
- ㉖ METALS WASH DOWN SUMP & PUMP

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	40	70	12.2	21.3
	MEDIUM	-	-	-	-
	LARGE	-	-	-	-
SMALL GENERATOR	MINIMUM	40	70	12.2	21.3

Figure 12-1. Equipment layout for deactivation module (module DEACT).

Figure 12-2. Process functional diagram for deactivation module (module DEACT).

NOTE: MASS FLOW QUANTITIES ARE BASED ON 100 LBS/HR OF INPUT WASTE

MODE	DESCRIPTION	LB/HR	LB/HR
1	REACTIVE METAL SOLIDS	100	0
2	SA. B. METALS	65.1	0
3	METAL WASH WATER	1,417	0
4	WASHED METALS	64.7	0
5	SIZE REDUCED METALS	64.6	0
6	METAL DUST	0.1	0
7	DUST COLLECTION	0.1	0
8	NON-RAD METAL	40	0
9	RAD METAL	44.6	0
10	LIME	25	17.5
11	WATER	221	150.2
12	LIME SLURRY	246	165
13	LIME SLURRY	0	2.8
14	U METAL	4.9	0
15	Nb METAL	10	0
16	ACID	45	0
17	ORGAS	0.4	0
18	ALCOHOL WASTE	1,415.6	0
19	ORGAS	0.1	0.1

MODE	DESCRIPTION	LB/HR	LB/HR
20	REACTION LIQUIDS	124	160.4
21	ALCOHOL WASTE	0	0.1
22	SODIUM HYPO-CHLORITE	0	0.7
23	PEROXIDE	0	0
24	REACTIVE METALS LIQUIDS	0	90
25	REACTIVE METALS LIQUIDS	0	10
26	CHEMICAL TREATMENT	0	90.8
27	FERRIC SULFATE	0	6.4
28	POLYMER	0	0.4
29	PRE-CIPITATION EFFLUENT	0	99.4
30	FILTRATION LIQUIDS	245.6	260.8
31	FILTRATION EFFLUENT SOLIDS	13	19
32	ION EXCHANGE EFFLUENT	120.6	127.3
33	TREATED WATER	120	118.4
34	ALCOHOL WASTE	0.6	0.6
35	SPENT RESINS	0.5	0.5
36	ACID	7.7	6.4
37	METAL WASH FILTER WASTE	0.4	0
38	WATER	1,361	0

Figure 12-2. (continued).

13. SHREDDING AND COMPACTION (MODULE CMPCT)

13.1 Basic Information

The shredding and compaction module, shown in Figure 13-1, is used either in conjunction with the treatment front-end and back-end support modules (see modules ADMIN, RCINS, OSORT, MAINT, and CSHIP) or as an addition to existing facilities where similar functions are already available. Module CMPCT is applicable to alpha waste and nonalpha waste. Unit operations are shown in the PFD in Figure 13-2.

For MLLW, only the shredding portion of this module is applicable and has cost information provided, due to the low capacity requirements.

13.2 Technical Bases and Assumptions

13.2.1 Function and Operation of Large Generator Module

The large module is designed to shred incoming waste and package it in 55-gal drums. This module is equipped with a dust collection and filtration unit to treat air containing fugitive dust from the shredding operations. The small and medium modules have such low capacities that the expense of a compactor cannot be economically justified and is not included. For the small and medium modules, the waste must be placed into drums before it is further processed.

At the compaction unit operation, a lift device places the filled drums onto press conveyors. The operator selects a drum from one of the conveyors and feeds it to the press through an airlock. A device pierces the drum to release gases that may be trapped in the drum. A high-pressure compactor (supercompactor) compresses the drum and transfers the pressed drum from the press to a staging conveyor (or turntable). A lift device picks up the compressed drum and places it into one of several overpacks located on an adjacent conveyor. After each overpack is filled, the operator feeds it to the grout station where grout is added to fill any spaces in the overpack. The overpack is then sent to the sorting machine where a cap is placed on the overpack and sealed. The operator moves the sealed overpack to a drum washing unit where high-pressure water spray jets remove any loose contamination on the outside surface of the overpack.

Any liquid discharged during press operation is directed to a sump which pumps it to the aqueous waste treatment module. The compacted waste is ready for radioassay and final certification, which are included in the certification and shipping module (CSHIP).

13.2.2 Integration of Large Generator Module

Primary module inputs are bulk waste from the open, dump, and sort module (module OSORT) and directly from generator sites. Major O&M purchased materials, such as personal protective equipment, laboratory material, and overpacks, are assumed to be consumable supplies and their costs are estimated accordingly.

Major module outputs are compacted drums containing alpha or nonalpha waste which are transferred to a back-end support module (module CSHIP). The overpacks (85-gal drums) containing compacted waste are the main output from this module. Treated offgas is discharged into the atmosphere.

13.3 Cost Bases, Assumptions, and Results

Waste size reduction and preparation (shredders), and supercompactor are the major equipment capital cost items. Major equipment capital costs are verified against the purchased costs incurred by a U.S. Navy LLW processing facility (B&W facility at Lynchburg, West Virginia) that recently started operation. Budgetary cost for the preparation and feed unit is based on vendor quotes for shredders, conveyors, and dust collection equipment. Supercompactor prices are based on budgetary quotes by Stock Equipment Company, Chagrin Falls, Ohio. Estimated FTEs and PLCC versus capacity is shown in Figures 13-3 to 13-7.

EQUIPMENT LIST

- ① DRUM PUSHER
- ② INCOMING WASTE BIN
- ③ SKIP
- ④ SHREDDER (2) WITH FEED HOPPER, DUST HOOD AND HYDRAULIC RAM
- ⑤ AUGER FEEDER
- ⑥ WASTE TRANSFER BIN
- ⑦ UNDERHUNG CRANE IN ENCLOSED PROCESS AREA
- ⑧ LIVE BOTTOM BULK STORAGE HOPPER
- ⑨ TERTIARY SHREDDER
- ⑩ AUGER FEEDER
- ⑪ SHREDDED WASTE COMPACTOR (30 TON)
- ⑫ HEPA FILTER AND FAN
- ⑬ DRUM STAGING CONVEYOR (POWERED ROLL)
- ⑭ OVERPACK TOP SEAMING STATION
- ⑮ STACK
- ⑯ DRUM TOP SEAMING STATION
- ⑰ SUPERCOMPACTOR FEED CONVEYOR (POWERED ROLL)
- ⑱ MODULAR SUPERCOMPACTOR UNIT
- ⑲ EMPTY OVERPACK STAGING CONVEYOR (POWERED ROLL)
- ⑳ SUPERCOMPACTED CONTAINER STAGING CONVEYOR (POWERED ROLL)
- ㉑ MODULAR HYDRAULIC POWER UNIT
- ㉒ STORAGE BIN
- ㉓ DRUM STORAGE CONVEYOR (GRAVITY) (NOT SHOWN)
- ㉔ DAY BIN
- ㉕ PNEUMATIC CONVEYOR

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	40	150	12.2	45.7
	MEDIUM	40	150	12.2	45.7
	LARGE	50	202	15.2	61.6
SMALL GENERATOR	MINIMUM	-	-	-	-

Figure 13-1. Equipment layout for shredding and compaction module (module CMPCT).

Figure 13-2. Process functional diagram for shredding and compaction module (module CMPCT).

NOTE: MASS FLOW QUANTITIES ARE BASED ON 100 LB/HR OF INPUT WASTE

NODE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
DESCRIPTION	REACTIVE METAL SOLIDS	Ba, Be, Cd, Cr, Se METALS	METAL WASH WATER	WASHED METALS	SIZE REDUCED METALS	METAL DUST	DUST COLLECTION	NON-RAD METAL	RAD METAL	LIME	WATER	LIME SLURRY	LIME SLURRY	U METAL	Nb METAL	ACID	OFFGAS	AQUEOUS WASTE	OFFGAS
LB/HR	100	85.1	1,417	84.7	84.6	0.1	0.1	40	44.6	25	221	246	0	4.9	10	45	0.4	1,415.6	0.1
LB/HR	0	0	0	0	0	0	0	0	0	17.5	150.2	165	2.6	0	0	0	0	0	0.1

NODE	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
DESCRIPTION	REACTOR LIQUIDS	AQUEOUS WASTE	SODIUM HYPOCHLORITE	PEROXIDE	REACTIVE METALS LIQUIDS	REACTIVE METALS LIQUIDS	CHEMICAL PRE-TREATMENT	FERRIC SULFATE	POLYMER	PRE-CIPITATION EFFLUENT	FILTRATION EFFLUENT LIQUIDS	FILTRATION EFFLUENT SOLIDS	ION EXCHANGE EFFLUENT	TREATED WATER	AQUEOUS WASTE	SPENT RESINS	ACID	METAL WASH FILTER WASTE	WATER
LB/HR	258.6	124	0	0	0	0	0	0	0	0	245.6	13	120.8	120	0.6	0.5	7.7	0.4	1,361
LB/HR	180.4	133	0.1	0.7	90	10	90.6	5.4	0.4	99.4	260.6	19	127.3	116.4	0.6	0.5	5.4	0	0

Figure 13-2. (continued).

Figure 13-3. FTE workers capacity for nonalpha waste for shredding and compaction module (module CMPCT).

Figure 13-4. FTE workers versus capacity for alpha waste for shredding and compaction module (module CMPCT).

Figure 13-5. PLCC versus capacity for nonalpha waste for shredding and compaction module (module CMPCT).

Figure 13-6. PLCC versus capacity for alpha waste for shredding and compaction module (module CMPCT).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 13-7. PLCC versus capacity including unit rates for shredding and compaction module (module CMPCT).

14. SLUDGE WASHING (MODULE SWASH)

14.1 Basic Information

The sludge washing module, shown in Figure 14-1, collects and treats sludges contaminated with organic residues. The module uses liquid carbon dioxide as a solvent. Liquid carbon dioxide's low viscosity, density, and surface tension allow for high rates of organic extraction relative to conventional solvents. These physical properties also accelerate gravity settling of the waste material/solvent mixture following extraction. Due to its high volatility, liquified carbon dioxide is easily recovered from the waste matrix using a low-energy vapor recompression cycle, and its potential presence in the treated soils is minimized.

It has been assumed that the waste stream consists of organic sludges and particulates containing up to 10% organics and has a moisture content of at least 50% water by weight.

The unit operations that complete the required functions are shown in Figure 14-2.

14.2 Technical Bases and Assumptions

The carbon dioxide extraction modules is comprised of a feed preparation system, extraction/gravity settling system, a treated solids filtration system, a solvent recovery system, and associated utility and reagent systems.

In the feed preparation system, the contaminated sludge is temporarily stored in day tanks. From the tanks, the sludge is screened, released into a feed hopper, and pumped into the solvent extraction system. The carbon dioxide solvent extraction process does not require other forms of soil pretreatment.

The extraction/gravity settling system consists of one or more agitation extraction vessels where contaminated sludge is mixed with liquid carbon dioxide. The number and sizes of the vessels determine the rate of throughput and the degree of organics removal. After each stage of extraction, the agitators are stopped and gravity separation of the waste material and carbon dioxide is allowed to occur. Following gravity separation, the solvent/organic phase is drained to the solvent recovery system, where the carbon dioxide is recovered in a vapor recompression cycle. This entire process is repeated in the extraction vessel until the organic extraction is complete. Once the extraction is complete, water is injected into the extraction vessel to displace and remove the residual carbon dioxide. The water and treated waste material form a sludge which is fed to the filtration system.

The treated solids filtration system includes a day tank, centrifuge, and all required drums and pumps for routine operation. The treated cake from the centrifuge has high compressive strength and is suitable for land disposal. The treated cake also has the appropriate moisture content for addition of stabilization reagents to fixate metals, if required. Filtrate from the centrifuge is collected and purified for reuse.

The solvent recovery system contains surge vessels, a solvent recovery still and compressor, a solvent condenser, and a recycle pump. The solvent and organics mixture flows from the agitation extraction vessels through the surge vessels to the recovery still, where liquid carbon dioxide is vaporized using the heat of condensation from the compressor. Carbon dioxide vapor from the still is condensed, stored, and reintroduced on demand into the extraction/gravity settling system. In the boiler section of the still, oil-rich extract flows to a low-pressure organic recovery tank, residual carbon dioxide is removed from the extract and sent to the vent gas recovery system and recovered oil is sent to organics storage. A low-pressure compressor recovers carbon dioxide vapor from the organic recovery tank and the oil product storage. The vapor is compressed and returned to the still for recycling.

14.2.1 Facility Integration

Input waste to the sludge washing process comes from the receiving and shipping module. The solvent extraction output is dewatered filter cake and recovered organics. The filter cake is sent to the stabilization module and the recovered organics are handled in the wet oxidation portion of the aqueous waste treatment module. Treated water is reused. Materials purchased for O&M include such consumables as personal protective equipment, liquid carbon dioxide, and containers.

14.3 Cost Bases, Assumptions and Results

The cost estimates for all equipment are based on budgetary prices provided by CF Systems, a subsidiary of MK Environmental Services. The equipment used in the process as well as the itemized costs of the equipment are considered proprietary information. The costs which have been provided are total costs for individual units that make up the process. Estimated FTE workers are shown in Figures 14-3 and 14-4.

Cost summaries for the sludge washing module are shown in Figures 14-5, 14-6 and 14-7.

EQUIPMENT LIST

- ① FEED PREPARATION
- ② SOLVENT EXTRACTION
- ③ SOLVENT RECOVERY
- ④ FILTRATION
- ⑤ ELECTRICAL/MCC
- ⑥ UTILITIES/MECHANICAL

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	40	140	12.2	42.7
	MEDIUM	50	115	15.2	35.1
	LARGE	60	145	18.3	44.2
SMALL GENERATOR	MINIMUM	-	-	-	-

Figure 14-1. Equipment layout for sludge washing module (module SWASH).

Figure 14-2. Process functional diagram for sludge washing module (module SWASH).

Figure 14-3. FTE workers versus capacity for nonalpha waste for sludge washing module (module SWASH).

Figure 14-4. FTE workers versus capacity for alpha waste for sludge washing module (module SWASH).

Figure 14-5. PLCC versus capacity for nonalpha waste for sludge washing module (module SWASH).

Figure 14-6. PLCC versus capacity for alpha waste for sludge washing module (module SWASH).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 14-7. PLCC versus capacity including unit rates for sludge washing module (module SWASH).

15. SOIL WASHING (MODULE EWASH)

15.1 Basic Information

The soils washing module, shown in Figure 15-1, is a flameless organic removal unit that collects and treats soils contaminated with organic residues. The module must be used in conjunction with the receiving and shipping module (module RCINS), the aqueous treatment module (AQWTR) and the stabilization module (module GROUT or PLYMR) or be installed at a location where similar functions are available in existing facilities.

It is assumed that 50% of the input soils contain up to 10% organics.

The module has a number of unit operations that accomplish the required functions, as shown in Figure 15-2.

15.2 Technical Bases and Assumptions

Soils contaminated with organic waste will be treated using a detergent washing process. The process consists of a material size separation and washing system, an oil/water/solids separator, a soils washing system, and ancillary support systems.

Soils, stones, and other debris are washed in a primary washing trommel using warm water mixed with 5% surfactant. Undersized material, smaller than ¼-inch, is pumped to an oil/water/solids separator. Oversized material is introduced into a secondary washing trommel, rinsed with clean water, and discharged onto a concrete pad for dewatering. Water from the concrete pad is cleaned and reused.

The oil/water/solids separator performs three functions on the undersized material. First, oil collects on the surface of the waste water retention tank, and is drawn off into a small internal collection tank. Second, the waste water is pumped through bag filters and ion exchange units and recirculated. The waste oil collected at the separator and the oily substances obtained from the ion exchange units are collected and sent to the organic destruction portion of the aqueous waste treatment module (AQWTR). Third, solids from the incoming waste stream are removed. Inclined plates in the retention tank allow the solids to settle to the bottom where a low-velocity drag conveyor removes the material. The solids are then pumped into the soils washing system.

The soils washing system consists of an agitator scrubber and rinser. Undersized solids from the separator are mixed with clean water. The resulting sludge is pumped to a centrifuge and the final clean soil product is produced. Filtrate from the centrifuge is collected in the filtrate water tank and purified for reuse. Solids are sent to stabilization.

15.2.1 Facility Integration

Input waste to the soils washing modules comes from the receiving and shipping module. The output consists of dewatered cake, recovered organics, and cleaned oversized debris. The cake and debris are sent to the stabilization module, and the recovered organics are sent to the

organics destruction module. Materials purchased for O&M include such consumables as personal protective equipment, surfactant, and containers.

15.3 Cost Bases, Assumptions and Results

The cost estimates for all equipment are based on budgetary prices submitted by various vendors. Estimated FTE workers versus capacity is shown in Figures 15-3 and 15-4.

Cost summaries for the soils washing module are shown in Figures 15-5, 15-6 and 15-7.

EQUIPMENT LIST

- ① PRIMARY WASHING TROMMEL
- ② PUMP
- ③ DRAG CONVEYOR
- ④ SECONDARY WASHING TROMMEL
- ⑤ PUMP
- ⑥ STACKING CONVEYOR
- ⑦ MAKE UP WATER TANK
- ⑧ PUMP
- ⑨ DRUM
- ⑩ TANK
- ⑪ PUMP
- ⑫ OIL/WATER SOLIDS SEPARATOR
- ⑬ SLURRY PUMP
- ⑭ AGITATION SCRUBBER/RINSE
- ⑮ SCRUBBER/RINSE DISCHARGE PUMP
- ⑯ PUMP
- ⑰ CENTRIFUGE
- ⑱ FILTER CAKE CONTAINER
- ⑲ HYDROGEN UNIT FOR FILTER PRESS
- ⑳ FILTRATION & ION EXCHANGE AREA
- ㉑ SUMP PUMP

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	40	48	12.2	14.6
	MEDIUM	50	63	15.2	19.2
	LARGE	60	81	18.3	24.7
SMALL GENERATOR	MINIMUM	-	-	-	-

Figure 15-1. Equipment layout for soil washing module (module EWASH).

Figure 15-2. Process functional diagram for soil washing module (module EWASH).

Figure 15-3. FTE workers versus capacity for nonalpha waste for soil washing module (module EWASH).

Figure 15-4. FTE workers versus capacity for alpha waste for soil washing module (module EWASH).

Figure 15-5. PLCC versus capacity for nonalpha waste for soil washing module (module EWASH).

Figure 15-6. PLCC versus capacity for alpha waste for soil washing module (module EWASH).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 15-7. PLCC versus capacity including unit rates for soil washing module (module EWASH).

16. DEBRIS WASHING (MODULE DWASH)

16.1 Basic Information

The debris washing module, shown in Figure 16-1, is a flameless unit that collects and treats oversized material contaminated with organic residues. The module must either be used in conjunction with the receiving and shipping module (module RCINS), the aqueous treatment module (AQWTR) and stabilization module (modules GROUT or PLYMR) or installed at a location where similar functions are available at existing facilities. This module also accepts oversized debris from the soils washing module.

The module is designed for processing cemented solids containing no more than 2% organics and debris containing up to 5% organics. It is assumed that 75% of the material to be processed is cemented solids with other debris comprising the remaining 25%.

The unit operations that complete the required module functions are shown in Figure 16-2.

16.2 Technical Bases and Assumptions

The module consists of a feed preparation unit, a surfactant spray and washing system, an oil/water/solids separator, and ancillary support systems.

In the feed preparation unit, all debris will be reduced to a maximum 2-inch particle size by a single auger shredder. The reduced debris is transported by drag conveyor to the surfactant spray and washing system.

The surfactant spray and washing system consists of two high-pressure spray wash tanks. The tanks are equipped with high-pressure nozzles to discharge the surfactant solution over the incoming debris. The tanks are vented through condensers to prevent emission of organics to the atmosphere.

The surfactant solution consists of water and 5 percent surfactant (detergent). The solution is initially preheated and pumped into a storage tank. After washing the debris, the surfactant solution is collected in the sump portion of the drag conveyers below the tanks and pumped into a wash solution hold tank. The wash solution hold tank has an inclined bottom for sludge collection. The sludge is pumped to an oil/water/solids separator.

The washed debris from the surfactant spray and washing system is sent to a third high-pressure spray tank and rinsed with clean water. The cleaned debris is then deposited on a concrete pad for dewatering. The water collected from the concrete pad is cleaned and reused.

The oil/water/solids separator performs three functions on the sludge. Oil collects on the surface of the waste water retention tank, and is drawn off into a small internal collection tank. The waste water is pumped through bag filters and ion exchange units and recirculated. The waste oil collected at the separator and the oily substances obtained from the ion exchange units are collected and sent to the organics destruction portion of the aqueous water treatment module.

(AQWTR). Solids from the incoming waste stream are removed. Inclined plates in the retention tank allow the solids to settle to the bottom where a low-velocity drag conveyor removes the material. The solids are then pumped into the secondary high-pressure spray tank for surfactant washing. The solids are subsequently sent to stabilization.

16.2.1 Facility Integration

Input waste to the debris washing module comes from the receiving and shipping module. The output is dewatered filter cake and recovered organics. The filter cake is sent to the stabilization module, and the recovered organics are sent to the organics destruction module. Materials purchased for O&M include such consumables as personal protective equipment, surfactant, and containers.

16.3 Cost Basis, Assumptions and Results

The cost estimates for all equipment are based on budgetary prices submitted by various vendors. Estimated FTE workers versus capacity is shown in Figures 16-3 and 16-4. Cost summaries for the soils washing module are shown in Figures 16-5, 16-6, and 16-7.

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Figure 16-2. Process functional diagram for debris washing module (module DWASH).

Figure 16-3. FTE workers versus capacity for nonalpha waste for debris washing module (module DWASH).

Figure 16-4. FTE workers versus capacity for alpha waste for debris washing module (module DWASH).

Figure 16-5. PLCC versus capacity for nonalpha waste for debris washing module (module DWASH).

Figure 16-6. PLCC versus capacity for alpha waste for debris washing module (module DWASH).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 16-7. PLCC versus capacity including unit rates for debris washing module (module DWASH).

17. AQUEOUS WASTE TREATMENT (MODULE AQWTR)

17.1 Basic Information

The aqueous waste treatment module, shown in Figures 17-1, 17-2 and 17-3, must be either used in conjunction with the receiving-and-inspection module (module RCINS) and stabilization module (module PLYMR) or installed at a location where similar functions are available in existing facilities.

The aqueous waste treatment module collects and treats input aqueous waste, which is generally assumed to contain less than 1% total organic carbon (TOC). The aqueous waste is received at the module in cans, drums, special transport containers having several different capacities, or by pipeline. In addition to the input waste, the aqueous waste treatment module treats the secondary waste (floor drains, equipment drains, and chemical wastes) from the alpha and nonalpha waste treatment facility. This module also contains a wet-air oxidation unit operation which is used for organic destruction. The module has a number of unit operations that accomplish the required functions. These unit operations are shown in the PFD in Figure 17-4.

17.2 Technical Basis and Assumptions

17.2.1 Function and Operation of Large Generator Modules

The aqueous waste treatment module has all the unit operations needed for treating an incoming liquid waste having a broad range of RCRA-controlled toxic, heavy-metal, and organic contaminants. Toxic metal contaminants can include mercury, cadmium, chromium, and lead. Organic contaminants can include VOCs, such as carbon tetrachloride, chloroform, methylene chloride, tetrachloroethylene, trichlorethylene, and trichloroethane; aromatics, such as benzene, toluene, and xylene; alcohols; glycols; ketones, such as methyl ethyl ketone and methyl isobutyl ketone; phenols; and petroleum compounds. The unit operations also have the capability to treat secondary liquid waste generated by the alpha and nonalpha waste treatment facility, such as distillate from air pollution control (module INCIN), rinse water from container washdown operations (modules RCINS and PLYMR), and liquids collected from the module equipment and floor drains.

The incoming liquid waste is precharacterized before it is brought to the treatment module. For bulk operations, the incoming waste is segregated into four different groups: high TOC liquid (between 1 and 10,000 parts per million [ppm]), liquid with a low concentration (less than 100 ppm) of total dissolved solids (TDS), high TDS liquid (greater than 100 ppm TDS), and mercury contaminated liquid.

The aqueous waste treatment unit operations have maximum flexibility and can be used in series, in parallel, or as stand alone units. Flexible piping connectors are provided at the inlet and outlet of each treatment device. The waste is transferred from the transport containers to appropriate batch tanks or directly to a desired treatment unit operation.

Typical steps for treating bulk quantities of the various waste categories are as follows (refer to Figure 17-4):

High TOC waste: Waste high in TOC is first processed through a gross-organic removal unit. Typical treatment techniques used in this unit operation could include flotation thickeners or coalescing devices. The organics from the gross-organic removal unit are collected and sent to an incineration module. The aqueous phase is sent to a suspended solids filtration unit utilizing typical techniques including super-fine filtration or back-flushable filters. Solids captured by the filtration unit are sent as a slurry to a concentration unit that further concentrates the sludge. The sludge phase is sent to the stabilization module while the liquid phase is sent for final polishing by a dissolved-solids removal unit, which could use a combination of cation, anion, and mixed-bed ion exchange resins. The aqueous phase from the suspended solids filtration unit is sent to a dissolved organic removal unit that, typically, could use an activated carbon unit for removing VOCs and aromatics. This is followed by a combination of stripping and chemical oxidation for removing alcohols, ketones, phenols, and glycols. Organics removed by the dissolved organic removal unit are oxidized and discharged or are captured using activated carbon. The aqueous effluent from the dissolved organics removal unit is sent to the dissolved solids removal unit for final polishing. The treated water is then sent to a sampling unit before recycling and reuse. If the high TOC input waste also has a high TDS content, it is further processed through an intermediate step involving a neutralization and settling unit, as appropriate.

Low TDS waste: Waste low in TDS is processed through the suspended solids filtration unit followed by the dissolved solids removal unit. The treated water is then sent to a sampling unit before recycling and reuse. If the input waste has organic contamination, it is processed through intermediate steps involving gross-organic removal and dissolved organic removal, as appropriate. Inorganic solids and organic liquids removed during treatment of low TDS waste are handled in the same manner as described for high TOC waste.

High TDS waste: Waste high in TDS is processed through the neutralization and settling unit, where chemicals are added to neutralize, precipitate, and enhance settling of solids as sludge. The sludge is sent to the concentration unit, where the water is removed and the resulting concentrated sludge is sent to the stabilization module. Supernate from the neutralization and settling unit is sent to the suspended solids filtration unit, followed by a final polishing by the dissolved solids removal unit. The treated water is then sent to a sampling unit before recycling and reuse. Solids and organic liquids removed during treatment of low TDS waste treatment steps are handled in the same manner as described for high TOC waste.

Mercury contaminated waste: Waste that contains mercury (or other toxic metals) is sent to the neutralization and settling unit operation, where precipitating chemicals are added to force settling of the heavy metal as an insoluble salt and concentrate them as a bottom sludge. The bottom sludge is sent to the concentration unit, where the water is removed. The resulting concentrated sludge is sent to the stabilization module. The aqueous waste from the precipitation and neutralization unit is sent to the suspended solids removal unit, followed by the dissolved solids removal unit. This latter unit has absorbent and ion-exchange media (e.g., thiol ion-exchange resin media, such as Duolite GT-83 or Ionac SR-4, designed to remove trace quantities of mercury). The treated water is sent to a sampling tank before recycling and reuse.

Solids and organic liquids removed during the treatment of low TDS waste are handled in the same manner as described for high TOC waste.

The unit operations remove radioactivity and RCRA-regulated metal and organics to a level such that the treated water can be either recycled for reuse or discharged, if allowed by the site discharge permits.

17.2.2 Integration of Large Generator Modules

Input waste to the aqueous waste treatment module comes from the receiving and inspection module or from onsite waste generators which have been pre-characterized. Other input includes secondary waste from the incineration, decontamination, organic liquids and stabilization modules. Output from the aqueous waste treatment module to the stabilization module includes spent resins, spent carbon, and concentrated sludge. Treated water output is sent to various modules for reuse. Recovered liquid organics are sent either to the organic liquids wet-air oxidation module or to the incineration module. Materials purchased for O&M, such as personal protective equipment, ion-exchange resins, activated carbon, chemicals, and containers, are assumed to be consumable supplies, and their costs are estimated accordingly.

17.2.3 Function and Operation of Small Generator Fixed Module in a New or Existing Building

Functions and operations of a small generator aqueous waste treatment module are essentially the same as for a large generator module.

Existing building space required for installation of this module is 2900 ft² (269 m²). The required ceiling height is 25 ft (7.6 m). The area required for the new building is the same.

17.2.4 Integration of Small Generator Fixed Module in a New or Existing Building

Integration of the module is the same as a large generator module with the exception that the module interfaces with the small generator front-end and back-end module (module FBSPT).

17.2.5 Function and Operation of Portable Module.

The portable small aqueous waste treatment module requires the use of four process trailers and a control trailer. Each trailer is of standard roadway size: 8 feet wide by 40 feet long. The trailers contain all equipment and support units necessary to treat aqueous waste. Trailer A contains the liquid waste batch tanks, gross organic removal, suspended solids removal and dissolved solids removal. Trailer B contains the precipitation, neutralization, and settling unit and part of the dissolved organic removal unit. Trailer C contains the remainder of the dissolved organics removal and the concentration unit. Trailer D contains the treated water sampling unit and all mechanical and utility equipment. This trailer contains the instrumentation and communication equipment necessary for the operation of the module.

Input waste to the module comes from the generators at the installation. For each waste treatment campaign, the module is mobilized and demobilized. Costs are presented for campaigns involving treatment of waste in increments of 88 f³ (2½ m³) per campaign.

17.2.6 Integration of Portable Module

The portable aqueous waste treatment module is capable of treating waste from any of the following modules if located at the installation: storage, front-end and back-end support, fixed or portable decontamination, fixed incineration, fixed or portable wet-air oxidation (WOX) modules, fixed or portable thermal desorption, fixed mercury separation and fixed or portable stabilization modules. Output from the portable aqueous treatment module includes spent resins, spent carbon, and concentrated sludge, which must be sent to a stabilization module. Another module output is treated water meeting installation discharge standards. Recovered liquid organics are sent to a fixed incineration module. Items purchased for O&M are assumed to be consumable supplies and their costs are estimated accordingly.

17.3 Cost Basis, Assumptions and Results

Input waste is assumed to consist of (see mass flow rates in Figure 17-4) 33% high TOC liquid, 25% low TDS liquid, 38% high TDS liquid, and 4% mercury contaminated waste. The precipitation and neutralization unit, gross-organic removal filter, backflushable filters, ion exchanger, organic distillation unit, charcoal filter, and evaporator constitute the major equipment capital cost items; their costs are based on budgetary prices submitted by various vendors. The cost estimate for the gross-organic removal unit is based on a quotation by McTighe Industries, Inc., located in Mitchell, South Dakota. The cost estimate for the organic-stripper unit is based on a quotation by APV Crepaco, Inc., located in Tonawanda, New York. The cost estimate for the evaporation unit is based on a quotation by LCI Processing, Inc., of Charlotte, North Carolina. The cost estimate for the chemical oxidation using a combination of hydrogen peroxide and ultraviolet light is based on a quotation by Peroxidation System, Inc., of Tucson, Arizona. The cost estimate for the suspended solids filtration unit is based on using a membrane filtration system called Memberalox, whose price was quoted by United States Filter Corporation of Warrendale, Pennsylvania. Operating manpower staffing for the small generator module is based on an approximate flow rate of 9.1 kg/hr. Portable module is based on processing campaign. Estimated FTE workers for the small generator treatment module is shown in Table 17-1 and Figures 17-5 and 17-6.

Cost versus capacity for the aqueous waste treatment module is shown in Figures 17-7, 17-8, and 17-9. Cost for small generator module in either a new or existing building is presented in Table 17-2. Cost for the portable module is presented in Table 17-2.

Table 17-1. FTE workers for the small generator aqueous waste treatment module.

Cost component	Type of small generator module		
	Fixed, in new building(s)	Fixed, in existing building(s)	Portable
(1.0) Studies and bench-scale tests	43	30	36
(2.0) Demonstration			
(3.0) Production facility			
(4.0) Operations-budget-funded activities			
(5.0) O&M	38	31	113
(6.0) D&D			
All cost components (total for 10 years O&M)	81	61	149

Table 17-2. PLCC (\$1,000) for the small generator aqueous waste treatment module.

Cost component	Type of small generator module		
	Fixed, in new building(s)	Fixed, in existing building(s)	Portable
(1.0) Studies and bench-scale tests	10,971	7,914	9,103
(2.0) Demonstration			
(3.0) Production facility			
(4.0) Operations-budget-funded activities			
(5.0) O&M	5,585	5,244	9,545
(6.0) D&D			
All cost components (total for 10 years O&M)	16,556	13,157	18,648
Cost per campaign	—	—	311

Figure 17-1. Equipment layout for aqueous waste treatment module (module AQWTR).

EQUIPMENT LIST

- 1 BATCH TANKS WITH AGITATOR (TYP 4)
- 2 OIL AND WATER SEPARATOR
- 3 SOLIDS FILTER
- 4 NEUTRALIZER TANK WITH AGITATOR
- 5 REACTOR TANK WITH AGITATOR
- 6 SETTLING TANK
- 7 EVAPORATOR UNIT
- 8 CONDENSER
- 9 CONDENSED WATER TANK
- 10 VAPOR PHASE CARBON FILTER
- 11 VACUUM PUMP
- 12 BATCH STILL
- 13 STILL CONDENSER
- 14 VAPOR PHASE CARBON FILTER
- 15 ION EXCHANGE UNIT
- 16 UV AND PEROXIDE UNIT
- 17 CARBON FILTER DRUMS

NOTE: WALLS NOT SHOWN FOR CLARITY

FACILITY SIZE	DIMENSION IN FEET		DIMENSION IN METERS	
	A	B	A	B
SMALL	40	50	12.2	15.2
MEDIUM	50	76	15.2	23.2
LARGE	60	100	18.3	30.5
MINIMUM	40	50	12.2	15.2

Figure 17-3. Equipment layout for control trailer for portable aqueous waste treatment module (module AQWTR)

Figure 17-4. Process functional diagram for aqueous waste treatment module (module AQWTR).

TRAILER D - CONTAINS UNIT OPERATION 8 & SUPPORT UTILITIES

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NODE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
DESCRIPTION	HIGH-TOC LIQUIDS	LIQUIDS WITH LOW DISSOLVED SOLIDS	LIQUIDS WITH HIGH DISSOLVED SOLIDS	MERCURY CONTAINING LIQUIDS	ORGANICS	AQUEOUS WASTE	LOW DISSOLVED SOLIDS	LOW DISSOLVED SOLIDS	AQUEOUS WASTE	CLARIFIED WASTE	SLUDGE	AQUEOUS WASTE	CONDENSATE	AQUEOUS WASTE	AQUEOUS CONTAINING DISSOLVED ORGANICS
LB/HR	100	0	0	0	1.7	98.3	0	0	98.3	0	0	98.3	0	78.6	16.7
LB/HR	0	100	0	0	0	0	16	84	84	14.4	1.6	98.4	1.3	78.7	16.7
LB/HR	0	0	100	0	0	0	0	0	0	90	10	90	8.1	72	15.3
LB/HR	0	0	0	100	0	0	0	0	0	90	10	90	8.1	72	15.3

NODE	16	17	18	19	20	21	22	23	24	25	26	27	28	29
DESCRIPTION	TREATED WATER	STRIPPED AQUEOUS WASTE	TREATED WATER	RECOVERED ORGANICS	CONDENSER CONCENTRATE	SPENT RESIN	TREATED WATER	SPENT CARBON	TREATED OFFGAS	EVAPORATOR CONCENTRATE	RECYCLED WATER	1% ORGANICS	RESINS	CARBON
LB/HR	94.4	5.7	10	1	0	3	5.7	3	0	0	94.4	2.9	3	3
LB/HR	95.7	5.7	10	1	1.4	3	7	3	0.1	0.2	95.7	3	3	3
LB/HR	94.4	4.3	10	1	8.5	3	12.4	3	0.4	1.5	94.4	2.7	3	3
LB/HR	94.4	4.3	10	1	8.5	3	12.4	3	0.4	1.5	94.4	2.7	3	3

NOTE: MASS FLOW QUANTITIES ARE BASED ON 100 LBS/HR OF INPUT WASTE

Figure 17-4. (continued).

Figure 17-5. FTE workers versus capacity for nonalpha waste for aqueous waste treatment module (module AQWTR).

Figure 17-6. FTE workers versus capacity for alpha waste for aqueous waste treatment module (module AQWTR).

Figure 17-7. PLCC versus capacity for nonalpha waste for aqueous waste treatment module (module AQWTR).

Figure 17-8. PLCC versus capacity for alpha waste for aqueous waste treatment module (module AQWTR).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 17-9. PLCC versus capacity including unit rates for aqueous waste treatment module (module AQWTR).

18. GROUT STABILIZATION (MODULE GROUT)

18.1 Basic Information

The grout stabilization module, shown in Figure 18-1, provides secondary waste treatment capability and is used at the end of the treatment modules. The module output is sent to the certification and shipping module (module CSHIP or FBSPT). The primary purpose of this module is to solidify solid and liquid waste and sludge that arrive from treatment modules, storage facilities, or the generators. Module GROUT is applicable to both alpha waste and for nonalpha waste. Unit operations are shown in the PFD in Figure 18-2.

The module is composed of five main process unit operations that incorporate all buildings, systems, processes, equipment, devices, controls, and accessories required to prepare the incoming waste and stabilize it either by macro- or microencapsulation techniques.

18.2 Technical Bases and Assumptions

18.2.1 Function and Operation of Large Generator Modules

The module receives concentrated liquid waste and sludge via a pipeline. A chemical addition unit is used to adjust the chemistry of the feed before it is fed to the solidification unit operation. A preparation and feed unit crushes and shreds incoming solid waste; the shredded waste is then collected in a storage hopper.

The microsolidification unit operation solidifies concentrated liquid waste, sludge, or a combination of the two. The unit has a remotely operated in-drum solidification assembly equipped with intake tanks and hoppers for sludge, liquid waste and grout. To accomplish the solidification process, a drum is placed onto a transfer cart. The cart moves the drum to various fill stations where feeders place sludge and liquid waste and binder in the drum. Next, the cart moves the filled drum to a mixing station where the drum is capped and tumbled to achieve the required mixture. The cart moves the drum for a repeat of the filling and mixing steps to maximize the fill efficiency.

The macroencapsulation unit operation solidifies bulkier solids, such as spent filters, shredded solids and pelletized debris. This waste material and these objects are placed in a drum, and binding agents are added. Macroencapsulation operation is accomplished by placing the solids in a drum, adding grout and mixing the two components. In large generator modules, a pugmill accomplishes this function.

After encapsulation, the operator remotely moves the filled container to a capping and washing unit. This unit operation provides for sample collection, capping of the container, and removal of loose contamination from the container surface by high-pressure spray water jets. The containerized waste is ready for processing through radioassay and final certification, which are included in the back-end module (module FBSPT or CSHIP).

18.2.2 Integration of Large Generator Modules

Input to the module consists of concentrator bottom from aqueous waste treatment (module AQWTR), process residues from the open, dump, and sort module (module OSORT), ash from the incinerator (module INCIN), sludge from wet-air oxidation (module WETOX), filtration solids from deactivation (module DEACT), spent filters from treatment modules, and drums, containers, and inorganic debris from the shredding and compaction module (module CMPCT). Major O&M purchased materials, such as personal protective equipment, laboratory material, binder, and containers, are assumed to be consumable supplies, and their costs are estimated accordingly.

Output consists mainly of drummed, solidified nonalpha and alpha waste, all of which are moved to a back-end module (module FBSPT or CSHIP). Waste water from drum washing is sent to the aqueous waste treatment module (module AQWTR). Treated offgas is discharged to the atmosphere.

18.2.3 Function of Small Generator Fixed Module Installed in a New or Existing Building

The small generator grout stabilization module was combined with the small generator polymer stabilization module (see Section 19).

18.3 Cost Bases, Assumptions, and Results

Incoming waste size reduction and preparation units (shredders) and solidification mixers are the major equipment capital cost items. Budgetary costs for the preparation and feed unit are based on vendor quotes for shredders, conveyors, and dust collection equipment. Solidification module assembly prices are based on quotes by Stock Equipment Company. Estimated FTEs and PLCC versus capacity for the large module are shown in Figures 18-3 to 18-7.

EQUIPMENT LIST

- 1 DRUM PUSHER
- 2 INCOMING WASTE BIN
- 3 BIN HOIST
- 4 SHREDDER (2) WITH FEED HOPPER, DUST HOOD AND HYDRAULIC RAY
- 5 AUGER FEEDER
- 6 WASTE TRANSFER BIN
- 7 UNDERDUNG CHAINE IN ENCLOSED PROCESS AREA
- 8 LIVE BOTTOM BULK STORAGE HOPPER
- 9 AUGER FEEDER
- 10 DUST COLLECTOR, FAN AND HEPA FILTER
- 11 DRUM STAGING CONVEYOR (POWERED ROLL)
- 12 DRUM STAGING CONVEYOR (POWERED ROLL)
- 13 SOLIDIFICATION SYSTEM
- 14 DRUM CAPPING AND WASHING SYSTEM
- 15 RECEIVING TANK
- 16 PUMP
- 17 FILTER
- 18 ION EXCHANGE VESSELS
- 19 TREATED WASTE TANK
- 20 PUMP
- 21 SLUDGE TANK
- 22 PUMP
- 23 UNDERDUNG CHAINE IN ENCLOSED MAINTENANCE AREA
- 24 HEPA FILTER AND FAN
- 25 STACK
- 26 BINDER STORAGE SILO
- 27 BLOWER
- 28 PNEUMATIC CONVEYOR
- 29 DAY BIN
- 30 DRUM STAGING CONVEYOR (GRAVITY)
- 31 PRECIPITATION TANK
- 32 ORGANIC REMOVAL FILTER VESSELS

FACILITY SIZE	LARGE GENERATOR			SMALL GENERATOR		
	SMALL	MEDIUM	LARGE	SMALL	MEDIUM	LARGE
DIMENSION IN FEET	40	50	60	100	109	127
	A	B	A	A	B	B
DIMENSION IN METERS	12.2	15.2	18.3	30.5	33.2	38.7
	A	B	A	A	B	B

Figure 18-1. Equipment layout for grout stabilization module (module GROUT).

Figure 18-2. Process functional diagram for grout stabilization module (module GROUT).

Figure 18-3. FTE workers versus capacity for nonalpha waste for grout stabilization module (module GROUT).

Figure 18-4. FTE workers versus capacity for alpha waste for grout stabilization module (module GROUT).

Figure 18-5. PLCC versus capacity for nonalpha waste for grout stabilization module (module GROUT).

Figure 18-6. PLCC versus capacity for alpha waste for grout stabilization module (module GROUT).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 18-7. PLCC versus capacity including unit rates for grout stabilization module (module GROUT).

19. POLYMER STABILIZATION (MODULE PLYMR)

19.1 Basic Information

The polymer stabilization module, shown in Figures 19-1 and 19-2, is used for micro- or macro-encapsulating solids and slurries discharged from the treatment modules in the waste treatment facility. The module consists of several main unit operations that incorporate all systems, processes, equipment, devices, controls, and accessories required to encapsulate the incoming waste. This module must be used in conjunction with the receiving and inspection module (module RCINS or FBSPT).

Input waste to this module consists of inorganic debris, spent filters, spent carbon, spent resins, incinerator ash, sludges, and concentrator bottom. All waste input is pretreated to a level that facilitates compliance of the stabilized material with the TCLP criteria of the Land Disposal Restrictions imposed by EPA.

All stabilized and encapsulated waste is packaged in drums and sent to the certification and shipping module for shipment to an appropriate disposal module. Most of the secondary waste is recycled. Distillate from a sludge dryer unit and rinse water from drum cleaning are sent to the aqueous waste treatment module (module AQWTR). Figure 19-3 presents a PFD of the module.

19.2 Technical Basis and Assumptions

19.2.1 Function and Operation of Large Generator Modules

Input waste is sent to a preparation and feed unit operation, after which it goes to a dryer. All waste input is pretreated to a level such that the stabilized material complies with the TCLP criteria of the land disposal restrictions. At a proportioning and blending unit operation, the dried waste and polymer agent are metered into drums and then mixed in a blender. Once blended, the polymer and waste mixture is transferred to the encapsulation unit operation.

The encapsulation unit operation consists of an extruder that melts and pushes the waste and polymer matrix into 55-gallon drums. When filled, the drums are transferred to an enclosure where cooling is achieved by forced air ventilation. After cooling, the drum is moved to the drum capping-and-washing unit operation. Then the drums are moved to the certification and shipping module for final disposal.

19.2.2 Integration of Large Generator Modules

The stabilization module receives primary waste (shredded inorganic debris) from the receiving and inspection module and receives secondary waste (concentrator bottom, spent carbon, and spent resins from aqueous waste treatment (module AQWTR), slag and lead from lead recovery (module PBRCL), and salts from special processing (module SPPRO) and from open, dump, and sort (OSORT). All empty transfer containers are returned to the receiving and inspection module for reuse.

The stabilization module has three secondary waste streams: (1) contaminated air from the process area, which is filtered through active carbon and released to the atmosphere, (2) contaminated distillate from the drying unit operation, which is sent to the aqueous waste treatment module, and (3) contaminated rinse water from the drum capping-and-washing unit operation, which is also sent to the aqueous waste treatment module.

The major output waste type from this module is stabilized waste. Materials purchased for O&M include personal protective equipment, laboratory material, polymers for encapsulation, HEPA and carbon filters, and disposal containers, which are all assumed to be consumable supplies.

19.2.3 Function and Operation of Small Generator Fixed Module in a New or Existing Building

A fixed small generator suitable for installation in a new or existing building space has been cost estimated. Function and operation of the fixed small generator modules are essentially the same as for the large generator modules. The small generator module can also accomplish grout stabilization. Figure 19-4 shows a PFD of the small generator modules.

Existing building space required for installation of this module is 3478 ft² (323 m²). The required ceiling height is 25 ft (7.6 m). The area required for a new building is the same.

19.2.4 Integration of Small Generator Fixed Module in a New or Existing Building

The stabilization module receives waste from the front-end and back-end support module, the aqueous waste treatment module, and the lead recovery module. Module input includes spent carbon, spent resins, salts, slag, lead, and concentrator bottom. Materials purchased for O&M include personal protective equipment, laboratory material, polymers for encapsulation, HEPA and carbon filters, and disposal containers, which are assumed to be consumable supplies. The major output waste type from this module is stabilized waste. Contaminated air, distillate, and rinse water are collected and transferred to the appropriate treatment modules.

19.2.5 Function and Operation of Portable Module

The portable stabilization module contains all equipment and support units necessary to stabilize the incoming waste. In order to accommodate all equipment and support units, four standard roadway trailers are required: three process trailers and one control trailer. Trailer A houses the drying, proportioning and blending unit operations. Trailer B contains the encapsulation, the drum cooling, and the drum capping and washing unit operations. A control trailer contains the instrumentation and communication equipment necessary for the operation of this module. The portable stabilization module receives waste from the specific sites where the mobile unit is operating. It is assumed all feed preparation is provided by the host facility. The portable module can also accomplish grout stabilization.

19.2.6 Integration of Portable Module

The portable stabilization module may receive input waste from the following modules if they are located at the host site: storage facilities, front-end and back-end support module, fixed or portable aqueous waste treatment module, fixed or portable decontamination module, incineration module, fixed or transportation thermal desorption module, mercury separation module, and fixed or portable WOX modules. A portable module layout appears in Figure 19-2. The major type of output waste from this module is stabilized waste. Distillate and rinse water are collected and transferred to the appropriate treatment modules. The portable stabilization module must be accompanied by the portable aqueous waste treatment module when dispatched to sites without this capability.

19.3 Cost Bases, Assumptions and Results

One part of polymer is required for one part of waste. Estimated manpower for small generator module O&M is based on the assumption that batch operations are used and that incoming waste is stabilized at a rate of about 9.1 kg/hr. For the portable stabilization module, a waste process rate of 88.3 ft³ (2½ m³) per campaign is assumed. Estimated FTE workers versus capacity is shown in Figures 19-5 and 19.6. Figures 19-7, 19-8, and 19-9 show the relationship between the PLCC and capacity.

Budgetary costs for equipment in this module are based on vendor quotes. The incoming-waste dryer, blender, and extruder are the major equipment capital cost items. The cost estimate for the drying equipment is based on prices obtained from Wyssmont Co., Inc., of Fort Lee, New Jersey. The cost estimate for the blending equipment is based on prices obtained from Velmac Associates, Inc., of Novato, California. The cost estimate for the extruder equipment is based on prices obtained from Sterling Extruders, Davis-Standard Division, located in Edison, New Jersey. FTE estimates and PLCC for small generator fixed and portable modules are shown in Tables 19-1 and 19-2.

Table 19-1. FTE workers for the small generator polymer stabilization module.

Cost component	Type of small generator module		
	Fixed, in new building(s)	Fixed, in existing building(s)	Portable
(1.0) Studies and bench-scale tests	44	29	29
(2.0) Demonstration			
(3.0) Production facility			
(4.0) Operations-budget-funded activities			
(5.0) O&M	46	30	98
(6.0) D&D			
All cost components (total for 10 years O&M)	90	60	127

Table 19-2. PLCC (\$1,000) for the small generator polymer stabilization module.

Cost component	Type of small generator module		
	Fixed, in new building(s)	Fixed, in existing building(s)	Portable
(1.0) Studies and bench-scale tests	10,644	7,491	7,349
(2.0) Demonstration			
(3.0) Production facility			
(4.0) Operations-budget-funded activities			
(5.0) O&M	6,114	6,215	8,236
(6.0) D&D			
All cost components (total for 10 years O&M)	16,758	13,706	15,584
Cost per campaign	—	—	260

Figure 19-1. Equipment layout for polymer stabilization module (module PLYMR).

EQUIPMENT LIST

- ① POLYMER STORAGE & FEED
- ② BLENDER
- ③ DRUM DUMP
- ④ DRYER
- ⑤ DRYER ANCILLARY EQUIPMENT
- ⑥ EXTRUDER
- ⑦ DRUM COOLING
- ⑧ DRUM CAPPING & WASHING
- ⑨ GROUTING BOOTH
- ⑩ GROUTING MIXER
- ⑪ SAND STORAGE
- ⑫ CEMENT STORAGE
- ⑬ MIX WATER STRAGE
- ⑭ CONTROL PANEL
- ⑮ WEIGH STATION

Figure 19-2. Equipment layout for portable polymer stabilization module (module PLYMR).

Figure 19-3. Process functional diagram for polymer stabilization module (module PLYMR).

Figure 19-5. FTE workers versus capacity for nonalpha waste for polymer stabilization module (module PLYMR).

Figure 19-6. FTE workers versus capacity for alpha waste for polymer stabilization module (module PLYMR).

Figure 19-7. PLCC versus capacity for nonalpha waste for polymer stabilization module (module PLYMR).

Figure 19-8. PLCC versus capacity for alpha waste for polymer stabilization module (module PLYMR).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 19-9. PLCC versus capacity including unit rates for polymer stabilization module (module PLYMR).

20. VITRIFICATION (MODULE VITRF)

20.1 Basic Information

The vitrification module, shown in Figure 20-1, consists of twelve operations designed to convert the incoming waste into a leach-resistant, rock-like or glass-like material. Vitrified alpha and nonalpha waste that is similar in composition to iron-enriched basalt should meet both the land disposal restrictions and DOE disposal requirements (Roads 1992). Secondary liquid is sent to aqueous waste treatment module AQWTR. Offgas is sent to the offgas treatment unit operation. Secondary waste treatment by-products, such as offgas scrubber sludge, are sent to the polymer solidification treatment module PLYMR. Unit operations are shown in the PFD in Figure 20-2.

The vitrification module processes noncombustible waste such as inorganic sludge, ash, soil, brick, concrete, and other similar material. The module can process solid waste of various shapes and forms. The size limitation imposed by the crusher/shredder is approximately 1 ft³ and the incoming waste can contain as much as 10% combustibles. The module is equipped with a predryer for processing wet sludge and solids.

20.2 Technical Basis and Assumptions

20.2.1 Function and Operation of Large Generator Module

Specific operations include an input waste preparation and feed unit that crushes and shreds the incoming waste and transfers it to a melter unit operation. At the melter unit operation, a predryer, operating at approximately 300-400° F, receives, dries, and feeds shredded waste and any sludge that must be vitrified to a vitrification furnace (or melter). Soil is added to the melter through a soil storage and feed unit operation. The furnace melts the soil and waste to form a molten slag. A slag cooling and packaging unit is used to receive the molten slag from the melter and cast it into containers. Containers are then sealed and washed by high pressure water to remove loose contamination from the container surface. Containers are then sent out of this module to the Certification and Shipping (CSHIP) module.

The melter is equipped with a secondary combustion unit that completes the volatile gas destruction. An induced air blower moves the secondary combustor effluent through the air pollution control device that is designed to remove particulates. A surge tank retains offgas for reprocessing in the event of a process upset. Secondary liquid waste is sent to the aqueous waste-treatment module.

20.2.2 Integration of Large Generator Modules

Major module inputs include waste from the open, dump, and sort module (module OSORT), waste from the generator sites, and soil. Major O&M purchased materials are consumables, such as personal protective equipment, laboratory material, binder, soil, and disposable containers.

Major module outputs are containerized and vitrified. Nonalpha and alpha wastes are transported to a certification and shipping module (see Module CSHIP). Treated offgas is discharged into the atmosphere. Secondary liquid waste is sent to the aqueous waste treatment module.

20.3 Cost Bases, Assumptions, and Results

Incoming waste sizing and preparation (shredders), melter and its offgas unit are the major equipment capital cost items. Cost for the preparation and feed unit are based on vendor quotes for shredders, conveyors, and dust collection equipment. Melter prices are based on budgetary quotes received from two vendors, Callidus Technologies and Retec. Callidus Technologies provided budgetary quotes for the various offgas units. Estimated FTEs and PLCC versus capacity is shown in Figures 20-3 to 20-7.

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	80	214	24.4	65.2
	MEDIUM	100	180	30.5	54.9
	LARGE	120	196	36.6	59.8
SMALL GENERATOR	MINIMUM	—	—	—	—

Figure 20-1. Equipment layout for vitrification module (module VITRF).

Figure 20-2. Process functional diagram for vitrification module (module VITRF).

Figure 20-3. FTE workers capacity for nonalpha waste for vitrification module (module VITRF).

Figure 20-4. FTE workers versus capacity for alpha waste for vitrification module (module VITRF).

Figure 20-5. PLCC versus capacity for nonalpha waste for vitrification module (module VITRF).

Figure 20-6. PLCC workers versus capacity for alpha waste for vitrification module (module VITRF).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 20-7. PLCC versus capacity including unit rates for vitrification module (module VITRF).

21. CERTIFICATION AND SHIPPING (MODULE CSHIP)

The certification and shipping module, shown in Figure 21-1, is the same for alpha and nonalpha waste. There are only minor differences in the assay and certification equipment that do not affect the overall PLCC estimates. Unit operations are shown in the PFD in Figure 21-2.

21.1 Basic Information

The certification and shipping module consists of three unit operations: incoming material storage, assay and certification, and truck loading. This module receives packaged waste containers from treatment modules and provides temporary storage, radiological and physical characterization of the waste, and shipment of the containers.

The certification and shipping module is used for large generator facilities only. It is used in conjunction with treatment modules when the required functions are not available at existing facilities. The module includes all equipment needed for certification of the waste in compliance with the transportation, storage, and disposal regulations and requirements.

21.2 Technical Bases and Assumptions

21.2.1 Function and Operation of Large Generator Modules

Packaged waste containers arrive from treatment modules on conveyors, carts, or other transport devices. Containers are removed from the transport devices and placed in a staging area. The containers are then visually examined, tagged, logged, recorded, and sent to an assay-and-certification unit operation. In this unit operation, the containers are examined by radioassay devices to allow both alpha and gamma radioactivity classification in accordance with transportation, storage, and disposal criteria. Various devices, such as PAN counting and SGS instruments, may be used.

Next, the containers are weighed and measured to determine waste density. The presence of material restricted by transportation, storage, and disposal criteria is determined by nondestructive examination by ultrasonic instruments or an RTR device. After examination, each container is labeled and its properties are logged and recorded into a computerized database. After inspection, the container is moved to a temporary storage area until readied for shipment to an interim storage or disposal facility. Containers that do not meet the transportation dose criteria are shipped in a truck equipped with shield overpacks.

The shipping and certification module is equipped with a bridge crane and a forklift. Containers can be loaded onto flat-bed trailer or van trucks. Containers can also be loaded into large transportation overpacks (e.g., TRAMPAC). This module is designed to be installed contiguous to a treatment module.

To allow year-round operations and minimize the effects of a potential spill, it is assumed that the certification and shipping operations will take place indoors.

21.2.2 Integration of Large Generator Modules

Module input includes packaged waste from treatment modules. Input from the site includes utilities, service water, normal and emergency power, and communications. O&M consumables including personal protective equipment must be purchased. Module output includes truck shipments of containerized alpha and nonalpha waste, which are sent to storage and disposal modules.

21.2.3 Small Generator Fixed and Portable Module

No separate or portable small generator certification and shipping module has been developed. Module FBSPT includes certification and shipping functions for a portable or small generator facility.

21.3 Cost Bases, Assumptions and Results

Major equipment capital cost items for this module are a 20-ton bridge crane, alpha assay, gamma assay, and RTR units. The equipment estimates were obtained as discussed in this report's sections describing a receiving/inspection module. Estimated FTE workers versus capacity is shown in Figure 21-3. Cost versus capacity for the certification and shipping module is shown in Figures 21-4 and 21-5.

FACILITY SIZE		DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	100	64	30.5	19.5
	MEDIUM	140	140	42.7	42.7
	LARGE	200	236	61.0	72.0
SMALL GENERATOR	MINIMUM	-	-	-	-

EQUIPMENT LIST

- ① ASSAY AND INSPECT STATION
- ② BRIDGE CRANE AND LOAD GRAPPLER
- ③ SELF-GUIDED VEHICLE

Figure 21-1. Equipment layout for certification and shipping module (module CSHIP).

Figure 21-2. Process functional diagram for certification and shipping module (module CSHIP).

Figure 21-3. FTE workers versus capacity for certification and shipping module (module CSHIP).

Figure 21-4. PLCC versus capacity for certification and shipping module (module CSHIP).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 21-5. PLCC versus capacity including unit rates for certification and shipping module (module CSHIP).

22. STORAGE FRONT-END AND BACK-END SUPPORT (MODULES SADMN AND SRC SH)

22.1 Basic Information

The storage front-end and back-end support module is used in conjunction with the storage modules (module STORE) and supply all the necessary accommodations for storing alpha and nonalpha wastes. The modules combine receiving and inspection operations with administration, laboratory, unloading and shipping functions.

22.2 Technical Bases and Requirements

22.2.1 Function and Operation of Modules

Containers arrive on a transport vehicle and are unloaded using a forklift or overhead bridge crane, and placed in a staging area. The containers are visually examined, labeled, logged, recorded, and sent to inspection and assay. At the inspection and assay operation, the category of the received waste is verified against the results obtained from the back-end treatment module. After inspection, the containers are moved to a storage area. The module is also used for shipping and loading containers that are ready for transport to disposal modules.

The technical bases and requirements for storage front-end and back-end support modules are the same as outlined in the treatment front-end support module, receiving and inspection module, and shipping and certification module, except that the assay, inspection, and certification functions are for verification purposes only. In addition, the storage front-end and back-end support module is equipped with a computer inventory system that tracks the incoming and outgoing waste, as well as types of sampling and analysis that may be performed at the staging area (nondestructive) or the laboratory. Secondary waste generated by sampling activities is treated and packaged.

22.2.2 Integration of Modules

Module input includes vehicles that carry waste from the treatment module or forklift trucks that carry waste containers from storage areas (module STORE). Module output includes containerized alpha and nonalpha waste and TRU waste, which are transferred to the storage bays or loaded onto trucks in containers for transport to disposal sites.

22.3 Cost Bases, Assumptions, and Results

Staffing levels were estimated based on the number of personnel required to support about ten separate support functions similar to treatment front-end support, receiving and inspection, and shipping and certification. Staffing levels reflect waste input (unload and inspection) and waste output (certification and shipping) throughput requirements. For a large module, staffing levels could support, as an example, 20 drums per hour input in addition to 20 drums per hour as output. Major equipment capital cost items for this module are the laboratory analytical equipment and overhead bridge crane. An allowance is made for the analytical instruments and

components needed for a mixed waste laboratory. Mixed waste laboratory vendors have been consulted to ensure that the laboratory allowance is adequate. The crane cost is estimated based on vendor quotes. FTE and cost summaries for the storage front-end support modules are shown in Figures 22-1 through 22-6. Table 22-1 lists plan dimensions of storage front-end support module. Table 22-2 lists plan dimensions of storage receiving and shipping module.

Table 22-1. Plan dimensions of storage front-end support module (SADMN).

Module size	Dimensions (feet)		Dimensions (meters)	
	Width	Length	Width	Length
Large generator				
Small	50	50	15.2	15.2
Medium	50	100	15.2	30.5
Large	50	156	15.2	47.5
Small generator	—	—	—	—

Table 22-2. Plan dimensions of storage receiving and shipping module (SRCSH).

Module size	Dimensions (feet)		Dimensions (meters)	
	Width	Length	Width	Length
Large generator				
Small	19.5	40.9	5.9	12.5
Medium	36.6	37.8	11.1	11.5
Large	73.2	42.4	22.3	12.9
Small generator	—	—	—	—

Figure 22-1. FTE workers versus capacity for storage front-end support module (modules SADMN and SRCSH).

Figure 22-2. PLCC versus capacity for storage front-end support module (modules SADMN and SRCSH).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 22-3. PLCC versus capacity plus unit rates for storage front-end support module (modules SADMN and SRCSH).

Figure 22-4. FTE workers versus capacity for storage receiving and shipping module (modules SADMN and SRCSH).

Figure 22-5. PLCC versus capacity for storage receiving and shipping module (modules SADMN and SRCSH).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 22-6. PLCC versus capacity plus unit rates for storage receiving and shipping module (modules SADMN and SRCSH).

23. STORAGE (MODULE STORE)

23.1 Basic Information

The storage module (Figure 23-1) consists of three unit operations (Figure 23-2). Waste that arrives from assay and inspection is stored at a specified location. The module is equipped with a cleanup unit operation for responding to potential spills. The module also has permanent monitoring capabilities to ensure the integrity of the stored waste containers. The module should be used in conjunction with the storage front-end and back-end support module (see modules SADMN and SRCSH) or as an addition to an existing facility where similar functions are already available.

23.2 Technical Bases and Assumptions

23.2.1 Function and Operation of Modules

The storage areas include features, such as spill collection and a combination of sloping floors and sumps, that achieve compliance with the storage requirements of RCRA. Designated storage areas are separated by 6-inch-high (minimum) concrete berms that extend the length of the storage bays. In bays located along the outside walls, floors slope to the rear of the module. Floors in the remainder of the bays are sloped to the center. Area monitors are included for both gamma and alpha radiation control.

23.2.2 Integration of Modules

Module interfaces include packaged waste to and from the staging or assay-and-inspection area at the storage front-end and back-end support module (module SADMN).

23.3 Cost Bases, Assumptions and Results

The storage capacity has been sized to handle an accumulation of up to 20 years worth of waste input from treatment modules. This module includes no major equipment capital cost items. The storage building is the only major (cost) element, which in turn, depends on the size of the facility. Accordingly, a preconceptual design of the storage building with concrete walls and concrete roof was developed for several module sizes. These designs were used to generate an estimate. Estimated FTE workers and PLCC versus capacity are shown in Figures 23-3 through 23-5.

	FACILITY SIZE	DIMENSION IN FEET		DIMENSION IN METERS	
		A	B	A	B
LARGE GENERATOR	SMALL	64	155	19.51	47.26
	MEDIUM	120	157	36.58	47.86
	LARGE	240	446	73.17	135.97
SMALL GENERATOR	MINIMUM	--	--	--	--

Figure 23-1. Equipment layout for storage module (module STORE).

Figure 23-2. FTE workers versus capacity for storage module (module STORE).

Figure 23-3. PLCC versus capacity for storage module (module STORE).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 23-4. PLCC versus capacity including unit rates for storage module (module STORE).

24. DISPOSAL FRONT-END SUPPORT (MODULE DADMN)

24.1 Basic Information

The disposal front-end support module is used in conjunction with the disposal modules (modules AGDSP, SLDSP, SIDSP, ADDSP, and BHDSP) and provides all the necessary common functions for disposal of alpha and nonalpha waste. The disposal front-end support module unit operations include truck loading and unloading areas, administrative offices, analytical laboratory facilities, and truck inspection and washdown.

24.2 Technical Bases and Assumptions

24.2.1 Function and Operation of Modules

The containers arrive in a transport vehicle, are unloaded using a forklift or overhead bridge crane, and are placed in a staging area. The containers are visually examined, labeled, logged, and sent to inspection and assay. At the inspection and assay unit, the category of the received waste is verified against the results obtained from the back-end treatment or storage modules. After inspection, the drums are sent to the disposal module.

The technical bases and requirements for all disposal front-end support modules are the same as those outlined in the treatment receiving and inspection and administration modules except that the assay-and-inspection and certification functions are for verification purposes only.

24.2.2 Integration of Modules

Module input includes packaged waste brought from the treatment or storage modules. O&M consumables include personal protective equipment, which must be purchased. Module output consists of certified containers that are transferred to the disposal modules.

24.3 Cost Bases, Assumptions and Assessments

The cost and design of the module are based on several simplifying assumptions and information gathered from a variety of sources. Major equipment and module cost items for this module are based on data obtained from the Illinois LLW Disposal Facility (Morrison Knudsen/Chem Nuclear Services 1991). Staffing levels were estimated based on the number of personnel required for support of approximately ten separate support functions similar to those identified in the treatment administration and receiving/inspection modules.

FTE staffing levels are based on data obtained from the Illinois LLW Disposal Facility (Morrison Knudsen/Chem Nuclear Services 1991). A \$1 million allowance is made for the analytical instruments and components needed for a mixed-waste laboratory. FTE and cost summaries for the disposal front-end support module are shown in Figures 24-1 through 24-3. Table 24-1 shows the plan dimensions of disposal front-end support module.

Table 24-1. Plan dimensions of disposal front-end support module (DADMN).

Module size	Dimensions (feet)		Dimensions (meters)	
	Width	Length	Width	Length
Large generator				
Small	100	92.5	30.5	28.2
Medium	100	172.5	30.5	52.6
Large	150	176	45.7	53.6
Small generator	—	—	—	—

Figure 24-1. FTE workers versus capacity for disposal front-end support module (module DADMN).

Figure 24-2. PLCC versus capacity for disposal front-end support module (module DADMN).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 24-3. PLCC versus capacity plus unit rates for disposal front-end support module (module DADMN).

25. ENGINEERED DISPOSAL (MODULE AGDSP)

25.1 Basic Information

The engineered disposal module, shown in Figure 25-1, should be used in conjunction with the disposal front-end support module (module DADMN) or as an addition to existing facilities where similar functions are already available. The module consists of engineered disposal units that are based on the Illinois LLW disposal module design, shown in Figure 25-1, which uses an earth mound and concrete cell concept (Morrison Knudsen/Chem Nuclear Services, 1991). Engineered disposal modules for non-RCRA waste and RCRA waste are essentially the same except that a RCRA disposal unit has a double leachate collection system in compliance with the RCRA requirements. Unit operations are shown in the PFD in Figure 25-2.

The unit operations include receiving the inspected drums from the front-end module, placing the drums into concrete canisters, and constructing the disposal units that will house incoming concrete waste canisters. Disposal unit construction includes foundation, leachate collection system, and monitoring system, concrete vaults, and earth covers. Construction of the modules is intended to be a continuous process concurrent with the placement of the canisters.

25.2 Technical Bases and Assumptions

25.2.1 Function and Operation of Modules

The containers received from the disposal front-end support module are packaged into concrete canisters that are then sealed with grout. The canisters are transported to the disposal units for placement. Each disposal unit is comprised of a double row of concrete cells with an access aisle between the rows. Concrete canisters that arrive from the packaging area are placed in a cell by overhead crane or forklift from the access aisle and stacked three canisters high. Once the cell is full, it is backfilled with sand and a concrete cover is concurrently constructed to seal the cells.

The cells are capped with an earth layer that is engineered to withstand long-term environmental and weathering effects. The layered cap consists of sandy drain layers placed directly over the cells, an impervious clay layer, a high density polyethylene liner, and another drain layer to deter seepage into the cells. The top layer consists of either subsoil and vegetative material or subsoil, bedding, and riprap. The monitoring system includes sensors that will detect any leakage from the cells.

D&D includes module demolition and the disposal unit maintenance. Disposal unit maintenance is planned in two stages, each with two substages: (1) short-term maintenance, which consists of closure and post-closure periods, and (2) long-term maintenance, which consists of active institutional care and passive institutional care.

Closure activities take place during the first two years after the facility ceases to accept waste. Closure includes decontamination of the modules, initial demolition of buildings, site development, closure of the cells, site remediation, and monitoring of the cell performance and

groundwater. Years 1 through 10 after the facility ceases to accept waste are designated as the post-closure period. During this period monitoring of the groundwater and cell performance will continue, as well as site remediation and restoration. Active institutional care is planned for 11 to 100 years following the post-closure period. During this stage, any buildings not previously demolished are torn down and all site services are removed, in addition to ongoing monitoring activities. The last stage, passive institutional care, extends from 101 to 300 years after the facility ceases to accept waste. Passive institutional care includes closing the center aisles of the vaults, completing the earth caps and site grading, removing the retention ponds and retaining walls, and installing passive drains. Site maintenance is discontinued after 300 years.

25.2.2 Integration of Modules

Input interfaces include waste drums received from the front-end module (refer to Module DADMN). O&M consumables, including empty concrete canisters, grout, sand, and personal protective equipment, must be purchased. The module is intended for permanent disposal of the waste and designed for site maintenance and monitoring as described above. No module output is anticipated for the post-closure period (at least 300 years).

25.3 Cost Bases, Assumptions and Results

Major equipment capital cost items are a forklift and an overhead crane for placement of the drums into canisters and placement of filled canisters into the concrete cells. Costs for these items are based on vendor quotes.

Estimated FTE workers versus capacity is shown in Figure 25-3. This staffing is based on data on the Illinois LLW Disposal Facility (Morrison Knudsen/Chem Nuclear Services 1991) and a DOE conceptual design report (DOE 1987).

Construction of the disposal units is a major cost item. A preconceptual design of one disposal unit that applies to all modules, including the concrete cell and cover design, was developed based on the design of the Illinois LLW Disposal Facility. A unit cost per cell was developed based on data from the Illinois facility, and an estimate was generated according to the rate of incoming waste and number of cells required for each small, medium, and large module. Minimum size capacity is provided as a lower bound for the smallest economical engineering designed facility. Estimates are based on a disposal facility in accordance with DOE and NRC criteria, but a NRC license is not assumed. Cost versus capacity for the engineered disposal module is shown in Figure 25-4 and 25-5.

Figure 25-1. Equipment layout for engineered disposal module (module AGDSP).

Figure 25-2. Process functional diagram for engineered disposal module (module AGDSP).

Figure 25-3. FTE workers versus capacity for engineered disposal module (module AGDSP).

Figure 25-4. PLCC versus capacity for engineered disposal module (module AGDSP).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 25-5. PLCC versus capacity including unit rates for engineered disposal module (module AGDSP).

26. SHALLOW LAND DISPOSAL (MODULE SLDSP)

26.1 Basic Information

The shallow land disposal module essentially consists of trench disposal without engineered features. The cost for a shallow land disposal consists of three components: front-end module capital cost, disposal O&M cost, and site closure cost. Front-end module capital cost is discussed in Module DADMN, and should be added only if a new disposal module is under consideration. Since shallow land trench disposal units are commonly used by both the DOE and the commercial nuclear industry, a preconceptual design of disposal units to develop capital and O&M costs was not necessary.

26.2 Technical Bases and Assumptions

26.2.1 Function and Operation of Modules

Containers received from the disposal front-end support module are transported to a disposal unit. Each disposal unit consists of an excavated trench. The containers are stacked in the bottom of the trench using a boom crane. After one row is completed, a layer of fill is placed on top of the containers. The cap consists of at least seven feet of engineered fill dirt and clay. The disposal site includes all of the appropriate storm drainage collection and discharge equipment. Site monitoring includes both groundwater and air sampling systems.

26.2.2 Integration of Modules

Input interfaces include waste drums received from the disposal front-end module (refer to Module DADMN). O&M consumables, including personal protective equipment, must be purchased. No module output is anticipated for a post-closure period (at least 300 years).

26.3 Cost Bases, Assumptions and Assessments

The cost for disposal of contact-handled waste at Idaho National Engineering Laboratory has historically ranged from \$50/ft³ (\$1,766/m³) (for 100,000 ft³/yr; 2,832 m³/yr) to 150/ft³ (\$5,297/m³) (for 25,000 ft³/year; 708 m³/yr).^j Disposal costs have varied considerably because of varying annual disposal volumes. Site closure costs should be added to the shallow land disposal costs to obtain the total Module SLDSP cost. As an alternative, shallow land disposal costs can be compared to rates from commercial disposal sites. Disposal fees at commercial sites include all of the three cost components. FTE and cost versus capacity for the shallow land disposal module are shown in Figures 26-2 through 26-4.

j. Based on RWMC contact-handled alpha and nonalpha waste disposal costs calculated by Darris Bright of EG&G Idaho, and on a memorandum (JAL-5-92) by J.A. Logan regarding costs of waste disposal.

Figure 26-1. Process functional diagram for shallow-land disposal module (module SLDSP).

Figure 26-2. FTE workers versus capacity for shallow-land disposal module (module SLDSP).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 26-3. PLCC versus capacity for shallow-land disposal module (module SLDSP).

27. SILO DISPOSAL (MODULE SIDSP)

27.1 Basic Information

The silo disposal module, shown in Figure 27-1, is used in conjunction with the receiving, preparation, and shipping module. This module should be used for sites requiring disposal of a small quantity of waste. In addition, the module can directly accept packaged waste from generators or other sources. The unit operations are shown in the PFD in Figure 27-2.

27.2 Technical Bases and Assumptions

27.2.1 Function and Operation of Modules

Waste material arrives in 55-gallon drums placed in the transportation casks mounted on flat-bed trailers. Drums are removed by overhead bridge crane or boom crane and transported to the silo area. Silos are constructed in place with reinforced concrete on a concrete pad and underlying liner and leachate collection system. Drums are placed by boom crane five drums in a row and seven drums high. Silos are backfilled with sand, and a reinforced concrete cap seals the silo. A multi-layered earth materials mound covers all silo areas.

27.2.2 Integration of Modules

Input includes waste drums received from the generators. O&M consumables, including personal protective equipment, must be purchased. No module output is anticipated for the post-closure (at least 300 years).

27.3 Cost Bases, Assumptions and Assessments

FTE and cost versus capacity for the silo disposal module are shown in Figures 27-3 through 27-7.

Figure 27-1. Equipment layout for silo disposal module (module SIDSP).

Figure 27-2. Process functional diagram for silo disposal module (module SIDSP).

Figure 27-3. FTE workers versus capacity for silo disposal module (module SIDSP).

Figure 27-4. PLCC versus capacity for silo disposal module (module SIDSP).

Note: Basis includes 10 years O&M

Note: Basis includes 10 years O&M

Figure 27-5. PLCC versus capacity including unit rates for silo disposal module (module SIDSP).

28. BOREHOLE DISPOSAL (MODULE BHDSP)

28.1 Basic Information

The borehole concept, shown in Figure 28-1, is considered an alternative disposal method for small generator installations. A single borehole allows disposal of 1 m³ of waste. This disposal concept may not meet the RCRA requirement for a double liner leachate collection system. Also, the borehole may not be acceptable where groundwater is within 8½ m of the ground surface.

28.2 Technical Bases and Assumptions

28.2.1 Function and Operation of the Module

A borehole is drilled 1 m in diameter and 7½ m deep. Concrete is placed in the lower 0.6 m of the hole. Waste material arrives in 55-gallon drums placed in the transportation casks mounted on flat-bed trailers. Five drums are lowered into the hole, stacked one on top of another. The hole is grouted around the drums to the surface. A cover, consisting of a 2.4-m-thick concrete slab, is constructed atop the borehole. A 2-m-thick engineered earth cover is constructed on top of the concrete cover. Boreholes installed in low- versus high-sensitivity areas would be constructed in a similar manner. Additional site characterization would be required at high-sensitivity areas.

In low-sensitivity areas, such as at existing DOE sites, which are well above the water table, and with borehole installation associated with the installation of other modules for which NEPA permitting activities have been included, the borehole would require minimal attention.

In high-sensitivity areas, such as a non-DOE facility that is near a populated area, close to the water table, and requiring NEPA permitting activities or front end support, a much higher level of attention throughout its life term would be necessary.

28.2.2 Integration of the Module

Input includes waste drums received from storage. O&M consumables, including personnel protective equipment, must be purchased. No module output is anticipated for a lengthy time period (at least 300 years).

28.3 Cost Bases, Assumptions, and Results

The major capital cost item is the drill rig if subcontracting the drilling is not feasible. Costs for excavating and completing the borehole for use in disposal is based on past experience with similar excavations and wells used for other purposes. Table 28-1 presents estimates of FTE workers and PLCC for each borehole at both low and high sensitive areas. Data shown in Table 28-1 do not include site characterization, NEPA, for the low sensitive area but does include it plus front end support for the high sensitive area. If detailed site characterization and NEPA are required for the low sensitive area, an estimated cost of \$7.4 million should be added to the

operation budget funded activities. The cost for 100 years of active monitoring and 200 years of inactive monitoring is included in the \$14.77 million for D&D.

Table 28-1. FTE workers and PLCC (\$1,000) per excavation for the borehole disposal module.

Cost component	Low-sensitivity		High-sensitivity	
	PLCC	FTE workers	PLCC	FTE workers
(1.0) Studies and bench-scale tests	—	—	—	—
(2.0) Demonstration	—	—	—	—
(3.0) Production facility	52	1	437	8
(4.0) Operations-budget-funded activities	32	0	7,059	42
(5.0) O&M (10 years)	284	2	4,100	26
(6.0) D&D	1,757	7	14,770	59
All cost components	2,125	10	26,366	135

Figure 28-1. Equipment layout for borehole disposal module (module BHDSP).

29. ESTIMATION PROCEDURE

29.1 Overview

The report up to this point describes how the costs and FTEs of the various TSD modules were estimated. These costs and FTEs were estimated over a wide range of input capacities. These data were used to define cost and FTE-versus-capacity relationships for large generator modules, represented by curves on a graph. For fixed small generator and portable modules, tables containing a single cost and FTE data are presented. The data in these tables are applicable to a limited capacity range of the lowest end of the given treatment modules. From either a curve or a table, one can estimate the costs and FTEs of a module given its capacity. From a group of such curves and tables, one can estimate the FTEs and cost for treating, storing, and disposing of a given inventory of any combination of nonalpha and alpha MLLW. A combination of modules that treats, stores, and disposes of a given inventory of such waste is referred to as a treatment scenario. Figure 29-1 shows how modules can be combined to create a treatment facility based on thermal desorption of debris. Figure 29-2 shows a layout of a thermal (flame) integrated facility; and Figure 29-3 shows a layout of a nonthermal (flameless) facility.

The cost estimation procedure in this section has been developed to allow the reader to estimate the total cost for a scenario for treating, storing, and disposing of this waste. The scenario estimation procedure essentially consists of three major steps which are discussed in the following subsections.

29.2 Waste Loads Definition

In the waste loads definition step, the capacity requirement for each module is defined. To use the WMFCI cost and FTE data, the total capacity requirements need to be converted into the appropriate processing rate (e.g., kg/hr, m³/hr) or total storage or disposal capacities (e.g., m³) by developing operating assumptions. There are three basic calculations that an estimator may need to use. These calculations are required to establish treatment processing rates, storage and disposal input/through-put rates, and storage and disposal total volumetric requirements. The basic calculations and examples are provided as follows:

1. *Front-end and treatment modules.* The total unprocessed waste volume (m³) can be converted to a treatment input capacity processing rate (kg/hr) by the following calculations. The total volume in cubic meters (m³) is multiplied by the unprocessed waste density (kg/m³) to obtain the total mass in kilograms (kg). This mass is divided by the total hours of facility (module) operations. An example is as follows: $(1,000 \text{ m}^3 \times 1,242 \text{ kg/m}^3 \text{ (density of soil)}) / (4,032 \text{ hrs/hr} \times 10 \text{ years of operation}) = 30.8 \text{ kg/hr}$ processing rate for 10 years.
2. *Storage front-end and back-end support, disposal front-end support.* The total processed waste (kg/hr) can be converted to a post-treatment storage or disposal throughput capacity (m³/hr) by the following calculations. The processed waste rate (kg/hr) is divided by the processed waste density (kg/m³) to obtain the throughput capacity rate for storage or disposal. An example is as follows: $1,000 \text{ kg/hr} / 2,013 \text{ kg/m}^3 \text{ (density of)}$

soils that have been processed and grouted) = $0.50 \text{ m}^3/\text{hr}$ storage input/output (or disposal input) capacity.

3. **Storage and disposal modules:** The front-end/back-end storage and front-end disposal throughput rates (m^3/hr) can be converted into total volumes (m^3) for storage or disposal by the following calculations. The storage input/output (or disposal input) capacity is multiplied by the total hours of facility (module) operations. An example is as follows: $(0.50 \text{ m}^3/\text{hr} \times 4,032 \text{ hrs/yr} \times 10 \text{ years of operation}) = 20,030 \text{ m}^3$ total volume for storage (or disposal).

These calculations would need to be completed for existing or new facilities. The existing facility capacities are used for estimating O&M and D&D costs and FTE's only. New facility capacities are used to define the Pre-operations, Facility Construction, O&M, and D&D costs, and DTE's.

There are three types of modules in the WMFCI report: treatment, storage, and disposal. Processing rates for each type of module may be defined as described in the following sections.

29.2.1 Large Generator Facility Treatment Waste Loads.

Large generator facility treatment waste loads may be documented in a data sheet similar to that shown in Figure 29-4. As shown, the treatment modules are separated into four categories which are discussed below.

- **Treatment front-end modules.** To estimate cost and FTEs for the front-end module, the total processing rate of the treatment facility must be defined. The processing rate of the treatment facility is used to size the treatment front-end modules even though some of the modules (e.g., maintenance module) do not process the input waste per se. For large generator facilities, there are four front-end modules: front-end support (analytical laboratory and administration building); receiving and inspection; open, dump & sort; and maintenance modules. The user must define both the existing and new module loads for each of the four modules.
- **Primary treatment modules.** The total treatment processing rate must be subdivided according to the processing needs. The treatment modules in this report are designed to satisfy the processing needs of the nineteen MLLW categories defined in the MWIR report. A summary of the waste categories and the modules needed for treating a majority of the waste in each category is presented in Table 29-1. The recommended treatment modules are based on three overall waste treatment strategies, LDR compliance (thermal treatment) strategy, no-flame strategy, and vitrification strategy. It should be noted that the modules recommended in Table 29-1 handle a majority of the waste in the given category, but a small portion (slip stream) of the waste in each category might have to be sent to other treatment modules. For more accurate estimation results, the slip stream feed rates and the amount of waste that will be discharged from one primary treatment module to another primary treatment module will need to be defined. This can be done by referring to the mass balance flow rates depicted in the PFDs in this report.

Table 29-1. Recommended treatment modules for the 19 MLLW categories given in MWIR.

Waste Category	Strategy		
	LDR Compliance	No-Flame	Vitrification
1. Organic Liquids	ADMIN, OSORT, INCIN, RCINS, AQWTR, PLYMR, GROUT, CSHIP	ADMIN, OSORT, AQWTR, RCINS, PLYMR, GROUT, CSHIP	ADMIN, OSORT, RCINS, INCIN, AQWTR, PLYMR, VITRF, CSHIP
2. Aqueous Liquids	ADMIN, OSORT, AQWTR, RCINS, INCIN, PLYMR, GROUT, CSHIP	ADMIN, OSORT, AQWTR, RCINS, SWASH, PLYMR, GROUT, CSHIP	ADMIN, OSORT, RCINS, INCIN, AQWTR, PLYMR, VITRF, CSHIP
3. Organic Sludge	ADMIN, OSORT, INCIN, RCINS, PLYMR, GROUT, CSHIP	ADMIN, OSORT, AQWTR, RCINS, SWASH, PLYMR, GROUT, CSHIP	ADMIN, OSORT, RCINS, INCIN, PLYMR, VITRF, MMELT, CSHIP
4. Inorganic Sludge	ADMIN, OSORT, INCIN, RCINS, PLYMR, GROUT, CSHIP	ADMIN, OSORT, AQWTR, RCINS, SWASH, PLYMR, GROUT, CSHIP	ADMIN, OSORT, RCINS, INCIN, PLYMR, VITRF, MMELT, CSHIP
5. Cemented Solids	ADMIN, OSORT, INCIN, RCINS, PLYMR, GROUT, CSHIP	ADMIN, OSORT, AQWTR, RCINS, SWASH, PLYMR, GROUT, CSHIP	ADMIN, OSORT, RCINS, INCIN, PLYMR, VITRF, MMELT, CSHIP
6. Organic Debris	ADMIN, OSORT, CMPCT, RCINS, THDRB, INCIN, PLYMR, GROUT, CSHIP	ADMIN, OSORT, CMPCT, RCINS, DWASH, GROUT, CSHIP	ADMIN, OSORT, RCINS, PLYMR, INCIN, VITRF, MMELT, CSHIP
7. Inorganic Debris	ADMIN, OSORT, CMPCT, RCINS, THDRB, INCIN, PLYMR, GROUT, CSHIP	ADMIN, OSORT, CMPCT, RCINS, DWASH, GROUT, CSHIP	ADMIN, OSORT, RCINS, PLYMR, INCIN, VITRF, MMELT, CSHIP
8. Heterogeneous Debris	ADMIN, OSORT, CMPCT, RCINS, THDRB, INCIN, PLYMR, GROUT, CSHIP	ADMIN, OSORT, CMPCT, RCINS, DWASH, GROUT, CSHIP	ADMIN, OSORT, RCINS, PLYMR, INCIN, VITRF, MMELT, CSHIP
9. Soil < 50% Debris	ADMIN, OSORT, INCIN, RCINS, CMPCT, THDRB, PLYMR, GROUT, CSHIP	ADMIN, OSORT, EWASH, INCIN, DWASH, GROUT, CSHIP	ADMIN, OSORT, RCINS, PLYMR, MMELT, VITRF, INCIN, CSHIP
10. Soil	ADMIN, OSORT, INCIN, RCINS, CMPCT, THDRB, PLYMR, GROUT, CSHIP	ADMIN, OSORT, EWASH, INCIN, DWASH, GROUT, CSHIP	ADMIN, OSORT, RCINS, PLYMR, MMELT, VITRF, INCIN, CSHIP

Table 29-1. (continued).

Waste Category	Strategy		
	LDR Compliance	No-Flame	Vitrification
11. Lab Packs ^w /metals	RCINS, ADMIN, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP
12. Lab Packs ^{wo} /metals	RCINS, ADMIN, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP
13. Reactive Metals	RCINS, ADMIN, OSORT, DEACT, CSHIP	ADMIN, RCINS, OSORT, DEACT, CSHIP, GROUT	ADMIN, RCINS, OSORT, DEACT, CSHIP, VITRF
14. Explosives	RCINS, ADMIN, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP
15. Compressed gases	RCINS, ADMIN, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP
16. Liquid Mercury	RCINS, ADMIN, OSORT, RMERC, CSHIP	ADMIN, RCINS, OSORT, PBRCR, CSHIP, PLYMR	ADMIN, RCINS, OSORT, PBRCR, CSHIP, PLYMR
17. Elemental Lead	RCINS, ADMIN, OSORT, PBRCR, CSHIP	ADMIN, RCINS, OSORT, PBRCR, CSHIP, PLYMR	ADMIN, RCINS, OSORT, PBRCR, CSHIP, PLYMR
18. Beryllium Metals	RCINS, ADMIN, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP	ADMIN, RCINS, OSORT, SPPRO, CSHIP
19. Batteries	RCINS, ADMIN, OSORT, PBRCR, CSHIP	ADMIN, RCINS, OSORT, PBRCR, CSHIP, PLYMR	ADMIN, RCINS, OSORT, PBRCR, PLYMR, CSHIP

- Secondary treatment and stabilization modules.** The processing rate for the secondary treatment and stabilization modules must be defined by considering two sources. The first source is the input unprocessed waste that bypasses the primary treatment modules. For example, the vitrification module will receive both the ash from an incinerator plus inorganic solids that do not need primary treatment. The second source is the secondary waste from the primary treatment systems. For example, the concentrated aqueous waste discharged from the aqueous waste treatment module will have to be treated by the polymer stabilization module. The secondary waste generation rates can be determined from the mass balance data depicted on the PFDs. Of the four secondary waste treatment and stabilization modules, polymer and grout stabilization and shredding and compaction modules are used for the non-flame and LDR compliance treatment strategies (the shredding module is used to compress and micro-encapsulate the output waste from the thermal desorption module). The vitrification module is used in the vitrification treatment strategy.
- Treatment back-end module.** The waste load for the back-end module is defined by summing the output waste from the secondary treatment and stabilization modules.

Table 29-1. (continued).

There are also some wastes that do not require secondary treatment (e.g., amalgamated waste from the mercury separation module), which must be added to the sum of the output from the secondary treatment and stabilization modules.

29.2.2 Small Generator Facility and Portable Treatment Waste Loads

The fixed small generator treatment facility and the portable treatment trailer concept are useful for installations requiring an overall processing rate of approximately less than 700 ft³/yr (20 m³/yr). The FTEs and cost data in this report are included for estimating a fixed small generator module either in an existing building space or in a new building. The fixed small generator and portable treatment waste loads may be documented in a data sheet similar to that shown in Figure 29-5. As shown, the small generator facility has three categories of modules because all of the front-end and back-end functions are combined into a single module. There are also fewer primary and secondary treatment modules than with a large generator facility because of the expectation that a more limited variety of waste will be treated at a small generator facility.

The processing rate for the small generator modules can be determined the same way as for the large generator modules, above. The portable module capacity is defined by determining the number of treatment campaigns.

29.2.3 Storage and Disposal Waste Loads

Unlike the treatment modules, which use mass feed rates as waste loads, storage and disposal capacities are expressed in volumetric feed rates or as total volumes (i.e., stored, disposal). Figure 29-6 may be used to document the storage and disposal feed rates. As shown, there are four storage and disposal module categories: storage front-end and back-end support, storage, disposal front-end support, and disposal. As with treatment, the existing and new capacities must be defined for each of the four categories.

29.3 Estimating TSD Facility Cost and FTEs

Estimates of FTEs and PLCC for TSD facilities are prepared based on the processing requirements developed in the waste load definition step. The corresponding FTEs and cost for each module are developed by referring to the FTEs and cost-versus-capacity curves and tables given in this report. For existing capacities, operating costs (which consists of O&M and D&D costs) will need to be defined. For new capacity needs, the facility construction and pre-operation estimates must be added to the facility O&M and D&D costs. To obtain total TSD facilities cost, a sum of the cost or FTEs from all TSD modules must be prepared.

29.4 Transportation Costs

Transportation costs can be estimated by defining the total volume of waste to be transported and the distance in each of the potential transport segments (e.g., from generator to

treatment facility, from treatment facility to storage facility, or from storage facility to disposal facility). Once the volumes and milages are defined for each transportation segment, the cost data presented in the "Waste Management Facilities Cost Information for Transportation of Radioactive Materials" report (EGG-EM-10877) can be used to calculate the number of shipments and the associated transportation costs.

Figure 29-1. Layout for integrated treatment facility based on thermal desorption of debris.

Figure 29-2. Layout for thermal (flame) full-capability integrated treatment facility.

MODULES	UNIT	TOTAL CAPACITY	EXISTING CAPACITY	NEW CAPACITY
I. STORAGE FRONT-END & BACK-END SUPPORT				
(1A) STORAGE FRONT-END & BACK-END SUPPORT	M ³ /HR			
II. STORAGE				
(1B) STORAGE	M ³			
III. TREATMENT FRONT-END				
(1C) FRONT-END SUPPORT	KG/HR			
(1D) RECEIVING & INSPECTION	KG/HR			
(1E) OPEN, DUMP, & SORT	KG/HR			
(1F) MAINTENANCE	KG/HR			
II. PRIMARY TREATMENT				
(2) DEBRIS WASHING	KG/HR			
(3) SOIL WASHING	KG/HR			
(4) SLUDGE WASHING	KG/HR			
(5) AQUEOUS WASTE TREATMENT	KG/HR			
(6) DEACTIVATION	KG/HR			
(7) MERCURY SEPARATION	KG/HR			
(8) LEAD RECOVERY	KG/HR			
(9) THERMAL DESORPTION	KG/HR			
(10) ORGANIC-SOLIDS WET-AIR OXIDATION	KG/HR			
(11) SPECIAL PROCESSING	KG/HR			
(12) INCINERATION	KG/HR			
(13) BYPASS PRIMARY (NOT A MODULE)	KG/HR			
III. SECONDARY TREATMENT & STABILIZATION				
(14) GROUT STABILIZATION	KG/HR			
(15) VITRIFICATION	KG/HR			
(16) POLYMER STABILIZATION	KG/HR			
(17) SHREDDING AND COMPACTION	KG/HR			
IV. TREATMENT BACK END				
(18) CERTIFICATION AND SHIPPING	KG/HR			

Figure 29-4. Treatment waste load data sheet for large generator facility.

MODULES	UNIT	TOTAL CAPACITY	EXISTING CAPACITY	NEW CAPACITY (*)	PORTABLE MODULE CAPACITY (**)
I. STORAGE FRONT-END & BACK-END SUPPORT					
(1A) STORAGE FRONT-END & BACK-END SUPPORT	M ³ /HR				
II. STORAGE					
(1B) STORAGE	M ³				
I. TREATMENT FRONT-END & BACK-END					
(1C) FRONT-END & BACK-END SUPPORT	KG/HR				
II. PRIMARY TREATMENT					
(2) PRIMARY BYPASS (NOT A MODULE)	KG/HR				
(3) INCINERATION	KG/HR				
(4) AQUEOUS WASTE TREATMENT	KG/HR				
(5) ORGANIC-SOLIDS WET-AIR OXIDATION	KG/HR				
(6) THERMAL DESORPTION	KG/HR				
(7) LEAD RECOVERY	KG/HR				
(8) MERCURY SEPARATION	KG/HR				
(9) DEACTIVATION	KG/HR				
III. SECONDARY TREATMENT & STABILIZATION					
(10) GROUT STABILIZATION	KG/HR				
(11) POLYMER STABILIZATION	KG/HR				

(*) THIS COLUMN MAY BE FURTHER DIVIDED TO INCLUDE NEW EQUIPMENT IN EXISTING BUILDING OR NEW EQUIPMENT IN NEW BUILDING.
 (**) UNIT IS NUMBER OF CAMPAIGNS

Figure 29-5. Treatment waste load data sheet for small generator facility.

MODULES	UNIT	TOTAL CAPACITY	EXISTING CAPACITY	NEW CAPACITY
I. TREATMENT FRONT-END & BACK-END SUPPORT				
① STORAGE FRONT-END AND BACK-END SUPPORT	M ³ /HR			
II. STORAGE				
② STORAGE	M ³			
III. DISPOSAL FRONT END				
③ DISPOSAL FRONT-END SUPPORT	M ³ /HR			
IV. DISPOSAL				
④ ENGINEERED DISPOSAL	M ³			
⑤ SHALLOW LAND DISPOSAL	M ³			
⑥ SHALLOW LAND DISPOSAL	M ³			
⑦ BORE-HOLE DISPOSAL	M ³			

Figure 29-6. Storage and disposal waste load data sheet.

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