October 1992 • NREL/TP-431-4988C

Data Summary of Municipal Solid Waste Management Alternatives

Volume III: Appendix A—Mass Burn Technologies

SRI International
Menlo Park, California

National Renewable Energy Laboratory
A Division of Midwest Research Institute
Operated for the U.S. Department of Energy
Under Contract No. DE-AC02-83CH10093

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Price: Microfiche A01
Printed Copy A08

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issue of the following publications which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements* and Index (*GRA* and I); *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

NREL/TP-431-4988C • UC Category 249 • DE92016433

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A Division of Midwest Research Institute
Operated for the U.S. Department of Energy
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Prepared under subcontract no: RF-1-1103

October 1992

Report Organization

This report, *Data Summary of Municipal Solid Waste Management Alternatives*, comprises 12 separately bound volumes. Volume I contains the report text. Volume II contains supporting exhibits. Volumes III through X are appendices, each addressing a specific MSW management technology. Volumes XI and XII contain project bibliographies. The document control page at the back of this volume contains contacts for obtaining copies of the other volumes.

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APPENDIX A.

MASS BURN TECHNOLOGIES

This appendix on Mass Bum Technologies is the first in a series designed to identify, describe and assess the suitability of several currently or potentially available generic technologies for the management of municipal solid waste (MSW). These appendices, which cover eight core thermoconversion, bioconversion and recycling technologies, reflect public domain information gathered from many sources. Representative sources include: professional journal articles, conference proceedings, selected municipality solid waste management plans and subscription technology data bases. The information presented is intended to serve as background information that will facilitate the preparation of the technoeconomic and life cycle mass, energy and environmental analyses that are being developed for each of the technologies.

A.1 INTRODUCTION/OVERVIEW

Mass burn has been and continues to be the predominant technology in Europe for the management of MSW. In the United States, the majority of the existing waste-to-energy projects utilize this technology and nearly 90 percent of all currently planned facilities have selected mass bum systems (387).

Mass burning generally refers to the direct feeding and combustion of municipal solid waste in a furnace without any significant waste preprocessing. The only materials typically removed from the waste stream prior to combustion are large bulky objects and potentially hazardous or undesirable wastes. The technology has evolved over the last 100 or so years from simple incineration to the most highly developed and commercially proven process available for both reducing the volume of MSW and for recovering energy in the forms of steam and electricity. In general, mass bum plants are considered to operate reliably with high availability (025).

Several system design, operations, and performance evaluation projects have been undertaken to characterize the economics, energy, and environmental aspects of MSW mass burning technology (e.g., 354, 402, 471, 472, 799). A number of studies have also been conducted to address health risk concerns, and include comparisons with the other MSW management approaches such as landfills (e.g., 298, 373,439, 537). Improvements in mass bum technology continue to be made in such areas as combustor design, ash residue handling, pollution control equipment, and continuous emissions monitoring systems (402).

Recently planned facilities such as those in Monmouth County, New Jersey and Gaston County, North Carolina plan to incorporate front-end processing systems that are expected to significantly improve facility operability as well as enable the recovery of recyclables from MSW. With this integrated approach, materials that could adversely affect combustion (aluminum and glass) or cause potentially serious emissions problems (household batteries) when burned, are removed from the MSW prior to combustion.

The types of mass burn systems are defined below followed by the current status of facilities employing this technology. Section A-2 presents technology descriptions, followed by economic data (capital and O&M cost data) in Section A-3, energy production and usage information in Section A-4, and a summary of environmental releases and impacts data in Section A-5. It should be noted that much of the actual data reported in the data tables were derived from the 1991 Resource Recovery Yearbook (387) and data base developed by Governmental Advisory Associates, Inc. Selected groupings of data and analyses were developed from the overall data base specifically for this study.

A.1.1 Types of Mass Burn Systems

MWC facilities that utilize the mass burn technology can be classified according to the nature of construction; i.e., field erected or modular shop fabricated (472). Field-erected systems are usually medium- to large-scale (200 to 3000 TPD) waterwall or refractory-lined furnaces that combust MSW under excess air conditions while modular systems are usually small-scale (up to 300 TPD) systems comprised of predesigned modules that are manufactured at a factory and assembled onsite. Modular systems also feature separate primary and secondary combustion chambers and separate heat recovery boilers (484).

The distinction between field-erected and shop-fabricated systems has become less clear in recent years as shop-fabricated installations have become larger. Many shop-fabricated systems have adopted features, such as moving grates and pit and crane systems, that were once limited to field-erected systems. In addition, large shop-fabricated system installations may require more on-site assembly and more substantial foundations and buildings due to the large size of their component modules. At the same time, modular construction techniques are beginning to be used to reduce the costs of smaller field-erected systems (484). For waterwall systems, the modularization of components can reduce the amount of field construction and thus reduce or slow the escalation of facility costs. This would enable waterwall systems to be more cost competitive with shop-fabricated incinerator systems (574).

A.1.1.1 Field-Erected Facilities

Mass burning of municipal solid waste has been practiced in the U.S. since 1885 when an incinerator was constructed on Governors Island, New York (574). This facility served only as a means of volume reduction without any consideration given to energy recovery. The first facility that recovered energy from the combustion of municipal solid waste began operation in 1896 in Hamburg, Germany. Two years later, the first U.S. energy recovery from MSW facility began operation in New York City. The abundance of inexpensive alternative fuels restricted widespread development of MSW-fired energy recovery systems in the U.S.

In the 1930s, facilities in Atlanta, Chicago, Miami, and Louisville produced steam for space heating and industrial use. Also, hot water heating coils were used in the secondary chambers of some refractory lined furnaces (271). Up until the early 1940s, all U.S. mass burn incinerators were batch systems. In 1943, a continuous feed system designed by the Danish firm Volund began operations in Atlanta, Georgia (574). In the mid 1950s, a breakthrough was achieved in continuous gravity feeding at the Betts Avenue incinerator plant in New York City (271). This technology breakthrough led to the development of the first waterwall continuous feed incinerator in Berne, Switzerland. European firms provided most of the subsequent technology development, due to the lack of interest in waste incineration in the U.S. in the 1960s. German and Swiss firms such as Joseph Martin Gmbh, Deutsche Babcock Anlagen, and Von Roll contributed significantly to the development of continuous mass burning energy recovery systems.

The first U.S. waterwall unit was installed at the Norfolk, Virginia Naval Shipyard in 1967. Designed and constructed by Foster-Wheeler, a U.S. firm, the system was procured, owned, and operated by the government using a relatively specialized waste stream. Thus, it was viewed as having limited relevance in the municipal market (574).

European waterwall systems were introduced into the U.S. in 1967 when Joseph Martin Gmbh teamed with the Ovitron Corporation to bid a four unit, 1600 TPD facility in Chicago (started up in 1970). In 1969, Von Roll formed a teaming arrangement with Rust Engineering, an American firm. Other European and Japanese firms followed, establishing themselves in the U.S. market.

The enactment of the Clean Air Act of 1970 caused nearly 50 percent of the existing conventional MSW incinerators to close due to the prohibitive cost of installing the air pollution control equipment necessary for compliance. Waterwall systems presented an advantage which aided in their penetrating the market.

Because the watertubes help cool the walls of the combustion chamber, less combustion air is required with waterwall systems than with refractory lined units. Since air pollution control equipment size and cost are directly related to the volume of air to be treated, the reduction in combustion air was an important consideration (574). The shortage of landfill space aided in spurring the development of the industry during the 1980s.

A.1.1.2 Modular Facilities

Modular incinerators were initially developed in the late 1950s to address the small scale market such as apartment buildings, hospitals, and commercial centers. Smoke from these types of uncontrolled incinerators was a major problem and concern. Through the 1960s, modular incinerators were small batch fed, refractory-lined, two chamber, controlled air units with capacities in the range of 100 to 800 pounds per hour. More than 4,000 such systems without energy recovery were constructed in the U.S. from the late 1960s through the mid 1970s (574).

Competition among modular system vendors led to technology advancements with the most significant improvement being the development of a continuous ash removal system in 1973. This improvement allowed modular facilities to operate 24 hours per day. The first modular MSW system recovering energy began operation in 1975 in Siloam Springs, Arkansas (eventually closed and dismantled). In 1977, Consumat, the equipment vendor, began operation of the first continuously operating modular MSW incinerator in North Little Rock, Arkansas. This was the first full-time, small-scale modular system to use MSW effectively as an energy resource as well as to reduce the quantity of waste for disposal. The experience gained from this project led other communities to solicit system vendors with both equipment supply and operations capabilities for their projects.

A.1.2 Status

Mass burn facilities have steadily increased their share of the municipal waste combustor market. Table A-1 lists 1990 data for field-erected and modular facilities as a percentage of the total number of existing and advanced planned MWCs (387). This table clearly shows the increased interest in field-erected mass burn facilities. These facilities represent nearly double the percentage of the total number of planned MWCs compared to the total number of existing MWCs.

TABLE A-1. MASS BURN PERCENTAGE OF TOTAL MWC MARKET(387)

	Existing	Planned
Field-Erected	39%	79%
Modular	35%	8%
Total Mass Burn	74%	87%

Table A-2 lists the 158 existing and advanced planned U.S. mass burn facilities (387). The facilities are grouped by type as follows: refractory - 5, waterwall - 75, rotary combustor - 20, modular - 54, and sludge co-disposal - 4. As of 1990, there were 97 operational mass-burn MWCs that recovered energy in the U.S. (387), compared to approximately 500 mass-burn facilities operating worldwide (799).

TABLE A-2. EXISTING AND ADVANCED PLANNED U.S. MASS BURN FACILITIES 1990 DATA (387)

NAME	CITY	ST	OPER YEAR	DESIGN TPD	OWNER	OPERATOR
					PROCESS: MB - Refractory	
Betts Avenue	Queens	NY	64	1000	City of New York	City of New York
City of Waukesha (Old Plant)	Waukesha	WI	79	175	City of Waukesha	City of Waukesha
Davis County	Layton	UT	88	400	Davis Co. S.W.M. & Energy Recovery Dist.	Davis Energy Systems (Katy-Seghers)
McKay Bay Refuse-To-Energy Facility	Tampa	FL	85	1000	City of Tampa	Wheelabrator Mackay Bay, Inc.
Muscoda	Muscoda	WI	89	125	Village of Muscoda	Muscoda Solid Waste Commission
					PROCESS: MB - Waterwall	
Albany (American Ref-Fuel)	Bethlehem	NY		1500	American Ref-Fuel, Inc.	American Ref-Fuel, Inc.
Alexandria/Arlington R.R. Facility	Alexandria	VA	88	975	Ogden Martin Systems of Alex./Arlington	Ogden Martin Systems of Alex./Arlington
Babylon Resource Recovery Project	Babylon	NY	89	750	Babylon Industrial Development Authority	Ogden Martin Systems of Babylon, Inc.
Bergen County	Ridgefield	NJ		3000	American Ref-Fuel, Inc.	American Ref-Fuel, Inc.
Bridgeport RESCO	Bridgeport	CT	88	2250	Wheelabrator Technologies, Inc./CRRA	Wheelabrator Technologies, Inc.
Bristol	Bristol	CT	88	650	Ogden Martin Systems of Bristol	Ogden Martin Systems of Bristol
Brooklyn Navy Yard	Brooklyn	NY		3000	Wheelabrator Technologies, Inc.	Wheelabrator Technologies, Inc.
Broome County	Kirkwood	NY		571	Broome Co. R.R. Authority/Foster Wheeler	Foster Wheeler Power Systems, Inc.
Broward County (Northern Facility)	Pompano Beach	FL		2250	Wheelabrator Technologies, Inc.	Wheelabrator Technologies, Inc.
Broward County (Southern Facility)	Broward County	FL		2250	Wheelabrator Technologies, Inc.	Wheelabrator Technologies, Inc.
Camden County (Foster Wheeler)	Camden	NJ		1050	Camden County Energy Recovery Associates	Camden County Energy Recovery Associates
Camden County (Pennsauken)	Pennsauken	NJ		500	Pennsauken Solid Waste Mgmt. Authority	Ogden Martin Systems of Pennsauken, Inc.
Central Mass. Resource Recovery Project	Millbury	MA	88	1500	Ford Motor Credit Corporation	Wheelabrator Technologies, Inc.
Charleston County	North Charleston	SC	89	644	AT&T Credit Corporation	Foster Wheeler Res. Recovery-Charleston
City of Commerce	Commerce	CA	87	400	Commerce Refuse-To-Energy Authority	L.A. County Sanitation Districts
Concord Regional S.W. Recovery Facility	Penacook	NH	89	500	Wheelabrator Technologies, Inc.	Wheelabrator Technologies, Inc.
Dakota County	Rosemount/Empire Twp.	MN		800	Dakota County	A.B.B. Resource Recovery Systems (C.E.)
Davidson County	Madison (Nashville)	TN		210	Third National Bank	Enerco Systems, Inc.
East Bridgewater (American Ref-Fuel)	East Bridgewater	MA		1500	American Ref-Fuel, Inc.	American Ref-Fuel, Inc.
Eastern-Central Project	Cromwell (or Portland)	CT		550	Ogden Projects, Inc.	Ogden Projects, Inc.
Essex County	Newark	NJ		2277	Amer. Ref-Fuel/Port Authority of NY & NJ	American Ref-Fuel, Inc.
Fairfax County	Lorton	VA	90	3000	Ogden Martin Systems of Fairfax, Inc.	Ogden Martin Systems of Fairfax, Inc.
Falls Township (Wheelabrator)	Falls Township	PA		2250	Wheelabrator Technologies, Inc.	Wheelabrator Technologies, Inc.
Glendon	Glendon	PA		500	Glendon Energy Company	Delmarva Operating Services
Gloucester County	West Deptford Township	NJ	90	575	Wheelabrator Technologies, Inc.	Wheelabrator Technologies, Inc.
Hampton/NASA Project Recoup	Hampton	VA	80	200	NASA/City of Hampton	City of Hampton
Harrisburg	Harrisburg	PA	72	720	City of Harrisburg	City of Harrisburg
Haverhill (Mass Burn)	Haverhill	MA	89	1650	Ogden Martin Systems of Haverhill, Inc.	Ogden Martin Systems of Haverhill, Inc.
Hempstead (American Ref-Fuel)	Westbury	NY	90	2505	American Ref-Fuel, Inc.	American Ref-Fuel, Inc.
Hennepin County (Blount)	Minneapolis	MN	90	1200	General Electric Credit Corporation	Blount Energy Resources Corporation
Hillsborough County S.W.E.R. Facility	Brandon	FL	87	1200	Hillsborough County	Ogden Martin Systems of Hillsborough
Hudson County	Kearny	NJ		1500	Ogden Martin Systems of Hudson County	Ogden Martin Systems of Hudson County
Huntington	East Northport	NY		750	Ogden Martin Systems of Huntington	Ogden Martin Systems of Huntington
Jackson County/Southern MI State Prison	Jackson	MI	87	200	Jackson County	Metcalf & Eddy, Inc.

TABLE A-2. EXISTING AND ADVANCED PLANNED U.S. MASS BURN FACILITIES 1990 DATA (Cont)

NAME	CITY	ST	OPER YEAR	DESIGN TPD	OWNER	OPERATOR
Johnston (Central Landfill)	Johnston	RI		750	RI Solid Waste Management Corporation	Ogden Martin Systems of Johnston, Inc.
Kent County	Grand Rapids	MI	90	625	Kent County	Ogden Martin Systems of Kent, Inc.
Lake County	Okahumpka	FL		528	Ogden Martin Systems of Lake County	Ogden Martin Systems of Lake County
Lancaster County	Conoy Township	PA		1200	Lancaster County S.W. Mgmt. Authority	Ogden Martin Systems of Lancaster Co.
Lee County	Lee County	FL		1800	Lee County	Ogden Martin Systems of Lee, Inc.
Lisbon	Lisbon	CT		500	(Public Authority - TBD)	Wheelabrator Technologies, Inc.
Marion County Solid W-T-E Facility	Brooks	OR	86	550	Ogden Martin Systems of Marion County	Ogden Martin Systems of Marion County
Montgomery County	Dickerson	MD		1800	N.E. Maryland Waste Disposal Authority	Ogden Martin Systems of Montgomery Co.
Montgomery County	Plymouth Township	PA		1200	Montenay Power Corporation	Montenay Power Corporation
Morris County	Roxbury Township	NJ		1340	Morris County	Foster Wheeler Power Systems, Inc.
Nashville Thermal Transfer Corp. (NTTC)	Nashville	TN	74	1120	Metropolitan Government of Nashville	Nashville Thermal Transfer Corporation
New Hampshire/Vermont S.W. Project	Claremont	NH	87	200	Wheelabrator Technologies, Inc.	Wheelabrator Technologies, Inc.
Norfolk Naval Station	Norfolk	VA	67	360	U.S. Navy	Public Works Ctr., Norfolk Naval Station
North Andover	North Andover	MA	85	1500	Wheelabrator Technologies, Inc.	Mass. Refusetech, Inc. (Wheelabrator)
North Hempstead	Port Washington	NY		990	North Hempstead S.W. Mgmt. Authority	Babcock & Wilcox
Northwest Waste-To-Energy Facility	Chicago	IL	70	1600	City of Chicago	City of Chicago
Oklahoma City	Oklahoma City	OK	85	820	CMI Energy Conversion Systems	Zurn Industries (boiler)/CMI (front-end)
Olmstead County	Rochester	MN	87	200	Olmstead County	Olmstead County
Onondaga County	Onondaga	NY		990	Ogden Martin Systems of Onondaga County	Ogden Martin Systems of Onondaga County
Oyster Bay	Old Bethpage	NY		1000	American Ref-Fuel, Inc.	American Ref-Fuel, Inc.
Pasco County	Springhill	FL		1050	Pasco County	Ogden Martin Systems of Pasco County
Passaic County	Passaic	NJ		1434	Foster Wheeler Passaic, Inc.	Foster Wheeler Passaic, Inc.
Pinellas County (Wheelabrator)	Pinellas County	FL	83	3150	Pinellas County	Wheelabrator Technologies, Inc.
Portland	Portland	ME	88	500	Regional Waste Systems (20 communities)	Regional Waste Systems, Inc.
Preston (Southeastern Connecticut)	Preston	CT		600	American Ref-Fuel, Inc./CRRA	American Ref-Fuel, Inc.
Quonset Point	North Kingston	RI		710	RI Solid Waste Management Corporation	Blount Energy Resources Corporation
S.E. Resource Recovery Facility (SERRF)	Long Beach	CA	88	1380	S.E. Resource Recovery Facility Auth.	Montenay Pacific Power Corporation
S.W. Resource Recovery Facility (BRESCO)	Baltimore	MD	85	2250	Baltimore Refuse Energy Systems Company	Wheelabrator Technologies, Inc.
Saugus	Saugus	MA	75	1500	RESCO (Wheelabrator Technologies, Inc.)	Wheelabrator Technologies, Inc.
Savannah	Savannah	GA	87	500	Katy-Seghers, Inc.	Katy-Seghers, Inc.
Spokane	Spokane	WA		800	City of Spokane	Wheelabrator Technologies, Inc.
Stanislaus County Res. Recovery Facility	Crows Landing	CA	89	800	Ogden Martin Systems of Stanilaus County	Ogden Martin Systems of Stanilaus County
Sturgis	Sturgis	MI		560	Something of Value, Inc.	Something of Value, Inc.
Union County	Rahway	NJ		1440	Union County Utilities Authority	Ogden Martin Systems of Union County
University City Res. Recovery Facility	Charlotte	NC	89	235	Mecklenburg County	MK Environmental
Walter B. Hall Res. Recovery Facility	Tulsa	OK	86	1125	Manu. Hanover Trust/CIT Group/Bank of OK	Ogden Martin Systems of Tulsa, Inc.
Warren County	Oxford Township	NJ	88	400	Blount Energy Resources Corporation	Blount Energy Resources Corporation
Washington/Warren Counties	Hudson Falls	NY		400	Adirondack Resource Recovery Associates	Adirondack Resource Recovery Associates
Wayne County	Goldsboro	NC		300	Enerco Systems, Inc.	Enerco Systems, Inc.
West Pottsgrove Recycling/R.R. Facility	West Pottsgrove Twp.	PA		1500	Wheelabrator Pottsgrove, Inc.	Wheelabrator Pottsgrove, Inc.
Westchester	Peekskill	NY	84	2250	Wheelabrator Technologies, Inc.	Wheelabrator Technologies, Inc.

TABLE A-2. EXISTING AND ADVANCED PLANNED U.S. MASS BURN FACILITIES 1990 DATA (Cont)

NAME	CITY	ST	OPER YEAR	DESIGN TPD	OWNER	OPERATOR
			PROCESS: MB - Modular			
Agawam/Springfield	Agawam	MA	88	360	Fluor R.R. of Mass. Limited Partnership	Springfield Resource Recovery (Fluor)
Barron County	Almena	WI	86	80	Barron County	Consumat Systems, Inc.
Batesville	Batesville	AR	81	100	City of Batesville	City of Batesville
Bellingham	Bellingham	WA	86	100	Recomp (formerly Thermal Reduction Co.)	Recomp
Beto 1 Unit (Texas Dept. of Corrections)	Palestine	TX	80	25	State of Texas	State of Texas
Cassia County	Heyburn	ID	82	50	Cassia County	Cassia County
Cattaraugus County R-T-E Facility	Cuba	NY	83	112	Cattaraugus County	Kinetics Technology, Inc.
Center	Center	TX	86	40	City of Center	City of Center
City of Carthage/Panola County	Carthage	TX	86	40	City of Carthage/Panola County	City of Carthage
Cleburne	Cleburne	TX	86	115	City of Cleburne	City of Cleburne
Collegeville	Collegeville	MN	81	50	St. Johns University	St. Johns University
Dyersburg	Dyersburg	TN	80	100	City of Dyersburg	City of Dyersburg
Eau Claire County	Seymour Township	WI		150	ENSCO, Inc. (Envir. Systems Company)	Consumat Systems, Inc.
Elk River R.R. Authority (TERRA)	Tullahoma	TN		200	Elk River Resource Recovery Authority	Montenay International
Energy Gen. Facility at Pigeon Point	Newcastle	DE	87	600	United Associates of DE/GE Credit Corp.	United Power Servicea, Inc.
Fergus Falls	Fergus Falls	MN	88	94	City of Fergus Falls	City of Fergus Falls
Fort Dix	Wrightstown	NJ	86	80	U.S. Army	North American Resource Recovery Corp.
Fort Leonard Wood	Fort Leonard Wood	MO	82	75	U.S. Army	Harbert International
Fort Lewis (U.S. Army)	Fort Lewis	WA		120	U.S. Army	U.S. Army, Directorate of Eng. & Housing
Gatesville (Texas Dept. of Corrections)	Gatesville	TX	80	13	State of Texas	State of Texas
Hampton	Hampton	SC	85	270	Southland Exchange, Joint Venture	Southland Exchange, Joint Venture
Harford County	Edgewood	MD	88	360	Waste Energy Partners Ltd. Partnership	Consumat Systems, Inc.
Harrisonburg	Harrisonburg	VA	82	100	City of Harrisonburg	City of Harrisonburg
Key West	Key West	FL	86	150	Montenay KW Corporation	Montenay KW Corporation
Lamprey Regional Solid Waste Cooperative	Durham	NH	80	108	Lamprey Regional Solid Waste Cooperative	Lamprey Regional Solid Waste Cooperative
Lassen Community College	Susanville	CA	84	100	Susanville Resources (DeCom)	Susanville Resources (DeCom)
Lewis County	Hohenwald	TN	88	50	Hohenwald Partners	Enerco Systems, Inc.
Long Beach	Long Beach	NY	88	200	Catalyst W-T-E Corp. of Long Beach	Montenay Power Corporation
Manchester	Manchester	NH		560	City of Manchester	Intercon
Mayport Naval Station	Mayport	FL	79	50	U.S. Navy (Mayport Naval Station)	International Research & Development
Miami	Miami	OK	82	108	City of Miami	Consumat Systems, Inc.
Miami International Airport	Miami	FL	83	60	Dade County Aviation Department	Dade County Aviation Department
Muskegon County	Muskegon	MI		180	Muskegon County	Muskegon County
New Hanover County	Wilmington	NC	84	100	New Hanover County	New Hanover County
North Slope Borough/Prudhoe Bay	Deadhorse	AK	81	100	North Slope Borough	North Slope Borough
Oneida County	Rome	NY	85	200	Oneida County	Oneida/Herkimer S.W. Mgmt. Authority
Osceola	Osceola	AR	80	50	City of Osceola	City of Osceola
Oswego County	Volney	NY	86	200	Oswego County	Oswego County
Park County	Livingston	MT	82	75	Park County	Park County
Pascagoula	Moss Point	MS	85	150	City of Pascagoula	CFB, Inc.
Perham	Perham	MN	86	116	Quadrant Company (Otter Tail Power Co.)	Quadrant Company
Pittsfield	Pittsfield	MA	81	240	Vicon Recovery Associates, Inc.	Vicon Recovery Associates, Inc.
Polk County	Fosston	MN	88	80	Polk County	Polk County
Pope-Douglas W-T-E Facility	Alexandria	MN	87	80	Pope-Douglas Counties Joint S.W. Board	Pope-Douglas Counties Joint S.W. Board
Red Wing	Red Wing	MN	82	72	City of Red Wing	City of Red Wing

TABLE A-2. EXISTING AND ADVANCED PLANNED U.S. MASS BURN FACILITIES 1990 DATA (Cont)

NAME	CITY	ST	OPER YEAR	DESIGN TPD	OWNER	OPERATOR
Richard Asphalt	Savage	MN	82	57	Richards Asphalt Company	Richards Asphalt Company
Rutland	Rutland	VT	88	240	Vermont Integrated Waste Solutions	Meridian Group
Salem	Salem	VA	78	100	City of Salem	City of Salem
St. Croix County	New Richmond	WI	89	115	American Res. Recovery Ltd. Partnership	American Res. Recov. General Partnership
Tuscaloosa Energy Recovery Facility	Tuscaloosa	AL	84	300	Tuscaloosa Solid Waste Disposal Auth.	Consumat Systems, Inc.
Wallingford	Wallingford	CT	89	420	Ogden Martin Systems of Wallingford/CRRA	Ogden Martin Systems of Wallingford
Waxahachie	Waxahachie	TX	82	50	City of Waxahachie	City of Waxahachie
Westmoreland County	Hempfield Township	PA	88	50	Westmoreland County	Westmoreland County
Windham	Windham	CT	81	108	Town of Windham	Town of Windham

PROCESS: MB - Rotary Combustor

NAME	CITY	ST	OPER YEAR	DESIGN TPD	OWNER	OPERATOR
Auburn (New Plant)	Auburn	ME		200	Mid-Maine Waste Action Authority	American Energy Corporation
Delaware County Regional R.R. Project	Chester	PA		2688	Delaware County Resource Mgmt. Inc.	Westinghouse Resource Energy Systems
Dutchess County	Poughkeepsie	NY	88	506	Dutchess County Res. Recovery Agency	Dutchess Resource Mgmt. (Westinghouse)
Falls Township (Technochem)	Falls Township	PA		70	Technochem, Inc.	Technochem, Inc.
Galax	Galax	VA	86	56	City of Galax	City of Galax
Gaston County/Westinghouse R.R. Center	High Shoals	NC		440	Gaston County	Westinghouse Resource Energy Systems
MacArthur Energy Recovery Facility	Islip	NY	89	518	Islip Resource Recovery Agency	Montenay Islip, Inc.
Mercer County	Hamilton Township	NJ		975	Mercer County Improvement Authority	Westinghouse-Mercer Waste Mgmt., Inc.
Monmouth County	Tinton Falls	NJ		1700	Monmouth County	Westinghouse Resource Energy Systems
Monroe County	Bloomington	IN		500	Westinghouse Electric Corporation	Westinghouse Electric Corporation
Montgomery County (North)	Dayton	OH	88	300	Montgomery County	Montgomery County
Montgomery County (South)	Dayton	OH		900	Montgomery County	Montgomery County
Oakland County	Auburn Hills	MI		2000	Oakland County	Westinghouse Resource Energy Systems
San Juan Resource Recovery Facility	San Juan	PR		1040	(Third Party Leasee - TBD)	San Juan Resource Mgmt. (Wstinghouse)
Sangamon County	Illiopolis	IL		450	Kirby-Coffman, Inc.	Laurent Bouillet/Kirby-Coffman
Skagit County	Mount Vernon	WA	88	178	Skagit County	Skagit County
Sumner County	Gallatin	TN	81	200	Resource Authority in Sumner County	Resource Authority in Sumner County
Waukesha County (New Plant)	Waukesha	WI		600	Waukesha County	Westinghouse Resource Energy Systems
Westinghouse/Bay Resource Mgmt. Center	Panama City	FL	87	510	Ford Motor Credit Corporation	Westinghouse Resource Energy Systems
York County	Manchester Township	PA	89	1344	York Co. Solid Waste & Refuse Authority	York Res. Energy Systems (Westinghouse)

PROCESS: MB - Sludge Co-Disposal

NAME	CITY	ST	OPER YEAR	DESIGN TPD	OWNER	OPERATOR
Glen Cove	Glen Cove	NY	83	250	City of Glen Cove	MMB Energy Glen Cove Corp. (Montenay)
Huntsville	Huntsville	AL	90	690	Huntsville Solid Waste Disposal Auth.	Ogden Martin Systems of Huntsville
Indianapolis Resource Recovery Facility	Indianapolis	IN	88	2362	Ogden Martin Systems of Indianapolis	Ogden Martin Systems of Indianapolis
Sitka	Sitka	AK	85	24	City & Borough of Sitka	Sheldon Jackson College

A.2 TECHNOLOGY DESCRIPTION

Figure A-1 shows a generic flow diagram for a mass burn facility (799). Both field-erected and modular systems have the same general process subsystems -- waste storage and feed system, grate system, combustion area and boiler, energy recovery, electricity generation, air pollution control, and ash handling. A comparison of these features for field-erected and shop-fabricated mass burn systems is presented in Table A-3.

A.2.1 Field-Erected Systems

Most large mass burn systems utilize a pit and crane system for MSW storage and feed (275, 799). In this arrangement, large overhead cranes move MSW from the storage pit to the furnace charging hoppers. The crane-feed system allows for some mixing of the MSW due to the action of the crane. Disadvantages of the pit and crane system are the "last in, first out" operating scheme, higher capital costs than the tipping floor method, and the difficulty in previewing or sorting the waste prior to feeding (799). A backup crane is normally provided, since there is no other means of feeding MSW into the system if the crane is inoperable. The charging hoppers typically discharge into the furnace by gravity, although many systems include a cycling ram at the furnace opening to control the feed rate. A minimum pit storage capacity of 3 days is recommended to ensure adequate feed material for a 3-day holiday weekend (799).

All successful field erected mass burn plants have either a moving grate in one or several parallel planes, or the less common rotary kiln type of geometry (799). The typical mass burn grate is constructed of several sections which can be horizontal but are usually slightly inclined. MSW is moved along the grate by the combined action of moving grate elements and gravity. Often steps are used along the grate so that the waste tumbles as it passes, exposing new combustibles to the oxidizing conditions of the furnace, thus improving the material burnout. The multiple grate sections, each usually with its own separate undergrate air system, are the initial grate, often called the drying grate, the burning grate, and the burnout or finishing grate, which discharges the bottom ash usually to a wet quench pit (303). Reciprocating grates are the most frequently used in field erected mass burn units (799).

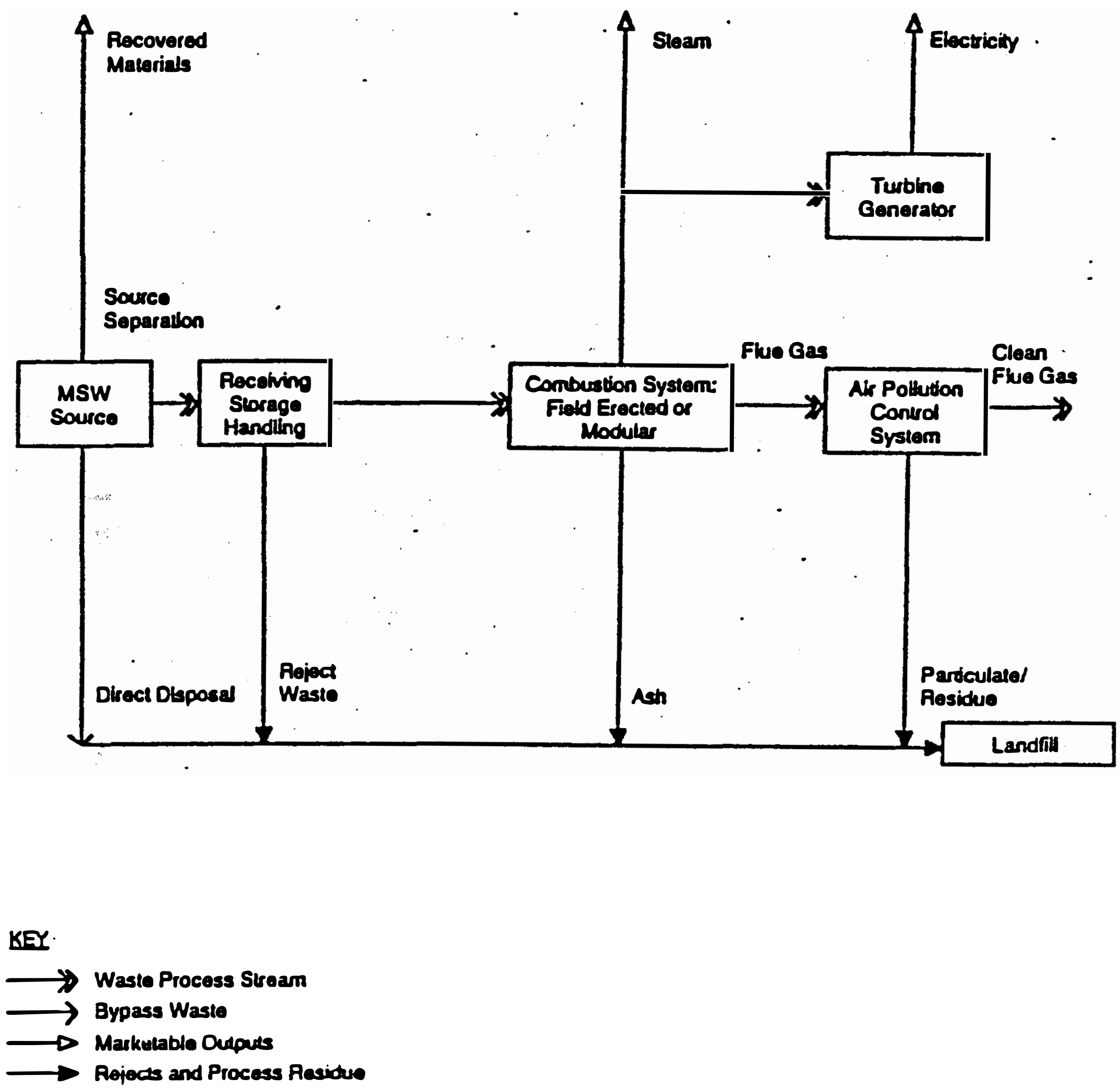


Figure A-1. Mass Burn Facility -- Generic Flow Diagram (799)

TABLE A-3. COMPARISON OF THE CHARACTERISTICS OF FIELD-ERECTED AND MODULAR MASS BURN SYSTEMS (484)

PROCESS FEATURES	FIELD ERECTED SYSTEMS	MODULAR SYSTEMS
Waste Storage and Handling	Pit and Crane	Tipping Floor with Front End Loaders
Waste Feeding	Hopper with Chute, Gravity fed	Hopper with Horizontal Hydraulic Charging Ram
Combustion	Single Combustion Chamber	Separate Primary and Secondary
	Excess Air	Starved Air in Primary Chamber; Excess Air in Secondary
	Moving Grates	Step-hearth with Hydraulic Transfer Rams
Energy Recovery	Waterwall (integral) Boiler or Water-tube Waste-heat Boiler	Water-tube or Fire-tube Waste-heat Boiler
Ash Handling	Ash Pit with Conveyor or Quench Tank with Drag-chain	Ash Pit with Conveyor or Quench Tank with Drag-chain
Air Pollution Control	Electrostatic Precipitator or Baghouse with Scrubber	Either no APC or the Same Types as Field Erected System

The existing and planned field erected mass burn facilities are listed by grate manufacturer in Attachment 1 to this appendix. The major grate manufacturers are Martin of Germany, Von Roll of Switzerland, and Detroit Stoker of the U.S. Other manufacturers such as VKW, are major suppliers in the European market.

The Martin grate, developed in 1959, has an 18 degree incline, with a reverse action, feeding burning waste underneath freshly fed material to dry it (277). The Von Roll grate was developed in the mid 1960s and has an 18 degree incline, with steel grate blocks giving alternate fixed and moving sections. The two leading field erected mass burn facility system vendors, Ogden Martin and Wheelabrator Environmental Systems, use predominantly Martin and Von Roll grates, respectively. The Von Roll grate technology is also used at two Canadian facilities in Montreal and by Quebec City. The Detroit Stoker reciprocating grate (Figure A-2) has most recently been used in the Commerce, California 400 TPD facility.

Other examples of moving grates include: the Dusseldorf roller grate (Figure A-3), developed by Deutsche Babcock Anlagen in 1960 (277), and distinguished by a design that consists of a series of rollers that tumble the waste at a controlled rate (235); and the DeBartolomeis S.p.A. grate that has alternating fixed and moving stepped reciprocating bars which move at any angle between horizontal and 21 degrees (277).

The other general variety of mass burn grate is the rotary kiln. The refractory-lined rotary kiln, originally developed by Volund, is now available from a few different manufacturers in several configurations. The Westinghouse/O'Connor combustor is the only waterwall version of the rotary kiln; shown in Figure A-4 (799).

The combustion process involves the drying, devolatilization, and ignition of MSW on the grate inside the combustion area in a section referred to as the furnace (402). Controlled air combustion and excess air combustion are the two most prevalent types of combustion methods. Controlled air separates the ignition step by combusting volatilized gases in a chamber separate from where the MSW is dried, volatilized, and turned to char. Excess air combustion completes drying, devolatilization, and ignition in the same chamber, each step of which is usually viewed as a stage on the moving grate on which the waste rests (472). Gas temperatures in the furnace zone of a mass burn facility typically exceed 1,800 degrees F (402).

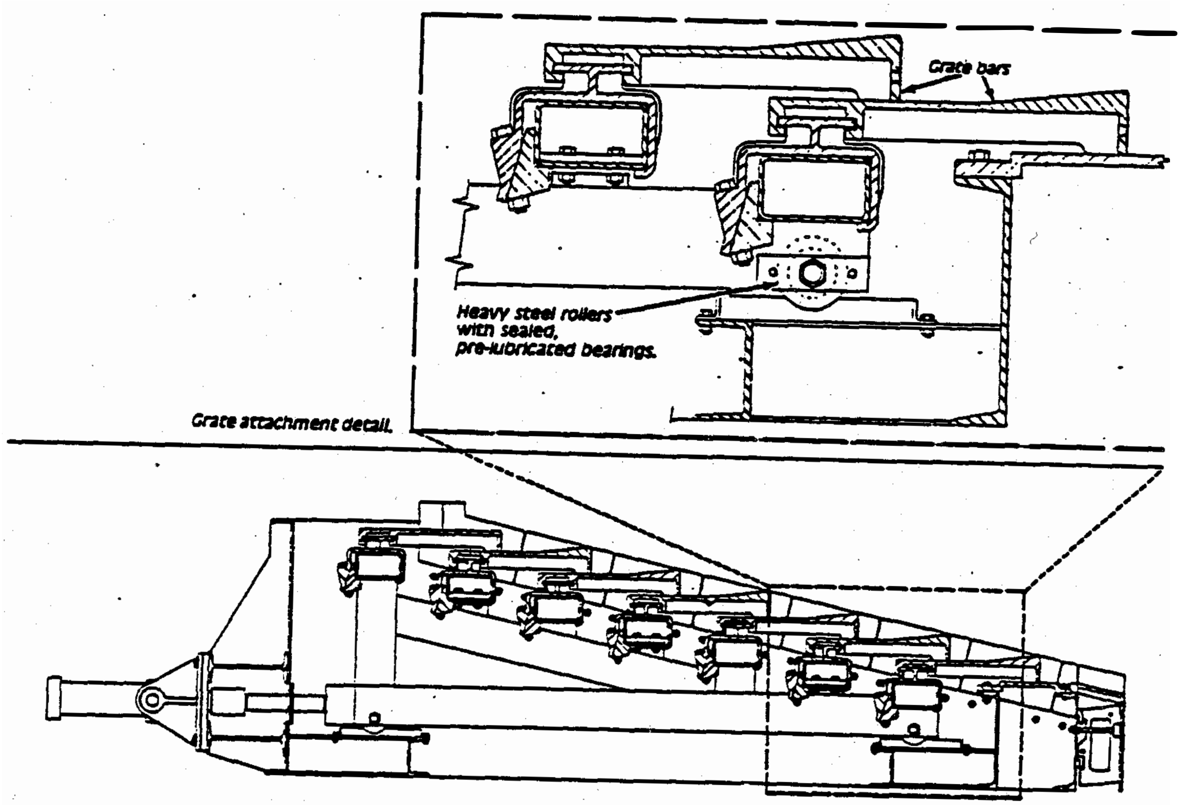


Figure A-2. Detroit Stoker Reciprocating Grate Stoker (472)

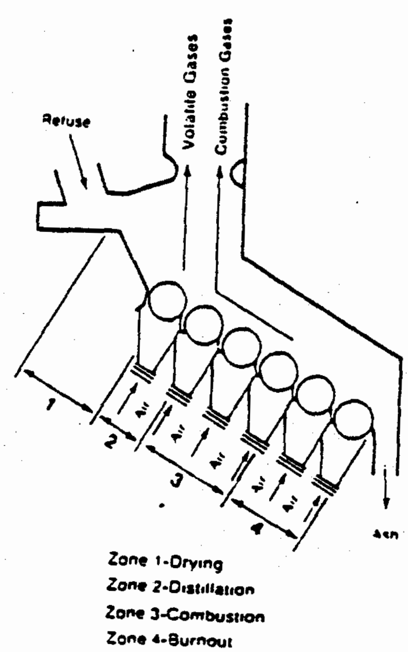


Figure A-3. Deutsche-Babcock Dusseldorf Roller Grate (472)

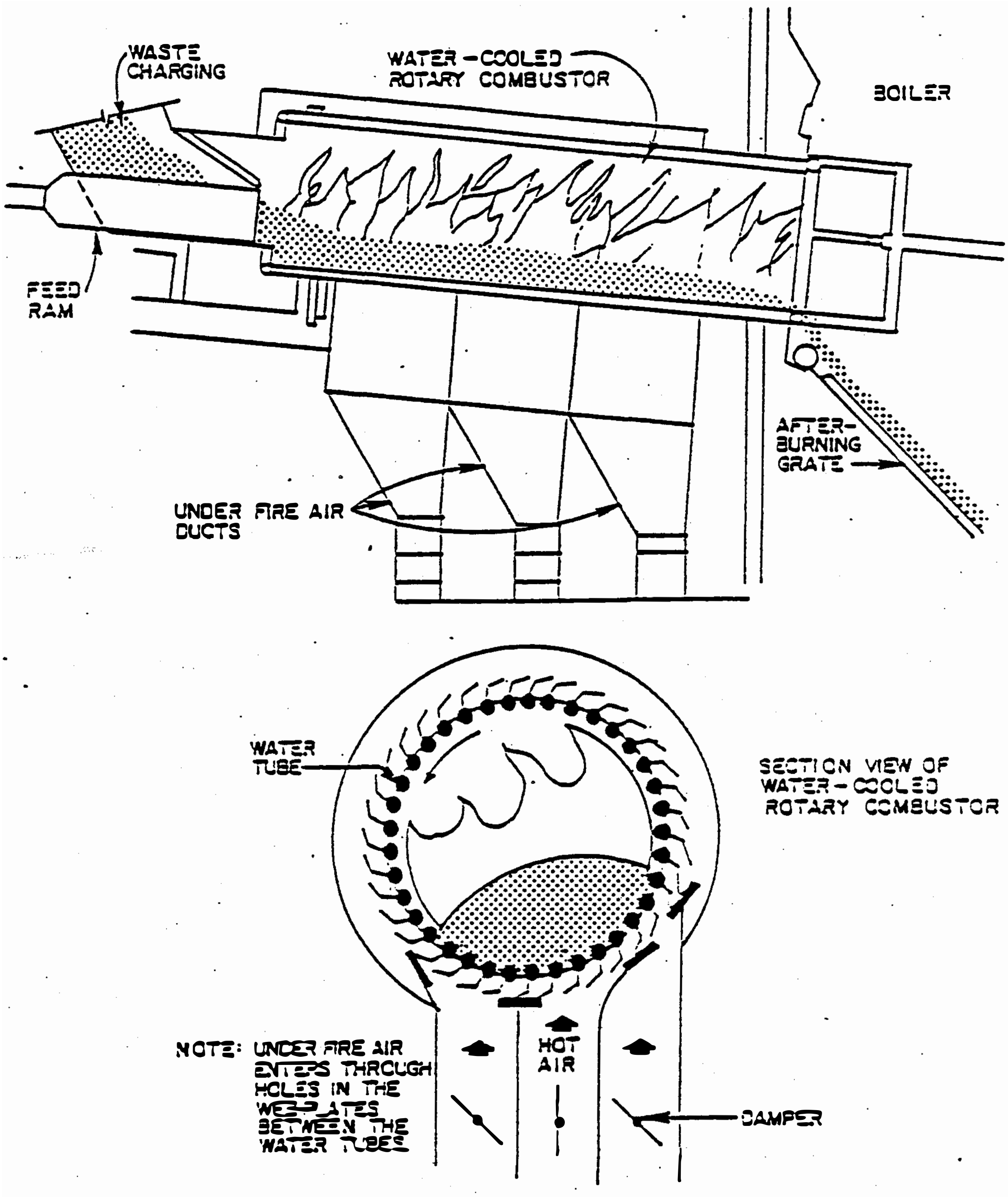


Figure A-4. Waterwall Rotary Combustor (799)

There are two distinct designs for the combustion area of a field erected system: a refractory-lined furnace chamber with a separate waterwall boiler, referred to as a "refractory system"; and a refractory-lined waterwall furnace and boiler, referred to as a "waterwall system" (799). Babcock & Wilcox, Foster-Wheeler, Riley Stoker, and Zum Industries are the major boiler manufacturers in the U.S. Attachment 2 lists all field-erected mass burn facilities by boiler manufacturer.

A.2.1.1 <u>Refractory Systems</u>

Refractory-lined furnaces and rotary kilns are equipped with a waste heat boiler located downstream of the furnace chamber. The furnaces are lined with a refractory coating such as silicon carbide to protect subsurfaces from corrosive gases inside the furnace. Silicon carbide, often in a tile form and grouted in place, is applied with a calcium bonding agent over carbon steel studs (120, 472). The fact that refractory furnaces can handle low quality fuels and still maintain adequate combustion temperatures attests to their use in a variety of applications. However, the energy recovery from a refractory furnace is 3 to 10 percent lower in efficiency than that from a waterwall due to the protective refractory covering that limits the heat absorbing quality of the furnace. As a result, a very large furnace volume per Btu of energy release is needed. Auxiliary fuel burners are typically provided to supplement the main fuel in the event that the fuel is extremely wet or if the supply is interrupted. These burners also will fire to maintain the combustion temperature at about 1,800 degrees F or above; the temperatures considered necessary to control dioxin/furan emissions (402).

The operating conditions in the combustion area that can be controlled include the MSW feed rate, the oxygen concentration and the temperature within the combustion zones, the auxiliary fuel firing rate, and the fuel residence time within the combustor. It is important to constantly monitor the operating conditions of the incinerator because of the highly variable composition and heat content of MSW. Figure A-5 shows a typical refractory lined combustor.

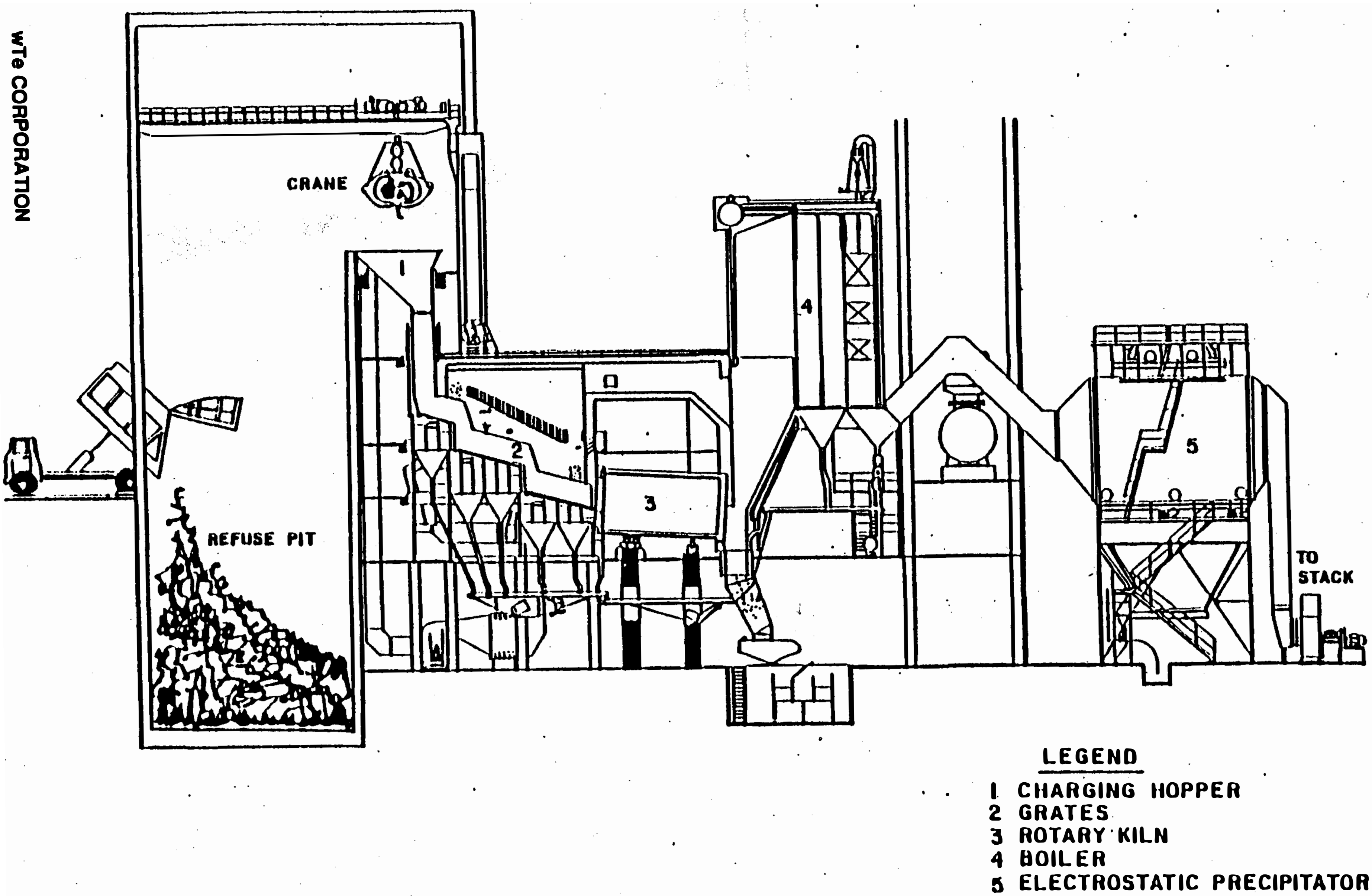


Figure A-5. Typical Refractory Lined Boiler System (Volund) (799)

A.2.1.2 Waterwall Systems

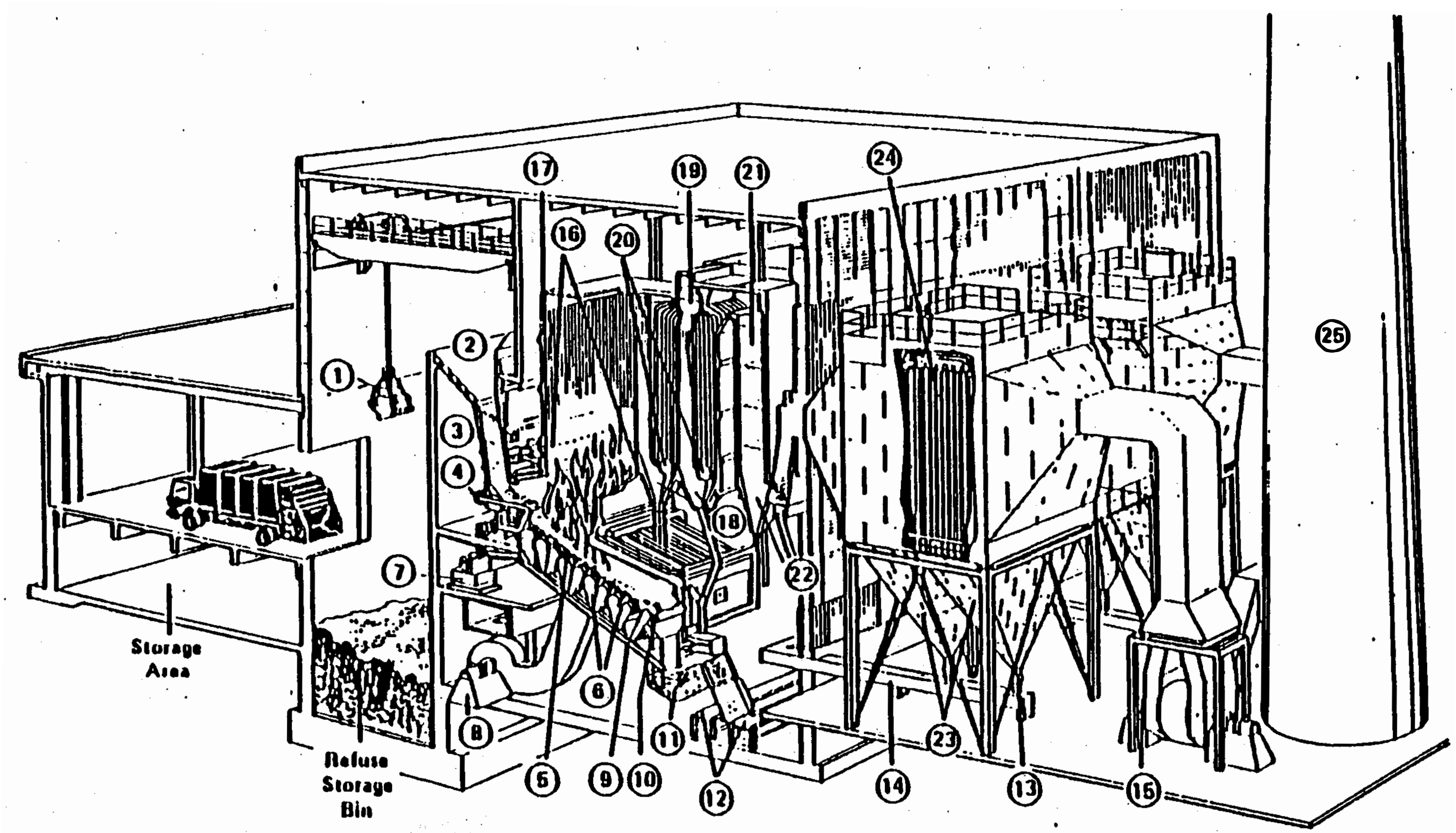
Waterwall MSW incinerators are becoming more common than refractory-lined combustors because of their improved heat recovery capabilities (471). Waterwall units consist of a furnace-boiler combination constructed with water tube membrane walls that allow the heat from the combustion process to be transferred to the water inside the tubes. The water cooled walls minimize slagging by absorbing some radiant energy. Many of the present-day waterwall furnaces have a refractory covering on the lower portion of the tube walls as protection against corrosion and erosion, blurring the distinction between waterwall and refractory furnaces (275). Generally, waterwall furnaces are limited to field erected mass burn systems. A typical waterwall boiler system is shown in Figure A-6.

A.2.2 Modular Systems

Modular plants typically use tipping floors and wheel loaders for infeed to their furnaces, although some have used the pit and overhead crane approach (799). Sitka, Alaska is an example of a modular system using the pit and crane approach (86). The tipping floor method affords better waste sorting and removal, while simplifying building and foundation design. The principal disadvantages of this storage method are the large building area required to provide sufficient waste storage and the abuse absorbed by the floor and loader (799).

The grate systems used by modular mass burn facilities are primarily the products of domestic companies. The grate system varies from vendor to vendor, some using variations of a moving hearth or reciprocating grate system, others using transfer rams to sequentially move the waste through the furnace. Most vendors manufacture their own grate system as part of the modular unit.

Within the modular MWC technology there are two sub-categories: the starved air system and the excess air system. The starved air modular uses a substoichiometric condition in the primary furnace, and superstoichiometric conditions in the secondary furnace. The objective of this system is to achieve combustion quiescence in the primary chamber to minimize particulate carryover, and therefore minimize air pollution control (APC) requirements. A substoichiometric design allows low turbulence, low temperature, and a low combustion air flux, all of which assist with the goal of quiescence. The excess air modular system also utilizes two (or more) furnace chambers, but the primary chamber is subject to superstoichiometric conditions in which excess combustion air is provided to maximize combustion.



1. Crane
2. Feed Hopper
3. Feed Chute
4. Feeder Rams
5. Reverse Reciprocating Stoker
6. Undergrate Air Plenum Chambers
7. Hydraulic Pump
8. Forced Draft Fan
9. Automatic Siftings Removal Systems
10. Residue Roller
11. Residue Discharger
12. Residue Conveyors
13. Rotary Valve
14. Fly Ash Conveyor
15. Induced Draft Fan
16. Overfire Air Nozzles
17. Waterwalls (Welded Panel Const.)
18. Boiler Fly Ash Hoppers
19. Steam Drum
20. Bottom Boiler Drum
21. Economizer
22. Economizer Fly Ash Hopper
23. Fly Ash Hoppers
24. Electrostatic Precipitators
25. Stack

Figure A-6. Typical Waterwall Boiler System (Martin) (799)

Regardless of type, the primary and secondary combustion chambers are usually refractory lined (303). Waste is fed into the primary chamber only, and ash is continuously removed from the primary chamber. The excess air type uses up to 200 percent excess air in its primary chamber. This means that it uses three times the amount of air theoretically needed to consume the combustible fraction of the waste. This large amount of air simply passes through the furnace, recovery boiler, and air pollution control system, leaving the system via the stack at an elevated temperature, causing considerable thermal losses and a reduced boiler efficiency.

The starved, or controlled air type may be substoichiometric in the primary combustion chamber, thus creating weakly combustible gases which are ignited and consumed in the secondary chamber. The secondary chamber accepts products of complete or partial combustion and entrained ash particulate from the primary chamber. Thus, the primary chamber temperature is 1500 to 1800 degrees F, while the secondary chamber operates at 1800 to 2000 degrees F. In the secondary chamber the gases are treated to high turbulence, additional residence time at an elevated temperature, and thoroughly oxidizing conditions. The starved air technology has an overall excess air of 140 to 170 percent, which is significantly lower than the excess air modular approach, but still much higher than a single furnace, large-scale mass burn system. The fully oxidized products of combustion leave the secondary chamber and proceed typically through a waste heat boiler, and then through an air pollution control (APC) device.

One characteristic of most modular systems is the discontinuous, quasi-batch feeding arrangement. This causes some problems with combustion regularity and emissions. Once the waste is in the furnace, it is advanced mechanically in a fairly regular fashion by an active furnace floor. Because many of the modulars operate substoichiometrically in the primary chamber, the carbon burnout of their solids is naturally poorer than in a fully oxidizing furnace. The average wet ash residue is 27 percent of the MSW feed stream for modulars, whereas the average ash residue for all MWCs is 23 percent (387).

In modular incinerators, the furnaces are usually completely uncooled. All heat transfer takes place far downstream of the combustion zone, so no protection is required for the heat transfer surface. However, due to the large overall excess air used in modulars, the gas temperature is low entering the waste heat boiler. Thus, considerably more heat transfer surface area is required to remove the same amount of heat from a modular system compared to the high-temperature, furnace-cooled field erected mass burn combustion system. Examples of modular system designs are shown in Figures A-7 and A-8.

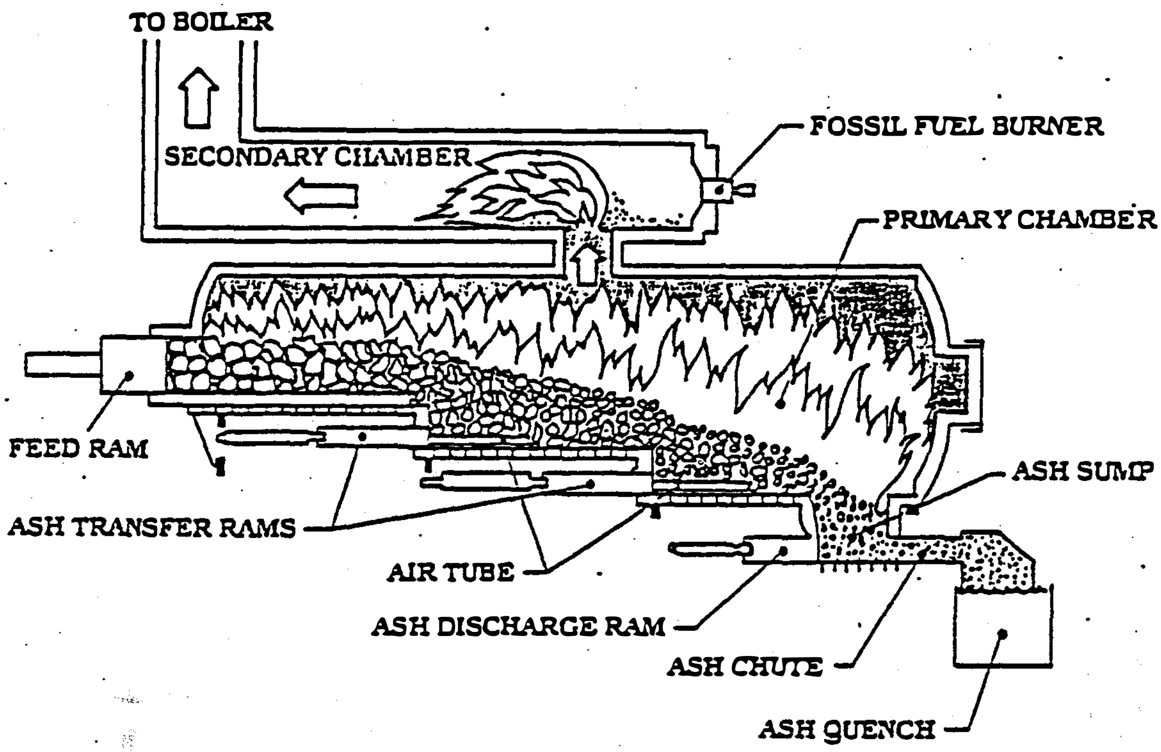


Figure A-7. Modular Mass Burn System – Consumat (799)

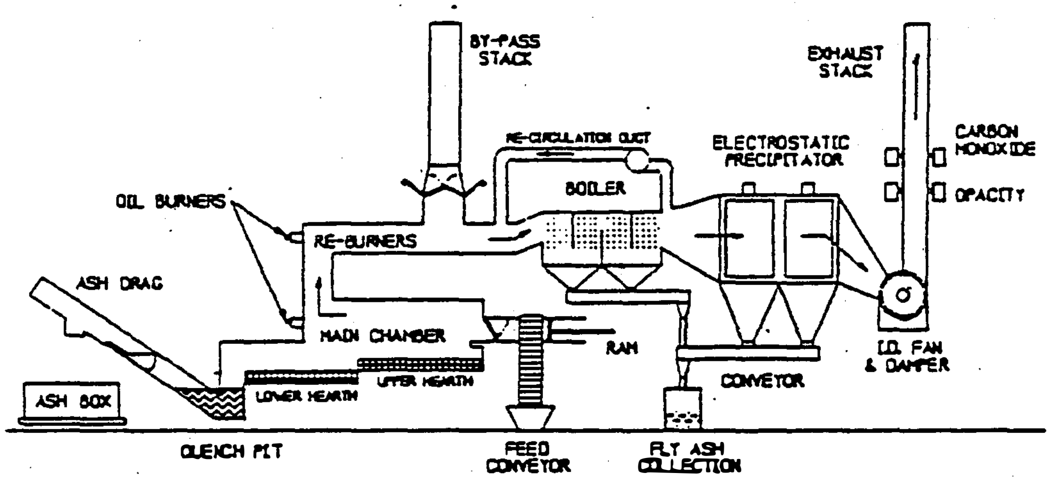


Figure A-8. Modular Mass Burn System – Basic Environmental Engineering (472)

A.2.3 Energy Recovery and Power Generation

Energy recovered from MSW is typically in the form of steam. The steam produced may be used internally in turbine drives on plant equipment such as induced draft fans and boiler feed pumps, for district heating or cooling, for off-site industrial process use, to drive a turbine generator for electricity production, or a combination of these options (89). The simultaneous production from one fuel source of two energy forms, normally steam and electricity in waste-to-energy facilities, is known as cogeneration. In situations where a steam market exists, it is highly desirable to cogenerate steam and electricity. Such a system will operate at an overall thermal efficiency of up to 2.5 to 3 times that of an electricity-only system, provided that the exhaust heat can be captured and partially used for thermal energy production (89). Often a portion of the generated electricity is used internally to power the plant equipment.

Steam produced from the combustion process can be converted into electrical energy in a turbine generator. The most efficient generation of electricity from steam requires the use of high pressure, superheated steam, at a temperature of at least 700 degrees F (75, 89). This is because the Btu's of superheated steam can be utilized more efficiently than those of saturated steam (89). However, the majority of MSW-fired power plants are designed for steam at around 650 degrees F in order to reduce boiler corrosion problems (89).

The steam turbine produces shaft power which turns a generator, thus producing electricity. Maximum power output per unit of steam flow input can be achieved through the use of a condensing turbine, i.e., one that uses the energy contained in the steam for power generation only. Less conventional and less efficient noncondensing turbines are also available for specific conditions. Noncondensing turbines exhaust steam at the back end of the turbine for process use or space heating. Figure A-9 (89) shows the components of a waste-to-energy system with a condensing turbine. Turbines are available in single or multiple stages, with multi-stage units being more efficient (89). Nearly all condensing turbines used in waste-to-energy power production are multi-stage units (89).

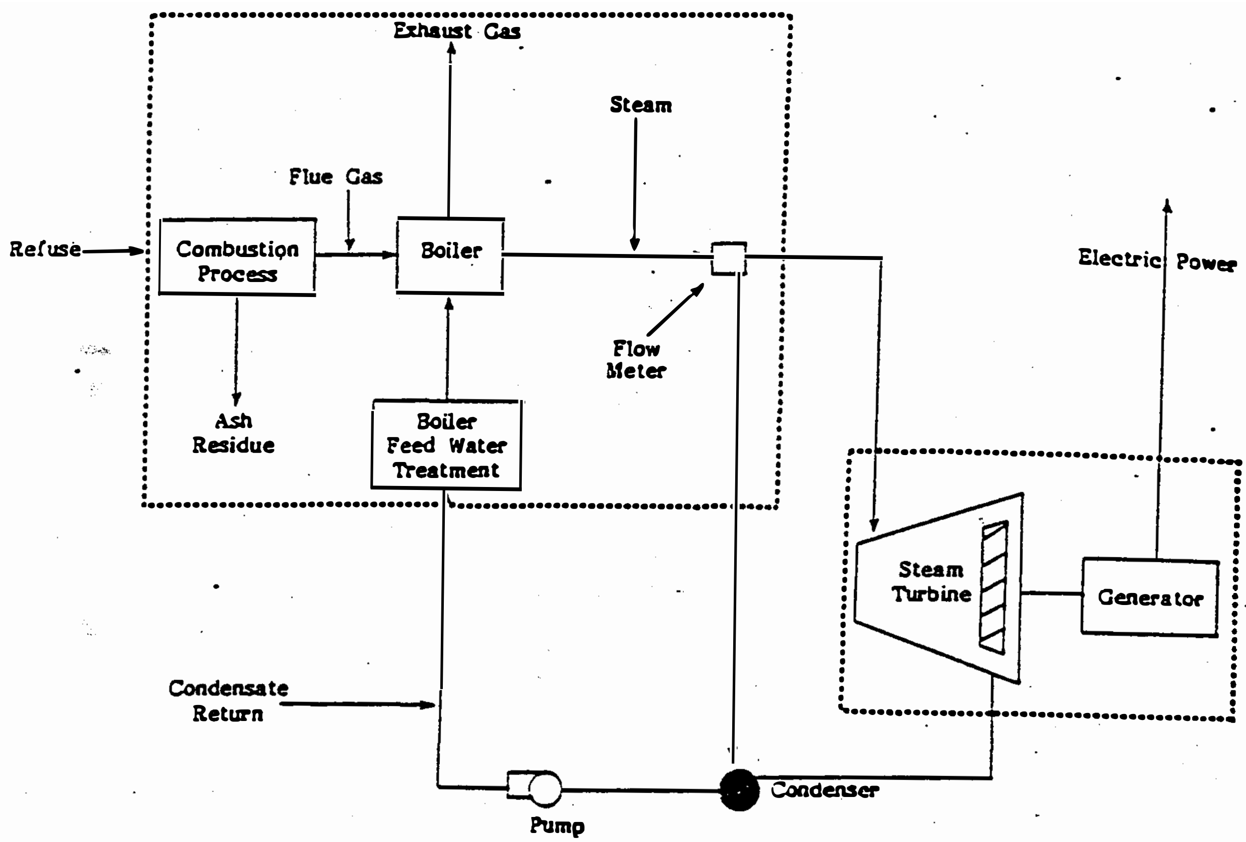


Figure A-9. Basic Components of a Waste-to-Energy System with a Condensing Turbine (89)

Two basic turbine types are available for MSW cogeneration systems: backpressure and extraction turbines (89). A backpressure turbine exhausts steam at pressures above atmospheric pressure; this steam can be put to further use. An extraction turbine acts as a combination of a backpressure and a condensing turbine. All of the steam is directed into the turbine, and a portion of the steam flow is extracted after passing through some of the turbine blades. The extracted steam can be used for any desired purpose. The remaining steam in the turbine is carried all the way to condensing, thus maximizing electricity production (89).

The efficiency and cost of steam turbines are strongly related to size. The larger machines are much more efficient and economical, than the small turbine-generators which are relatively inefficient and expensive on a per-kw basis. The effect of size, as shown in Table A-4, is very dramatic (89).

TABLE A-4. TURBINE GENERATOR EFFICIENCY (89)

Size (MW)	T-G Efficiency, Overall
.5 - 1	45 - 58
1 - 3	58 - 65
3 - 7	65 - 72
7 - 15	72 - 77
20 +	78 - 81

A.2.4 Residue Handling

The residue from mass burn systems consists of bottom ash and fly ash. Bottom ash is the material remaining on the grate after combustion and also includes grate siftings, the material that falls through the grate system. Fly ash is the solid materials removed from the flue gas by the air pollution control equipment. Both wet and dry ash systems are available, although wet ash handling is preferred over dry systems (85).

In a wet ash system, bottom ash is discharged into a water-filled tank for quenching. The ash is removed from the tank by a ram or drag conveyor via an inclined dewatering ramp and transferred to a storage area prior to ultimate disposal most likely in a landfill. Dry ash systems use a chute to store the bottom ash until cooled sufficiently to be removed by a belt conveyor. A water mist can be applied to control dust. Fly ash is collected from the air pollution control equipment and conditioned to minimize dust. The fly ash can be combined with the bottom ash or disposed of separately.

Most modem modular units are equipped with continuous ash removal systems using an arrangement similar to submerged drag chain conveyors (799).

HDR Engineering, Inc. reports that ash from field erected mass bum plants is 15 to 25 percent by dry weight of the as-received MSW and is approximately 5 to 10 percent by volume. The ash has a moisture content of about 25 percent and is 20 to 35 percent by wet weight of the as-received MSW (799). Government Advisory Associates (387) reports the average wet ash residue to be 24 percent of the MSW mass for mass bum facilities. For comparison purposes, average wet ash residue is 13 percent of MSW on a mass basis for an RDF MWC (387).

The disposal, treatment, and utilization of ash is discussed in Section A.5.3.

A.2.5 Air Pollution Control Systems

On February 11, 1991, the U.S. Environmental Protection Agency issued revised performance standards and emission guidelines for new and existing MWC facilities (561). These New Source Performance Standards (NSPS) limit the following MWC emissions:

- o Organics - measured as dioxins and furans
- o Metals - measured as particulate matter
- o Acid Gases - measured as sulfur dioxide and HCl
- o Nitrogen Oxides (NOx)

The NSPS for both new and existing facilities are provided in Table A-5. The standards for new facilities only apply if the capacity is over 250 TPD. Standards for facilities 250 TPD or less are required by the Clean Air Act to be promulgated within two years. Further, the Clean Air Act requires that NSPS be revised within one year. These revisions will include standards for mercury, cadmium, and lead.

The EPA has selected various techniques, referred to as Best Demonstrated Technology (BDT), that serve as the basis for the establishment of the standards. A BDT has been specified for each MWC class for metals, acid gas and NOx control. These BDTs are indicated in Table A-5. For new MWCs larger than 250 TPD, BDT is defined as good combustion practice coupled with a spray dryer absorber followed by a fabric filter for organics, acid gas and metals control. The BDT for NOx control is defined as selective noncatalytic reduction.

The revisions to these standards mandated by the Clean Air Act will reflect the Maximum Achievable Control Technology (MACT). MACT will require new facilities to utilize technology that is no less stringent than the best performing similar unit.

Table A-6 presents data on the numbers and percentages of all planned and existing field erected MWC facilities using each of the major air pollution control (APC) systems (387). Similar data is provided for modular facilities in Table A-7.

Dry scrubbers with fabric filters is the overwhelming choice of planned facilities, with 75 percent of the modular facilities and 94 percent of field erected facilities intending to use this technology. ESPs are installed on 46 percent of existing field erected mass burn facilities; 52 percent are equipped with dry scrubbers. Figure A-10 shows a typical dry scrubber/fabric filter air pollution control system (223).

None of the planned modular facilities intend to include NOx control, but 59 percent of the planned field erected units do plan on including this technology. Three facilities in southern California have incorporated NOx controls in their air pollution control systems: Commerce, Stanislaus County, and Long Beach (SERRF).

TABLE A-5. 1991 PERFORMANCE STANDARDS AND EMISSION GUIDELINES FOR NEW AND EXISTING MWC FACILITIES (561)

	NEW FACILITIES OVER 250 TPD	EXISTING FACILITIES OVER 1100 TPD	EXISTING FACILITIES LESS THAN 1100 TPD
Good Combustion Practice			
Steam Load (a)	110%	110%	110%
PM Control Inlet Temp (b)	30	30	30
CO (ppmv 24 Hr Average)	150	200	200
MWC Organics			
Dioxin/Furan (ng/dscm)	30	60	250
MWC Metals			
PM (mg/dscm)	34	34	69
Opacity (% - 6 min avg)	10%	10%	10%
Basis (BDT)	FF	ESP	ESP
Acid Gases (higher of:)			
SO_2 (ppmv) or:	30	30	30
SO_2 (% reduction)	80%	70%	50%
HCl (ppmv) or:	25	25	25
HCl (% reduction)	95%	90%	50%
Basis (BDT)	SDA/FF	SDA/ESP	DSI/ESP
Oxides of Nitrogen			
NOx (ppmv 24 Hr Avg)	180	---	---
Basis (BDT)	SNCR		

(a) Expressed as a percent of MCR as measured during the most recent dioxin/furan compliance test.

(b) Expressed as maximum allowable deviation (degrees F) above a site specific particulate matter (PM) control device inlet temperature as established during the most recent dioxin/furan compliance test.

(c) FF = Fabric Filter, SDA = spray dryer absorber (dry scrubber), ESP = electrostatic precipitator, DSI = duct sorbent injection, SNCR = selective noncatalytic reduction.

TABLE A-6. APC SYSTEMS FOR FIELD ERECTED FACILITIES (387)

APC Equipment	Planned	Existing
Electrostatic Precipitator (ESP)		23 (33%)
ESP with Dry Scrubber	1 (3%)	9 (13%)
Dry Scrubbers with Fabric Filter	12 (35%)	30 (43%)
Dry Scrubbers, Fabric Filter & NOx Control	20 (59%)	6 (9%)
Baghouse		1 (1%)
Wet Scrubber with Baghouse		1 (1%)
Not Determined	1 (3%)	
	34 (100%)	70 (100%)

TABLE A-7. APC SYSTEMS FOR MODULAR FACILITIES (387)

APC Equipment	Planned	Existing
Electrostatic Precipitator (ESP)		13 (26%)
ESP with Two Chamber Furnace		6 (12%)
ESP with Dry Scrubber		1 (2%)
ESP with Wet Scrubber		2 (4%)
Dry Scrubber		1 (2%)
Dry Scrubbers with Fabric Filter	3 (75%)	6 (12%)
Dry Scrubbers, Fabric Filter & NOx Control		1 (2%)
Baghouse with Two Chamber Furnace		1 (2%)
Wet Scrubber with Baghouse		1 (2%)
Two Chamber Furnace		11 (22%)
Two Chamber Furnace with Wet Scrubber		2 (4%)
Two Chamber Furnace with Cyclone		1 (2%)
Cyclones		3 (6%)
Wet Scrubber		1 (2%)
Not Determined	1 (25%)	
	4 (100%)	50 (100%)

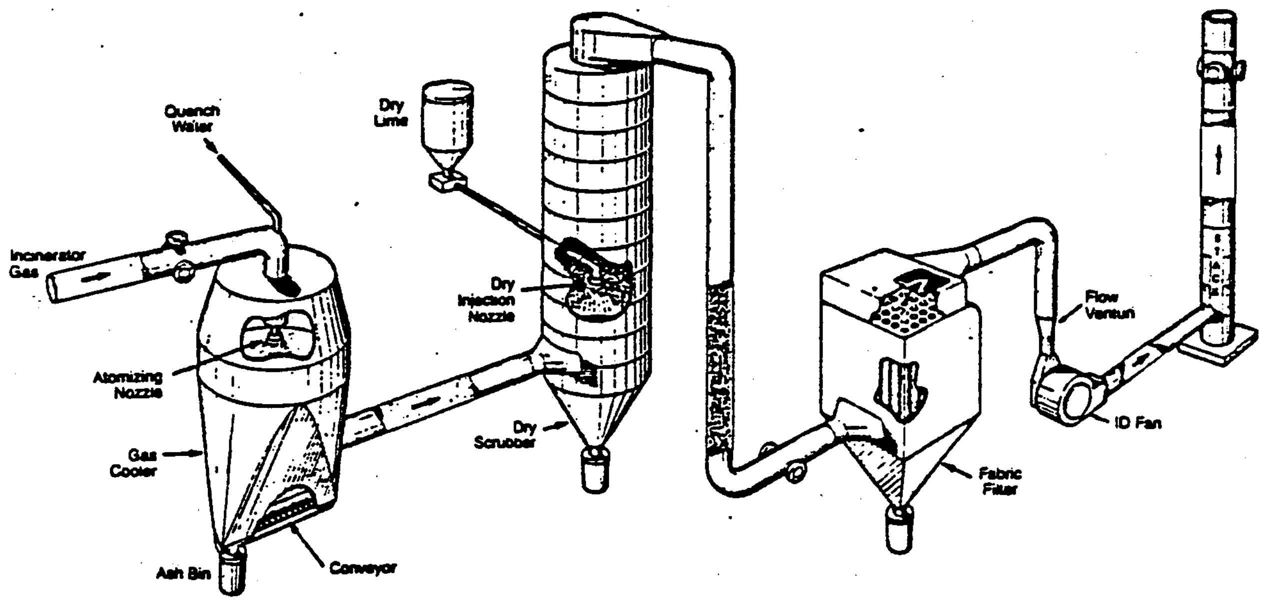


Figure A-10. Components of Typical Dry Scrubber/Fabric Filter Spray Dryer System (223)

A.2.5.1 Good Combustion Practice

Good combustion practice (GCP) can be used as a form of APC technology. GCP consists of controlling the amount and distribution of excess air in the flue gas to ensure there is enough oxygen for complete combustion. Good combustion practice combines the three "T"s of combustion - time, temperature, and turbulence, with an adequate supply of oxygen (402). GCP can be effective in controlling both carbon monoxide (CO) and dioxin/furan (PCDD/PCDF) emissions by providing the necessary conditions for complete burnout and dioxin destruction. A recent Swedish study on the formation and destruction of dioxins showed that 99.86 percent of the dioxins are destroyed at the normal incineration conditions of 800 to 1100 degrees C for 1 to 2 seconds in a flue gas containing 7 percent oxygen (857). This study also showed that if the oxygen concentration exceeds 10 percent, significant quantities of dioxins were not destroyed, or were reformed after initial destruction. Further, furnace temperatures less than 800 degrees C result in virtually no dioxin destruction.

Good combustion practice for field erected mass burn facilities is as follows (298):

- 1800 degrees F at fully mixed height
- Four underfire air zones
- Overfire air = 40 percent of total
- Overfire air pressure for full penetration
- Auxiliary fuel for 1800 degrees F
- 6 to 12 percent O_2 (dry)
- Operating limits of 80 to 110 percent
- CO 50 ppm @ 12 percent CO_2

GCP for starved air modular MWCs is the same as for mass burn facilities except for the following (298):

- Overfire air = 80 percent of total
- 6 to 12 percent O_2 (dry)

Combustion control can have considerable effectiveness for NOx reduction. Minimal excess air or even conditions that favor chemical reduction at the point of combustion reduce the amount of oxygen available to react with nitrogen and lowers combustion temperatures, tending to lower the NOx emission. The products of combustion from this first zone can be subsequently treated with additional air to achieve reasonable overall stoichiometry while minimizing NOx. This can be effected in a typical MWC by varying the proportions of undergrate and overfire air, resulting in a minimum NOx level of about 100 ppm. Combining Selective Non-Catalytic Reduction with good combustion control can drop the minimum NOx concentration in the flue gas to about 70 ppm. If Selective Catalytic Reduction is also used, the NOx concentration can be further reduced down to 50 to 60 ppm. If a large amount of catalyst is used, a concentration of 10 ppm NOx can be achieved (591).

Data from Norway (534) show a 30 percent reduction in NOx by increasing primary air and CO above the traditional 60:40 ratio of primary air to overfire air. New Jersey tests have shown that a ratio of 60:40 resulted in a NOx concentration of 300 ppm, while a ratio of 80:20 resulted in 225 ppm with no ill effects on CO or opacity (534).

A.2.5.2 APC Equipment

Air pollution control equipment for MWCs can be classified according to the pollutant they are designed to control or according to their operating principals (367). Individual control equipment is usually installed in series to effect a reduction in the number and amount of pollutants, as indicated above. Brief descriptions of the APC equipment noted in Tables A-6 through A-8 are provided below.

A.2.5.2.1 Particulate Matter (PM) Control. The electrostatic precipitator can be used alone for particulate matter capture, or following a spray dryer for acid gas removal. Newer ESPs have four or five fields, or sets of electrodes and plates in series, through which the flue gas flow. The fabric filter (FF) has been designated as Best Demonstrated Technology for new MWCs. Fabric filters can be classified according to the method of cleaning the bags: shake/deflate, reverse air, and pulse-jet (533); as applied to MWCs, the majority are the pulse-jet or reverse air types. When used in conjunction with an acid gas control device, fabric filters can achieve greater than 99% removal of particulate matter (303).

A centrifugal separator (cyclone) can be used for low efficiency large-sized particulate capture. The efficiency is poor but the technology is useful as a pre-cleanup device, referred to as a "roughing" cyclone.

A.2.5.2.2 Acid Gas Control. Duct sorbent injection (DSI) involves the injection of a dry, chemically active alkali sorbent into the furnace breeching at some point downstream of the furnace and upstream of the particulate control device (preferably a FF). Various removal efficiencies for DSI units have been reported: Kuykendal (303) notes typical removal of 60 to 95% HCl, and 40 to 70% for SO_2; Bma (370) notes that a DSI/FF system results in 90 to 95% HCl capture and 75 to 80% SO_2. Using hydrated lime as a sorbent, SO_2 removal is optimized at 1750 degrees F whereas HCl and HF capture is best at 800 degrees F. Thus, multiple injection points for the sorbent are appropriate. As an example, Katy-Seghers' 400-TPD Davis County, Utah plant utilizes an ESP and dry hydrated lime injection at three points in the boiler, the furnace breech, between the superheater and convective section, and between the convective section and economizer. The result is 70% HCl capture and 80% SO_2 capture with 2.45 stoichiometry, which is 20 lb lime/ton MSW. The particulate emission is also low, at 0.015 gr/DSCF.

Furnace sorbent injection (FSI) is similar to DSI except that the sorbent is injected directly into the furnace section of the combustor (303). Removal of 90% HCl requires a very high stoichiometric ratio (greater than 5:1) because the lime-HCl reaction is hindered by the high furnace temperatures (27).

Combinations of FSI and DSI are often more economical than either method used alone, because a high temperature favors the SO_2 reaction, and a low temperature favors HCl. Using hydrated lime and 2.45 stoichiometry with an ESP only, this combined approach can capture 70% HCl and 80% SO_2 if injection of lime is at three points: furnace breech, between the superheater and convective section, and between the convective section and economizer (26).

The spray dryer absorber (SDA), also called dry scrubber absorber (DSA), involves the distribution of a chemically active, slurried sorbent into the flue gas. The temperature of the flue gas causes evaporation of the slurry's water, resulting in dry conditions downstream of the scrubber. The sorbent reactions provide very high removal efficiencies of 99% HCl, 95 % SO_2, 99% SO_3, and 95% HF. The method is also effective for dioxins and volatile metals (367). Semi-dry or wet alkali treatment followed by a fabric filter can eliminate 99% of HCl, total solid particulates (TSP), and other micro-pollutants (282). For mercury (Hg) control, the addition of small amounts of activated carbon or sodium sulfide upstream of SDA can result in greater than 90% capture (367). An Hg capture rate of 90% is possible with SDA/FF alone, or 35 to 70% with SDA/ESP (370).

Combinations of DSI and SDA provide another effective approach for dioxin, Hg, and even NOx control. This involves the injection of powered dry additive up or downstream of the SDA. NOx removal is 41 to 53%, and Hg capture is 91 to 95% (31). Use of the SDA/FF technology can achieve compliance with the New Source Performance Standards for HCl, SO_2, CDD/CDF, and TSP (28).

Wet scrubbing can use water only for capture of particulate matter and volatile metals, or it can be chemically active for acid gas control and particulate capture. Because wet scrubbers alone are not adequately effective in removing particulates, a typical wet scrubber installation consists of two stages of wet scrubbing located downstream of an ESP (367). The first stage (the venturi stage) is for HCl removal and the second stage (absorber stage) is for SO_2 removal. A wet scrubber following particulate control can result in more than 90% mercury removal (367). Additional removal of submicron particles and metallic vapors can be achieved by using a heat exchanger downstream of the wet scrubber.

The Japanese have developed a wet scrubber system in which a liquid chelating agent and cupric chloride are injected for the absorption of the atomic mercury contained in the flue gas (532). This system has been shown to result in greater than 90% Hg removal. Another Japanese wet scrubber system incorporates sodium hypochlorite injection at a concentration of several tens of ppm to form $HgCl_2$ (532). This system can result in 90 to 95% mercury capture.

The following are the major advantages and disadvantages of wet scrubbing systems (367):

Advantages

- o Inexpensive to install and require a relatively small area,
- o Can achieve very high removal efficiencies for acid gases (> 99 percent for HCl and > 95 percent for SO_2),
- o Capable of high removal efficiencies for many volatile trace compounds, and
- o Require the lowest reagent stoichiometry (1.0 to 1.2) of any of the alternatives.

Disadvantages

- o Produce a wet effluent which requires additional complex treatment prior to disposal,
- o Are more prone to corrosion problems and may require expensive materials of construction, and
- o Have historically experienced more operating problems and higher maintenance requirements than the alternatives.

A.2.5.2.3 NOx Control. Selective catalytic reduction (SCR) uses ammonia (NH_3) injection upstream of a catalytic reactor to reduce NOx to nitrogen and water (367). NOx reduction of 80 to 85% has been achieved with SCR on a wide range of combustion sources (367). Another estimate places the NOx capture at 80 to 90% for an NH_3/NO ratio of 1 and 5 vppm NH3 slip (or breakthrough) (27). Ammonia slip is the amount of unreacted ammonia remaining in the flue gas after the SCR device. The presence of HCl can cause the SCR catalyst to fail, and particulate can erode the catalyst. Thus, in order for SCR to function successfully on MSW, the SCR unit must be installed downstream of the acid gas and particulate control systems (367). Because of the thermal losses in the acid gas removal unit, the flue gas must be subsequently reheated to the optimum temperature range for the catalyst. These complex conditions have restricted the application of SCR to MWCs.

Selective non-catalytic reduction (SNCR), also known as "Thermal De-NOx" or "Exxon DeNOx" is a patented, in-furnace technique similar to SCR but requiring no catalyst. The process operates in an optimum temperature range of 1700 to 1900 degrees F where it selectively and economically reduces NO to N_2 (27). This process has been successfully applied to many combustion sources in over 60 commercial installations; however, very few of these are MWCs (77). The Southeast Resource Recovery Facility (SERRF), Long Beach, CA, uses Exxon's Thermal DeNOx system (546), as does the Commerce, CA facility (88). Up to 65% NOx reduction has been demonstrated for this technology at an approximate ammonia to NOx ratio of 2 and down to a 5 ppm ammonia breakthrough (367). Limited test data from the Stanislaus County, CA, Ogden-Martin facility indicates approximate NOx removal efficiencies from 60 to 72% using the DeNOx system (34).

A.2.5.2.4 Technology Developments

There are a number of systems in the developmental stage. The electron beam (E-beam) process uses either ammonia or lime to to react with and remove NOx and SO_2 in the presence of a high-intensity electron beam (69). The electron beam provides the activation energy to allow the reaction to occur, eliminating the need for high temperatures. This system apparently has not been demonstrated at a full-scale MWC facility.

Natural gas rebuming (rebum) for NOx control has been investigated by Riley-Takuma, IGT, and GRI (535). This pilot study demonstrated that rebum can reduce CO and hydrocarbons, and result in a 50 to 70%. NOx reduction. In the rebum process, overfire air above the grate is replaced with natural gas mixed with recirculated flue gas. The rebum technology allows reduced overall excess air, which provides an increase in efficiency of 2 percent. Study results showed that a 0.9 second residence time in the rebum zone at a stoichiometric ratio of 0.85 to 0.95 resulted in a 50 percent NOx reduction, and a 1.4 second residence time resulted in a 70 percent NOx reduction. Carbon monoxide, although a problem with flue gas recirculation alone, was not a problem with the rebum process.

Another method of NOx control is urea injection. This method has been demonstrated on full scale MWCs both in Europe and the U.S. (367). Urea has an advantage over ammonia in that it is not considered to be a hazardous material whereas ammonia is considered to be hazardous. Tests using urea injection have resulted in more than 65% NOx reduction with a very low ammonia slip of about 5 ppm (367).

The Occidental ammonia control system is an experimental bench scale technology that attempts to provide simultaneous control of PCDD/PCDF, HCl and NOx and SO_2 to a lesser degree, all by use of NH_3 (514). The theory that Occidental believes is the basis for their process, one of two theories proposed, is that ammonia can prevent the formation of PCDD/PCDF by competing with the hydrocarbon precursors present for the available chlorine. Because NH_3 is much more reactive with chlorine than the hydrocarbons are, ammonia chloride is more likely to form than PCDD/PCDF. HCl and SO_2 control can be achieved by the reaction of these acid gases with NH_3 to form ammonium salts. The challenge is to provide the optimum temperatures for salt formation and to condense it and capture it before it is discharged as a dense white haze out the stack. NOx reduction is accomplished by combining an Thermal DeNox system or a SCR system with the Occidental technology.

This process has certain advantages over other techniques. For example, any technology that uses a sorbent must handle and ultimately dispose of the spent sorbent. With the Occidental concept, formation of dioxin is prevented in the first place. There is no landfill requirement because spent sorbent is not generated. Further, particulate matter can be cost effectively controlled with an electrostatic precipitator alone; a fabric filter with dry sorbent injection for bag surface conversion of dioxin, is not required.

Lab scale tests using the Occidental NH_3 process were very encouraging; achieving 94% suppression of PCDD, 100 percent suppression of PCDF, and 97% reduction of HCl. Pilot scale tests are reportedly proceeding at Occidental's Niagara Falls facility.

A.2.6 System Vendors

A.2.6.1 Field Erected Systems

Table A-8 lists, by vendor, all the U.S. field erected mass burn facilities that were existing or in advanced planning as of 1990 (387). Dominating this market are Ogden Projects, Inc. with 17 facilities and Wheelabrator Technologies, Inc. with 14 facilities. The major vendors are described briefly following the table.

TABLE A-8. SYSTEM VENDORS - FIELD ERECTED MASS BURN FACILITIES (387)

NAME	CITY	STATE	DESIGN TPD	OWNER
PROCESS: MB - Refractory				
VENDOR - (N.A.)				
Betts Avenue	Queens	NY	1000	City of New York
City of Waukesha (Old Plant)	Waukesha	WI	175	City of Waukesha
VENDOR - Estech Corporation				
Muscoda	Muscoda	WI	125	Village of Muscoda
VENDOR - Katy-Seghers Corporation				
Davis County	Layton	UT	400	Davis Co. S.W.M. & Energy Recovery Dist.
VENDOR - Wheelabrator/Waste Mgmt. Energy Systems				
McKay Bay Refuse-To-Energy Facility	Tampa	FL	1000	City of Tampa
PROCESS: MB - Waterwall				
VENDOR - (N.A.)				
Hampton/NASA Project Recoup	Hampton	VA	200	NASA/City of Hampton
Harrisburg	Harrisburg	PA	720	City of Harrisburg
Nashville Thermal Transfer Corp. (NTTC)	Nashville	TN	1120	Metropolitan Government of Nashville
VENDOR - (N.A., Martin Grate System)				
Northwest Waste-To-Energy Facility	Chicago	IL	1600	City of Chicago
VENDOR - (TBD)				
Sturgis	Sturgis	MI	560	Something of Value, Inc.
VENDOR - A.B.B. Resource Recovery Systems (C.E.)				
Dakota County	Rosemount/Empire Twp.	MN	800	Dakota County
VENDOR - American Energy Corp. (Dravo)				
Portland	Portland	ME	500	Regional Waste Systems (20 communities)
VENDOR - American Ref-Fuel, Inc.				
Albany (American Ref-Fuel)	Bethlehem	NY	1500	American Ref-Fuel, Inc.
Bergen County	Ridgefield	NJ	3000	American Ref-Fuel, Inc.
East Bridgewater (American Ref-Fuel)	East Bridgewater	MA	1500	American Ref-Fuel, Inc.
Essex County	Newark	NJ	2277	Amer. Ref-Fuel/Port Authority of NY & NJ
Hempstead (American Ref-Fuel)	Westbury	NY	2505	American Ref-Fuel, Inc.
Oyster Bay	Old Bethpage	NY	1000	American Ref-Fuel, Inc.
Preston (Southeastern Connecticut)	Preston	CT	600	American Ref-Fuel, Inc./CRRA
VENDOR - Babcock & Wilcox/Ebasco Services				
North Hempstead	Port Washington	NY	990	North Hempstead S.W. Mgmt. Authority
VENDOR - Blount Energy Resources Corporation				
Hennepin County (Blount)	Minneapolis	MN	1200	General Electric Credit Corporation
Quonset Point	North Kingston	RI	710	RI Solid Waste Management Corporation
Warren County	Oxford Township	NJ	400	Blount Energy Resources Corporation

TABLE A-8. SYSTEM VENDORS - FIELD ERECTED MASS BURN FACILITIES (Cont)

NAME	CITY	STATE	DESIGN TPD	OWNER
VENDOR - CMI Energy Conversion Systems, Inc.				
Oklahoma City	Oklahoma City	OK	820	CMI Energy Conversion Systems
VENDOR - Enerco Systems, Inc.				
Davidson County	Madison (Nashville)	TN	210	Third National Bank
Wayne County	Goldsboro	NC	300	Enerco Systems, Inc.
VENDOR - Foster Wheeler Power Systems, Inc.				
Broome County	Kirkwood	NY	571	Broome Co. R.R. Authority/Foster Wheeler
Camden County (Foster Wheeler)	Camden	NJ	1050	Camden County Energy Recovery Associates
Charleston County	North Charleston	SC	644	AT&T Credit Corporation
City of Commerce	Commerce	CA	400	Commerce Refuse-To-Energy Authority
Morris County	Roxbury Township	NJ	1340	Morris County
Norfolk Naval Station	Norfolk	VA	360	U.S. Navy
Passaic County	Passaic	NJ	1434	Foster Wheeler Passaic, Inc.
Washington/Warren Counties	Hudson Falls	NY	400	Adirondack Resource Recovery Associates
VENDOR - Katy-Seghers Corporation				
Savannah	Savannah	GA	500	Katy-Seghers, Inc.
VENDOR - M.K. Ferguson Company, Inc.				
University City Res. Recovery Facility	Charlotte	NC	235	Mecklenburg County
VENDOR - Montenay Power Corporation (Dravo)				
Montgomery County	Plymouth Township	PA	1200	Montenay Power Corporation
S.E. Resource Recovery Facility (SERRF)	Long Beach	CA	1380	S.E. Resource Recovery Facility Auth.
VENDOR - Ogden Projects, Inc.				
Alexandria/Arlington R.R. Facility	Alexandria	VA	975	Ogden Martin Systems of Alex./Arlington
Babylon Resource Recovery Project	Babylon	NY	750	Babylon Industrial Development Authority
Bristol	Bristol	CT	650	Ogden Martin Systems of Bristol
Camden County (Pennsauken)	Pennsauken	NJ	500	Pennsauken Solid Waste Mgmt. Authority
Eastern-Central Project	Cromwell (or Portland)	CT	550	Ogden Projects, Inc.
Fairfax County	Lorton	VA	3000	Ogden Martin Systems of Fairfax, Inc.
Haverhill (Mass Burn)	Haverhill	MA	1650	Ogden Martin Systems of Haverhill, Inc.
Hillsborough County S.W.E.R. Facility	Brandon	FL	1200	Hillsborough County
Hudson County	Kearny	NJ	1500	Ogden Martin Systems of Hudson County
Huntington	East Northport	NY	750	Ogden Martin Systems of Huntington
Johnston (Central Landfill)	Johnston	RI	750	RI Solid Waste Management Corporation
Kent County	Grand Rapids	MI	625	Kent County
Lake County	Okahumpka	FL	528	Ogden Martin Systems of Lake County
Lancaster County	Conoy Township	PA	1200	Lancaster County S.W. Mgmt. Authority
Lee County	Lee County	FL	1800	Lee County
Marion County Solid W-T-E Facility	Brooks	OR	550	Ogden Martin Systems of Marion County
Montgomery County	Dickerson	MD	1800	N.E. Maryland Waste Disposal Authority
Onondaga County	Onondaga	NY	990	Ogden Martin Systems of Onondaga County
Pasco County	Springhill	FL	1050	Pasco County
Stanislaus County Res. Recovery Facility	Crows Landing	CA	800	Ogden Martin Systems of Stanilaus County

TABLE A-8. SYSTEM VENDORS -- FIELD ERECTED MASS BURN FACILITIES (Cont)

NAME	CITY	STATE	DESIGN TPD	OWNER
Union County	Rahway	NJ	1440	Union County Utilities Authority
Walter B. Hall Res. Recovery Facility	Tulsa	OK	1125	Manu. Hanover Trust/CIT Group/Bank of OK
VENDOR - Riley Stoker/Takuma				
Jackson County/Southern MI State Prison	Jackson	MI	200	Jackson County
Olmstead County	Rochester	MN	200	Olmstead County
VENDOR - Riley/Takuma (Glendon Energy Company)				
Glendon	Glendon	PA	500	Glendon Energy Company
VENDOR - Wheelabrator Technologies, Inc.				
Bridgeport RESCO	Bridgeport	CT	2250	Wheelabrator Technologies, Inc./CRRA
Brooklyn Navy Yard	Brooklyn	NY	3000	Wheelabrator Technologies, Inc.
Broward County (Northern Facility)	Pompano Beach	FL	2250	Wheelabrator Technologies, Inc.
Broward County (Southern Facility)	Broward County	FL	2250	Wheelabrator Technologies, Inc.
Central Mass. Resource Recovery Project	Millbury	MA	1500	Ford Motor Credit Corporation
Concord Regional S.W. Recovery Facility	Penacook	NH	500	Wheelabrator Technologies, Inc.
Falls Township (Wheelabrator)	Falls Township	PA	2250	Wheelabrator Technologies, Inc.
Gloucester County	West Deptford Township	NJ	575	Wheelabrator Technologies, Inc.
Lisbon	Lisbon	CT	500	(Public Authority - TBD)
North Andover	North Andover	MA	1500	Wheelabrator Technologies, Inc.
Pinellas County (Wheelabrator)	Pinellas County	FL	3150	Pinellas County
S.W. Resource Recovery Facility (BRESCO)	Baltimore	MD	2250	Baltimore Refuse Energy Systems Company
Saugus	Saugus	MA	1500	RESCO (Wheelabrator Technologies, Inc.)
Spokane	Spokane	WA	800	City of Spokane
West Pottsgrove Recycling/R.R. Facility	West Pottsgrove Twp.	PA	1500	Wheelabrator Pottsgrove, Inc.
Westchester	Peekskill	NY	2250	Wheelabrator Technologies, Inc.
VENDOR - Wheelabrator Technologies/Clark-Kenith				
New Hampshire/Vermont S.W. Project	Claremont	NH	200	Wheelabrator Technologies, Inc.
	PROCESS: MB - Rotary Combustor			
VENDOR - (N.A.)				
Montgomery County (North)	Dayton	OH	300	Montgomery County
Montgomery County (South)	Dayton	OH	900	Montgomery County
VENDOR - American Energy Corp. (Laurent Bouillet)				
Auburn (New Plant)	Auburn	ME	200	Mid-Maine Waste Action Authority
VENDOR - C&H Combustors				
Galax	Galax	VA	56	City of Galax
VENDOR - Laurent Bouillet				
Sangamon County	Illiopolis	IL	450	Kirby-Coffman, Inc.
VENDOR - Technochem Environmental Services				
Falls Township (Technochem)	Falls Township	PA	70	Technochem, Inc.

TABLE A-8. SYSTEM VENDORS -- FIELD ERECTED MASS BURN FACILITIES (Cont)

NAME	CITY	STATE	DESIGN TPD	OWNER
VENDOR - Westinghouse Electric Corporation				
Monroe County	Bloomington	IN	500	Westinghouse Electric Corporation
VENDOR - Westinghouse Resource Energy Systems				
Delaware County Regional R.R. Project	Chester	PA	2688	Delaware County Resource Mgmt. Inc.
Gaston County/Westinghouse R.R. Center	High Shoals	NC	440	Gaston County
Mercer County	Hamilton Township	NJ	975	Mercer County Improvement Authority
Monmouth County	Tinton Falls	NJ	1700	Monmouth County
Oakland County	Auburn Hills	MI	2000	Oakland County
San Juan Resource Recovery Facility	San Juan	PR	1040	(Third Party Leasee - TBD)
Waukesha County (New Plant)	Waukesha	WI	600	Waukesha County
Westinghouse/Bay Resource Mgmt. Center	Panama City	FL	510	Ford Motor Credit Corporation
York County	Manchester Township	PA	1344	York Co. Solid Waste & Refuse Authority
VENDOR - Westinghouse/O'Connor				
Sumner County	Gallatin	TN	200	Resource Authority in Sumner County
VENDOR - Westinghouse/Pennsylvania Energy				
Dutchess County	Poughkeepsie	NY	506	Dutchess County Res. Recovery Agency
MacArthur Energy Recovery Facility	Islip	NY	518	Islip Resource Recovery Agency
VENDOR - Wright-Schuchart-Harbor/Energy Res. Rec.				
Skagit County	Mount Vernon	WA	178	Skagit County
	PROCESS: MB - Sludge Co-Disposal			
VENDOR - (N.A.)				
Glen Cove	Glen Cove	NY	250	City of Glen Cove
VENDOR - Ogden Projects, Inc.				
Huntsville	Huntsville	AL	690	Huntsville Solid Waste Disposal Auth.
Indianapolis Resource Recovery Facility	Indianapolis	IN	2362	Ogden Martin Systems of Indianapolis
VENDOR - Sigoure Freres, Inc.				
Sitka	Sitka	AK	24	City & Borough of Sitka

The American Energy Corporation has acquired the domestic rights to the Steinmuller technology from Dravo Energy Resources, Inc. This system utilizes a European style reciprocating grate, waterwall, excess air technology. Plants using this technology are usually larger than 550 TPD (472). As of 1990, three U.S. facilities used the Steinmuller technology, one of which (Portland, Maine) is an American Energy Corporation facility (387). The American Energy Corporation also holds domestic rights to the French Laurent-Bouillet rotary kiln technology (472). As of 1990, there were no Laurent-Bouillet facilities in the U.S.

American Ref-Fuel holds U.S. rights to the German Dusseldorf roller grate technology. The American Ref-Fuel technology is applied at a scale usually from 1,000 to 3,000 TPD. Two facilities were in shakedown and one in operation as of 1990; four were in advanced planning or construction stages.

Asea Brown Boveri/Combustion Engineering has rights to the DeBartolomeis S.p.A. grate. As of 1990, Asea Brown Boveri/Combustion Engineering had one facility (Dakota County, Minnesota, 800 TPD) in advanced planning with none in construction or start-up (387).

Foster-Wheeler Power Systems, Inc. does not have exclusive licensing rights to any mass burn technology and uses a Detroit Stoker reciprocating grate, or a Dusseldorf grate (472). As of 1990, five Foster-Wheeler facilities existed in the U.S. using the Detroit Stoker system (387). All Foster-Wheeler facilities use Foster-Wheeler boilers; American Ref-Fuel's Essex County, NJ facility also uses a Foster-Wheeler boiler. Foster-Wheeler's facilities range from the 360 TPD Norfolk, VA plant to the 1,050 TPD Camden County, NJ facility.

Katy-Seghers, a unit of Katy Industries, provides excess air systems as equipment only or as a full-service (472) and is one of the few boiler vendors offering a refractory furnace. Katy Industries holds the U.S. license to the European Seghers Engineering reciprocating inclined grate. Support services are provided by Fulton Iron Works, a subsidiary of Katy Industries. There are two 550 TPD plants developed by Katy-Seghers operating in the U.S.: one in Savannah, Georgia and the other in Davis County, Utah (472, 387). Seghers Engineering has approximately 18 domestic waste processing plants operating in Europe (605).

The Keeler Boiler Company and Keeler/Dorr-Oliver offer both a rotary kiln mass burn system and a reciprocating grate system (235, 472). Unit capacities range from 50 to 750 TPD, and modularization of the units is an option in some applications. As of 1990, four U.S. facilities used the Keeler reciprocating grate boiler system (grates are actually manufactured by Martin, Von Roll, or Detroit Stoker) (387). The Delaware County, PA facility uses a Keeler boiler with the Westinghouse/O'Connor rotary combustor.

The Montenay Power Corporation has the rights to the Morse-Boulger cascading grate, but Montenay also uses Von Roll, O'Connor, Martin, Steinmuller and Zurn (472). Montenay is involved with the construction or operation of eight facilities in the U.S. and Canada (472). The only U.S. facility originally developed by Montenay is the Key West, Florida facility; all other Montenay plants involve either facility renovation and/or operation contracts (472). Montenay took over two Dravo facilities, the Montgomery County, PA plant, and the S.E. Resource Recovery Facility (SERRF) plant in Long Beach, CA.

Ogden Martin owns the U.S. rights to the reverse-reciprocating Martin grate. The fuel feed chute and the ash discharger are also proprietary equipment (235). As of 1990, Ogden Martin had twelve plants on line, one in startup, and four in construction (387). Ogden Martin primarily constructs plants larger than 550 TPD (472).

Riley Energy Systems is a full service design/erect company with domestic rights to the Japanese Takuma reciprocating grate (402). Riley systems are excess air systems with the Takuma step grate stoker. Riley provides a system called Automatic Combustion Control that stabilizes the steam flow at a predetermined rate by averaging the fuel fluctuations and maintains the desired steam flow by automatically varying the fuel input (235). In addition to regulating the steam flow, this system also controls the furnace conditions. As of 1990, Riley had constructed two facilities in the U.S. (387).

The Volund Company is a Danish firm that offers the System Volund mass burn technology. The domestic branch, Volund USA, is jointly owned by The Volund Company and Waste Management. Volund USA holds the North American rights to the System Volund technology with the exception of a few geographic areas where Wheelabrator Environmental holds the license. The Volund technology consists of a stepped reciprocating grate similar to the Riley/Takuma system (472). Most of the lower furnace is lined with refractory. Volund offers the only two way gas system that completely mixes the flue gases. Volund had a rotary kiln type combustor, but no longer offers it for mass burn (472). As of 1990, Volund provided boiler systems for three U.S. facilities ranging from 235 to 2250 TPD (387).

The Westinghouse Electric Corporation has obtained the rights to the O'Connor rotary kiln combustor. The O'Connor combustor combines the better features of rotary kilns without the disadvantages of a refractory liner and uses a waterwall boiler without a moving grate system (608). The train size for the O'Connor technology is usually 120 to 170 TPD (472). As of 1990, Westinghouse had one facility in construction and five in operation using the O'Connor rotary combustor (387). This technology has also been applied in Japan and Thailand.

Wheelabrator Environmental Systems has the domestic rights to the European Von Roll grate technology (472). As of 1990, Wheelabrator had 14 existing facilities in the U.S. (387), 11 of which use the Von Roll grate system. Two of the remaining three facilities use Martin grates, while the other uses the Volund system. Babcock & Wilcox (B&W) waterwall boilers are used at eight of their fourteen facilities, the remainder use Volund and Riley Stoker (two facilities each), and Von Roll and Keeler/Dorr-Oliver (one facility each) (387). Wheelabrator acquired all of Waste Management's waste-to-energy assets in 1988. Waste Management had previously acquired selected rights to the System Volund technology, and Volund is licensed to manufacture the Eckrohr boiler. The Eckrohr boiler is the most commonly used natural circulation boiler both in Europe and Japan for MSW combustion (235).

A.2.6.2 Modular Systems

Table A-9 lists, by system vendor, all the U.S. modular mass burn facilities that were in advanced planning or existing as of 1990 (387). The primary MWC modular boiler supplier is Abco, who supplies the waste heat boilers to Consumat and Synergy Clear Air (472), both modular system vendors. Consumat dominated the modular market in the early 1980s, but has won relatively few projects in the second half of the decade (520). The system vendors are described briefly following the table.

TABLE A-9. SYSTEM VENDORS - MODULAR MASS BURN FACILITIES (387)

NAME	CITY	STATE	DESIGN TPD	OWNER
PROCESS: MB - Modular				
VENDOR - (N.A.)				
Fort Lewis (U.S. Army)	Fort Lewis	WA	120	U.S. Army
New Hanover County	Wilmington	NC	100	New Hanover County
VENDOR - Advanced Combustion Systems, Inc.				
Mayport Naval Station	Mayport	FL	50	U.S. Navy (Mayport Naval Station)
VENDOR - Basic Environmental Engineering				
Collegeville	Collegeville	MN	50	St. Johns University
VENDOR - Basic Environmental Systems, Inc.				
North Slope Borough/Prudhoe Bay	Deadhorse	AK	100	North Slope Borough
VENDOR - Cadoux, Inc.				
Cleburne	Cleburne	TX	115	City of Cleburne
St. Croix County	New Richmond	WI	115	American Res. Recovery Ltd. Partnership
VENDOR - Cadoux, Inc./American Resource Recovery				
Pope-Douglas W-T-E Facility	Alexandria	MN	80	Pope-Douglas Counties Joint S.W. Board
VENDOR - Clear Air, Inc./American Bridge				
Fort Dix	Wrightstown	NJ	80	U.S. Army
VENDOR - Clear Air, Inc./R.W. Taylor Steel Co.				
Oneida County	Rome	NY	200	Oneida County
VENDOR - Clear Air, Inc./Synergy				
Cattaraugus County R-T-E Facility	Cuba	NY	112	Cattaraugus County
Miami International Airport	Miami	FL	60	Dade County Aviation Department
Waxahachie	Waxahachie	TX	50	City of Waxahachie
VENDOR - Consumat Systems, Inc.				
Barron County	Almena	WI	80	Barron County
Batesville	Batesville	AR	100	City of Batesville
Beto 1 Unit (Texas Dept. of Corrections)	Palestine	TX	25	State of Texas
Cassia County	Heyburn	ID	50	Cassia County
Center	Center	TX	40	City of Center
City of Carthage/Panola County	Carthage	TX	40	City of Carthage/Panola County
Dyersburg	Dyersburg	TN	100	City of Dyersburg

TABLE A-9. SYSTEM VENDORS - MODULAR MASS BURN FACILITIES (Cont)

NAME	CITY	STATE	DESIGN TPD	OWNER
Eau Claire County	Seymour Township	WI	150	ENSCO, Inc. (Envir. Systems Company)
Gatesville (Texas Dept. of Corrections)	Gatesville	TX	13	State of Texas
Hampton	Hampton	SC	270	Southland Exchange, Joint Venture
Harford County	Edgewood	MD	360	Waste Energy Partners Ltd. Partnership
Lamprey Regional Solid Waste Cooperative	Durham	NH	108	Lamprey Regional Solid Waste Cooperative
Miami	Miami	OK	108	City of Miami
Muskegon County	Muskegon	MI	180	Muskegon County
Osceola	Osceola	AR	50	City of Osceola
Oswego County	Volney	NY	200	Oswego County
Park County	Livingston	MT	75	Park County
Red Wing	Red Wing	MN	72	City of Red Wing
Salem	Salem	VA	100	City of Salem
Tuscaloosa Energy Recovery Facility	Tuscaloosa	AL	300	Tuscaloosa Solid Waste Disposal Auth.
Windham	Windham	CT	108	Town of Windham
VENDOR - Consumat Systems, Inc./Thermal Reduction				
Bellingham	Bellingham	WA	100	Recomp (formerly Thermal Reduction Co.)
VENDOR - Environmental Control Products				
Fort Leonard Wood	Fort Leonard Wood	MO	75	U.S. Army
VENDOR - Fluor Daniel/Vicon Recovery Systems				
Agawam/Springfield	Agawam	MA	360	Fluor R.R. of Mass. Limited Partnership
VENDOR - Intercon				
Manchester	Manchester	NH	560	City of Manchester
VENDOR - John Zink Company				
Fergus Falls	Fergus Falls	MN	94	City of Fergus Falls
Polk County	Fosston	MN	80	Polk County
Westmoreland County	Hempfield Township	PA	50	Westmoreland County
VENDOR - Lahonton Alternative Energy Systems				
Lassen Community College	Susanville	CA	100	Susanville Resources (DeCom)
VENDOR - Meridian (Vicon Recovery Systems, Inc.)				
Rutland	Rutland	VT	240	Vermont Integrated Waste Solutions
VENDOR - Montenay Power Corporation/Catalyst				
Key West	Key West	FL	150	Montenay KW Corporation
Long Beach	Long Beach	NY	200	Catalyst W-T-E Corp. of Long Beach

TABLE A-9. SYSTEM VENDORS - MODULAR MASS BURN FACILITIES (Cont)

NAME	CITY	STATE	DESIGN TPD	OWNER
VENDOR - Montenay/I.C. Thomasson/Stanley Jones				
Elk River R.R. Authority (TERRA)	Tullahoma	TN	200	Elk River Resource Recovery Authority
VENDOR - Morse Boulger, Inc.				
Harrisonburg	Harrisonburg	VA	100	City of Harrisonburg
VENDOR - Morse Boulger/Brule Refuse Incinerator				
Richard Asphalt	Savage	MN	57	Richards Asphalt Company
VENDOR - Ogden Projects, Inc. (originally Vicon)				
Wallingford	Wallingford	CT	420	Ogden Martin Systems of Wallingford/CRRA
VENDOR - Sigoure Freres, Inc.				
Pascagoula	Moss Point	MS	150	City of Pascagoula
VENDOR - Sverdrup Corporatioh				
Lewis County	Hohenwald	TN	50	Hohenwald Partners
VENDOR - Synergy Systems Corp./Quadrant Company				
Perham	Perham	MN	116	Quadrant Company (Otter Tail Power Co.)
VENDOR - United Power Services (Vicon)				
Energy Gen. Facility at Pigeon Point	Newcastle	DE	600	United Associates of DE/GE Credit Corp.
VENDOR - Vicon Recovery Associates, Inc.				
Pittsfield	Pittsfield	MA	240	Vicon Recovery Associates, Inc.

Basic Environmental Engineering manufactures a multi-stage, waterwall boiler unit (235). These units are mainly provided for dedicated facilities and hospital incineration systems, although they have constructed two MSW facilities in the U.S. (387, 472). Individual units can be continuous or batch fed and range in size from 4 million to 64 million Btu/hr of input energy (235). Basic Envirohmental is the only controlled air vendor to offer a waterwall membrane in the primary chamber in addition to the normal waste heat boiler downstream. Major modifications were made on Basic's two facilities, reportedly due to defective refractory material. Many of the system modifications developed for these two facilities are reported to have been incorporated into new designs (472).

Cadoux America, Inc., offers systems ranging in size from 25 to 200 TPD, in both starved and excess air versions (472). Cadoux uses the pit and crane feed method, and rams to move the material through the combustion chamber (606). Both the primary and secondary chambers are refractory brick and coating lined. As of 1990, Cadoux has three facilities in operation, all using multiples of their 38.4 TPD unit (472). One of these facilities, located in Cleburne, Texas, combusts medical wastes.

Clear Air, Inc. uses the controlled air technology and is batch fed, with a reciprocating grate in the primary chamber (472). Auxiliary fuel burners are used to supplement the primary fuel if its calorific value is too low (612). Material is fed into the primary chamber by a ram feeder and is moved through the chamber by a reciprocating grate. As of 1990, Clear Air had five operating plants in the U.S. (387).

Consumat Systems, Inc. is the largest supplier of modular MSW systems (235, 472). Reportedly, over 70 systems are under construction or operating to produce energy from miscellaneous wastes (611); although GAA reports only 20 U.S. MSW facilities (387). The total number of worldwide installations including energy and non-energy systems exceeds 4,500 with facilities in all 50 states and 34 foreign countries (611). The size of their plants usually is in the range of 40 to 100 TPD, although the largest Consumat system is 360 TPD.

Consumat utilizes the starved air, sub-stoichiometric primary chamber approach (472). The tipping floor/wheel loader method of storage and feed is used, with a ram feeder introducing the material into the primary combustion chamber. Transfer rams move the material through the chamber. A wet ash removal system is utilized.

Ecolaire markets the Brunn & Sorenson technology. Brunn & Sorenson is a small Danish company that produces high temperature hot water (HTHW) systems (277). One plant has been built in Susanville, CA, though it is reported as being unsuccessful (574). Government Advisory Associates reports that this facility is temporarily shut down for modifications (387).

Synergy Systems manufactures a modular mass burn reciprocating grate. They provided this system on two Clear Air projects (Miami, Florida and Waxahachie, Texas) and on one facility developed independently. Reportedly, the company has been sold (472).

Technique Environment Sigoure is a French company formerly known as Sigoure-Freres. Sigoure-Freres constructed two U.S. facilities in Sitka, Alaska and Pascagoula, Mississippi (387). Each of these uses a different modular design. The Sitka facility co-disposes sludge in a York Shipley boiler. The Pascagoula facility uses a primary furnace that rotates about a vertical axis. The waste is agitated by two sets of pokers which lift and turn it to expose all sides to the combustion conditions. Ash is plowed off by a stationary plow (472).

Technochem Environmental Systems, Inc. is the U.S. company of Technitalia S.p.A. This firm offers a modular technology with a continuous cast refractory lined rotary kiln, and two combustion chambers. The rotary kiln drum has internal flighting to lift and advance the MSW (472). As of 1990, Technochem has provided equipment for only one facility -- Skagit County, Washington (387). A second facility using Technochem equipment is reportedly planned for Williams Township, PA (387, 472).

A.3 ECONOMIC DATA

Economics are a major determinant in the decision to construct and operate a waste-to-energy system. As indicated earlier, the source of much of the cost data used in this appendix for mass burn facilities is the Government Advisory Associates 1991 Resource Recovery Yearbook (387). Summary cost tables are presented later in this section and the corresponding detailed tables derived from that database are included as attachments to this document.

Models based on the design and cost of municipal waste combustors often provide valuable insight into the key factors that drive capital, O&M and annualized costs, in general.

A model for the estimation of plant capital costs (at the plus or minus 25% level for 1990) has been developed on the basis of 61 randomly selected waste-to-energy facilities ranging in size from 150 to 3500 TPD (20). Multiple linear regression analysis was performed on vendor quoted costs exclusive of land acquisition, infrastructure improvements and owner administration expenses, which can drive the costs up by as much as 50% (472).

Key parameters upon which the model is based include: plant capacity, number of combustion units, type of facility constructed (modular or field-erected), year the plant was priced, location of plant, type of air pollution control equipment, procurement method, power block construction, combustion chamber (refractory or water wall), energy product and any unique features.

The algorithm developed by Rigo and Conley (20) for predicting 1990 capital costs is presented below. The multiple regression coefficient is 0.914 and the coefficients derived are statistically significant (472).

$$\$1000/TPD = 112.6 - .0129(TPD) + 7.41(FAB1) - 10.4(FAB2) - 26.1(FTYPE) - 23.4(ETYPE)$$

where: TPD = nameplate,
FAB1 = 1 for modular, 0 for other,
FAB2 = 1 for extensive use of modular techniques,
FTYPE = 1 for refractory wall,
ETYPE = 1 for heating steam only.

Several earlier modeling efforts have been reported by Rood (471). Of those, an earlier algorithm by Conley and Rigo is presented here to further illustrate the capital cost functionality according to the parameters mentioned above. The original equation as reported (471) has been adjusted for escalation using the CE plant equipment cost index from 1988 to 1990.

$$\$1,000/TPD = (1.044)\,[92.92 - .0227(TPD) + 51.37(FACTOR1) - 41.21(FACTOR2) + 8.47(FACTOR3) - 8.17(FACTOR4) - 5.63)FACTOR5)]$$

where: FACTOR1 = 1 if TPD > 2000, 0 if TPD < 2000, (MSW combusted),
FACTOR2 = 1 if modular, 0 if other (mass burn or RDF)
FACTOR3 = 1 if spray dryer/fabric filter, 0 if other (electrostatic precipitator),
FACTOR4 = 1 if steam, 0 if producing electrical power or cogenerating both steam for process use and electrical power,
FACTOR5 = 1 if using Architectural/Engineering firm for procurement, 0 if a full-service or turnkey approach is used.

A.3.1 Field Erected Units

A.3.1.1 Capital Costs

Detailed capital cost data for all existing and advanced planned field erected mass burn facilities (as of 1989) are provided in Attachments 3 and 4 to this document. Original capital costs are given along with costs in 1990 dollars. Facilities are listed by air pollution control methods (Attachment 3) and by type of energy produced (Attachment 4). There is a significant range in the capital costs expressed on a dollars/TPD basis which can be attributed to differences in the components of the capital cost, the type of air pollution control equipment included, the type of energy produced, and the year the facility was constructed. Tables A-10 and A-11 summarize the data provided in the attachments with respect to dollars/ton.

The 1989 Monmouth County, NJ Resource Recovery Facility Plan (441) describes a plant with 1,700 TPD capacity, 40 MWe power output, an air-cooled condenser, dry scrubber/fabric filter air pollution control equipment, three front-end processing lines to recover recyclables, and three combustion lines. The front-end processing system is a key element in the facility design that integrates the mass burn and recycling technologies. It is planned to recover aluminum, ferrous metals, corrugated cardboard, batteries, PET, HDPE, and film plastic. Appendix E (Material Recovery/Material Recycling Technologies) provides a detailed discussion on this facility. The capital costs, as estimated in the plan (Table A-12), include $20 million for the front-end separation system. For a throughput of 1,700 TPD, this project has a capital cost of $135,294 per TPD including the front-end system, or $123,529 without the front-end system. The availability is expected to be 85 percent for the combustion plant. The facility is planned to have 156 employees including 75 hand pickers.

TABLE A-10. SUMMARY OF CAPITAL COST BY APC TYPE IN 1990 $/TPD FOR FIELD ERECTED MASS BURN FACILITIES (387)

	NO. OF FACILITIES	LOW	HIGH	AVG	STANDARD DEVIATION
Refractory					
ESP	4	$ 21,595	$104,234	$ 58,666	$ 35,033
Dry Scrubber	1	$ 70,338	$ 70,338	$ 70,338	$ 0
Waterwall					
ESP	23	$ 29,930	$159,858	$ 85,922	$ 33,997
Dry Scrubber	50	$ 45,488	$204,667	$115,621	$ 31,966
Baghouse/FF	1	$128,989	$128,989	$128,989	$ 0
To Be Determined	1	$ 90,000	$ 90,000	$ 90,000	$ 0
Rotary Combustor					
ESP	4	$ 23,424	$ 85,628	$ 63,398	$ 24,552
Baghouse/FF	1	$ 41,825	$ 41,825	$ 41,825	$ 0
Dry Scrubber	15	$ 70,730	$200,000	$108,741	$ 34,942
MSW/Sludge Co-fired					
ESP	2	$175,626	$198,784	$187,205	$ 11,579
Dry Scrubber	2	$ 40,136	$105,072	$ 72,604	$ 32,468

TABLE A-11. SUMMARY OF CAPITAL COST BY ENERGY TYPE IN 1990 $/TPD FOR FIELD ERECTED MASS BURN FACILITIES (387)

	NO. OF FACILITIES	LOW	HIGH	AVG	STANDARD DEVIATION
Refractory					
Steam	3	$ 21,595	$104,234	$ 51,193	$ 37,590
Electricity	1	$ 81,084	$ 81,084	$ 81,084	$ 0
Steam & Elec.	1	$ 70,388	$ 70,388	$ 70,388	$ 0
Waterwall					
Steam	4	$ 36,098	$142,000	$ 85,072	$ 37,713
Electricity	58	$ 45,488	$204,667	$110,691	$ 32,515
Steam & Elec.	13	$ 32,930	$159,858	$ 93,149	$ 39,364
Rotary Combustor					
Steam	1	$ 41,825	$ 41,825	$ 41,825	$ 0
Electricity	13	$ 23,424	$132,500	$ 91,728	$ 27,471
Steam & Elec.	6	$ 63,277	$200,000	$115,374	$ 50,187
MSW/Sludge Co-fired					
Steam	3	$ 40,136	$198,784	$114,664	$ 65,122
Steam & Elec.	1	$175,626	$175,626	$175,626	$ 0

TABLE A-12. ESTIMATED CAPITAL COSTS FOR THE MONMOUTH COUNTY RESOURCE RECOVERY FACILITY (441)

	COST ($MM)
Site work	11
Buildings	28
Process equipment	18
Combustion and ancillaries	112
Start-up and testing	9
Insurance and non-equipment	14
Engineering, permitting, CM	17
Contingency	21

	$ 230

A.3.1.2 Operation and Maintenance Costs

Attachment 5 shows the operation and maintenance costs for all existing and planned field erected mass burn facilities as of 1990 (387). These data are summarized in Table A-13.

TABLE A-13. AVERAGE O&M COSTS FOR FIELD-ERECTED MASS BURN FACILITIES (387)

	AVG. SIZE, TPD	$/TON WITH DEBT SERVICE	$/TON WITHOUT DEBT SERVICE	$/YEAR WITH DEBT SERVICE	$/YEAR WITHOUT DEBT SERVICE
Refractory	540	$67	$27	$7,606,250	$3,395,000
Waterwall	1138	$62	$25	$20,008,478	$8,007,144
Rotary	759	$50	$19	$10,222,591	$4,721,405
MSW/Sludge	832	$44	$33	$12,196,667	$4,080,000

The estimated O&M costs for the proposed Monmouth County, NJ facility are presented in Table A-14.

TABLE A-14. ESTIMATED O&M COSTS FOR THE MONMOUTH COUNTY RESOURCE RECOVERY FACILITY (441)

	COST, $MM/YR
O&M	$13.6
Insurance	0.8
Utilities	0.2
Residue Disposal	5.6
County Admin.	0.3
Host Fee	0.5
Total	$21.0

Of this $21 million annual total, $10 million is for the front-end process. On a unit cost basis, this is $34 per ton including the front-end process, or $18 per ton excluding the front-end process.

Attachment 6 details the full-time staff for field erected mass burn facilities, including management and non-management employees. Also, the total number of full time employees is normalized on a per 100 TPD basis. These data are summarized in Table A-15.

TABLE A-15. SUMMARY STAFFING DATA FOR FIELD-ERECTED MASS BURN FACILITIES (387)

	NUMBER OF FACILITIES	FULL TIME EMPLOYEES PER 100 TPD	STANDARD DEVIATION
Refractory	5	7.8	2.0
Waterwall	74	5.7	3.4
Rotary Combustor	20	10.4	9.7
MSW/Sludge	4	10.7	7.2

A.3.2 Modular Systems

A.3.2.1 Capital Costs

Cost data on all existing and planned modular systems as of 1990 (387) are detailed in Attachments 7 and 8 according to air pollution control equipment utilized and type of energy produced, respectively. The overall capital cost for modular systems in 1990 dollars ranges considerably, from $16,742 to $159,437 per TPD. This large range may be attributed to differences in the components of the capital cost, the type of air pollution control equipment included, the type of energy produced, and the year the facility was constructed. Tables A-16 and A-17 summarize this data. Of the 60 plants listed in the attachments, 22 had undergone modifications, the cost of which ranged from $100,000 to $25,000,000. Modifications included upgrading of air pollution control systems, boiler repair, and installation of additional units.

TABLE A-16. SUMMARY OF MODULAR FACILITY CAPITAL COST IN 1990 $/TPD BY APC TYPE (387)

	LOW	HIGH	AVG	STANDARD DEVIATION
Electrostatic Precip	$35,970	$159,437	$81,351	$35,512
Dry Scrubber	$22,473	$101,497	$74,419	$22,675
Baghouse/Fabric Filter	$33,484	$90,620	$62,052	$28,568
Two Chamber Furnace	$16,742	$81,139	$48,458	$17,593
Cyclones	$31,972	$68,482	$47,695	$15,329
Wet Scrubber	$45,917	$45,917	$45,917	$0

TABLE A-17. SUMMARY OF MODULAR FACILITY CAPITAL COST IN 1990 $/TPD BY ENERGY TYPE (387)

	LOW	HIGH	AVG	STANDARD DEVIATION
Steam	$16,742	$93,144	$56,884	$20,384
Electricity	$22,473	$147,665	$88,507	$37,688
Steam & Electricity	$44,241	$159,437	$88,922	$30,602
Hot Water	$83,709	$83,709	$83,709	$0

A.3.2.2 Operation and Maintenance Costs

Attachment 9 provides the operation and maintenance costs for all planned and existing modular mass burn facilities as of 1990 (387). The average O&M cost per ton for modular system is shown to be $57/ton including debt service, and $43/ton without debt service costs. Attachment 10 shows the staffing levels for all existing and planned modular mass burn facilities as of 1990 (387). Both management and non-management employees are included. Normalized on a per 100 TPD basis, the average full time staff totals 16.8, including both management and non-management employees.

A.3.3 Air Pollution Control Equipment Costs

The capital and O&M costs of various systems for controlling MWC emissions are presented in Tables A-18 through A-23. These costs were estimated using the model plant approach (298). Original costs were August 1986 prices; they have been escalated to 1990 costs using the Chemical Engineering Plant Cost Indices. The capital cost estimates are based on 25 percent excess combustor capacity plus a 20 percent contingency. The cost of the control system and any auxiliary system such as ductwork, I.D. fan, etc are included. Spray dryer systems do not require a special acid resistant lining and consequently, a credit has been applied to the cost of spray dryer systems to account for this cost savings. Separate costs are provided for modular and field erected facilities, and a separate tabulation is provided for new and existing model facilities.

TABLE A-18. ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS
NEW MODEL MWC FACILITIES ($000 based on 8000 hr/yr operation) (298)

PM LEVEL AFTER CONTROL, gr/dscf @ 12 % CO2	FIELD ERECTED 250 TPD CAPACITY	FIELD ERECTED 1000 TPD CAPACITY	FIELD ERECTED 3000 TPD CAPACITY	MODULAR 100 TPD CAPACITY	MODULAR 250 TPD CAPACITY	MODULAR 400 TPD CAPACITY
ESP SYSTEM						
0.03	1740	4380	11489	383	781	1146
0.02	2191	5271	13286	502	949	1341
0.01	2529	6201	15842	547	1043	1476
SPRAY DRYER/ESP SYSTEM						
0.03	4614	10503	26053	1602	2718	3537
0.02	5154	11507	27503	1703	2837	3919
0.01	5467	12260	29921	1757	2974	4053
SPRAY DRYER/FF SYSTEM						
0.03	4764	10001	24362	2201	3567	4694
0.02	4764	10001	24362	2201	3567	4694
0.01	4965	10628	26053	2269	3702	5367

The capital cost estimates were developed for control systems at 125% of actual size and include a 20% contingency.
Spray dryer designed for 90 and 70 percent control of HCl and SO2, respectively.
Original 1986 costs escalated to 1990 costs using CE plant cost indices.

TABLE A-19. ESTIMATED ANNUALIZED COSTS OF EMISSION CONTROL SYSTEMS NEW MODEL MWC FACILITIES ($000 based on 8000 hr/yr operation) (298)

PM LEVEL AFTER CONTROL, gr/dscf @ 12 % CO2	FIELD ERECTED 250 TPD CAPACITY	FIELD ERECTED 1000 TPD CAPACITY	FIELD ERECTED 3000 TPD CAPACITY	MODULAR 100 TPD CAPACITY	MODULAR 250 TPD CAPACITY	MODULAR 400 TPD CAPACITY
ESP SYSTEM						
0.03	416	1034	2751	101	182	257
0.02	498	1198	3082	124	213	293
0.01	560	1370	3552	131	231	318
SPRAY DRYER/ESP SYSTEM						
0.03	1192	2840	7317	427	724	964
0.02	1298	3039	7605	447	748	1039
0.01	1361	3189	8084	458	776	1066
SPRAY DRYER/FF SYSTEM						
0.03	1252	2863	7343	559	927	1247
0.02	1252	2863	7345	559	927	1247
0.01	1292	2989	7680	573	954	1380

Spray dryer designed for 90 and 70 percent control of HCl and SO2, respectively.
Original 1986 costs escalated to 1990 costs using CE plant cost indices.

TABLE A-20. ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS
EXISTING MODEL REFRACTORY MWC FACILITIES ($000 based on 6500 hr/yr operation) (298)

CONTROL DEVICE	FIELD ERECTED 200 TPD CAPACITY	FIELD ERECTED 450 TPD CAPACITY	FIELD ERECTED 600 TPD CAPACITY	FIELD ERECTED 750 TPD CAPACITY	FIELD ERECTED 1200 TPD CAPACITY	MODULAR 100 TPD CAPACITY
ESP SYSTEM (1)						591
DRY SCRUBBER SYSTEM (2)			6744	7726	11596	
DRY SCRUBBER/ESP (1,2)						3166
DRY SCRUBBER/FF (1,2)	7115	12743	12424	14295	21053	

(1) 0.02 gr/dscf corrected to 12% CO2.
(2) 90 and 70 percent reduction of HCl and SO2, respectively.
(3) Original 1986 costs escalated to 1990 costs using CE plant cost indices.

TABLE A-21. ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS
EXISTING MODEL REFRACTORY MWC FACILITIES ($000 based on 6500 hr/yr operation) (298)

CONTROL DEVICE	FIELD ERECTED 200 TPD CAPACITY	FIELD ERECTED 450 TPD CAPACITY	FIELD ERECTED 600 TPD CAPACITY	FIELD ERECTED 750 TPD CAPACITY	FIELD ERECTED 1200 TPD CAPACITY	MODULAR 100 TPD CAPACITY
ESP SYSTEM (1)						138
DRY SCRUBBER SYSTEM (2)			1874	2180	3239	
DRY SCRUBBER/ESP (1,2)						724
DRY SCRUBBER/FF (1,2)	1660	3017	3023	3509	5163	

(1) 0.02 gr/dscf corrected to 12% CO2.
(2) 90 and 70 percent reduction of HCl and SO2, respectively.
(3) Original 1986 costs escalated to 1990 costs using CE plant cost indices.

TABLE A-22. ESTIMATED CAPITAL COSTS OF EMISSION CONTROL SYSTEMS EXISTING MODEL WATERWALL MWC FACILITIES ($000 based on 6500 hr/yr operation) (298)

CONTROL DEVICE	FIELD ERECTED 200 TPD CAPACITY	FIELD ERECTED 400 TPD CAPACITY	FIELD ERECTED 1000 TPD CAPACITY	FIELD ERECTED 2200 TPD CAPACITY	MODULAR 100 TPD CAPACITY	MODULAR 200 TPD CAPACITY	MODULAR 300 TPD CAPACITY
ESP SYSTEM (1)					547	879	1122
DRY SCRUBBER	3440	5103	11120	16120			
DRY SCRUBBER/ESP (1,2)					2865	4327	5464
DRY SCRUBBER/FF (1,2)	6735	9590	20991	28423			

(1) 0.02 gr/dscf corrected to 12% CO_2.
(2) 90 and 70 percent reduction of HCl and SO_2, respectively.
(3) Original 1986 costs escalated to 1990 costs using CE plant cost indices.

TABLE A-23. ESTIMATED ANNUALIZED OPERATING COSTS OF EMISSION CONTROL SYSTEMS EXISTING MODEL WATERWALL MWC FACILITIES ($000 based on 6500 hr/yr operation) (298)

CONTROL DEVICE	FIELD ERECTED 200 TPD CAPACITY	FIELD ERECTED 400 TPD CAPACITY	FIELD ERECTED 1000 TPD CAPACITY	FIELD ERECTED 2200 TPD CAPACITY	MODULAR 100 TPD CAPACITY	MODULAR 200 TPD CAPACITY	MODULAR 300 TPD CAPACITY
ESP SYSTEM (1)					129	199	252
DRY SCRUBBER	910	1372	3059	4805			
DRY SCRUBBER/ESP (1,2)					649	993	1262
DRY SCRUBBER/FF (1,2)	1571	2280	5061	7349			

(1) 0.02 gr/dscf corrected to 12% CO_2.
(2) 90 and 70 percent reduction of HCl and SO_2, respectively.
(3) Original 1986 costs escalated to 1990 costs using CE plant cost indices.

Tables A-18 and A-19 present capital and operation and maintenance costs, respectively, for new model MWC facilities. The three types of air pollution control included in these cost tabulations include electrostatic precipitators, dry scrubbing with an electrostatic precipitator, and dry scrubbing with a fabric filter. Costs are included for three levels of particulate matter emission: 0.03, 0.02, and 0.01 gr/dscf at 12 percent CO_2. Further, costs are included for field-erected facilities ranging from 250 to 3,000 TPD and for modular facilities ranging from 100 to 400 TPD. As expected, the capital costs and O&M costs for each of the options increases as the desired particulate matter concentration in the exhaust gas is decreased. However, this effect is much less pronounced with a dry scrubber/fabric filter system than for the other two options.

Tables A-20 and A-21 present capital and operation and maintenance costs, respectively, for model existing refractory MWC facilities. The four types of air pollution control included in these cost tabulations include electrostatic precipitators, dry scrubbing, dry scrubbing with an electrostatic precipitator, and dry scrubbing with a fabric filter. Costs, where available, are included for field-erected facilities ranging from 200 to 1,200 TPD and for a 100 TPD modular facility.

Tables A-22 and A-23 present capital and operation and maintenance costs, respectively, for model existing waterwall MWC facilities. The four types of air pollution control included in these cost tabulations include electrostatic precipitators, dry scrubbing, dry scrubbing with an electrostatic precipitator, and dry scrubbing with a fabric filter. Costs, where available, are included for field-erected facilities ranging from 200 to 2,200 TPD and for modular facilities ranging from 100 to 300 TPD.

Kapner and Schwarz (218) compared the cost of a dry scrubber/fabric filter emission control system versus a dry scrubber/ESP system for a facility consisting of three 350 TPD waterwall incinerators. Both systems were specified to meet a pollutant removal criterion of 0.01 gr/dscf for particulate, and 90 percent removal of incoming hydrogen chloride and sulfur dioxide. Four vendors supplied cost estimates for the equipment, and all four priced their fabric filter systems below their precipitators. The average cost for the fabric filter and precipitator systems quoted were $6.9 million and $7.3 million, respectively. Nearly 60 percent of the system cost was credited to the dry scrubber in both cases. The price differences between the two systems ranged from 1 to 9 percent.

Kapner and Schwarz also compared operation and maintenance costs for the two emission control systems. Data on both systems were obtained from vendor literature and from a survey of incinerator operators. The cost components included in the estimate were electricity, replacement parts such as filter bags, dry scrubber reagent, and labor for routine operation and maintenance. The estimated costs for the dry scrubber/fabric filter system were about 4 percent higher than for the dry scrubber/ESP system, at $906,000 per year versus $875,000 per year.

A comparison was made of the Flakt Dry Lime Adsorption System (DAS) versus the spray dryer (DRYPAC) for organics and dioxin removal (137). The capital cost comparison showed that the DAS is 8 percent less costly than the spray dryer system. A comparison of the O&M costs indicated that the DAS is 12.5 percent less expensive than the spray dryer system.

NOx removal systems require a substantial capital investment. The capital cost of a selective catalytic reduction (SCR) system for NOx removal is estimated at approximately $3,000,000 in 1990 dollars for a 1,000 TPD mass burn stoker fired facility (69). By way of contrast, an alternate, relatively experimental, method of NOx removal, the electron beam process, has a much higher capital cost of approximately $18,000,000 in 1990 dollars for the same facility (69). The electron beam capital cost includes all costs for a complete system including a pre-scrubber and a fabric filter. An equipment scale up of 6:1 was required to calculate the estimated capital cost for the electron beam system because of its relatively preliminary status, commercially.

The Thermal DeNOx system for NOx removal can be very cost effective if high NOx reduction is required. Typical costs for a two train 1,000 TPD MWC are estimated to be $385,000 for equipment only, and $800,000 including equipment, labor, overhead, construction supervision, all erection costs, engineering, and contingency (77). All costs are originally 1985 dollars escalated to 1990 costs using the Chemical Engineering Plant Cost Indices, and they are based on southern California labor rates. These typical DeNOx facility costs include one 120 lb/hr ammonia vaporizer, one 12,000 gallon liquid ammonia storage tank, injectors, piping, and instruments. The untreated flue gas is assumed to contain 230 vppm NOx at 12 percent carbon dioxide. The system is designed to remove 65% of the NOx. Table A-24 shows the annual O&M costs for this system.

TABLE A-24. O&M COSTS FOR THERMAL DeNOx SYSTEM (77)
1,000 TPD FACILITY - 1990 COSTS

	Annual Use	Unit Cost	Annual Cost
NH_3	482 Tons	$275/Ton	$132,000
Carrier Steam (15 psi)	27 KTon	$13/Ton	$358,000
Vaporizer Electricity	158 MWH	$66/MWH	$ 9,900
			$499,900

All costs are original 1985 costs escalated to 1990 using the Chemical Engineering Plant Cost indices.

The costs of retrofitting the Olmstead County Waste to Energy Facility in Rochester, MN with two systems for reducing NOx emissions were estimated and compared (535). Natural gas reburning was compared with Thermal DeNOx to determine its applicability as an alternative to Thermal DeNOx. Both systems are comparable in terms of capital costs with the reburn system being slightly higher at $594,000 versus $564,000 for the DeNOx system. If the additional steam produced in the reburn unit can be sold or used to generate electricity, then the O&M, as well as the overall cost comparison, can decidedly favor natural gas burning (535). However, this analysis is heavily dependent on steam demand and natural gas and electricity costs. Moreover, MWCs are typically heat input limited systems. Therefore, it is unlikely, without derating the boiler, that a typical MWC system can realize the value of the proposed additional steam credit.

A.4 MASS AND ENERGY BALANCE

Figure A-11 shows the estimated mass and energy balances for a typical 550 TPD mass burn facility (716). The energy balance assumes the incoming waste has a higher heating value (HHV) of 5,000 Btu/lb. Approximately 85 percent of the electricity produced is available for sale, with the remaining 15 percent used internally. The ash is reported as 27 percent of the incoming waste stream on a wet basis after ferrous removal.

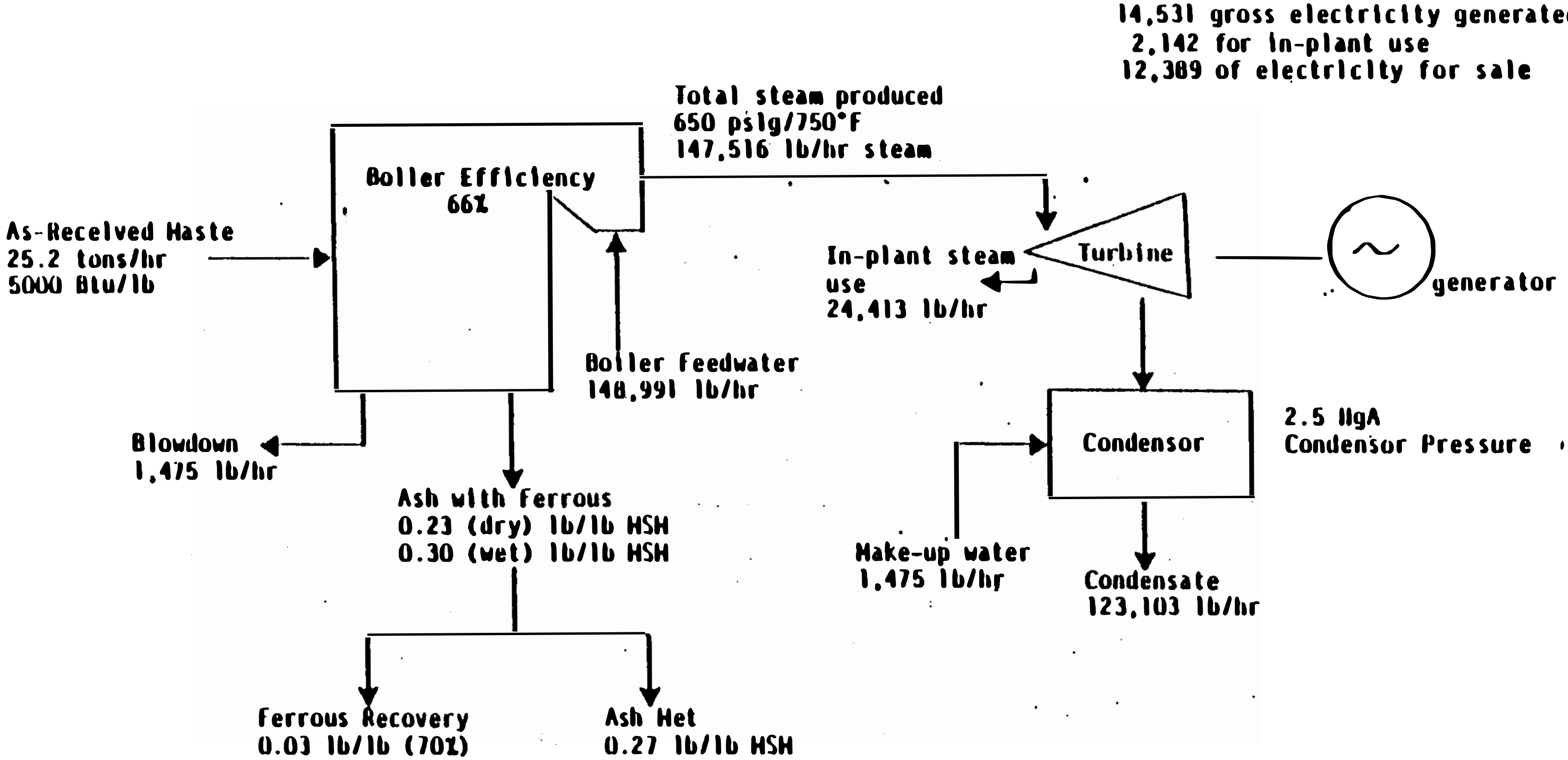


Figure A-11. Mass and Energy Balance - 500 TPD Mass Burn Facility (716)

Figure A-12 shows the estimated mass and energy balances for the Monmouth County proposed 2,000 TPD maximum daily combustion capacity facility (352). The energy balance assumes a HHV of 4,650 Btu/lb for the incoming waste. Approximately 88 percent of the electricity produced will be available for sale; the remaining 12 percent is planned for internal use. The ash is reported as approximately 21 percent of the incoming waste on a wet basis. (A lesser amount of ash is expected because of the front-end processing system associated with this facility which will remove a major portion of the non-combustibles.)

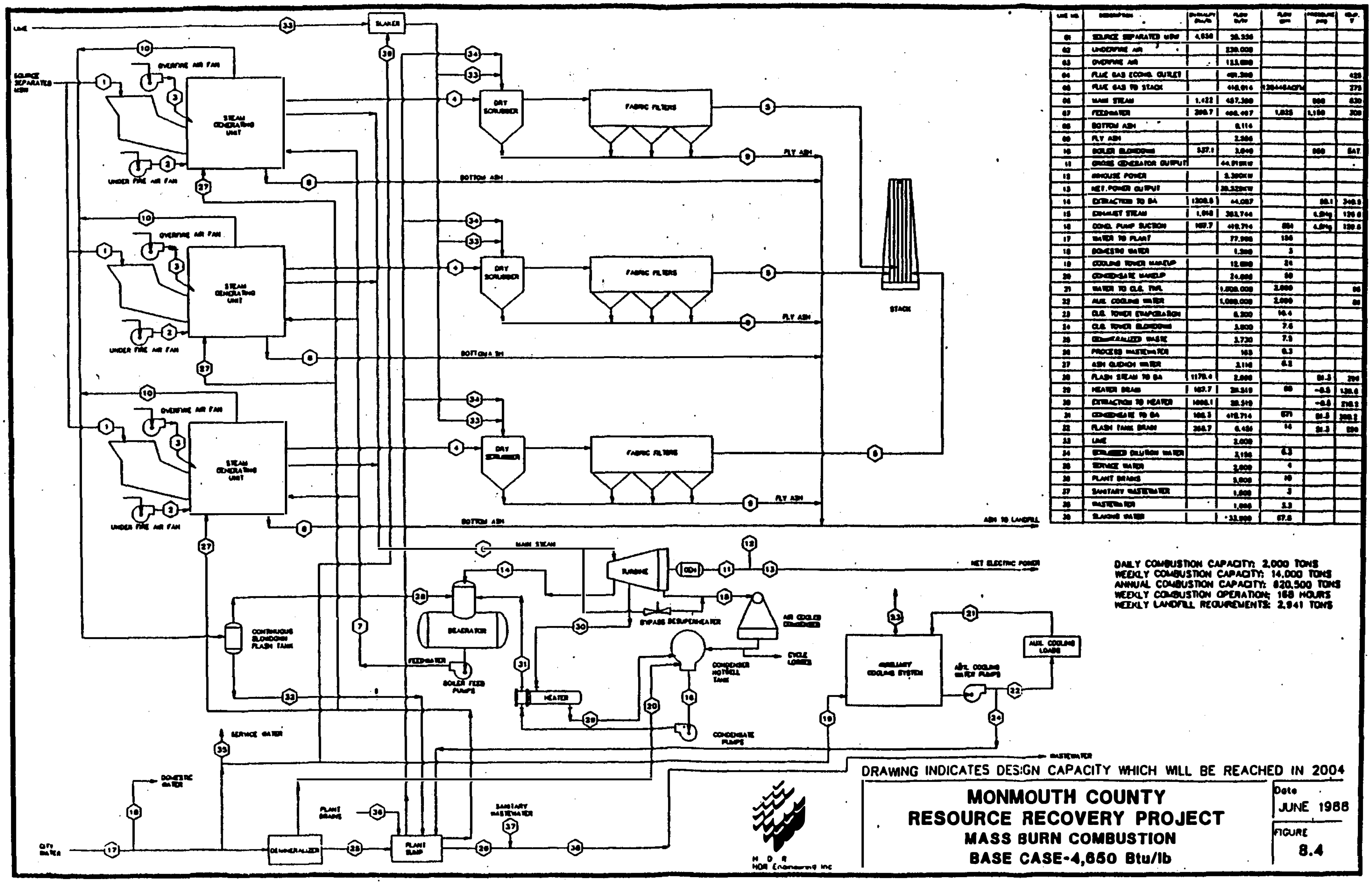
Table A-25 shows typical energy losses in both an excess air waterwall and a starved air modular municipal waste combustor assuming a fuel heating value of 5,000 Btu/lb.

TABLE A-25. TYPICAL LOSSES IN REFUSE-FIRED BOILERS (255)

	Excess Air Waterwall	Starved Air Modular
Dry flue gas	13.7%	13%
Evaporation	13.5%	12%
Unburned carbon	0.7%	3%
Heat in ash	0.6%	1%
Radiation, unaccountable	1.9%	6%

Assumes a fuel heating value of 5,000 Btu/lb

Table A-26 briefly summarizes the key process control and resultant energy recovery parameters for modular and field-erected mass burn systems. The specific process control parameters will depend on the energy user's requirements (e.g., fuel heating value, steam conditions, feedwater temperature, steam flow, and parasitic energy loads). While modular systems generally offer better economics at lower design capacities, the field-erected units are thermally more efficient. Even though their shear size limits their ability to respond quickly to varying load demands, this characteristic, in addition to higher thermal recovery, also offers a "thermal inertia" to overcome short-term swings and ensure better burnout of combustibles.



[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
01	SOURCE SEPARATED MSW	4,650	[illegible]			
02	UNDERFIRE AIR		230,000			
03	OVERFIRE AIR		122,000			
04	FLUE GAS ECONO. OUTLET		[illegible]			425
05	FLUE GAS TO STACK		418,014	120446ACFM		275
06	MAIN STEAM	1,422	437,300		900	830
07	FEEDWATER	290.7	446,407	1,025	1,150	300
08	BOTTOM ASH		8,114			
09	FLY ASH		2,306			
10	BOILER BLOWDOWN	537.1	3,040		950	SAT.
11	GROSS GENERATOR OUTPUT		44,[illegible]KW			
12	INHOUSE POWER		3,300KW			
13	NET POWER OUTPUT		[illegible]KW			
14	EXTRACTION TO DA	1208.8	44,087		80.1	348.5
15	EXHAUST STEAM	1,048	383,744		4.5"Hg	120.6
16	COND. PUMP SUCTION	107.7	419,714	850	4.5"Hg	120.6
17	WATER TO PLANT		77,900	156		
18	DOMESTIC WATER		1,300	3		
19	COOLING TOWER MAKEUP		12,000	24		
20	CONDENSATE MAKEUP		24,000	50		
21	WATER TO CLG. TWR.		1,500,000	3,000		95
22	AUX. COOLING WATER		1,000,000	2,000		85
23	CLG. TOWER EVAPORATION		6,300	14.4		
24	CLG. TOWER BLOWDOWN		3,800	7.6		
25	DEMINERALIZED WASTE		3,730	7.3		
26	PROCESS WASTEWATER		165	0.3		
27	ASH QUENCH WATER		3,110	6.2		
28	FLASH STEAM TO DA	1170.4	2,000		80.3	290
29	HEATER DRAIN	107.7	38,319	80	-0.5	138.6
30	EXTRACTION TO HEATER	1066.1	38,319		-0.6	218.2
31	CONDENSATE TO DA	186.3	419,714	871	80.3	208.2
32	FLASH TANK DRAIN	264.7	6,436	14	81.3	290
33	LIME		2,000			
34	SCRUBBER DILUTION WATER		3,190	6.3		
35	SERVICE WATER		2,000	4		
36	PLANT DRAINS		5,000	10		
37	SANITARY WASTEWATER		1,000	3		
38	WASTEWATER		1,000	3.3		
39	SLAKING WATER		*33,000	67.5		

Figure A-12. Mass and Energy Balance - 2,000 TPD Mass Burn Facility (352)

TABLE A-26. ENERGY RECOVERY COMPARISON
MODULAR vs FIELD ERECTED MASS BURN SYSTEMS (799)

Description	Modular	Field Erected
Higher Heating Value of MSW	4,500 Btu/lb	4,500 Btu/lb
Steam Conditions	600/600 psig/°F	625/755 psig/°F
Feedwater Temperature	300°F	300°F
Boiler Efficiency	40 - 60%	65 - 70%[1)]
Gross Steam Flow	3,500 - 5,300 lb/ton received waste	5,200 - 5,700 lb/ton received waste
Gross Electrical Output	320 - 480 kWh/ton	520 - 570 kWh/ton
Net Electrical Output	290 - 430 kWh/ton	470 - 510 kWh/ton

1) Waterwall furnace efficiency. Refractory furnace efficiencies may be as low as 60%.

Power production data for all types of mass burn facilities (387) is summarized in Table A-27. These data allow a comparison of the gross and net power output and kWh/ton. Because the data are limited, significant conclusions cannot be made. However, waterwall units have the ighest ratios indicating that they are the most efficient in terms of energy production. Attachment 11 provides detailed data for all of the field erected and modular mass burn facilities existing or in advanced planning in 1989.

TABLE A-27. RATIO OF NET/GROSS
POWER OUTPUT AND kWh/TON (387)

	Total No.	Net Gross kWh/T	% Reporting	Net Power Output	% Reporting
Waterwall	75	0.87	25	0.83	93
Refractory	5	0.67	20	0.73	40
Rotary	20	0.76	30	0.83	90
Modular	54	0.78	5	0.71	33

A.5 ENVIRONMENTAL RELEASES/IMPACTS

The major environmental releases from a mass bum MWC are the air emissions discharged from the stack, the residue discharged as bottom ash from the furnace and as fly ash from the air pollution control devices, and wastewater generated from facility and equipment washdown, boiler blowdown, and other miscellaneous uses.

A.5.1 Air Emissions

The air emissions of greatest interest are the criteria pollutants listed in Table A-6 (Section A.2.5) for which New Source Performance Standards (NSPS) have been recently promulgated. These pollutants are particulate matter, carbon monoxide, organics (dioxins/furans), acid gases (SO_2, HCl), and nitrogen oxides (NO and NO_2, together referred to as NOx). Other pollutants generated by the combustion of MSW include hydrogen fluoride and heavy metals -- arsenic, beryllium, cadmium, chromium, lead, mercury, and nickel. Table A-28 presents summary data on emissions measured from mass bum systems with varying levels of air pollution control (APC) equipment and operating conditions. Acid-gas capture efficiencies for selected APC technologies are presented in Table A-29.

To achieve the designated pollutant removal efficiencies, municipal waste combustors (MWCs) are required to utilize Best Demonstrated Technology (BDT) -- state-of-the-art APC equipment. Examples of systems in use at selected field-erected and modular mass bu m facilities are as follows:

- o Marion County, OR. This Ogden-Martin facility, which began operations in late 1986, was the first U.S. waste-to-energy facility to use a dry scrubber/fabric filter combination for air pollution control (387). It consists of two 275 TPD waterwall units. Each unit has a Teller-design spray dryer and fabric filter for acid gas and particulate emission control. Flue gases leave the boiler economizer and enter the bottom of the spray dryer through a cyclonic inlet for the removal of large particles. A slaked pebble lime reagent is mixed with water and injected into the spray dryer through nozzles at a lime to HCl ratio of 2.5. A dry venturi follows the spray dryer, where Tesisorb[tm] material is injected to enhance the collection performance and reduce the pressure drop across the subsequent fabric filter.

TABLE A-28. SUMMARY OF EMISSIONS MEASURED FROM MASS BURN/MODULAR COMBUSTORS (471)

Pollutant	Mass Burn	Modular
Particulate Matter	5.5 - 1,530 mg/Nm^3	23 - 300 mg/Nm^3
	(0.002 - 0.669 gr/dscf)	(0.012 - 0.13 gr/dscf)
Sulfur dioxide	0.04 - 401 ppmdv	61 - 124 ppmdv
Nitrogen oxides	39 - 380 ppmdv	260 - 310 ppmdv
Carbon monoxide	18.5 - 1,350 ppmdv	3.2 - 67 ppmdv
Hydrogen chloride	7.5 - 477 ppmdv	160 - 1,270 ppmdv
Hydrogen fluoride	0.62 - 7.2 ppmdv	1.1 - 16 ppmdv
Arsenic	0.452 - 233 μg/Nm^3	6.1 - 119 μg/Nm^3
Beryllium	0.0005 - 0.33 μg/Nm^3	0.096 - 0.11 μg/Nm^3
Cadmium	6.2 - 500 μg/Nm^3	21 - 942 μg/Nm^3
Chromium	21 - 1,020 μg/Nm^3	3.6 - 390 μg/Nm^3
Lead	25 - 15,000 μg/Nm^3	237 - 15,500 μg/Nm^3
Mercury	9 - 2,200 μg/Nm^3	130 - 705 μg/Nm^3
Nickel	230 - 480 μg/Nm^3	<1.92 - 553 μg/Nm^3
TCDD	0.20 - 1,200 ng/Nm^3	1.0 - 43.7 ng/Nm^3
TCDF	0.32 - 4,600 ng/Nm^3	12.2 - 345 ng/Nm^3
PCDD	1.1 - 11,000 ng/Nm^3	63 - 1,540 ng/Nm^3
PCDF	0.423 - 15,000 ng/Nm^3	97 - 1,810 ng/Nm^3

TABLE A-29. APC CAPTURE EFFICIENCIES (%) (298)

	HCl (%)	HF (%)	SO_2 (%)	Temperature (degrees C)
DSI/FF	80	98	50	160-180
DSI/FBC/ESP	90	99	60	230
SDA/ESP	95+	99	50-70	
w/sorbent recycle	95+	99	70-90	140-160
SDA/FF	95+	99	50-70	
w/sorbent recycle	95+	99	80-95	200
Wet Scrubber	95+	99	90+	40-50
Dry/Wet Scrubber	95+	99	90+	40-50

DSI = Duct Sorbent Injection
FF = Fabric Filter
FBC = Fluidized-bed Combustor
ESP = Electrostatic Precipitator
SDA = Spray Dryer Absorber (Dry Scrubber)

- Long Beach, CA. The SouthEast Resource Recovery Facility (SERRF), operated by Montenay, uses a Steinmuller grate/furnace, 650 psi/750 degree F steam conditions, flue gas recirculation to help reduce NOx formation, a spray dryer absorber by Flakt with 1.6 stoichiometry, a rotary atomizer, and a fabric filter which uses a conservative 2:1 air to cloth ratio. Additional NOx control is by Exxon Thermal DeNOx, and the plant has a continuous online HCl monitor in the stack by Boden Seewerk (546).

- Dutchess County, NY. This Westinghouse plant, which started up in September, 1988, has two 200 TPD trains and a projected output of 8 MWe. It uses dry lime injection and a fabric filter for air pollution control. Dioxin emissions have been measured at 1.3 to 4.6 nanograms per standard cubic meter (ng/Nm^3) from this facility. Carbon monoxide varies from 40 to 170 ppm and NOx is about 100 ppm (545). The combustion process requires only about 50 percent excess air, helping to reduce NOx formation (608).

o Bridgeport, CT. This Wheelabrator facility which utilizes the Von Roll and Babcock and Wilcox technology, began operation in July, 1988 (540). The plant has 800 psi/840 degrees F steam conditions, three boiler trains, and is rated at 2,250 TPD and 70 MWe. It uses a spray dryer absorber and fabric filter for air pollution control. The total solid particulate (TSP) stack emission is less than 0.0015 grains per dry standard cubic foot of gas (gr/dscf); almost an order of magnitude less than the most stringent new source performance standards. Dioxin data has been measured as 0.01, 0.012, 0.067 micrograms per standard cubic meter (ug/Nm^3), which is 10 to 67 nanograms per standard cubic meter.

o Skagit County, WA. This Technochem Environmental Systems' facility, started up in 1989, has two lines for a 178 TPD total capacity. The units are rotary kilns with secondary chambers, and utilize Teller type (Research-Cottrell) spray-dryer absorbers and fabric filters using hydrated lime. The spray dryer absorber sprays lime in a water slurry into the flue gas with the objective of reacting with the acid gases, capturing the sulfur and chlorides as relatively harmless salts. The plant has one 2.5 megawatt electric output turbine, using 450 psi saturated steam conditions (541).

For new facilities, BDT has been determined to be a fabric filter for metals control, a spray dryer/fabric filter for acid gas control, and selective non-catalytic reduction for NOx control. The Commerce, CA 400-TPD facility uses this technology and claims to have the most modern air pollution control system of any MWC in the world (636). Designed by Foster-Wheeler, the Commerce facility utilizes a Detroit reciprocating grate. It produces 11.5 MWe from 5,500 to 6,000 Btu per pound of commercial waste. The Commerce facility uses the following air pollution control equipment and practices:

o Exxon Thermal DeNOx ammonia injection system for NOx control

o Teller dry scrubber with wet lime injection for acid-gas control

o Research-Cottrell reverse air baghouse for particulate control

o A roughing cyclone captures 90 percent of the total solid particulate (TSP) before the Teller spray dryer absorber

- Building air is used as combustion air to control odors

- Combustion temperatures are maintained above 1800 degrees F to minimize dioxin and related emissions

Emissions from this plant are among the lowest reported from U.S. MWCs (472). The system was designed for control efficiencies of 20 to 50% for NOx, 90% for SOx, and 95% for HCl (37). Table A-30 summarizes the air emission removal efficiencies achieved at the Commerce facility. The removal efficiencies were calculated from average measurements made with and without air pollution control. Testing was not simultaneous, and therefore actual removal efficiencies may vary from those shown.

TABLE A-30. AIR EMISSION REMOVAL EFFICIENCIES AT THE COMMERCE, CA FACILITY (636)

Component	Removal Efficiency, %
NOx	44.5
SOx	99.5
Particulate	99.8
HCl	98.8
Dioxins/Furans	95.2
Antimony	97.6
Arsenic	>98.8
Beryllium	>88.4
Cadmium	>99.8
Chromium	>98.8
Copper	>99.9
Lead	99.9
Mercury	0
Nickel	>94.9
Selenium	>89.4
Silver	>96.9
Thallium	>70.1
Zinc	>99.9

Risk assessments were performed for eleven planned facilities in 1985 (439). The facilities ranged in size from 500 TPD to 3,000 TPD, and all planned on installing scrubbers and high-efficiency ESPs or baghouses. The risk assessments were based on exposure via various pathways such as inhalation, ingestion and dermal contact with contaminated soils, and the food chain. Although the determination of acceptable risk levels is very subjective, the historical actions of regulatory and health agencies which perform and review health assessments have resulted in guideilnes which have been adopted in the industry. A maximum individual cancer risk of 1 case per million people exposed is normally considered to be an insignificant risk, while risk levels from 1 to 10 cancer cases per million people exposed is considered to be an acceptable risk. These risk levels assume that all reasonable means to reduce risk have been adopted. The carcinogenic risks of MWC emissions are considered to be greater than the non-carcinogenic risks, and the risks due to ingestion and dermal contact exceed those from inhalation.

All eleven of the planned facilities had estimated health risks that were within the acceptable range of 1 to 10 cancer cases in one million exposed people. These estimates included the cumulative risk from all sources and exposure pathways considered in the analysis. The practice of accumulating the individual risks is reported to result in an overestimation of the actual risk and is thus a conservative methodology (373). A health risk assessment for the Ogden Martin facility in Stanislaus County, California, showed that the actual average emissions were much lower than the maximum permitted emission levels based on health risk assessment estimates (537). The actual values ranged from 1 percent to 68 percent of the permitted values. The carcinogenic risk based on these average values is considered to be insignificant.

Health risks are 1 in 10,000 to 1 in 100,000 for existing MWC facilities (interpreted to mean those facilities having only a relatively inefficient particulate control device for APC) and 1 in 100,000 to 1 in 1,000,000 for new facilities (interpreted to include those with acid gas scrubbers and subject to new source performance standards) (298).

A.5.2 Wastewater Discharge

The sources of wastewater discharge from a mass burn facility include the following (348):

- Continuous and intermittent blowdown
- Equipment and facility washdown
- Pretreatment filter backwater
- Demineralizer-neutralized regenerate

- o Quench water
- o Site drainage
- o Sanitary water

Wastewater from blowdown, pretreatment filter backwater, and demineralizer-neutralized regenerate is considered to be clean wastewater and therefore can be used as washdown water. Washdown water, be it clean water or recycled wastewater, is typically piped to a sump where solids are settled out. The supernatant is then pumped to the ash quench tank.

Water loss from the quench tank is due to evaporation and absorption by the residue. Evaporation is a function of the amount of floating solids in the quench tank: the more solids the less evaporation. The ash/residue discharged from the quench tank is typically 30 percent water by weight, resulting in a significant amount of water loss by absorption. This type of water loss is estimated at about 2,500 gallons per day (GPD) for a 100 TPD facility and 12,500 GPD for a 500 TPD facility (636).

If the pretreatment filter backwash water and the demineralizer-neutralized regenerate are not used for quench water or other internal use, they are normally discharged to the sewer. Site drainage and sanitary wastewater are normally not a problem and are handled in the normal manner.

A.5.3 Ash Residue

The impending Resource Conservation and Recovery Act (RCRA) reauthorization may specify or mandate the development of treatment, utilization, and disposal criteria for incinerator ash. The type of ash (i.e., bottom ash, fly ash, or combined) can determine the extent of treatment or the type of disposal required. Fly ash usually contains higher concentrations of metals than bottom ash, and therefore may require more rigorous treatment or handling.

Under RCRA, all wastes are categorized as either hazardous (Subtitle C waste with fairly stringent and costly requirements) or nonhazardous (Subtitle D waste). The confusion over the regulatory status of MWC ash arises from conflicting interpretations of the household waste exclusion provision of RCRA (897). It states that burning only municipal waste in MWCs is not managing hazardous waste; however, it makes no mention of the ash produced. One interpretation maintains that the household waste exclusion also applies to MWC ash; another views that the subject ash is not included and if it fails ash testing it should be regulated as hazardous.

The U.S. EPA has taken different positions over the past few years regarding its interpretation of the intent of Congress on this subject. With no current formal position, it is now likely that EPA will defer to legislative action when Congress reauthorizes RCRA (897, 898). Also during this time, environmental groups have sought a judicial resolution of the household waste exemption. In lawsuits filed in Chicago, Illinois and Westchester County, New York, judges ruled that Congress had in fact exempted waste-to-energy plants from the requirements of RCRA Subtitle C. However, the U.S. Court of Appeals for the Seventh Circuit in Chicago, reversed the earlier decision, now ruling that MWC ash is subject to RCRA Subtitle C (899). This reversed decision conflicts with an upheld decision issued by the Court of Appeals for the Second Circuit located in New York City (900). Judicial action is likely to continue.

In addition to ash classification, ash residue testing is the other major issue in the ash controversy. The judicial challenge posed by environmental groups sought to force MWC facilities to test their ash for hazardous components and dispose of it as a hazardous waste, if necessary (898). However, nowhere in the RCRA regulations is there an explicit requirement that all waste generators test their wastes to determine if those wastes are hazardous. What the regulations do say is if the waste is not exempt from Subtitle C and is not already listed as a hazardous waste, then the generator must determine if the waste exhibits a hazardous characteristic. Once again, the uncertainty arises over the question of whether or not MWC ash is exempt from RCRA Subtitle C regulation (897).

Section 3001 of RCRA states that to be hazardous, a waste must be either listed specifically as a hazardous waste or exhibit characteristics of being ignitable, corrosive, reactive, or toxic. The only tests potentially applicable to ash are corrosivity (although, the pH of MWC ash generally falls within acceptable ranges), and the Toxicity Characteristic Leaching Procedure (TCLP), which replaces the former EP Toxicity test.

The TCLP is intended to simulate the leaching of toxic constituents found in MSW into the environment when co-disposed in a sanitary landfill. If after the waste in question is sieved and agitated with various extraction fluids, the resulting leachate equals or exceeds levels established for 40 constituents (listed in Table A-31), the waste is classified as hazardous (901). [It should be noted that TCLP incorporates all of the EP constituents, and the dilution attenuation factor (DAF) of 100 relates to fate and transport modeling based on the federal drinking water standards.] While TCLP is generally viewed as an improvement over the EP Tox test, the TCLP test suffers from difficulty in obtaining a representative sample, variability of testing procedures among laboratories, and relatively high cost. The accuracy with which TCLP or any artificial laboratory can predict actual leaching from ash in a landfill has been questioned (898).

TABLE A-31. TOXICITY CHARACTERISTIC CONSTITUENTS AND REGULATORY LEVELS (897)

EPA HW No.[1]	Constit ent (mg/L)	CAS No.[2]	Chronic toxicity reference level (mg/L)	Regulatory level (mg/L)
D004	Arsenic	7440-38-2	0.05	5.0
D005	Barium	7440-39-3	1.0	100.0
D018	Benzene	71-43-2	0.005	0.5
D006	Cadmium	7440-43-9	0.01	1.0
D019	Carbon tetrachloride	56-23-5	0.005	0.5
D020	Chlordane	57-74-9	0.0003	0.03
D021	Chlorobenzene	108-90-7	1	100.0
D022	Chloroform	67-66-3	0.06	6.0
D007	Chromium	7440-47-3	0.05	5.0
D023	o-Cresol	95-48-7	2	[4] 200.0
D024	m-Cresol	108-39-4	2	[4] 200.0
D025	p-Cresol	106-44-5	2	[4] 200.0
D026	Cresol		2	[4] 200.0
D016	2,4-D	94-75-7	0.1	10.0
D027	1,4-Dichlorobenzene	106-46-7	0.075	7.5
D028	1,2-Dichloroethane	107-06-2	0.005	0.5
D029	1,1-Dichloroethylene	75-35-4	0.007	0.7
D030	2,4-Dinitrotoluene	121-14-2	0.0005	[3] 0.13
D012	Endrin	72-20-8	0.0002	0.02
D031	Heptachlor (and its hydroxide)	76-44-8	0.00008	0.008
D032	Hexachlorobenzene	118-74-1	0.0002	[3] 0.13
D033	Hexachloro-1,3-butadiene	87-68-3	0.005	0.5
D034	Hexachloroethane	67-72-1	0.03	3.0
D008	Lead	7439-92-1	0.05	5.0
D013	Lindane	58-89-9	0.004	0.4
D009	Mercury	7439-97-6	0.002	0.2
D014	Methoxychlor	72-43-5	0.1	10.0
D035	Methyl ethyl ketone	78-93-3	2	200.0
D036	Nitrobenzene	98-95-3	0.02	2.0
D037	Pentachlorophenol	87-86-5	1	100.0
D038	Pyridine	110-86-1	0.04	[3] 5.0
D010	Selenium	7782-49 2	0.01	1.0
D011	Silver	7440-22-4	0.05	5.0
D039	Tetrachloroethylene	127-18-4	0.007	0.7
D015	Toxaphene	8001-35-2	0.005	0.5
D040	Trichloroethylene	79-01-6	0.005	0.5
D041	2,4,5-Trichlorophenol	95-95-4	4	400.0
D042	2,4,6-Trichlorophenol	88-06-2	0.02	2.0
D017	2,4,5-TP (Silvex)	93-72-1	0.01	1.0
D043	Vinyl chloride	75-01-4	0.002	0.2

[1] Hazardous waste number.
[2] Chemical abstracts service number.
[3] Quantitation limit is greater than the calc lated regulatory level. The quantitation limit therefore becomes the regulatory level.
[4] If o-, m-, and p-cresol concentrations cannot be differentiated, the total c esol (D026) concentration is used. The regulatory level for total cresol is 200 mg/l.

Whereas, for now, MWC ash is not classified at the Federal level, many states have established their own standards. Table A-32 summarizes states' requirements regarding ash testing (either EP Toxicity, TCLP or other state-approved procedures), disposal, and ash utilization standards (898).

A.5.3.1 Landfill Disposal

The simplest method of residue handling is the landfilling of untreated ash. In the case of co-disposal in a municipal solid waste landfill, the chemistry of MSW has been reported to be such that when combined with untreated flyash, it tends to accelerate leaching of the metals in the flyash. Because of this, dedicated ash monofills have been developed in recent years for the disposal of MWC ash (217). Conversely, a Florida study found that there are no significant differences between the leachate characteristics from a mixed disposal facility and from an unprocessed solid waste landfill (825). A survey of 15 states showed that 11 of the 15 required monofills for incinerator ash while only 4 allowed co-disposal of ash and MSW (825).

A.5.3.2 Treatment

Most ash treatments attempt to lower the leachable metal and salt concentrations and thus render the ash more environmentally acceptable. If the environmental aspects of the ash can be improved to within acceptable limits, the ash can possibly be utilized for a variety of purposes. Ash treatment processes are currently in all stages of development: available, in the patent stage, and under development. The treatments currently being considered or marketed include (825): ferrous metal separation, chemical extraction, compaction, solidification/stabilization, phosphate addition, and vitrification.

A.5.3.2.1 Ferrous Metals Separation. Because mass burn facilities typically do not have any front-end separation, their bottom ash contains approximately 15 percent ferrous metals (825). Many field erected mass burn facilities recover ferrous metals from the ash, yet few modular facilities do so. As of 1989, 61 percent of the 70 existing field erected facilities recovered ferrous metals from the ash while only 4 percent of the 50 existing modular facilities recovered ferrous metals (387).

A.5.3.2.2 Chemical Extraction. Chemical extraction is presently under development and is not available for full scale application. Hydrochloric acid has been used in the laboratory to remove up to 98 percent of the cadmium and 70 percent of the lead from a combined ash sample (825). The projected high costs of this process may limit its use to fly ash only. The estimated costs are from $20/ton for salt removal to $80/ton for heavy metals extraction and recovery (825).

TABLE A-32. SOME STATE ASH REGULATIONS AND POLICIES (898)

State	Ash Management Plan(1)	Ash Testing(2)	Monofill Only(3)	Co-Disposal Allowed(4)	Composite Liner(5)	Double Synthetic Liner(6)	Ash Utilization Standards(7)
Connecticut			X			X	
Florida	X	X		X	X	X	X
Maine		X	X			X	
Massachusetts		X	X		X		X
Michigan	X	X	X		X	X	X
Minnesota	X	X	X		X		
New Jersey	X	X	X		X	X(8)	
New York	X	X	X(9)	X	X(9)	X(10)	X
North Carolina	X			X			
Ohio		X	X			X	
Oregon		X	X		X		
Pennsylvania		X	X		X	X	
Virginia		X		X			
Washington	X	X	X		X		X
Wisconsin	X	X	X		X		

(1) State has a formal ash management plan
(2) Either Extraction Procedure, Toxicity Characteristic Leaching Procedure, or other state-approved test is required
(3) State requires ash to be disposed in a monofill
(4) State allows ash to be co-disposed with municipal solid waste; may require ash to be treated
(5) State either requires or allows composite landfill liners for ash fill areas
(6) State requires double synthetic landfill liners for ash fill areas
(7) State has formal ash utilization standards
(8) Dependent on geologic conditions
(9) Treated fly ash and bottom ash only if handled separately
(10) For co-disposal

A.5.3.2.3 **Compaction**. Wheelabrator Environmental Systems is experimenting with bottom ash compaction at their monofill in Saugus, MA. A technique for ash compaction has been established and patented in which densities of over 3,300 pounds per cubic yard are achieved. The permeability of the compacted ash has been measured to be from 1 X 10^{-6} to as low as 1 X 10^{-9} centimeters per second, comparable to or better than the typical landfill liner requirement of 1 X 10^{-7} centimeters per second (825). To prepare the ash for use as a landfill liner, Portland cement can be added in situ at 6 to 10 percent by weight, and lime at 6 to 7 percent by weight. The economics of using a 10 percent Portland cement/ash mixture as a liner are very favorable at approximately $50,000 per acre compared to synthetic or clay liners at $250,000 to $500,000 per acre (321, 361).

A.5.3.2.4 **Solidification/Stabilization**. Ash solidification or stabilization (S/S) can be accomplished by a variety of chemical methods. Most involve mixing a pozzolanic matrix such as Portland cement, cement kiln dust, or lime with the ash. The resulting monolithic structure and alkalinity reduce the release of contaminants in the ash. Portland cement mixed with ash produces a physically durable product when combined ash is used. When Portland cement is mixed with fly ash alone, the product has poor physical properties (359). The solidified cement/ash mixture can be used to fabricate masonry blocks or as a road base material.

The Japanese have developed a flue gas neutralization system for the removal of heavy metals from fly ash (532, 591). The process consists of dissolving the fly ash in quenching water and then neutralizing the solution with carbonic acid from the combustor exhaust gas. The neutralization process transforms the heavy metals into inactive insoluble carbonates. This process is similar to phosphatizing. Electrical power requirements are reportedly approximately 44 Kw/ton, and water requirements are about 116 gal/ton. This process has only a few actual applications in Japan. No practical use for the neutralized ash has been discovered.

The Japanese reportedly have many actual applications of the fly ash solidification process (532). They claim that the process is simple and is very effective in fixing heavy metals. Power consumption is estimated at 33 kw/ton, and about 364 pounds of cement per ton of ash are required. The mixture is weak just after molding, requiring curing equipment.

The U.S. EPA initiated the Municipal Waste Innovative Technology Evaluation (MITE) program to evaluate the physical, chemical, and leaching properties of treated and untreated MWC ash (358). Four commercial stabilization processes consisting of a cement based process, a silicate based process, a cement-kiln based process, and a phosphate based process were investigated. The MWC residue tested was collected from a state-of-the-art MWC that consisted of a primary combustor with vibratory grates, a secondary combustion chamber, a boiler and economizer, a wet/dry scrubber (spray drier) with lime, and particulate recovery using fabric filters.

The Toxicity Characteristic Leaching Procedure (TCLP) test protocol was used to evaluate the treated and untreated residue. All untreated bottom and combined ash samples passed the TCLP, whereas untreated air pollution control (APC) system residue consisting of flyash and spent scrubber sorbent failed the TCLP for barium, lead and mercury. The addition of Portland cement alone, and with additives such as silicates and polymers, allowed the APC residue to pass the TCLP, with the exception of barium (358).

Further results showed that the treated residue from all processes evaluated performed poorly in terms of the durability tests (359). APC residues apparently are not amenable to the processes evaluated because of a high release of salts (358). Since 30 to 50 percent of fly ash is salt, this high salt content can reduce the strength of the resulting material if pozzolanic fixation is used (591). Final test results from this program are expected to be published in late 1991.

Cement based solidification/stabilization processes offer the following potential advantages (824):

- Solidification can significantly reduce the rate of release of insoluble contaminants
- The amount of cement can be varied to produce high strength mixes, making the mixture a suitable subgrade material
- Cement mixing is a well known technology, and no specialized labor is required
- The leaching characteristics of the resulting product can be improved by coating the material with a sealant

The main disadvantages of cement based solidification are a result of the presence of impurities such as organic materials, silts, clays or salts (824). These impurities can delay the setting and curing of the Portland cement for several days and, in the case of salts, render the process ineffective.

MWC ash may also be stabilized by means of the circular fluidized-bed (CFB) technology. Preliminary tests on ash from a Scandinavian CFB indicate remarkably low toxicity, with fly ash less toxic than bottom ash (435). This could be due to waste composition; additional testing is needed. The manufacturer of the CFB claims that the long gas residence time of the CFB technology allows ash metals to bond tenaciously with bed sand and limestone while circulating through the furnace, therefore reducing the leaching characteristics.

A.5.3.2.5 Phosphate Addition. A commercial phosphate based process has been developed and patented by Wheelabrator Environmental Systems (825). Commercially known as "WES-PHix", this system reportedly reduces the lead and cadmium solubility in MWC ash. Phosphate is injected into the ash to bind the metals in a chemical matrix. Both bottom ash and fly ash can reportedly be treated successfully with this technology. Four of Wheelabrator's facilities have been equipped with WES-PHix systems.

A.5.3.2.6 Vitrification. Ash fixation can also be accomplished by ash melting, also called vitrification. This technology consists of a fusion process in a 2600 degrees F kiln for the purpose of binding contaminants in an alumina-silicate matrix (825). The resulting matrix can be ground into a course grit-like material. Vitrification can reduce the volume of ash by at least 60 percent while rendering the product very resistant to metal leaching. There are presently two major disadvantages of vitrification as a means of ash stabilization, its cost and the release of constituents during the vitrification process. The very high temperatures required by the process can result in the vaporization and release of constituents such as heavy metals and chlorides. Air pollution control equipment must be provided to remove this secondary residue from the process. The cost of ash vitrification is extremely high at $100 to $200 per ton of ash treated (825).

The Japanese have investigated ash vitrification and report that it is "perfect" except for problems with the respreading of heavy metals and the disposal of salts not hardened (591). The Japanese also have designed a system in which fly ash can be vitrified with an electric arc (532). This system is at the demonstration level. Approximately 10 percent of the fly ash treated forms a molten salt which requires additional treatment prior to disposal. Also requiring treatment is the exhaust gas stream, which collects heavy metals during the process. The resulting material can be used as backfill or road-bed material. Power consumption is estimated at 880 to 1300 kw/Ton of treated ash.

At the Japanese Takuma facility in Sohka, bottom ash is vitrified to prevent heavy metal leaching at the landfill (273). The ash is reduced in volume to one third of its original displacement. Ash remelting is accomplished using an oil-fired furnace that heats the ash to approximately 1300 degrees C. The process costs $118 per ton of ash, or $18 to $27 per ton of refuse (~1987 dollars). (273)

Another ash vitrification process, developed in the U.S. (503), features a large kiln fired with natural gas and liquid fuels, and supplemented with a natural gas/oxygen lance, followed by a puddling furnace, oxidizers, and spray dryer and fabric filter. The gases from the combustion process cause the ash feed to melt and the slag material is discharged from the oxidizer and cooled to produce approximately 100 TPD of aggregate. If the MWC produces electricity, an electrode may replace the gas/oxygen lance.

High temperature cement kiln technology has also proved successful in utilizing ash residue from the direct combustion of RDF in the production of cement. Blue Circle Industries (BCI) has been using RDF as a supplemental fuel in the commercial production of cement in England since 1980. One cement kiln operating at BCI's Westbury U.K. Plant (271, 902) relies on the insufflation of essentially powdered RDF into the kiln at 2600 degrees F. The high temperature and long residence time in the kiln provide complete combustion of the RDF, while the limestone used in cement manufacture provides a built-in acid gas scrubbing action. The RDF ash is compatible with and becomes a supplemental raw material for the cement product. Alternatively, this technology can accept the ash and combustion products from external RDF combustion units (903).

Penberthy Electromelt International, Inc. offers a system to vitrify MWC ash using an electric molten glass furnace (858). The system uses resistance heating with no arc and an oxidizing atmosphere. Electric melting is by resistive conduction through the molten glass, which is quiet and gives off no fume or dust. The only offgases are carbon dioxide from the limestone and water vapor, at low temperature. Chlorides and sulfates are claimed to be retained in the glass. If the ash does not include lime from an acid gas scrubber, it may be necessary to add small amounts of soda or lime to insure the proper "mix" to produce glass. Each furnace is rated at 50 TPD.

A.5.3.3 Uses of Ash

Incinerator ash is being considered for use as landfill cover, as aggregate for use in road base construction, and as aggregate for use in masonry block fabrication. Although incinerator ash appears to have potential for use in construction materials, the long-term liability of using an ash-based construction material is unknown (197). Studies are still trying to assess any long-term effect ash-based construction materials may have on the environment. Table A-33 lists examples of the currently envisioned alternative uses of ash.

TABLE A-33. EXAMPLES OF ALTERNATIVE USES OF ASH

Location	Comments
<u>LANDFILL COVER</u>	
Pinellas Cty, FL	Ash is processed to prepare an aggregate material. Has used the ash aggregate for landfill cover, as a substitute for limerock in road bases, to stabilize sandy or muddy areas, and to construct berms since 1983 (360).
<u>ROAD AGGREGATE</u>	
Houston, TX	In 1975 FHA tested a bituminous concrete made with 89 percent bottom ash aggregate maximum 1" in size, 9 percent asphalt, and 2 percent hydrated lime. The road exceeded stability and flow criteria for medium to heavy traffic (824).
Puente Hills, CA	Plans are underway to construct 15 acres of roads and tipping areas with a mixture of aggregate and asphalt at a landfill. Ash will be screened to 1", mixed with Portland cement, and broken into gravel. In process of obtaining permits (824).
Tampa, FL	Test street - aggregate contained 15 percent treated ash. Results promising, but limited test data (723).
McKay Bay, FL	Mixture of bottom ash and Portland cement is being marketed as "McKayanite" by private contractor. Used in the construction of a commercial parking area (360). Another private contractor is marketing a soil-cement substitute called "Permabase" made from bottom ash (360). This material has been used in various projects throughout Florida.
Yokahama, Japan	Prepared an incinerator gravel product consisting of 38.4 percent glass, 13.1 percent ceramics, 10.2 percent pebbles, 3.5 percent non-ferrous metals, 10.7 percent other materials, and 24.1 percent materials less than 5 mm in size. Consider this an appropriate material for use as a lower subbase course material in road construction. A total of 125,994 metric tons of this material has been utilized in the construction of 66 roadways from 1983 through 1987 (592).
<u>ARTIFICIAL REEFS</u>	
Stony Brook, NY	Constructed two reefs in 1987, one as a control and one from a cement/ash mixture. Blocks were 65-75 percent crushed combined ash, 15 percent Portland cement, and 10-20 percent sand. Have performed extensive leaching tests and found no leaching of ash contaminants to date. The cement/ash blocks have maintained their structural integrity better than the control blocks (824).
Pinellas Cty, FL	Conducting research on manufacture of artificial reefs from mixtures of ash and Portland cement (360).
<u>MASONRY BLOCKS</u>	
Stony Brook, NY	Constructed a boat house from blocks manufactured with 67 percent ash and 33 percent sand aggregate. Blocks are being continuously monitored for structural and environmental integrity, the interior air quality is being continuously monitored, and the surrounding soil is being tested for leached contaminants. Also considering the use of cement/ash blocks for use in the construction of coastline erosion control barriers (824).

REFERENCES

017 Hasselriis, F., "How Control of Combustion, Emissions and Ash Residues from Municipal Solid Waste can Minimize Environmental Risk," Resource Recovery of Municipal Solid Wastes. AIChE Symposium Series, no. 265, vol 84, P.J. Knox, ed, AIChE, 1988, pp. 154-167.

020 Rigo, H.G. and A.D. Conley, "Waste-to-Energy Facility Capital Costs," Proceedings of ASME National Waste Processing Conference, Philadelphia, PA, May 1988, pp. 23-28.

025 Velzy, C.O., "Incineration's Role in Integrated Solid Waste Management," Integrated Solid Waste Management, Options for Legislative Action, F. Kreith, ed, Genium Publishing Corp., 1990, pp. 103-120.

026 Beckman, A. H. and D.R. Spahn, "Dry Lime Injection for Acid Gas Control in Municipal Waste Incinerators," Air & Waste Management Association 82nd Annual Meeting. Anaheim, CA, June 1989.

027 Brna, T.G., "State-of-the-Art Flue Gas Cleaning Technologies for MSW Combustion," Resource Recovery of Municipal Solid Wastes, AIChE Symposium Series, vol 34, no. 265. P.J. Knox, ed. AIChE, New York, NY. 1988.

028 Brna, T.G.and J.D. Kilgroe, "The Impact of Particulate Emissions Control on the Control of Other MWC Air Emissions," J. Air & Waste Management Association, September 1990, pp. 1324-1330.

029 Dhargalkar, P.H. and J.T. Zmuda, "Dry Scrubbing Systems Experience in Resource Recovery Applications," Air & Waste Management Association 82nd Annual Meeting, Anaheim, CA, June 1989.

030 Donnelly, J.R. and K.S. Felsvang, "Low Outlet Temperature Operation for Resource Recovery SDA Emission Control Systems," Air & Waste Management Association 82nd Annual Meeting, Anaheim, CA, June 1989.

031 Donnelly, J.R. and K.S. Felsvang, "Joy/Niro SDA MSW Gas Cleaning Systems New Developments," Air & Waste Management Association 82nd Annual Meeting, Anaheim, CA, June 1989.

037 Pasek, R.J. and G.P. Lindner, "Toxic Emission Sampling at the Commerce Refuse to Energy Facility," Air & Waste Management Association 82nd Annual Meeting, Anaheim, CA, June 1989.

041 Visalli, J.R., "A Comparison of Dioxin, Furan, Combustion Gas Data from Test Programs at Three MSW Incinerators," J. Air Pollution Control Association, December 1987, pp. 1451-1463.

042 Yasuda, K., M. Kaneko et al, "Basic Research on the Emission of Polycyclic Aromatic Hydrocarbons Caused by Waste Incineration." J. Air & Waste Management Association, December 1989, pp. 1557-1561.

043 Denison, R.A., "The Hazards of Municipal Incinerator Ash and Fundamental Objectives of Ash Management," Resource Recovery of Municipal Solid Wastes, AIChE Symposium Series, vol 34, no. 265. P.J. Knox, ed, AIChE, 1988. pp. 148-153.

068 Tuttle, K.L., "Combustion Generated Particulate Emissions," Proceedings of ASME National Waste Processing Conference, Denver, CO, June 1986, pp. 1-8.

069 Hahn, J.L., "Innovative Technology for the Control of Air Pollution at Waste-to-Energy Plants," Proceedings of ASME National Waste Processing Conference, Denver, CO, June 1986, pp. 9-16.

075 Engdahl, R.B., "Energy Recovery from Raw versus Refined Municipal Wastes," Proceedings of ASME National Waste Processing Conference, Denver, CO, June 1986, pp. 105-112.

077 Hurst, B.E. and C.M. White, "Thermal DeNOx: A Commercial Selective Noncatalytic NOx Reduction Process for Waste-to-Energy Applications," Proceedings of ASME National Waste Processing Conference, Denver, CO, June 1986, pp. 119-127.

085 Stelian, J. and H.L. Greene, "Operating Experience and Performance of Two Wet Ash Handling Systems Used in Mass Burning Solid Waste Facilities," Proceedings of ASME National Waste Processing Conference, Denver, CO, June 1986, pp. 275-282.

086 Frounfelker, R., "Heat Recovery Incineration for the City and Borough of Sitka, Alaska," Proceedings of ASME National Waste Processing Conference, Denver, CO, June 1986, pp. 283-297.

088 Wheless, E. and M. Selna, "Commerce Refuse-to-Energy Facility, an Alternative to Landfilling," Proceedings of ASME National Waste Processing Conference, Denver, CO, June 1986, pp. 317-323.

089 Brickner, R.H. and W.D. Kean, "Power Generation Alternatives - Small Scale Waste-to-Energy Systems," Proceedings of ASME National Waste Processing Conference, Denver, CO, June 1986, pp. 325-340.

120 Vansant, C., "WTE Equipment: Big Gains in a Short Time," Solid Waste & Power, June 1991, pp. 12-16.

137 Frame, G.B., "A Comparison of Air Pollution Control Systems for Municipal Solid Waste Incinerators," J. Air Pollution Control Assoc. vol 39, no. 8, August 1988, pp. 1081-1087.

159 Hasselriis, F., "Optimization of Combustion Conditions to Minimize Dioxin Emissions," Waste Management & Research 5, 1987, pp. 311-326.

197 Denison, R.A., "Health and Environmental Hazards of Municipal Solid Waste Incinerator Ash," Resource Recovery, April 1989, pp. 14-17.

217 Repa, E.W. and J.V.L. Kiser, "Disposing Ash," Waste Alternatives/Landfill of the 90s, vol. 1, no. 3, published by National Solid Wastes Management Association, December 1988, pp. 74-79.

218 Kapner, M. and S. Schwarz, "A Guide to Air Pollution Control Equipment," Waste Alternatives/Waste-to-Energy, vol. 1, no. 2., published by National Solid Wastes Management Association, September 1988, pp. 38-43.

223 McInnes, R.G., "Spray Dryers and Fabric Filters: State of the Art," Solid Waste & Power, April 1990, pp. 24-30.

228 Minott, D.H., "Choosing Between Resource Recovery Facilities and Landfills," Solid Waste & Power, April 1989, pp. 18-24.

235 "Incineration Provides a Variety of Options," Solid Waste & Power, February 1988, pp. 12-19.

255 Reason, J., "Next Step for Waste-to-Energy: Better Availability, Efficiency," Power, July 1986, pp. 17-24.

271 Robinson, W.D., ed., The Solid Waste Handbook, A Practical Guide, John Wiley & Sons, Inc., 1986.

273 Hershkowitz, A. and E. Salerni, Garbage Management in Japan: Leading the Way, INFORM, Inc., New York, NY, 1987.

275 Hickman, H.L., Jr., W. D. Turner et al, Thermal Conversion Systems for Municipal Solid Waste, Noyes Data Corp., Park Ridge, NJ, 1984.

277 Scott, P.J. and W.R.H. Orchard, "A Review of Mass Burning Incineration in Western Europe," Proceedings: Energy Recovery Through Waste Combustion, Elsevier Science, 1988.

282 Cassitto, L.G., "Appropriate Choice of Large Scale Energy Recovery Systems from Municipal and Industrial Wastes," Proceedings: Energy Recovery Through Waste Combustion, Elsevier Science, 1988.

298 U.S. Environmental Protection Agency, Municipal Waste Combustion Study Report to Congress, EPA/530-SW-87-021a, June 1987.

303 U.S. Environmental Protection Agency, Locating and Estimating Air Toxics Emissions from Municipal Waste Combustors, EPA-450/2-89-006, April 1989.

305 Owens, W.L. and W.D. Conn, "Communicating Risks Associated with Existing and New Municipal Solid Waste Facilities," Proc., First U.S. Conference on Municipal Solid Waste Management: Solutions for the 90s, Vol I. Washington, DC, U.S. EPA Office of Solid Waste, June 1990.

321 Goodwin, R.W., "Utilization Applications of Resource Recovery Residue," Proc., First U.S. Conference on Municipal Solid Waste Management: Solutions for the 90s, Vol I. Washington, DC, U.S. EPA Office of Solid Waste, June 1990.

348 Gershman, Brickner & Bratton, Inc., Small-Scale Municipal Solid Waste Energy Recovery Systems, Van Nostrand Reinhold, 1986.

351 Bendersky, D., D.R. Keyes et al, Resource Recovery Processing Equipment, Pollution Technology Review No. 93, Noyes Data Corp., Park Ridge, NJ, 1982.

352 HDR Engineering, Inc., Detailed Technology Assessment Report for Monmouth County Waste Recovery System, June 1988.

358 Kosson, D.S., H. van der Sloot et al, "A Comparison of Solidification/Stabilization Processes for Treatment of Municipal Waste Combustor Residues, Part II - Leaching Properties," Municipal Waste Combustion Conference sponsored by U.S. EPA and AWMA, Tampa, FL, April 1991.

359 Holmes, T., D. Kosson and C. Wiles, "A Comparison of Five Solidification/Stabilization Processes for Treatment of Municipal Waste Combustion Residues, Part I - Physical Testing," Municipal Waste Combustion Conference sponsored by U.S. EPA and AWMA, Tampa, FL, April 1991.

360 Andrews, J.C., Jr., "Incinerator Ash Disposal in the Tampa Bay Region," Municipal Waste Combustion Conference sponsored by U.S. EPA and AWMA, Tampa, FL, April 1991.

361 Goodwin, R.W., "Engineering Evaluation of Resource Recovery Residue Utilization Modes," Municipal Waste Combustion Conference sponsored by U.S. EPA and AWMA, Tampa, FL, April 1991.

367 Donnelly, J.R., "Overview of Air Pollution Controls for Municipal Waste Combustors," Municipal Waste Combustion Conference sponsored by U.S. EPA and AWMA, Tampa, FL, April 1991.

370 Brna, T.G., "Toxic Metal Emissions from MWCs and Their Control," Municipal Waste Combustion Conference sponsored by U.S. EPA and AWMA, Tampa, FL, April 1991.

373 Levin, A., D.B. Fratt et al, "Comparative Analysis of Health Risk Assessments for Municipal Waste Combustors," J. Air & Waste Management Association, January 1991, pp. 20-31.

387 Berenyi, E. and R. Gould, 1991 Resource Recovery Yearbook, Directory & Guide, Governmental Advisory Associates, Inc., New York, NY, 1991.

402 Barrett, R.E. et al, Municipal Waste-to-Energy Technology Status, Battelle Memorial Institute Report, August 1989.

435 Minott, D.H., "Fluid-Bed Energy Recovery Facilities: Operating Principles and Environmental Performance," Proceedings: International Conference on Municipal Waste Combustion, Hollywood, FL, Minister of Supply and Services, Canada, April 1989, pp. 5A-1/5A-25.

439 Binder, J.J. and D.H. Minott, "Siting a Resource Recovery Facility: Community Decision-Making, Risk Education, and Multi-Faceted Compensation," Proc: International Conference on Municipal Waste Combustion, Hollywood, FL, Minister of Supply and Services, Canada, April 1989, pp. 8B-21/8B-47.

441 Murdoch, J.D., "Material Recovery with Incineration, Monmouth County, New Jersey," Proc: International Conference on Municipal Waste Combustion, Hollywood, FL, Minister of Supply and Services, Canada, April 1989, pp. 9A-1/9A-15.

471 Rood, M.J., Technological and Economic Evaluation of Municipal Solid Waste Incineration, Commissioned by OTT, U. of Illinois Center for Solid Waste Management and Research, Chicago, IL, September 1988.

472 Hegberg, B.A., W.H. Hallenbeck and G.R. Brenniman, Municipal Solid Waste Incineration with Energy Recovery, OTT, U. of Illinois Center for Solid Waste Management and Research, Chicago, IL, March 1990.

484 Richards, D. et al, Waste-to-Energy Commercial Facilities Profiles: Technical, Operational and Economic Perspectives, Noyes Data Corp., 1990.

492 Shaub, W.M., "Incineration - Some Environmental Perspectives," Emissions from Combustion Processes: Origin, Measurement, Control. R. Clement, R. Kagel, eds., Lewis Publishers, Inc., 1990.

514 Takacs, L. and G.L. Moilanen, "Simultaneous Control of PCDD/PCDF, HCl and NOx Emissions from MSW Incinerators with Ammonia Injection," J. Air & Waste Management Association, May 1991, pp. 716-722.

520 Kidder, Peabody, & Co., Inc., Industry Report: Waste-to-Energy Industry, November 1989.

530 Harlow, G.L. et al, "Ash Vitrification - A Technology Ready for Transfer," Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 143-150.

532 Nakazato, K., "Ash From MSW Incinerator," Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 163-169.

533 Davis, R.J., T.R. Kiska and S.W. Felix, "A Comparative Evaluation of High-Temperature Pulse-Jet Baghouse Filter Fabrics," Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 171-178.

534 Hands, L.M. and W.G. Schuetzenduebel, "Reducing Oxides of Nitrogen Emissions from Waste-to-Energy Facilities with Operational Controls," Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 179-184.

535 Penterson, C.A. et al, "Natural Gas Reburning Technology for NOx Reduction from MSW Combustion Systems," Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 185-191.

537 Hahn, J.L. and D.S. Sofaer, "A Comparison of Health Risk Assessments for Three Ogden Martin Systems, Inc. Resource Recovery Facilities Using Estimated (Permitted) and Actual Emission Levels," Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 255-272.

540 Worster, E.S. et al, "The Greater Bridgeport Regional Resource Recovery Project: A Waste-to-Energy Reincarnation," Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 345-351.

541 Butler, A.J., "Skagit County Resource Recovery Facility Design of a 178 TPD Waste-to-Energy Plant," Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 353-362.

545 Beachler, D.S. and N.M. Hirko, "Air Emission Test Results from the Dutchess County Resource Recovery Facility," Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 405-416.

546 Davis, W.H. and M.D. Carter, "History of the Southeast Resource Recovery Project." Proceedings of ASME National Waste Processing Conference, Long Beach, CA, June 1990, pp. 439-443.

547 Rankin, S., "Recycling Plastics in Municipal Solid Wastes I: Myths and Realities," J. Resource Management and Technology, October 1989, pp. 143-148.

561 U.S. Environmental Protection Agency, Federal Register, 40 CFR Parts 51, 52, and 60. Standards of Performance for New Stational Sources and Final Emission Guidelines; Final Rules. 11 Feb 1991.

574 Brickner, R.H., "Mass Burning Combustion Technologies for Municipal Solid Waste," presented to Resource Recovery Leadership Institute, U.S. Conf of Mayors/NRRA.

578 National Solid Wastes Management Association Institute of Resource Recovery, "Management of Municipal Waste Combustion Ash," 1987.

583 Walter, D.K., "Energy and Waste: A Status Report," Waste Age, May 1986, 4 p.

591 Ishizuka, M. and S. Katoh, "Current Evaluation and View of Technique of Municipal Waste Incineration," Proceedings: Eighth Japan-United States Governmental Conference on Solid Waste Management, Honolulu, HI, September 1989.

592 Aoki, H. and S. Koyanagi, "Facilities for Recycling Incineration Residue: Case Study of Sakae Plant," Proceedings: Eighth Japan-United States Governmental Conference on Solid Waste Management, Honolulu, HI, September 1989.

605 Katy Industries, Inc., "Katy Industries, Inc." International Small-Scale Municipal Waste-to-Energy Conference sponsored by Resource Recovery Report and GBB, Washington, DC, Feb-Mar 1985.

608 Honsaker, W.G., "The Westinghouse/O'Connor Combustor Approach to Small Scale Waste-to-Energy Facilities," International Small-Scale Municipal Waste-to-Energy Conference sponsored by Resource Recovery Report and GBB, Washington, DC, Feb-Mar 1985.

611 Consumat Systems, Inc., "Consumat Systems, Inc.," International Small-Scale Municipal Waste-to-Energy Conference sponsored b Resource Recovery Report and GBB, Washington, DC, Feb-Mar 1985.

612 Clear Air Inc., "Clear Air Inc.," International Small-Scale Municipal Waste-to-Energy Conference sponsored by Resource Recovery Report and GBB, Washington, DC, Feb-Mar 1985.

636 Barrett, R.E. et al, "Technology Status Assessment of Municipal Refuse-to-Energy Systems," Proceedings: 1989 Conference on Municipal Solid Waste as a Utility Fuel, EPRI GS-6994, February 1991.

716 Will County, IL, Will County Solid Waste Management Plan, Vol V - Waste to Energy Feasibility Study, January 1991.

723 Office of Technology Assessment, Congress of the U.S., "Facing America's Trash: What Next for Municipal Solid Waste?," Washington, DC, 1988.

797 Pompelia, M., "NOx: How Much of a Concern?," Waste Age, November 1989, 4 p.

799 HDR Engineering, Inc., Lake County (IL) Solid Waste Management Plan, Vol III, Appendices A1 - A5, prepared for Lake County Joint Action Solid Waste Planning Agency, April 1989.

824 "Treatment and Use: The Future of Ash Management?" Solid Waste & Power, October 1991, pp. 20-28.

825 Rogoff, M., "The Ash Debate: States Provide Solutions," Solid Waste & Power, October 1991, pp. 12-18.

857 Miller, H., "Dioxins from Combustion," Licentiate Thesis, University of Lund, 1989. As Cited In: Barrett, R.E. et al, Municipal Waste-to-Energy Technology Status, Battelle Memorial Institute Report, August 1989.

858 Martin, N., Personal communication with Penberthy Electromelt International, Inc., 1991.

859 New York State Department of Environmental Conservation, Phase 1 Resource Recovery Facility Emission Characterization Study - Overview Report, Albany, NY, May 1987. As Cited In: Binder, J.J. and D.H. Minott, "Siting a Resource Recovery Facility: Community Decision-Making, Risk Education, and Multi-Faceted Compensation," Proc: International Conference on Municipal Waste Combustion, Hollywood, FL, Minister of Supply and Services, Canada, April 1989, pp. 8B-21/8B-47.

897 Ujihara, A.M. and M. Gough, Managing Ash from Municipal Waste Incinerators - A Report. Center for Risk Management, Resources for the Future, Washington, DC, November 1989.

898 Rogoff, M.J., The Ash Debate: States Provide Solutions, Solid Waste & Power, October 1991, pp. 12-18.

899 Opinion of the United States Court of Appeals for the Seventh Circuit, Case No. 90-3060, Environmental Defense Fund, Inc., et al versus the City of Chicago, et al. Decided 19 November 1991.

900 MSW Ash Decision Reversed in Chicago, J. Air and Waste Management Association, January 1992.

901 Toxicity Characteristics Revisions; Final Rule. Federal Register, 40 CFR Part 261, Thursday, 29 March 1990.

902 U.S. Patent No. 4,022,630, Portland Cement-Making and Municipal Refuse Conversion (Direct Co-Firing), 10 May 1977.

903 U.S. Patent No. 4,081,285, Portland Cement Manufacture (Indirect Co-Firing), 28 March 1978.

ATTACHMENT 1.

GRATE MANUFACTURERS - MASS BURN FACILITIES

(Derived from 387)

NAME	CITY	STATE	DESIGN TPD	OWNER
PROCESS: MB - Refractory				
GRATE MANUFACTURER - Detroit Stoker				
City of Waukesha (Old Plant)	Waukesha	WI	175	City of Waukesha
GRATE MANUFACTURER - First Thermal				
Muscoda	Muscoda	WI	125	Village of Muscoda
GRATE MANUFACTURER - Illinois Traveling Grate				
Betts Avenue	Queens	NY	1000	City of New York
GRATE MANUFACTURER - Seghers, Inc.				
Davis County	Layton	UT	400	Davis Co. S.W.M. & Energy Recovery Dist.
GRATE MANUFACTURER - Volund USA, Inc.				
McKay Bay Refuse-To-Energy Facility	Tampa	FL	1000	City of Tampa
PROCESS: MB - Waterwall				
GRATE MANUFACTURER - (TBD)				
North Hempstead	Port Washington	NY	990	North Hempstead S.W. Mgmt. Authority
Sturgis	Sturgis	MI	560	Something of Value, Inc.
GRATE MANUFACTURER - DeBartolomeis Grate System				
Dakota County	Rosemount/Empire Twp.	MN	800	Dakota County
GRATE MANUFACTURER - Detroit Stoker				
Broome County	Kirkwood	NY	571	Broome Co. R.R. Authority/Foster Wheeler
Camden County (Foster Wheeler)	Camden	NJ	1050	Camden County Energy Recovery Associates
Charleston County	North Charleston	SC	644	AT&T Credit Corporation
City of Commerce	Commerce	CA	400	Commerce Refuse-To-Energy Authority
Hampton/NASA Project Recoup	Hampton	VA	200	NASA/City of Hampton
Morris County	Roxbury Township	NJ	1340	Morris County
Nashville Thermal Transfer Corp. (NTTC)	Nashville	TN	1120	Metropolitan Government of Nashville
Norfolk Naval Station	Norfolk	VA	360	U.S. Navy
Passaic County	Passaic	NJ	1434	Foster Wheeler Passaic, Inc.
Washington/Warren Counties	Hudson Falls	NY	400	Adirondack Resource Recovery Associates
GRATE MANUFACTURER - Deutsche Babcock Anlagen (DBA)				
Albany (American Ref-Fuel)	Bethlehem	NY	1500	American Ref-Fuel, Inc.
Bergen County	Ridgefield	NJ	3000	American Ref-Fuel, Inc.
East Bridgewater (American Ref-Fuel)	East Bridgewater	MA	1500	American Ref-Fuel, Inc.
Oyster Bay	Old Bethpage	NY	1000	American Ref-Fuel, Inc.
GRATE MANUFACTURER - Deutsche Babcock Anlagen (design/build)				
Essex County	Newark	NJ	2277	Amer. Ref-Fuel/Port Authority of NY & NJ
GRATE MANUFACTURER - Dusseldorf Roller Grate (DBA)				
Hempstead (American Ref-Fuel)	Westbury	NY	2505	American Ref-Fuel, Inc.
Preston (Southeastern Connecticut)	Preston	CT	600	American Ref-Fuel, Inc./CRRA

NAME	CITY	STATE	DESIGN TPD	OWNER
GRATE MANUFACTURER - Kablitz Stoker				
Davidson County	Madison (Nashville)	TN	210	Third National Bank
GRATE MANUFACTURER - L & C Steinmuller				
Montgomery County	Plymouth Township	PA	1200	Montenay Power Corporation
Portland	Portland	ME	500	Regional Waste Systems (20 communities)
S.E. Resource Recovery Facility (SERRF)	Long Beach	CA	1380	S.E. Resource Recovery Facility Auth.
GRATE MANUFACTURER - Martin				
Alexandria/Arlington R.R. Facility	Alexandria	VA	975	Ogden Martin Systems of Alex./Arlington
Babylon Resource Recovery Project	Babylon	NY	750	Babylon Industrial Development Authority
Bristol	Bristol	CT	650	Ogden Martin Systems of Bristol
Camden County (Pennsauken)	Pennsauken	NJ	500	Pennsauken Solid Waste Mgmt. Authority
Eastern-Central Project	Cromwell (or Portland)	CT	550	Ogden Projects, Inc.
Fairfax County	Lorton	VA	3000	Ogden Martin Systems of Fairfax, Inc.
Harrisburg	Harrisburg	PA	720	City of Harrisburg
Haverhill (Mass Burn)	Haverhill	MA	1650	Ogden Martin Systems of Haverhill, Inc.
Hillsborough County S.W.E.R. Facility	Brandon	FL	1200	Hillsborough County
Hudson County	Kearny	NJ	1500	Ogden Martin Systems of Hudson County
Huntington	East Northport	NY	750	Ogden Martin Systems of Huntington
Johnston (Central Landfill)	Johnston	RI	750	RI Solid Waste Management Corporation
Kent County	Grand Rapids	MI	625	Kent County
Lake County	Okahumpka	FL	528	Ogden Martin Systems of Lake County
Lancaster County	Conoy Township	PA	1200	Lancaster County S.W. Mgmt. Authority
Lee County	Lee County	FL	1800	Lee County
Marion County Solid W-T-E Facility	Brooks	OR	550	Ogden Martin Systems of Marion County
Montgomery County	Dickerson	MD	1800	N.E. Maryland Waste Disposal Authority
North Andover	North Andover	MA	1500	Wheelabrator Technologies, Inc.
Northwest Waste-To-Energy Facility	Chicago	IL	1600	City of Chicago
Onondaga County	Onondaga	NY	990	Ogden Martin Systems of Onondaga County
Pasco County	Springhill	FL	1050	Pasco County
Pinellas County (Wheelabrator)	Pinellas County	FL	3150	Pinellas County
Stanislaus County Res. Recovery Facility	Crows Landing	CA	800	Ogden Martin Systems of Stanilaus County
Union County	Rahway	NJ	1440	Union County Utilities Authority
Walter B. Hall Res. Recovery Facility	Tulsa	OK	1125	Manu. Hanover Trust/CIT Group/Bank of OK
GRATE MANUFACTURER - Ofag				
Wayne County	Goldsboro	NC	300	Enerco Systems, Inc.
GRATE MANUFACTURER - Riley Stoker/Takuma				
Glendon	Glendon	PA	500	Glendon Energy Company
Jackson County/Southern MI State Prison	Jackson	MI	200	Jackson County
Olmstead County	Rochester	MN	200	Olmstead County
GRATE MANUFACTURER - Seghers, Inc.				
Savannah	Savannah	GA	500	Katy-Seghers, Inc.

NAME	CITY	STATE	DESIGN TPD	OWNER
GRATE MANUFACTURER - Volund USA, Inc.				
University City Res. Recovery Facility	Charlotte	NC	235	Mecklenburg County
GRATE MANUFACTURER - Von Roll				
Bridgeport RESCO	Bridgeport	CT	2250	Wheelabrator Technologies, Inc./CRRA
Brooklyn Navy Yard	Brooklyn	NY	3000	Wheelabrator Technologies, Inc.
Broward County (Northern Facility)	Pompano Beach	FL	2250	Wheelabrator Technologies, Inc.
Broward County (Southern Facility)	Broward County	FL	2250	Wheelabrator Technologies, Inc.
Central Mass. Resource Recovery Project	Millbury	MA	1500	Ford Motor Credit Corporation
Concord Regional S.W. Recovery Facility	Penacook	NH	500	Wheelabrator Technologies, Inc.
Falls Township (Wheelabrator)	Falls Township	PA	2250	Wheelabrator Technologies, Inc.
Gloucester County	West Deptford Township	NJ	575	Wheelabrator Technologies, Inc.
Lisbon	Lisbon	CT	500	(Public Authority - TBD)
New Hampshire/Vermont S.W. Project	Claremont	NH	200	Wheelabrator Technologies, Inc.
S.W. Resource Recovery Facility (BRESCO)	Baltimore	MD	2250	Baltimore Refuse Energy Systems Company
Saugus	Saugus	MA	1500	RESCO (Wheelabrator Technologies, Inc.)
Spokane	Spokane	WA	800	City of Spokane
West Pottsgrove Recycling/R.R. Facility	West Pottsgrove Twp.	PA	1500	Wheelabrator Pottsgrove, Inc.
Westchester	Peekskill	NY	2250	Wheelabrator Technologies, Inc.
GRATE MANUFACTURER - W & E Environmental Systems				
Warren County	Oxford Township	NJ	400	Blount Energy Resources Corporation
GRATE MANUFACTURER - Widmer & Ernst				
Hennepin County (Blount)	Minneapolis	MN	1200	General Electric Credit Corporation
Quonset Point	North Kingston	RI	710	RI Solid Waste Management Corporation
GRATE MANUFACTURER - Zurn Industries, Inc.				
Oklahoma City	Oklahoma City	OK	820	CMI Energy Conversion Systems
	PROCESS: MB - Rotary Combustor			
GRATE MANUFACTURER - C&H Combustors				
Galax	Galax	VA	56	City of Galax
GRATE MANUFACTURER - Laurent Bouillet				
Auburn (New Plant)	Auburn	ME	200	Mid-Maine Waste Action Authority
Sangamon County	Illiopolis	IL	450	Kirby-Coffman, Inc.
GRATE MANUFACTURER - Montgomery County				
Montgomery County (North)	Dayton	OH	300	Montgomery County
Montgomery County (South)	Dayton	OH	900	Montgomery County
GRATE MANUFACTURER - Technitalia				
Falls Township (Technochem)	Falls Township	PA	70	Technochem, Inc.
GRATE MANUFACTURER - Tecnitalia				
Skagit County	Mount Vernon	WA	178	Skagit County

NAME	CITY	STATE	DESIGN TPD	OWNER
GRATE MANUFACTURER - Westinghouse/O'Connor Rotary Combustor				
Delaware County Regional R.R. Project	Chester	PA	2688	Delaware County Resource Mgmt. Inc.
Dutchess County	Poughkeepsie	NY	506	Dutchess County Res. Recovery Agency
Gaston County/Westinghouse R.R. Center	High Shoals	NC	440	Gaston County
MacArthur Energy Recovery Facility	Islip	NY	518	Islip Resource Recovery Agency
Mercer County	Hamilton Township	NJ	975	Mercer County Improvement Authority
Monmouth County	Tinton Falls	NJ	1700	Monmouth County
Monroe County	Bloomington	IN	500	Westinghouse Electric Corporation
Oakland County	Auburn Hills	MI	2000	Oakland County
San Juan Resource Recovery Facility	San Juan	PR	1040	(Third Party Leasee - TBD)
Sumner County	Gallatin	TN	200	Resource Authority in Sumner County
Waukesha County (New Plant)	Waukesha	WI	600	Waukesha County
Westinghouse/Bay Resource Mgmt. Center	Panama City	FL	510	Ford Motor Credit Corporation
York County	Manchester Township	PA	1344	York Co. Solid Waste & Refuse Authority
	PROCESS: MB - Sludge Co-Disposal			
GRATE MANUFACTURER - Martin				
Huntsville	Huntsville	AL	690	Huntsville Solid Waste Disposal Auth.
Indianapolis Resource Recovery Facility	Indianapolis	IN	2362	Ogden Martin Systems of Indianapolis
GRATE MANUFACTURER - Morse Boulger				
Glen Cove	Glen Cove	NY	250	City of Glen Cove
GRATE MANUFACTURER - York Shipley				
Sitka	Sitka	AK	24	City & Borough of Sitka

ATTACHMENT 2.

BOILER MANUFACTURERS - MASS BURN FACILITIES

(Derived from 387)

NAME	CITY	STATE	DESIGN TPD	OWNER
		PROCESS: MB - Refractory		
BOILER MANUFACTURER - Bigelow (waste heat)/Ship & Yorkley				
Betts Avenue	Queens	NY	1000	City of New York
BOILER MANUFACTURER - Deltak Corporation				
City of Waukesha (Old Plant)	Waukesha	WI	175	City of Waukesha
BOILER MANUFACTURER - First Thermal				
Muscoda	Muscoda	WI	125	Village of Muscoda
BOILER MANUFACTURER - Volund USA, Inc.				
McKay Bay Refuse-To-Energy Facility	Tampa	FL	1000	City of Tampa
BOILER MANUFACTURER - Zurn Industries, Inc.				
Davis County	Layton	UT	400	Davis Co. S.W.M. & Energy Recovery Dist.
		PROCESS: MB - Waterwall		
BOILER MANUFACTURER - (N.A.)				
Montgomery County	Dickerson	MD	1800	N.E. Maryland Waste Disposal Authority
BOILER MANUFACTURER - (TBO)				
Albany (American Ref-Fuel)	Bethlehem	NY	1500	American Ref-Fuel, Inc.
Bergen County	Ridgefield	NJ	3000	American Ref-Fuel, Inc.
East Bridgewater (American Ref-Fuel)	East Bridgewater	MA	1500	American Ref-Fuel, Inc.
Eastern-Central Project	Cromwell (or Portland)	CT	550	Ogden Projects, Inc.
Hudson County	Kearny	NJ	1500	Ogden Martin Systems of Hudson County
Johnston (Central Landfill)	Johnston	RI	750	RI Solid Waste Management Corporation
Lee County	Lee County	FL	1800	Lee County
Onondaga County	Onondaga	NY	990	Ogden Martin Systems of Onondaga County
Sturgis	Sturgis	MI	560	Something of Value, Inc.
Union County	Rahway	NJ	1440	Union County Utilities Authority
Wayne County	Goldsboro	NC	300	Enerco Systems, Inc.
BOILER MANUFACTURER - Babcock & Wilcox				
Bridgeport RESCO	Bridgeport	CT	2250	Wheelabrator Technologies, Inc./CRRA
Brooklyn Navy Yard	Brooklyn	NY	3000	Wheelabrator Technologies, Inc.
Broward County (Southern Facility)	Broward County	FL	2250	Wheelabrator Technologies, Inc.
Central Mass. Resource Recovery Project	Millbury	MA	1500	Ford Motor Credit Corporation
Concord Regional S.W. Recovery Facility	Penacook	NH	500	Wheelabrator Technologies, Inc.
Falls Township (Wheelabrator)	Falls Township	PA	2250	Wheelabrator Technologies, Inc.
Gloucester County	West Deptford Township	NJ	575	Wheelabrator Technologies, Inc.
Nashville Thermal Transfer Corp. (NTTC)	Nashville	TN	1120	Metropolitan Government of Nashville
North Hempstead	Port Washington	NY	990	North Hempstead S.W. Mgmt. Authority
S.W. Resource Recovery Facility (BRESCO)	Baltimore	MD	2250	Baltimore Refuse Energy Systems Company

NAME	CITY	STATE	DESIGN TPD	OWNER
Spokane	Spokane	WA	800	City of Spokane
West Pottsgrove Recycling/R.R. Facility	West Pottsgrove Twp.	PA	1500	Wheelabrator Pottsgrove, Inc.
Westchester	Peekskill	NY	2250	Wheelabrator Technologies, Inc.
BOILER MANUFACTURER - Babcock & Wilcox-design/Riley-builder				
Lisbon	Lisbon	CT	500	(Public Authority - TBD)
BOILER MANUFACTURER - Combustion Engineering				
Dakota County	Rosemount/Empire Twp.	MN	800	Dakota County
BOILER MANUFACTURER - Deutsche Babcock Anlagen (design)				
Oyster Bay	Old Bethpage	NY	1000	American Ref-Fuel, Inc.
BOILER MANUFACTURER - Distral Energy Corp. (Widmer & Ernst)				
Warren County	Oxford Township	NJ	400	Blount Energy Resources Corporation
BOILER MANUFACTURER - Distral Energy Corporation				
Hennepin County (Blount)	Minneapolis	MN	1200	General Electric Credit Corporation
Huntington	East Northport	NY	750	Ogden Martin Systems of Huntington
Pasco County	Springhill	FL	1050	Pasco County
Quonset Point	North Kingston	RI	710	RI Solid Waste Management Corporation
BOILER MANUFACTURER - Foster Wheeler				
Broome County	Kirkwood	NY	571	Broome Co. R.R. Authority/Foster Wheeler
Camden County (Foster Wheeler)	Camden	NJ	1050	Camden County Energy Recovery Associates
Charleston County	North Charleston	SC	644	AT&T Credit Corporation
City of Commerce	Commerce	CA	400	Commerce Refuse-To-Energy Authority
Essex County	Newark	NJ	2277	Amer. Ref-Fuel/Port Authority of NY & NJ
Morris County	Roxbury Township	NJ	1340	Morris County
Norfolk Naval Station	Norfolk	VA	360	U.S. Navy
Passaic County	Passaic	NJ	1434	Foster Wheeler Passaic, Inc.
Washington/Warren Counties	Hudson Falls	NY	400	Adirondack Resource Recovery Associates
BOILER MANUFACTURER - International Boiler Works Company				
Harrisburg	Harrisburg	PA	720	City of Harrisburg
BOILER MANUFACTURER - Kablitz Stoker				
Davidson County	Madison (Nashville)	TN	210	Third National Bank
BOILER MANUFACTURER - Keeler Boiler Company				
Hampton/NASA Project Recoup	Hampton	VA	200	NASA/City of Hampton

NAME	CITY	STATE	DESIGN TPD	OWNER
BOILER MANUFACTURER - Keeler/Dorr-Oliver				
Alexandria/Arlington R.R. Facility	Alexandria	VA	975	Ogden Martin Systems of Alex./Arlington
Kent County	Grand Rapids	MI	625	Kent County
New Hampshire/Vermont S.W. Project	Claremont	NH	200	Wheelabrator Technologies, Inc.
BOILER MANUFACTURER - L & C Steinmuller				
Montgomery County	Plymouth Township	PA	1200	Montenay Power Corporation
Portland	Portland	ME	500	Regional Waste Systems (20 communities)
S.E. Resource Recovery Facility (SERRF)	Long Beach	CA	1380	S.E. Resource Recovery Facility Auth.
BOILER MANUFACTURER - Riley Stoker				
Hillsborough County S.W.E.R. Facility	Brandon	FL	1200	Hillsborough County
North Andover	North Andover	MA	1500	Wheelabrator Technologies, Inc.
Olmstead County	Rochester	MN	200	Olmstead County
Pinellas County (Wheelabrator)	Pinellas County	FL	3150	Pinellas County
BOILER MANUFACTURER - Riley Stoker (DBA design)				
Hempstead (American Ref-Fuel)	Westbury	NY	2505	American Ref-Fuel, Inc.
Preston (Southeastern Connecticut)	Preston	CT	600	American Ref-Fuel, Inc./CRRA
BOILER MANUFACTURER - Riley Stoker/Takuma				
Glendon	Glendon	PA	500	Glendon Energy Company
Jackson County/Southern MI State Prison	Jackson	MI	200	Jackson County
BOILER MANUFACTURER - Volund USA, Inc.				
Broward County (Northern Facility)	Pompano Beach	FL	2250	Wheelabrator Technologies, Inc.
University City Res. Recovery Facility	Charlotte	NC	235	Mecklenburg County
BOILER MANUFACTURER - Von Roll				
Saugus	Saugus	MA	1500	RESCO (Wheelabrator Technologies, Inc.)
BOILER MANUFACTURER - Walther Boilers				
Northwest Waste-To-Energy Facility	Chicago	IL	1600	City of Chicago
BOILER MANUFACTURER - Zurn Industries, Inc.				
Babylon Resource Recovery Project	Babylon	NY	750	Babylon Industrial Development Authority
Bristol	Bristol	CT	650	Ogden Martin Systems of Bristol
Camden County (Pennsauken)	Pennsauken	NJ	500	Pennsauken Solid Waste Mgmt. Authority
Fairfax County	Lorton	VA	3000	Ogden Martin Systems of Fairfax, Inc.
Haverhill (Mass Burn)	Haverhill	MA	1650	Ogden Martin Systems of Haverhill, Inc.
Lancaster County	Conoy Township	PA	1200	Lancaster County S.W. Mgmt. Authority
Marion County Solid W-T-E Facility	Brooks	OR	550	Ogden Martin Systems of Marion County
Oklahoma City	Oklahoma City	OK	820	CMI Energy Conversion Systems
Savannah	Savannah	GA	500	Katy-Seghers, Inc.
Stanislaus County Res. Recovery Facility	Crows Landing	CA	800	Ogden Martin Systems of Stanilaus County

NAME	CITY	STATE	DESIGN TPD	OWNER
Walter B. Hall Res. Recovery Facility	Tulsa	OK	1125	Manu. Hanover Trust/CIT Group/Bank of OK
BOILER MANUFACTURER - Zurn/NEPCO				
Lake County	Okahumpka	FL	528	Ogden Martin Systems of Lake County
PROCESS: MB - Rotary Combustor				
BOILER MANUFACTURER - (TBD)				
Monmouth County	Tinton Falls	NJ	1700	Monmouth County
Monroe County	Bloomington	IN	500	Westinghouse Electric Corporation
Waukesha County (New Plant)	Waukesha	WI	600	Waukesha County
BOILER MANUFACTURER - American Shack				
Auburn (New Plant)	Auburn	ME	200	Mid-Maine Waste Action Authority
BOILER MANUFACTURER - Combustion Engineering				
Montgomery County (North)	Dayton	OH	300	Montgomery County
Montgomery County (South)	Dayton	OH	900	Montgomery County
BOILER MANUFACTURER - DeLaval				
Mercer County	Hamilton Township	NJ	975	Mercer County Improvement Authority
BOILER MANUFACTURER - Deltak Corporation				
Dutchess County	Poughkeepsie	NY	506	Dutchess County Res. Recovery Agency
MacArthur Energy Recovery Facility	Islip	NY	518	Islip Resource Recovery Agency
Westinghouse/Bay Resource Mgmt. Center	Panama City	FL	510	Ford Motor Credit Corporation
York County	Manchester Township	PA	1344	York Co. Solid Waste & Refuse Authority
BOILER MANUFACTURER - Keeler				
Oakland County	Auburn Hills	MI	2000	Oakland County
BOILER MANUFACTURER - Keeler/Dorr-Oliver				
Delaware County Regional R.R. Project	Chester	PA	2688	Delaware County Resource Mgmt. Inc.
BOILER MANUFACTURER - Laurent Bouillet				
Sangamon County	Illiopolis	IL	450	Kirby-Coffman, Inc.
BOILER MANUFACTURER - Nebraska				
Galax	Galax	VA	56	City of Galax
BOILER MANUFACTURER - O'Connor/Keeler				
Sumner County	Gallatin	TN	200	Resource Authority in Sumner County

NAME	CITY	STATE	DESIGN TPD	OWNER
BOILER MANUFACTURER - Tampella-Keeler				
Gaston County/Westinghouse R.R. Center	High Shoals	NC	440	Gaston County
BOILER MANUFACTURER - Tampella/Keeler				
San Juan Resource Recovery Facility	San Juan	PR	1040	(Third Party Leasee - TBD)
BOILER MANUFACTURER - Technitalia				
Falls Township (Technochem)	Falls Township	PA	70	Technochem, Inc.
BOILER MANUFACTURER - Zurn Industries, Inc.				
Skagit County	Mount Vernon	WA	178	Skagit County
	PROCESS: MB - Sludge Co-Disposal			
BOILER MANUFACTURER - Riley Stoker				
Indianapolis Resource Recovery Facility.	Indianapolis	IN	2362	Ogden Martin Systems of Indianapolis
BOILER MANUFACTURER - York Shipley				
Sitka	Sitka	AK	24	City & Borough of Sitka
BOILER MANUFACTURER - Zurn Industries, Inc.				
Glen Cove	Glen Cove	NY	250	City of Glen Cove
Huntsville	Huntsville	AL	690	Huntsville Solid Waste Disposal Auth.

ATTACHMENT 3.

CAPITAL COSTS - FIELD-ERECTED MASS BURN FACILITIES

GROUPED BY APC METHOD

(Derived from 387)

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
PROCESS: MB - Refractory										
APC METHOD - Electrostatic Precipitator										
Betts Avenue	05	1000	5000000	65	21594896	21595	36500000	89	37440152	37440
City of Waukesha (Old Plant)	05	175	1700000	71	4856118	27749	3900000	79	5806047	33177
Davis County	05	400	40000000	88	41693608	104234	0		0	0
McKay Bay Refuse-To-Energy Facility	05	1000	72700000	85	81083856	81084	500000	87	532861	533
AVERAGE		644	29850000		37307120	58666	13633333		14593020	23717
STANDARD DEVIATION		365	28935661		28441103	35033	16228644		16298164	16485
APC METHOD - Dry Scrubber										
Muscoda	05	125	8250000	87	8792208	70338	0		0	0
AVERAGE		125	8250000		8792208	70338	0		0	0
STANDARD DEVIATION		0	0		0	0	0		0	0
PROCESS: MB - Waterwall										
APC METHOD - Electrostatic Precipitator										
Alexandria/Arlington R.R. Facility	05	975	75900000	85	84652896	86823	2000000	89	2051515	2104
Camden County (Foster Wheeler)	03	1050	96000000	87	102309328	97437	0		0	0
Central Mass. Resource Recovery Project	05	1500	140000000	86	152686272	101791	0		0	0
Charleston County	05	644	59000000	89	60519688	93975	0		0	0
Davidson County	03	210	7000000	87	7460056	35524	0		0	0
Essex County	03	2277	252500000	89	259003776	113748	0		0	0
Hampton/NASA Project Recoup	05	200	10400000	78	16823896	84119	2450000	87	2611020	13055
Harrisburg	05	720	8300000	71	23709280	32930	21300000	86	23230124	32264
Haverhill (Mass Burn)	05	1650	120000000	87	127886656	77507	0		0	0
Hillsborough County S.W.E.R. Facility	05	1200	80500000	87	85790640	71492	0		0	0
Nashville Thermal Transfer Corp. (NTTC)	05	1120	24500000	74	55058920	49160	36500000	85	40709224	36348
Norfolk Naval Station	08	360	3220000	67	12995170	36098	5400000	87	5754899	15986
North Andover	05	1500	185000000	85	206334432	137556	0		0	0
Northwest Waste-To-Energy Facility	05	1600	23000000	68	86385568	53991	5000000	88	5211701	3257
Olmstead County	05	200	30000000	87	31971664	159858	0		0	0
Pinellas County (Wheelabrator)	05	3150	83000000	83	94280208	29930	60000000	86	65436968	20774
Portland	05	500	45500000	87	48490360	96981	20600000	90	20600000	41200
S.W. Resource Recovery Facility (BRESCO)	05	2250	185000000	83	210142624	93397	0		0	0
Savannah	05	500	35000000	85	39036240	78072	0		0	0
University City Res. Recovery Facility	05	235	27000000	87	28774496	122445	0		0	0
Walter B. Hall Res. Recovery Facility	05	1125	114000000	87	121492320	107993	0		0	0
Washington/Warren Counties	03	400	50000000	90	50000000	125000	0		0	0
Westchester	05	2250	179000000	83	203327168	90368	0		0	0
AVERAGE		1114	79731304		91701376	85922	19156250		20700681	20624
STANDARD DEVIATION		791	67774360		70251289	33997	19166270		21054683	13827

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
APC METHOD - Dry Scrubber										
Albany (American Ref-Fuel)	02	1500	200000000	89	205151520	136768	0		0	0
Babylon Resource Recovery Project	05	750	85520000	85	95382272	127176	0		0	0
Bergen County	02	3000	335000000	91	335000000	111667	0		0	0
Bridgeport RESCO	05	2250	211000000	85	235332768	104592	0		0	0
Bristol	05	650	58800000	85	65580888	100894	0		0	0
Brooklyn Navy Yard	02	3000	426000000	90	426000000	142000	0		0	0
Broome County	02	571	77000000	90	77000000	134851	0		0	0
Broward County (Northern Facility)	03	2250	216007000	90	216007000	96003	0		0	0
Broward County (Southern Facility)	03	2250	277816000	90	277816000	123474	0		0	0
Camden County (Pennsauken)	03	500	88000000	90	88000000	176000	0		0	0
City of Commerce	05	400	35010000	86	38182472	95456	1000000	89	1025758	2564
Concord Regional S.W. Recovery Facility	05	500	53500000	85	59669688	119339	0		0	0
Dakota County	02	800	108852000	90	108852000	136065	0		0	0
East Bridgewater (American Ref-Fuel)	02	1500	150000000	90	150000000	100000	0		0	0
Eastern-Central Project	02	550	78000000	89	80009088	145471	0		0	0
Fairfax County	05	3000	195500000	88	203777536	67926	0		0	0
Falls Township (Wheelabrator)	02	2250	200000000	91	200000000	88889	0		0	0
Glendon	02	500	63500000	90	63500000	127000	0		0	0
Gloucester County	05	575	60000000	90	60000000	104348	0		0	0
Hempstead (American Ref-Fuel)	05	2505	255000000	85	284406912	113536	0		0	0
Hennepin County (Blount)	05	1200	80000000	88	83387216	69489	0		0	0
Hudson County	02	1500	179000000	89	183610592	122407	0		0	0
Huntington	03	750	153500000	90	153500000	204667	0		0	0
Jackson County/Southern MI State Prison	05	200	28000000	86	30537256	152686	0		0	0
Johnston (Central Landfill)	02	750	80000000	90	80000000	106667	0		0	0
Kent County	05	625	62200000	89	63802128	102083	0		0	0
Lake County	04	528	60000000	90	60000000	113636	0		0	0
Lancaster County	03	1200	102000000	89	104627280	87189	0		0	0
Lee County	02	1800	146964600	90	146964600	81647	0		0	0
Lisbon	02	500	100000000	90	100000000	200000	0		0	0
Marion County Solid W-T-E Facility	05	550	47500000	86	51804272	94190	0		0	0
Montgomery County	02	1800	280000000	89	287212096	159562	0		0	0
Montgomery County	03	1200	115000000	89	117962112	98302	0		0	0
Morris County	02	1340	141900000	89	145555008	108623	0		0	0
New Hampshire/Vermont S.W. Project	05	200	26500000	85	29556012	147780	0		0	0
North Hempstead	02	990	135000000	89	138477280	139876	0		0	0
Oklahoma City	08	820	35000000	87	37300272	45488	0		0	0
Onondaga County	02	990	132000000	90	132000000	133333	0		0	0
Oyster Bay	02	1000	135000000	90	135000000	135000	0		0	0
Pasco County	03	1050	90600000	89	92933632	88508	0		0	0
Passaic County	02	1434	142000000	90	142000000	99024	0		0	0
Preston (Southeastern Connecticut)	03	600	83000000	87	88454944	147425	0		0	0

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
Quonset Point	02	710	83000000	90	83000000	116901	0		0	0
S.E. Resource Recovery Facility (SERRF)	04	1380	106000000	87	112966544	81860	0		0	0
Saugus	05	1500	33000000	74	74160992	49441	95000000	90	95000000	63333
Spokane	03	800	82149000	87	87548016	109435	0		0	0
Stanislaus County Res. Recovery Facility	05	800	82200000	85	91679408	114599	0		0	0
Sturgis	02	560	0		0	0	0		0	0
Union County	02	1440	150000000	90	150000000	104167	0		0	0
West Pottsgrove Recycling/R.R. Facility	02	1500	150000000	91	150000000	100000	0		0	0
AVERAGE		1180	126857522		131096078	115621	48000000		48012879	32949
STANDARD DEVIATION		733	82661568		83024510	31966	47000000		46987121	30385
APC METHOD - Baghouse/Fabric Filter										
Warren County	05	400	50300000	89	51595608	128989	0		0	0
AVERAGE		400	50300000		51595608	128989	0		0	0
STANDARD DEVIATION		0	0		0	0	0		0	0
APC METHOD - To Be Determined										
Wayne County	02	300	27000000	90	27000000	90000	0		0	0
AVERAGE		300	27000000		27000000	90000	0		0	0
STANDARD DEVIATION		0	0		0	0	0		0	0
PROCESS: MB - Rotary Combustor										
APC METHOD - Electrostatic Precipitator										
Montgomery County (North)	05	300	7494000	69	25688292	85628	9700000	87	10337504	34458
Montgomery County (South)	02	900	6150000	69	21081268	23424	5000000	85	5576606	6196
Sumner County	05	200	9800000	81	12655414	63277	5340000	90	5340000	26700
Westinghouse/Bay Resource Mgmt. Center	05	510	38000000	86	41443416	81262	0		0	0
AVERAGE		478	15361000		25217098	63398	6680000		7084703	22451
STANDARD DEVIATION		268	13135650		10469198	24552	2139969		2302105	11923
APC METHOD - Dry Scrubber										
Auburn (New Plant)	03	200	26500000	90	26500000	132500	0		0	0
Delaware County Regional R.R. Project	03	2688	276000000	90	276000000	102679	0		0	0
Dutchess County	05	506	35000000	84	39213904	77498	0		0	0
Falls Township (Technochem)	02	70	7000000	90	7000000	100000	0		0	0
Gaston County/Westinghouse R.R. Center	02	440	42000000	89	43081824	97913	0		0	0
MacArthur Energy Recovery Facility	05	518	38700000	85	43162936	83326	2500000	91	2500000	4826
Mercer County	02	975	117500000	88	122474976	125615	0		0	0
Monmouth County	02	1700	220000000	90	220000000	129412	0		0	0
Monroe County	02	500	100000000	91	100000000	200000	0		0	0

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
Oakland County	02	2000	172000000	90	172000000	86000	0		0	0
San Juan Resource Recovery Facility	02	1040	91400000	89	93754240	90148	0		0	0
Sangamon County	02	450	38160000	90	38160000	84800	0		0	0
Skagit County	05	178	14000000	87	14920112	83821	0		0	0
Waukesha County (New Plant)	02	600	100000000	90	100000000	166667	0		0	0
York County	05	1344	91200000	88	95061424	70730	0		0	0
AVERAGE		881	91297333		92755294	108741	2500000		2500000	4826
STANDARD DEVIATION		727	75938453		75551457	34942	0		0	0
APC METHOD - Baghouse/Fabric Filter										
Galax	05	56	2100000	85	2342175	41825	160000	88	166774	2978
AVERAGE		56	2100000		2342175	41825	160000		166774	2978
STANDARD DEVIATION		0	0		0	0	0		0	0
PROCESS: MB - Sludge Co-Disposal										
APC METHOD - Electrostatic Precipitator										
Glen Cove	05	250	34000000	81	43906536	175626	300000	89	307727	1231
Sitka	05	24	4200000	83	4770806	198784	100000	87	106572	4441
AVERAGE		137	19100000		24338671	187205	200000		207150	2836
STANDARD DEVIATION		113	14900000		19567865	11579	100000		100578	1605
APC METHOD - Dry Scrubber										
Huntsville	05	690	72500000	90	72500000	105072	0		0	0
Indianapolis Resource Recovery Facility	05	2362	85000000	85	94802304	40136	0		0	0
AVERAGE		1526	78750000		83651152	72604	0		0	0
STANDARD DEVIATION		836	6250000		11151152	32468	0		0	0

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

ATTACHMENT 4.

CAPITAL COSTS -- FIELD-ERECTED MASS BURN FACILITIES

GROUPED BY TYPE OF ENERGY PRODUCTION

(Derived from 387)

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
PROCESS: MB - Refractory										
ENERGY TYPE - Steam										
Betts Avenue	05	1000	5000000	65	21594896	21595	36500000	89	37440152	37440
City of Waukesha (Old Plant)	05	175	1700000	71	4856118	27749	3900000	79	5806047	33177
Davis County	05	400	40000000	88	41693608	104234	0		0	0
AVERAGE		525	15566667		22714874	51193	20200000		21623100	35309
STANDARD DEVIATION		348	17329423		15059680	37590	16300000		15817053	2132
ENERGY TYPE - Electricity										
McKay Bay Refuse-To-Energy Facility	05	1000	72700000	85	81083856	81084	500000	87	532861	533
AVERAGE		1000	72700000		81083856	81084	500000		532861	533
STANDARD DEVIATION		0	0		0	0	0		0	0
ENERGY TYPE - Steam & Electricity										
Muscoda	05	125	8250000	87	8792208	70338	0		0	0
AVERAGE		125	8250000		8792208	70338	0		0	0
STANDARD DEVIATION		0	0		0	0	0		0	0
PROCESS: MB - Waterwall										
ENERGY TYPE - Steam										
Brooklyn Navy Yard	02	3000	426000000	90	426000000	142000	0		0	0
Hampton/NASA Project Recoup	05	200	10400000	78	16823896	84119	2450000	87	2611020	13055
Norfolk Naval Station	08	360	3220000	67	12995170	36098	5400000	87	5754899	15986
Savannah	05	500	35000000	85	39036240	78072	0		0	0
AVERAGE		1015	118655000		123713827	85072	3925000		4182960	14521
STANDARD DEVIATION		1151	177836647		174807968	37713	1475000		1571940	1466
ENERGY TYPE - Electricity										
Albany (American Ref-Fuel)	02	1500	200000000	89	205151520	136768	0		0	0
Alexandria/Arlington R.R. Facility	05	975	75900000	85	84652896	86823	2000000	89	2051515	2104
Babylon Resource Recovery Project	05	750	85520000	85	95382272	127176	0		0	0
Bergen County	02	3000	335000000	91	335000000	111667	0		0	0
Bridgeport RESCO	05	2250	211000000	85	235332768	104592	0		0	0
Bristol	05	650	58800000	85	65580888	100894	0		0	0
Broome County	02	571	77000000	90	77000000	134851	0		0	0
Broward County (Northern Facility)	03	2250	216007000	90	216007000	96003	0		0	0
Broward County (Southern Facility)	03	2250	277816000	90	277816000	123474	0		0	0
Camden County (Foster Wheeler)	03	1050	96000000	87	102309328	97437	0		0	0
Camden County (Pennsauken)	03	500	88000000	90	88000000	176000	0		0	0
Central Mass. Resource Recovery Project	05	1500	140000000	86	152686272	101791	0		0	0

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON. 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
City of Commerce	05	400	35010000	86	38182472	95456	1000000	89	1025758	2564
Concord Regional S.W. Recovery Facility	05	500	53500000	85	59669688	119339	0		0	0
Dakota County	02	800	108852000	90	108852000	136065	0		0	0
East Bridgewater (American Ref-Fuel)	02	1500	150000000	90	150000000	100000	0		0	0
Eastern-Central Project	02	550	78000000	89	80009088	145471	0		0	0
Essex County	03	2277	252500000	89	259003776	113748	0		0	0
Fairfax County	05	3000	195500000	88	203777536	67926	0		0	0
Falls Township (Wheelabrator)	02	2250	200000000	91	200000000	88889	0		0	0
Glendon	02	500	63500000	90	63500000	127000	0		0	0
Gloucester County	05	575	60000000	90	60000000	104348	0		0	0
Haverhill (Mass Burn)	05	1650	120000000	87	127886656	77507	0		0	0
Hempstead (American Ref-Fuel)	05	2505	255000000	85	284406912	113536	0		0	0
Hennepin County (Blount)	05	1200	80000000	88	83387216	69489	0		0	0
Hillsborough County S.W.E.R. Facility	05	1200	80500000	87	85790640	71492	0		0	0
Hudson County	02	1500	179000000	89	183610592	122407	0		0	0
Huntington	03	750	153500000	90	153500000	204667	0		0	0
Johnston (Central Landfill)	02	750	80000000	90	80000000	106667	0		0	0
Lake County	04	528	60000000	90	60000000	113636	0		0	0
Lancaster County	03	1200	102000000	89	104627280	87189	0		0	0
Lee County	02	1800	146964600	90	146964600	81647	0		0	0
Lisbon	02	500	100000000	90	100000000	200000	0		0	0
Marion County Solid W-T-E Facility	05	550	47500000	86	51804272	94190	0		0	0
Montgomery County	02	1800	280000000	89	287212096	159562	0		0	0
Montgomery County	03	1200	115000000	89	117962112	98302	0		0	0
Morris County	02	1340	141900000	89	145555008	108623	0		0	0
New Hampshire/Vermont S.W. Project	05	200	26500000	85	29556012	147780	0		0	0
North Andover	05	1500	185000000	85	206334432	137556	0		0	0
North Hempstead	02	990	135000000	89	138477280	139876	0		0	0
Oklahoma City	08	820	35000000	87	37300272	45488	0		0	0
Onondaga County	02	990	132000000	90	132000000	133333	0		0	0
Oyster Bay	02	1000	135000000	90	135000000	135000	0		0	0
Pasco County	03	1050	90600000	89	92933632	88508	0		0	0
Passaic County	02	1434	142000000	90	142000000	99024	0		0	0
Pinellas County (Wheelabrator)	05	3150	83000000	83	94280208	29930	60000000	86	65436968	20774
Portland	05	500	45500000	87	48490360	96981	20600000	90	20600000	41200
Preston (Southeastern Connecticut)	03	600	83000000	87	88454944	147425	0		0	0
S.E. Resource Recovery Facility (SERRF)	04	1380	106000000	87	112966544	81860	0		0	0
Saugus	05	1500	33000000	74	74160992	49441	95000000	90	95000000	63333
Spokane	03	800	82149000	87	87548016	109435	0		0	0
Stanislaus County Res. Recovery Facility	05	800	82200000	85	91679408	114599	0		0	0
Sturgis	02	560	0		0	0	0		0	0
Union County	02	1440	150000000	90	150000000	104167	0		0	0
Warren County	05	400	50300000	89	51595608	128989	0		0	0

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $•	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $•	ADDITIONAL CAP $/TON 1990 $
Washington/Warren Counties	03	400	50000000	90	50000000	125000	0		0	0
West Pottsgrove Recycling/R.R. Facility	02	1500	150000000	91	150000000	100000	0		0	0
Westchester	05	2250	179000000	83	203327168	90368	0		0	0
AVERAGE		1230	122359975		127837294	110691	35720000		36822848	25995
STANDARD DEVIATION		723	69637080		70966036	32515	36537017		37301493	23547
ENERGY TYPE - Steam & Electricity										
Charleston County	05	644	59000000	89	60519688	93975	0		0	0
Davidson County	03	210	7000000	87	7460056	35524	0		0	0
Harrisburg	05	720	8300000	71	23709280	32930	21300000	86	23230124	32264
Jackson County/Southern MI State Prison	05	200	28000000	86	30537256	152686	0		0	0
Kent County	05	625	62200000	89	63802128	102083	0		0	0
Nashville Thermal Transfer Corp. (NTTC)	05	1120	24500000	74	55058920	49160	36500000	85	40709224	36348
Northwest Waste-To-Energy Facility	05	1600	23000000	68	86385568	53991	5000000	88	5211701	3257
Olmstead County	05	200	30000000	87	31971664	159858	0		0	0
Quonset Point	02	710	83000000	90	83000000	116901	0		0	0
S.W. Resource Recovery Facility (BRESCO)	05	2250	185000000	83	210142624	93397	0		0	0
University City Res. Recovery Facility	05	235	27000000	87	28774496	122445	0		0	0
Walter B. Hall Res. Recovery Facility	05	1125	114000000	87	121492320	107993	0		0	0
Wayne County	02	300	27000000	90	27000000	90000	0		0	0
AVERAGE		765	52153846		63834923	93149	20933333		23050350	23956
STANDARD DEVIATION		597	48428117		52029873	39364	12862435		14492361	14731
PROCESS: MB - Rotary Combustor										
ENERGY TYPE - Steam										
Galax	05	56	2100000	85	2342175	41825	160000	88	166774	2978
AVERAGE		56	2100000		2342175	41825	160000		166774	2978
STANDARD DEVIATION		0	0		0	0	0		0	0
ENERGY TYPE - Electricity										
Auburn (New Plant)	03	200	26500000	90	26500000	132500	0		0	0
Delaware County Regional R.R. Project	03	2688	276000000	90	276000000	102679	0		0	0
Gaston County/Westinghouse R.R. Center	02	440	42000000	89	43081824	97913	0		0	0
MacArthur Energy Recovery Facility	05	518	38700000	85	43162936	83326	2500000	91	2500000	4826
Mercer County	02	975	117500000	88	122474976	125615	0		0	0
Monmouth County	02	1700	220000000	90	220000000	129412	0		0	0
Montgomery County (North)	05	300	7494000	69	25688292	85628	9700000	87	10337504	34458
Montgomery County (South)	02	900	6150000	69	21081268	23424	5000000	85	5576606	6196
Oakland County	02	2000	172000000	90	172000000	86000	0		0	0
San Juan Resource Recovery Facility	02	1040	91400000	89	93754240	90148	0		0	0
Skagit County	05	178	14000000	87	14920112	83821	0		0	0

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
Westinghouse/Bay Resource Mgmt. Center	05	510	38000000	86	41443416	81262	0		0	0
York County	05	1344	91200000	88	95061424	70730	0		0	0
AVERAGE		984	87764923		91936038	91728	5733333		6138037	15160
STANDARD DEVIATION		737	83297756		80657588	27471	2984776		3224182	13657
ENERGY TYPE - Steam & Electricity										
Dutchess County	05	506	35000000	84	39213904	77498	0		0	0
Falls Township (Technochem)	02	70	7000000	90	7000000	100000	0		0	0
Monroe County	02	500	100000000	91	100000000	200000	0		0	0
Sangamon County	02	450	38160000	90	38160000	84800	0		0	0
Sumner County	05	200	9800000	81	12655414	63277	5340000	90	5340000	26700
Waukesha County (New Plant)	02	600	100000000	90	100000000	166667	0		0	0
AVERAGE		388	48326667		49504886	115374	5340000		5340000	26700
STANDARD DEVIATION		188	38326286		37635694	50187	0		0	0
		PROCESS: MB - Sludge Co-Disposal								
ENERGY TYPE - Steam										
Huntsville	05	690	72500000	90	72500000	105072	0		0	0
Indianapolis Resource Recovery Facility	05	2362	85000000	85	94802304	40136	0		0	0
Sitka	05	24	4200000	83	4770806	198784	100000	87	106572	4441
AVERAGE		1025	53900000		57357703	114664	100000		106572	4441
STANDARD DEVIATION		983	35511782		38283021	65122	0		0	0
ENERGY TYPE - Steam & Electricity										
Glen Cove	05	250	34000000	81	43906536	175626	300000	89	307727	1231
AVERAGE		250	34000000		43906536	175626	300000		307727	1231
STANDARD DEVIATION		0	0		0	0	0		0	0

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

ATTACHMENT 5.

O&M COSTS -- FIELD-ERECTED MASS BURN FACILITIES

(Derived from 387)

NAME	STATUS	O&M COSTS PER TON W/DEBT SV	YEAR	O&M COSTS PER TON NO DEBT SV	YEAR	O&M COSTS PER YEAR W/DEBT SV	YEAR	O&M COSTS PER YEAR NO DEBT SV	YEAR
PROCESS: MB - Refractory									
Betts Avenue	05	0		23	90	0		6700000	90
City of Waukesha (Old Plant)	05	78	90	40	90	4040000	90	2040000	90
Davis County	05	46	90	14	90	5925000	90	1725000	90
McKay Bay Refuse-To-Energy Facility	05	61	90	18	90	18560000	90	5560000	90
Muscoda	05	83	90	42	90	1900000	90	950000	90
AVERAGE		67		27		7606250		3395000	
STANDARD DEVIATION		15		11		6482489		2289681	
PROCESS: MB - Waterwall									
Albany (American Ref-Fuel)	02	0		0		0		0	
Alexandria/Arlington R.R. Facility	05	0		0		0		0	
Babylon Resource Recovery Project	05	80	91	47	91	16700000	91	9900000	91
Bergen County	02	0		15	95	0		13100000	95
Bridgeport RESCO	05	55	90	23	90	39848000	90	16700000	90
Bristol	05	62	90	26	90	12108000	90	5076000	90
Brooklyn Navy Yard	02	0		13	95	0		12000000	95
Broome County	02	82	93	29	93	13505574	93	4784674	93
Broward County (Northern Facility)	03	61	92	29	92	50223000	92	24021000	92
Broward County (Southern Facility)	03	57	92	22	92	46803000	92	17930000	92
Camden County (Foster Wheeler)	03	0		38	91	0		11701000	91
Camden County (Pennsauken)	03	0		23	94	0		3645000	94
Central Mass. Resource Recovery Project	05	66	90	38	90	35000000	90	20000000	90
Charleston County	05	55	90	20	90	11500000	90	4200000	90
City of Commerce	05	95	90	45	90	10400000	90	5000000	90
Concord Regional S.W. Recovery Facility	05	0		0		0		0	
Dakota County	02	80	93	28	93	18800000	93	6500000	93
Davidson County	03	0		0		0		0	
East Bridgewater (American Ref-Fuel)	02	0		0		0		0	
Eastern-Central Project	02	0		0		0		0	
Essex County	03	49	90	17	90	35300000	90	15500000	90
Fairfax County	05	36	90	16	90	35397500	90	15697500	90
Falls Township (Wheelabrator)	02	0		0		0		0	
Glendon	02	0		0		0		0	
Gloucester County	05	0		0		0		0	
Hampton/NASA Project Recoup	05	44	90	34	90	3200000	90	2460000	90
Harrisburg	05	40	90	22	90	7900000	90	4400000	90
Haverhill (Mass Burn)	05	0		0		0		0	
Hempstead (American Ref-Fuel)	05	43	90	14	90	39520000	90	13148000	90
Hennepin County (Blount)	05	71	90	33	90	25800000	90	12000000	90
Hillsborough County S.W.E.R. Facility	05	0		16	87	0		6000000	87
Hudson County	02	0		18	93	0		8000000	93
Huntington	03	101	92	38	92	25500000	92	9500000	92

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	O&M COSTS PER TON W/DEBT SV	YEAR	O&M COSTS PER TON NO DEBT SV	YEAR	O&M COSTS PER YEAR W/DEBT SV	YEAR	O&M COSTS PER YEAR NO DEBT SV	YEAR
Jackson County/Southern MI State Prison	05	90	90	47	90	6268000	90	3268000	90
Johnston (Central Landfill)	02	0		19	93	0		4530000	93
Kent County	05	62	91	29	91	11966000	91	5600000	91
Lake County	04	62	91	28	91	10181000	91	4521000	91
Lancaster County	03	0		19	91	0		6200000	91
Lee County	02	0		0		0		0	
Lisbon	02	0		0		0		0	
Marion County Solid W-T-E Facility	05	48	91	20	91	9121000	91	3775000	91
Montgomery County	02	0		0		0		0	
Montgomery County	03	0		13	92	0		4700000	92
Morris County	02	0		16	95	0		7000000	95
Nashville Thermal Transfer Corp. (NTTC)	05	29	90	19	90	10162537	90	6632917	90
New Hampshire/Vermont S.W. Project	05	54	90	37	90	3500000	90	2400000	90
Norfolk Naval Station	08	0		28	86	0		1541700	86
North Andover	05	62	90	12	90	26777000	90	5397000	90
North Hempstead	02	0		0		0		0	
Northwest Waste-To-Energy Facility	05	0		9	90	0		3511000	90
Oklahoma City	08	40	90	27	90	12000000	90	8000000	90
Olmstead County	05	102	90	42	90	6000000	90	2500000	90
Onondaga County	02	133	94	60	94	41300000	94	18700000	94
Oyster Bay	02	0		0		0		0	
Pasco County	03	53	91	16	91	17375000	91	5375000	91
Passaic County	02	0		0		0		0	
Pinellas County (Wheelabrator)	05	41	90	14	90	37528000	90	12420000	90
Portland	05	67	90	21	90	11000000	90	3400000	90
Preston (Southeastern Connecticut)	03	72	91	36	91	13700000	91	6900000	91
Quonset Point	02	95	93	26	93	22700000	93	6200000	93
S.E. Resource Recovery Facility (SERRF)	04	54	90	18	90	22990000	90	7690000	90
S.W. Resource Recovery Facility (BRESCO)	05	48	89	27	89	34356000	89	19000000	89
Saugus	05	0		0		0		0	
Savannah	05	33	90	11	90	5850000	90	2000000	90
Spokane	03	56	91	23	91	13785000	91	5585000	91
Stanislaus County Res. Recovery Facility	05	46	91	22	91	13452000	91	6400000	91
Sturgis	02	0		0		0		0	
Union County	02	77	93	31	93	33500000	93	13500000	93
University City Res. Recovery Facility	05	0		20	90	0		1400000	90
Walter B. Hall Res. Recovery Facility	05	41	90	14	90	14100000	90	4800000	90
Warren County	05	37	90	28	90	4532000	90	3500000	90
Washington/Warren Counties	03	85	92	37	92	10699000	92	4676000	92
Wayne County	02	0		0		0		0	
West Pottsgrove Recycling/R.R. Facility	02	0		0		0		0	
Westchester	05	0		0		0		0	
AVERAGE		62		25		20008478		8007144	
STANDARD DEVIATION		22		11		13024298		5392875	

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	O&M COSTS PER TON W/DEBT SV	YEAR	O&M COSTS PER TON NO DEBT SV	YEAR	O&M COSTS PER YEAR W/DEBT SV	YEAR	O&M COSTS PER YEAR NO DEBT SV	YEAR
				PROCESS: MB - Rotary Combustor					
Auburn (New Plant)	03	70	92	23	92	4500000	92	1500000	92
Delaware County Regional R.R. Project	03	43	91	19	91	36000000	91	16000000	91
Dutchess County	05	55	90	21	90	6600000	90	2500000	90
Falls Township (Technochem)	02	0		0		0		0	
Galax	05	68	90	48	90	571000	90	401000	90
Gaston County/Westinghouse R.R. Center	02	0		0		0		0	
MacArthur Energy Recovery Facility	05	0		27	90	0		4390000	90
Mercer County	02	63	93	30	93	19006683	93	8974674	93
Monmouth County	02	0		0		0		0	
Monroe County	02	0		0		0		0	
Montgomery County (North)	05	27	90	23	90	7440000	90	6380000	90
Montgomery County (South)	02	39	90	33	90	8715000	90	7470000	90
Oakland County	02	0		0		0		0	
San Juan Resource Recovery Facility	02	40	93	17	93	12000000	93	5000000	93
Sangamon County	02	39	90	18	90	5592000	90	2592000	90
Skagit County	05	44	90	28	90	2369000	90	1492000	90
Sumner County	05	60	90	40	90	3600000	90	2400000	90
Waukesha County (New Plant)	02	0		0		0		0	
Westinghouse/Bay Resource Mgmt. Center	05	53	90	19	90	9800000	90	3500000	90
York County	05	44	90	9	90	16700000	90	3500000	90
AVERAGE		50		25		10222591		4721405	
STANDARD DEVIATION		13		10		9042420		3901503	
				PROCESS: MB - Sludge Co-Disposal					
Glen Cove	05	27	90	20	90	2150000	90	1600000	90
Huntsville	05	83	91	30	91	18240000	91	6540000	91
Indianapolis Resource Recovery Facility	05	23	90	11	90	16200000	90	7800000	90
Sitka	05	0		69	90	0		380000	90
AVERAGE		44		33		12196667		4080000	
STANDARD DEVIATION		27		22		7152717		3151603	

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

ATTACHMENT 6.

STAFFING LEVELS

FIELD-ERECTED MASS BURN FACILITIES

(Derived from 387)

NAME	STATUS	STATE	DESIGN TPD	FULL TIME MANAGEMENT EMPLOYEES	FULL TIME NON M'GMT EMPLOYEES	ALL FULL TIME EMPLOYEES	FULL TIME EMPLOYEES PER 100TPD
PROCESS: MB - Refractory							
Betts Avenue	05	NY	1000	1	89	90	9.0
City of Waukesha (Old Plant)	05	WI	175	1	17	18	10.3
Davis County	05	UT	400	6	18	24	6.0
McKay Bay Refuse-To-Energy Facility	05	FL	1000	16	34	50	5.0
Muscoda	05	WI	125	3	8	11	8.8
AVERAGE			540	5	33	39	7.8
STANDARD DEVIATION			387	6	29	29	2.0
PROCESS: MB - Waterwall							
Albany (American Ref-Fuel)	02	NY	1500	14	56	70	4.7
Alexandria/Arlington R.R. Facility	05	VA	975	6	35	41	4.2
Babylon Resource Recovery Project	05	NY	750	6	34	40	5.3
Bergen County	02	NJ	3000	0	0	67	2.2
Bridgeport RESCO	05	CT	2250	8	57	65	2.9
Bristol	05	CT	650	8	32	40	6.2
Brooklyn Navy Yard	02	NY	3000	0	0	84	2.8
Broome County	02	NY	571	6	31	37	6.5
Broward County (Northern Facility)	03	FL	2250	12	48	60	2.7
Broward County (Southern Facility)	03	FL	2250	12	48	60	2.7
Camden County (Foster Wheeler)	03	NJ	1050	5	40	45	4.3
Camden County (Pennsauken)	03	NJ	500	0	0	35	7.0
Central Mass. Resource Recovery Project	05	MA	1500	8	50	58	3.9
Charleston County	05	SC	644	7	27	34	5.3
City of Commerce	05	CA	400	2	33	35	8.8
Concord Regional S.W. Recovery Facility	05	NH	500	10	30	40	8.0
Dakota County	02	MN	800	12	43	55	6.9
Davidson County	03	TN	210	1	17	18	8.6
East Bridgewater (American Ref-Fuel)	02	MA	1500	15	60	75	5.0
Eastern-Central Project	02	CT	550	0	0	40	7.3
Essex County	03	NJ	2277	11	72	83	3.6
Fairfax County	05	VA	3000	4	48	52	1.7
Falls Township (Wheelabrator)	02	PA	2250	5	65	70	3.1
Glendon	02	PA	500	4	36	40	8.0
Gloucester County	05	NJ	575	13	31	44	7.7
Hampton/NASA Project Recoup	05	VA	200	7	26	33	16.5
Harrisburg	05	PA	720	8	67	75	10.4
Haverhill (Mass Burn)	05	MA	1650	5	31	36	2.2
Hempstead (American Ref-Fuel)	05	NY	2505	32	52	84	3.4
Hennepin County (Blount)	05	MN	1200	10	38	48	4.0
Hillsborough County S.W.E.R. Facility	05	FL	1200	9	25	34	2.8
Hudson County	02	NJ	1500	0	0	50	3.3
Huntington	03	NY	750	20	30	50	6.7

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	STATE	DESIGN TPD	FULL TIME MANAGEMENT EMPLOYEES	FULL TIME NON M'GMT EMPLOYEES	ALL FULL TIME EMPLOYEES	FULL TIME EMPLOYEES PER 100TPD
Jackson County/Southern MI State Prison	05	MI	200	8	24	32	16.0
Johnston (Central Landfill)	02	RI	750	6	24	30	4.0
Kent County	05	MI	625	6	32	38	6.1
Lake County	04	FL	528	6	24	30	5.7
Lancaster County	03	PA	1200	5	40	45	3.8
Lee County	02	FL	1800	7	40	47	2.6
Lisbon	02	CT	500	0	0	0	0.0
Marion County Solid W-T-E Facility	05	OR	550	1	29	30	5.5
Montgomery County	02	MD	1800	11	78	89	4.9
Montgomery County	03	PA	1200	9	30	39	3.3
Morris County	02	NJ	1340	7	28	35	2.6
Nashville Thermal Transfer Corp. (NTTC)	05	TN	1120	6	46	52	4.6
New Hampshire/Vermont S.W. Project	05	NH	200	4	31	35	17.5
Norfolk Naval Station	08	VA	360	5	22	27	7.5
North Andover	05	MA	1500	9	41	50	3.3
North Hempstead	02	NY	990	0	0	0	0.0
Northwest Waste-To-Energy Facility	05	IL	1600	10	77	87	5.4
Oklahoma City	08	OK	820	5	50	55	6.7
Olmstead County	05	MN	200	4	28	32	16.0
Onondaga County	02	NY	990	6	41	47	4.7
Oyster Bay	02	NY	1000	5	35	40	4.0
Pasco County	03	FL	1050	6	31	37	3.5
Passaic County	02	NJ	1434	5	35	40	2.8
Pinellas County (Wheelabrator)	05	FL	3150	12	48	60	1.9
Portland	05	ME	500	7	38	46	9.2
Preston (Southeastern Connecticut)	03	CT	600	7	27	34	5.7
Quonset Point	02	RI	710	10	40	50	7.0
S.E. Resource Recovery Facility (SERRF)	04	CA	1380	10	50	60	4.3
S.W. Resource Recovery Facility (BRESCO)	05	MD	2250	13	56	69	3.1
Saugus	05	MA	1500	4	46	50	3.3
Savannah	05	GA	500	3	24	27	5.4
Spokane	03	WA	800	10	35	45	5.6
Stanislaus County Res. Recovery Facility	05	CA	800	5	40	45	5.6
Sturgis	02	MI	560	5	15	20	3.6
Union County	02	NJ	1440	12	38	50	3.5
University City Res. Recovery Facility	05	NC	235	4	18	22	9.4
Walter B. Hall Res. Recovery Facility	05	OK	1125	4	36	40	3.6
Warren County	05	NJ	400	6	34	40	10.0
Washington/Warren Counties	03	NY	400	5	35	40	10.0
Wayne County	02	NC	300	0	0	16	5.3
West Pottsgrove Recycling/R.R. Facility	02	PA	1500	0	0	60	4.0
Westchester	05	NY	2250	5	65	70	3.1
AVERAGE			1138	8	39	47	5.7
STANDARD DEVIATION			754	5	14	17	3.4

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	STATE	DESIGN TPD	FULL TIME MANAGEMENT EMPLOYEES	FULL TIME NON M'GMT EMPLOYEES	ALL FULL TIME EMPLOYEES	FULL TIME EMPLOYEES PER 100TPD
PROCESS: MB - Rotary Combustor							
Auburn (New Plant)	03	ME	200	2	13	15	7.5
Delaware County Regional R.R. Project	03	PA	2688	11	89	100	3.7
Dutchess County	05	NY	506	9	26	35	6.9
Falls Township (Technochem)	02	PA	70	2	9	11	15.7
Galax	05	VA	56	1	8	9	16.1
Gaston County/Westinghouse R.R. Center	02	NC	440	10	75	85	19.3
MacArthur Energy Recovery Facility	05	NY	518	8	26	34	6.6
Mercer County	02	NJ	975	7	43	50	5.1
Monmouth County	02	NJ	1700	24	176	200	11.8
Monroe County	02	IN	500	0	0	45	9.0
Montgomery County (North)	05	OH	300	3	18	21	7.0
Montgomery County (South)	02	OH	900	10	55	65	7.2
Oakland County	02	MI	2000	7	53	60	3.0
San Juan Resource Recovery Facility	02	PR	1040	7	38	45	4.3
Sangamon County	02	IL	450	3	19	22	4.9
Skagit County	05	WA	178	6	15	21	11.8
Sumner County	05	TN	200	4	90	94	47.0
Waukesha County (New Plant)	02	WI	600	0	0	0	0.0
Westinghouse/Bay Resource Mgmt. Center	05	FL	510	5	35	40	7.8
York County	05	PA	1344	10	38	48	3.6
AVERAGE			759	7	46	53	10.4
STANDARD DEVIATION			680	5	40	43	9.7
PROCESS: MB - Sludge Co-Disposal							
Glen Cove	05	NY	250	5	30	35	14.0
Huntsville	05	AL	690	6	33	39	5.7
Indianapolis Resource Recovery Facility	05	IN	2362	8	46	54	2.3
Sitka	05	AK	24	1	4	5	20.8
AVERAGE			832	5	28	33	10.7
STANDARD DEVIATION			916	3	15	18	7.2

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

ATTACHMENT 7.

CAPITAL COSTS -- MODULAR MASS BURN FACILITIES

GROUPED BY APC METHOD

(Derived from 387)

PROCESS: MB - Modular

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
APC METHOD - Electrostatic Precipitator										
Barron County	05	80	5600000	85	6245799	78072	0		0	0
Cleburne	05	115	5500000	85	6134267	53341	0		0	0
Energy Gen. Facility at Pigeon Point	05	600	75000000	87	79929168	133215	0		0	0
Hampton	05	270	10000000	85	11153212	41308	2300000	87	2451161	9078
Harford County	05	360	23600000	87	25151044	69864	0		0	0
Harrisonburg	05	100	8200000	83	9314430	93144	0		0	0
Key West	05	150	12500000	86	13632702	90885	0		0	0
Long Beach	05	200	22300000	88	23244188	116221	0		0	0
New Hanover County	07	100	13100000	82	15943730	159437	25000000	90	25000000	250000
North Slope Borough/Prudhoe Bay	05	100	6000000	80	8370943	83709	2000000	87	2131445	21314
Oneida County	05	200	13800000	85	15391432	76957	1600000	85	1784514	8923
Oswego County	05	200	14500000	86	15813936	79070	0		0	0
Pascagoula	05	150	6900000	85	7695716	51305	0		0	0
Perham	05	116	6800000	85	7584184	65381	0		0	0
Pittsfield	05	240	10800000	81	13946780	58112	5000000	90	5000000	20833
Polk County	05	80	6800000	87	7246910	90586	740000	89	759061	9488
Pope-Douglas W-T-E Facility	05	80	5800000	87	6181189	77265	0		0	0
Red Wing	05	72	3000000	82	3651236	50712	750000	86	817962	11361
Richard Asphalt	05	57	2200000	82	2677573	46975	1300000	85	1449918	25437
Rutland	08	240	34000000	88	35439568	147665	5000000	90	5000000	20833
Tuscaloosa Energy Recovery Facility	05	300	9500000	83	10791108	35970	500000	87	532861	1776
Westmoreland County	05	50	4150000	86	4526057	90521	100000	90	100000	2000
AVERAGE		175	13638636		15002962	81351	4026364		4093357	34640
STANDARD DEVIATION		125	15297147		16110212	32512	6819640		6796162	68529
APC METHOD - Dry Scrubber										
Agawam/Springfield	05	360	25000000	86	27265404	75737	0		0	0
Bellingham	05	100	1000000	74	2247303	22473	8000000	90	8000000	80000
Collegeville	05	50	2400000	80	3348377	66968	0		0	0
Eau Claire County	02	150	13500000	88	14071592	93811	0		0	0
Fort Lewis (U.S. Army)	03	120	10000000	87	10657222	88810	7000000	90	7000000	58333
Lassen Community College	08	100	7100000	83	8064933	80649	3500000	90	3500000	35000
Manchester	02	560	50000000	87	53286104	95154	0		0	0
Muskegon County	02	180	10900000	87	11616372	64535	0		0	0
St. Croix County	05	115	9500000	89	9744698	84737	0		0	0
Wallingford	05	420	40000000	87	42628888	101497	0		0	0
Windham	05	108	3700000	81	4778064	44241	5700000	87	6074616	56246
AVERAGE		206	15736364		17064451	74419	6050000		6143654	57395
STANDARD DEVIATION		157	15264949		16075117	22675	1683003		1671304	15927

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
APC METHOD - Baghouse/Fabric Filter										
Fort Dix	05	80	6500000	85	7249588	90620	0		0	0
Osceola	05	50	1200000	80	1674189	33484	275000	90	275000	5500
AVERAGE		65	3850000		4461889	62052	275000		275000	5500
STANDARD DEVIATION		15	2650000		2787700	28568	0		0	0
APC METHOD - Two-Chamber Furnace										
Batesville	05	100	1200000	80	1674189	16742	850000	86	927024	9270
Beto 1 Unit (Texas Dept. of Corrections)	05	25	1000000	80	1395157	55806	0		0	0
Cassia County	05	50	1400000	82	1703910	34078	0		0	0
Cattaraugus County R-T-E Facility	05	112	5500000	83	6247483	55781	500000	85	557661	4979
Center	05	40	1800000	85	2007578	50189	0		0	0
City of Carthage/Panola County	05	40	1600000	85	1784514	44613	400000	89	410303	10258
Dyersburg	05	100	2000000	80	2790315	27903	450000	89	461591	4616
Fort Leonard Wood	05	75	3300000	81	4261517	56820	0		0	0
Gatesville (Texas Dept. of Corrections)	05	13	750000	80	1046368	80490	0		0	0
Miami	06	108	3140000	82	3821627	35385	0		0	0
Miami International Airport	06	60	4000000	82	4868315	81139	200000	82	243416	4057
Park County	06	75	2900000	82	3529529	47060	0		0	0
Salem	05	100	2390000	79	3558065	35581	100000	85	111532	1115
Waxahachie	06	50	2200000	81	2841011	56820	0		0	0
AVERAGE		68	2370000		2966398	48458	416667		451921	5716
STANDARD DEVIATION		31	1256060		1445205	17593	239212		257575	3134
APC METHOD - Cyclones										
Lamprey Regional Solid Waste Cooperative	05	108	3300000	80	4604019	42630	0		0	0
Lewis County	05	50	1500000	87	1598583	31972	0		0	0
Mayport Naval Station	05	50	2300000	79	3424079	68482	0		0	0
AVERAGE		69	2366667		3208894	47695	0		0	0
STANDARD DEVIATION		27	736357		1236363	15329	0		0	0
APC METHOD - Wet Scrubber										
Fergus Falls	05	94	4050000	87	4316175	45917	0		0	0
AVERAGE		94	4050000		4316175	45917	0		0	0
STANDARD DEVIATION		0	0		0	0	0		0	0
APC METHOD - To Be Determined										
Elk River R.R. Authority (TERRA)	02	200	14500000	90	14500000	72500	0		0	0
AVERAGE		200	14500000		14500000	72500	0		0	0
STANDARD DEVIATION		0	0		0	0	0		0	0

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

ATTACHMENT 8.

CAPITAL COSTS -- MODULAR MASS BURN FACILITIES

GROUPED BY TYPE OF ENERGY PRODUCTION

(Derived from 387)

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
PROCESS: MB - Modular										
ENERGY TYPE - Steam										
Batesville	05	100	1200000	80	1674189	16742	850000	86	927024	9270
Beto 1 Unit (Texas Dept. of Corrections)	05	25	1000000	80	1395157	55806	0		0	0
Cassia County	05	50	1400000	82	1703910	34078	0		0	0
Cattaraugus County R-T-E Facility	05	112	5500000	83	6247483	55781	500000	85	557661	4979
Center	05	40	1800000	85	2007578	50189	0		0	0
City of Carthage/Panola County	05	40	1600000	85	1784514	44613	400000	89	410303	10258
Collegeville	05	50	2400000	80	3348377	66968	0		0	0
Dyersburg	05	100	2000000	80	2790315	27903	450000	89	461591	4616
Elk River R.R. Authority (TERRA)	02	200	14500000	90	14500000	72500	0		0	0
Fergus Falls	05	94	4050000	87	4316175	45917	0		0	0
Fort Dix	05	80	6500000	85	7249588	90620	0		0	0
Fort Leonard Wood	05	75	3300000	81	4261517	56820	0		0	0
Fort Lewis (U.S. Army)	03	120	10000000	87	10657222	88810	7000000	90	7000000	58333
Gatesville (Texas Dept. of Corrections)	05	13	750000	80	1046368	80490	0		0	0
Hampton	05	270	10000000	85	11153212	41308	2300000	87	2451161	9078
Harford County	05	360	23600000	87	25151044	69864	0		0	0
Harrisonburg	05	100	8200000	83	9314430	93144	0		0	0
Lamprey Regional Solid Waste Cooperative	05	108	3300000	80	4604019	42630	0		0	0
Lewis County	05	50	1500000	87	1598583	31972	0		0	0
Mayport Naval Station	05	50	2300000	79	3424079	68482	0		0	0
Miami	06	108	3140000	82	3821627	35385	0		0	0
Miami International Airport	06	60	4000000	82	4868315	81139	200000	82	243416	4057
Osceola	05	50	1200000	80	1674189	33484	275000	90	275000	5500
Park County	06	75	2900000	82	3529529	47060	0		0	0
Pascagoula	05	150	6900000	85	7695716	51305	0		0	0
Perham	05	116	6800000	85	7584184	65381	0		0	0
Pittsfield	05	240	10800000	81	13946780	58112	5000000	90	5000000	20833
Polk County	05	80	6800000	87	7246910	90586	740000	89	759061	9488
Pope-Douglas W-T-E Facility	05	80	5800000	87	6181189	77265	0		0	0
Red Wing	05	72	3000000	82	3651236	50712	750000	86	817962	11361
Richard Asphalt	05	57	2200000	82	2677573	46975	1300000	85	1449918	25437
Salem	05	100	2390000	79	3558065	35581	100000	85	111532	1115
Tuscaloosa Energy Recovery Facility	05	300	9500000	83	10791108	35970	500000	87	532861	1776
Waxahachie	06	50	2200000	81	2841011	56820	0		0	0
Westmoreland County	05	50	4150000	86	4526057	90521	100000	90	100000	2000
AVERAGE		104	5048000		5794893	56884	1364333		1406499	11873
STANDARD DEVIATION		78	4595832		4854316	20384	1930279		1926571	14055

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	DESIGN TPD	ORIGINAL CAPITAL COSTS	YEAR	CAPITAL COST IN 1990 $	CAP COST PER TON 1990 $	ADDITIONAL CAPITAL COST	YEAR	ADDITIONAL COST IN 1990 $	ADDITIONAL CAP $/TON 1990 $
ENERGY TYPE - Electricity										
Bellingham	05	100	1000000	74	2247303	22473	8000000	90	8000000	80000
Cleburne	05	115	5500000	85	6134267	53341	0		0	0
Eau Claire County	02	150	13500000	88	14071592	93811	0		0	0
Kay West	05	150	12500000	86	13632702	90885	0		0	0
Long Beach	05	200	22300000	88	23244188	116221	0		0	0
Manchester	02	560	50000000	87	53286104	95154	0		0	0
Rutland	08	240	34000000	88	35439568	147665	5000000	90	5000000	20833
AVERAGE		216	19828571		21150818	88507	6500000		6500000	50417
STANDARD DEVIATION		147	15905230		16607676	37688	1500000		1500000	29584
ENERGY TYPE - Steam & Electricity										
Agawam/Springfield	05	360	25000000	86	27265404	75737	0		0	0
Barron County	05	80	5600000	85	6245799	78072	0		0	0
Energy Gen. Facility at Pigeon Point	05	600	75000000	87	79929168	133215	0		0	0
Lassen Community College	08	100	7100000	83	8064933	80649	3500000	90	3500000	35000
Muskegon County	02	180	10900000	87	11616372	64535	0		0	0
New Hanover County	07	100	13100000	82	15943730	159437	25000000	90	25000000	250000
Oneida County	05	200	13800000	85	15391432	76957	1600000	85	1784514	8923
Oswego County	05	200	14500000	86	15813936	79070	0		0	0
St. Croix County	05	115	9500000	89	9744698	84737	0		0	0
Wallingford	05	420	40000000	87	42628888	101497	0		0	0
Windham	05	108	3700000	81	4778064	44241	5700000	87	6074616	56246
AVERAGE		224	19836364		21583857	88922	8950000		9089783	87542
STANDARD DEVIATION		159	19996648		21154768	30602	9379366		9311805	95281
ENERGY TYPE - Hot Water										
North Slope Borough/Prudhoe Bay	05	100	6000000	80	8370943	83709	2000000	87	2131445	21314
AVERAGE		100	6000000		8370943	83709	2000000		2131445	21314
STANDARD DEVIATION		0	0		0	0	0		0	0

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

ATTACHMENT 9.

O&M COSTS -- MODULAR MASS BURN FACILITIES

(Derived from 387)

NAME	STATUS	O&M COSTS PER TON W/DEBT SV	YEAR	O&M COSTS PER TON NO DEBT SV	YEAR	O&M COSTS PER YEAR W/DEBT SV	YEAR	O&M COSTS PER YEAR NO DEBT SV	YEAR
		PROCESS: MB - Modular							
Agawam/Springfield	05	60	90	31	90	6700000	90	3500000	90
Barron County	05	57	90	34	90	1650000	90	1000000	90
Batesville	05	0		15	89	0		340000	89
Bellingham	05	0		0		0		0	
Beto 1 Unit (Texas Dept. of Corrections)	05	0		0		0		0	
Cassia County	05	0		28	90	0		235000	90
Cattaraugus County R-T-E Facility	05	37	90	32	90	1715625	90	1500000	90
Center	05	49	90	28	90	400180	90	228263	90
City of Carthage/Panola County	05	41	90	36	90	571000	90	496000	90
Cleburne	05	64	90	27	90	1296000	90	546000	90
Collegeville	05	0		8	90	0		50000	90
Dyersburg	05	38	90	28	90	996000	90	725000	90
Eau Claire County	02	45	93	39	93	2108523	93	1793523	93
Elk River R.R. Authority (TERRA)	02	0		27	92	0		17000000	92
Energy Gen. Facility at Pigeon Point	05	53	90	23	90	10500000	90	4500000	90
Fergus Falls	05	64	90	49	90	1750000	90	1350000	90
Fort Dix	05	0		46	90	0		725000	90
Fort Leonard Wood	05	0		19	89	0		205000	89
Fort Lewis (U.S. Army)	03	0		0		0		0	
Gatesville (Texas Dept. of Corrections)	05	0		0		0		0	
Hampton	05	0		0		0		0	
Harford County	05	34	89	17	89	4039000	89	2031000	89
Harrisonburg	05	72	90	25	90	1703000	90	598000	90
Key West	05	60	90	35	90	2788000	90	1650000	90
Lamprey Regional Solid Waste Cooperative	05	72	90	47	90	2639519	90	1729109	90
Lassen Community College	08	0		0		0		0	
Lewis County	05	0		0		0		0	
Long Beach	05	0		0		0		0	
Manchester	02	0		16	90	0		3000000	90
Mayport Naval Station	05	0		73	90	0		856000	90
Miami	06	0		20	90	0		380000	90
Miami International Airport	06	0		11	90	0		101900	90
Muskegon County	02	41	90	24	90	2230000	90	1300000	90
New Hanover County	07	146	90	69	90	4391650	90	2064700	90
North Slope Borough/Prudhoe Bay	05	0		499	90	0		7700000	90
Oneida County	05	81	90	41	90	4450000	90	2250000	90
Osceola	05	29	89	26	89	462800	89	427800	89
Oswego County	05	47	90	29	90	3300000	90	2000000	90
Park County	06	44	89	17	89	660400	89	260400	89
Pascagoula	05	41	90	27	90	1500000	90	1000000	90
Perham	05	0		0		0		0	
Pittsfield	05	54	90	36	90	4350000	90	2900000	90
Polk County	05	69	90	44	90	1720000	90	1111000	90
Pope-Douglas W-T-E Facility	05	104	90	72	90	1870000	90	1300000	90
Red Wing	05	57	90	37	90	1262000	90	812000	90

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	O&M COSTS PER TON W/DEBT SV	YEAR	O&M COSTS PER TON NO DEBT SV	YEAR	O&M COSTS PER YEAR W/DEBT SV	YEAR	O&M COSTS PER YEAR NO DEBT SV	YEAR
Richard Asphalt	05	48	90	36	90	1075000	90	800000	90
Rutland	08	0		0		0		0	
Salem	05	40	91	33	91	943576	91	776000	91
St. Croix County	05	47	90	23	90	1575000	90	775000	90
Tuscaloosa Energy Recovery Facility	05	0		13	90	0		1300000	90
Wallingford	05	67	90	43	90	9300000	90	6000000	90
Waxahachie	06	48	90	31	90	710000	90	460000	90
Westmoreland County	05	0		49	90	0		700000	90
Windham	05	70	90	41	90	2600000	90	1500000	90
AVERAGE		57		43		2621202		1817652	
STANDARD DEVIATION		22		71		2379601		2765037	

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

ATTACHMENT 10.

STAFFING LEVELS – MODULAR MASS BURN FACILITIES

(Derived from 387)

NAME	STATUS	STATE	DESIGN TPD	FULL TIME MANAGEMENT EMPLOYEES	FULL TIME NON M'GMT EMPLOYEES	ALL FULL TIME EMPLOYEES	FULL TIME EMPLOYEES PER 100TPD
		PROCESS: MB - Modular					
Agawam/Springfield	05	MA	360	4	34	38	10.6
Barron County	05	WI	80	1	13	14	17.5
Batesville	05	AR	100	4	7	11	11.0
Bellingham	05	WA	100	2	16	18	18.0
Beto 1 Unit (Texas Dept. of Corrections)	05	TX	25	2	0	2	8.0
Cassia County	05	ID	50	4	5	9	18.0
Cattaraugus County R-T-E Facility	05	NY	112	4	14	18	16.1
Center	05	TX	40	2	8	10	25.0
City of Carthage/Panola County	05	TX	40	2	10	12	30.0
Cleburne	05	TX	115	5	9	14	12.2
Collegeville	05	MN	50	1	4	5	10.0
Dyersburg	05	TN	100	2	15	17	17.0
Eau Claire County	02	WI	150	0	0	18	12.0
Elk River R.R. Authority (TERRA)	02	TN	200	0	0	14	7.0
Energy Gen. Facility at Pigeon Point	05	DE	600	10	50	60	10.0
Fergus Falls	05	MN	94	2	11	13	13.8
Fort Dix	05	NJ	80	2	17	19	23.8
Fort Leonard Wood	05	MO	75	0	0	12	16.0
Fort Lewis (U.S. Army)	03	WA	120	2	5	7	5.8
Gatesville (Texas Dept. of Corrections)	05	TX	13	2	0	2	15.4
Hampton	05	SC	270	7	78	85	31.5
Harford County	05	MD	360	8	27	35	9.7
Harrisonburg	05	VA	100	6	7	13	13.0
Key West	05	FL	150	8	24	32	21.3
Lamprey Regional Solid Waste Cooperative	05	NH	108	2	12	14	13.0
Lassen Community College	08	CA	100	12	48	60	60.0
Lewis County	05	TN	50	1	8	9	18.0
Long Beach	05	NY	200	5	20	25	12.5
Manchester	02	NH	560	0	0	32	5.7
Mayport Naval Station	05	FL	50	2	11	13	26.0
Miami	06	OK	108	4	6	10	9.3
Miami International Airport	06	FL	60	3	15	18	30.0
Muskegon County	02	MI	180	0	0	17	9.4
New Hanover County	07	NC	100	7	24	31	31.0
North Slope Borough/Prudhoe Bay	05	AK	100	4	26	30	30.0
Oneida County	05	NY	200	5	33	38	19.0
Osceola	05	AR	50	1	15	16	32.0
Oswego County	05	NY	200	8	20	28	14.0
Park County	06	MT	75	1	8	9	12.0
Pascagoula	05	MS	150	4	9	13	8.7
Perham	05	MN	116	1	12	13	11.2
Pittsfield	05	MA	240	2	28	30	12.5
Polk County	05	MN	80	3	12	15	18.8
Pope-Douglas W-T-E Facility	05	MN	80	1	12	13	16.3
Red Wing	05	MN	72	2	9	11	15.3

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

NAME	STATUS	STATE	DESIGN TPD	FULL TIME MANAGEMENT EMPLOYEES	FULL TIME NON M'GMT EMPLOYEES	ALL FULL TIME EMPLOYEES	FULL TIME EMPLOYEES PER 100TPD
Richard Asphalt	05	MN	57	1	5	6	10.5
Rutland	08	VT	240	5	25	30	12.5
Salem	05	VA	100	5	11	16	16.0
St. Croix County	05	WI	115	1	12	13	11.3
Tuscaloosa Energy Recovery Facility	05	AL	300	7	19	26	8.7
Wallingford	05	CT	420	11	26	37	8.8
Waxahachie	06	TX	50	2	8	10	20.0
Westmoreland County	05	PA	50	1	9	10	20.0
Windham	05	CT	108	1	21	22	20.4
AVERAGE			143	4	17	20	16.8
STANDARD DEVIATION			122	3	14	15	9.1

FACILITY STATUS: ADVANCED PLANNING - 02, CONSTRUCTION - 03, SHAKEDOWN - 04, OPERATION - 05 THRU 07, AND TEMPORARILY SHUTDOWN - 08

ATTACHMENT 11. POWER PRODUCTION
MASS BURN FACILITIES

(Derived from 387)

FACILITY	ST	DESIGN CAPACITY (TPD)	NET PWR OUTPUT (MW)	GROSS PWR OUTPUT (MW)	RATIO NET/GROSS PWR OUTPUT	NET KWH PER TON PROCESSED	GROSS KWH PER TON PROCESSED	RATIO NET/GROSS KWH/TON	POUNDS' PER HOUR STEAM	BTUs PER POUND	STARTUP YEAR
				PROCESS: MB - Refractory							
Betts Avenue	NY	1000	N/A	N/A	N/A	N/A	N/A	N/A	31250	N/A	64
City of Waukesha (Old Plant)	WI	175	N/A	N/A	N/A	N/A	N/A	N/A	35000	N/A	79
Davis County	UT	400	N/A	N/A	N/A	N/A	N/A	N/A	110000	N/A	88
McKay Bay Refuse-To-Energy Facility	FL	1000	15	17	0.88	450	N/A	N/A	208400	5000	85
Muscoda	WI	125	1	1	0.57	100	150	0.67	28000	5450	89
NUMERICAL AVERAGE OF NON-ZERO VALUES		540	8	9	0.73	275	150	0.67	82530	5225	
STANDARD DEVIATION		387	7	8	0.16	175	0	0.00	69943	225	
				PROCESS: MB - Waterwall							
Albany (American Ref-Fuel)	NY	1500	40	50	0.80	N/A	N/A	N/A	400000	5500	
Alexandria/Arlington R.R. Facility	VA	975	20	22	0.90	470	520	0.90	255000	4800	88
Babylon Resource Recovery Project	NY	750	14	17	0.82	410	N/A	N/A	185000	5000	89
Bergen County	NJ	3000	80	88	0.91	482	N/A	N/A	808000	4500	
Bridgeport RESCO	CT	2250	60	67	0.90	640	720	0.89	576000	5300	88
Bristol	CT	650	14	16	0.84	535	620	0.86	148000	5000	88
Brooklyn Navy Yard	NY	3000	N/A	N/A	N/A	N/A	N/A	N/A	847000	N/A	
Broome County	NY	571	15	18	0.83	467	560	0.83	184000	5200	
Broward County (Northern Facility)	FL	2250	60	67	0.90	638	709	0.90	573500	5200	
Broward County (Southern Facility)	FL	2250	57	63	0.90	608	676	0.90	576700	5200	
Camden County (Foster Wheeler)	NJ	1050	21	30	0.70	482	N/A	N/A	260400	4500	
Camden County (Pennsauken)	NJ	500	10	13	0.78	425	N/A	N/A	110000	5200	
Central Mass. Resource Recovery Project	MA	1500	36	40	0.90	600	N/A	N/A	336000	5000	88
Charleston County	SC	644	11	13	0.84	N/A	N/A	N/A	164000	5000	89
City of Commerce	CA	400	10	12	0.87	630	725	0.87	115000	5600	87
Concord Regional S.W. Recovery Facility	NH	500	12	13	0.92	470	550	0.85	135400	5000	89
Dakota County	MN	800	20	23	0.87	550	N/A	N/A	410000	5000	
Davidson County	TN	210	3	4	0.81	N/A	N/A	N/A	34000	6000	
East Bridgewater (American Ref-Fuel)	MA	1500	40	50	0.80	N/A	N/A	N/A	400000	5500	
Eastern-Central Project	CT	550	12	15	0.83	560	N/A	N/A	155500	5300	
Essex County	NJ	2277	72	76	0.95	N/A	501	N/A	633000	4500	
Fairfax County	VA	3000	73	85	0.86	540	610	0.89	822504	4400	90
Falls Township (Wheelabrator)	PA	2250	65	72	0.90	600	N/A	N/A	570000	5200	
Glendon	PA	500	13	14	0.89	525	N/A	N/A	130000	5200	
Gloucester County	NJ	575	12	14	0.86	425	475	0.89	135400	4500	90
Hampton/NASA Project Recoup	VA	200	N/A	N/A	N/A	N/A	N/A	N/A	66000	N/A	80
Harrisburg	PA	720	5	8	0.64	500	N/A	N/A	170000	4500	72

N/A = Not Available

FACILITY	ST	DESIGN CAPACITY (TPD)	NET PWR OUTPUT (MW)	GROSS PWR OUTPUT (MW)	RATIO NET/GROSS PWR OUTPUT	NET KWH PER TON PROCESSED	GROSS KWH PER TON PROCESSED	RATIO NET/GROSS KWH/TON	POUNDS PER HOUR STEAM	BTUs PER POUND	STARTUP YEAR
Haverhill (Mass Burn)	MA	1650	41	46	0.89	572	N/A	N/A	396000	5081	89
Hempstead (American Ref-Fuel)	NY	2505	64	72	0.89	570	N/A	N/A	604000	4500	90
Hennepin County (Blount)	MN	1200	33	38	0.88	540	700	0.77	350000	5800	90
Hillsborough County S.W.E.R. Facility	FL	1200	28	30	0.92	492	N/A	N/A	270000	4500	87
Hudson County	NJ	1500	38	45	0.85	455	N/A	N/A	410000	4500	
Huntington	NY	750	21	25	0.84	627	736	0.85	225000	6000	
Jackson County/Southern MI State Prison	MI	200	2	2	0.85	N/A	N/A	N/A	49600	4900	87
Johnston (Central Landfill)	RI	750	17	21	0.81	543	N/A	N/A	150000	5200	
Kent County	MI	625	16	18	0.86	410	N/A	N/A	158000	5350	90
Lake County	FL	528	10	15	0.69	N/A	525	N/A	120000	5000	
Lancaster County	PA	1200	30	36	0.83	560	N/A	N/A	291000	5000	
Lee County	FL	1800	47	50	0.94	630	N/A	N/A	506250	5000	
Lisbon	CT	500	13	15	0.87	550	600	0.92	135400	4500	
Marion County Solid W-T-E Facility	OR	550	11	13	0.84	450	N/A	N/A	133446	4700	86
Montgomery County	MD	1800	69	84	0.83	644	N/A	N/A	512000	5500	
Montgomery County	PA	1200	29	34	0.85	N/A	460	N/A	269082	4500	
Morris County	NJ	1340	34	40	0.85	N/A	535	N/A	433300	5500	
Nashville Thermal Transfer Corp. (NTTC)	TN	1120	3	7	0.40	N/A	N/A	N/A	308000	4900	74
New Hampshire/Vermont S.W. Project	NH	200	4	5	0.84	N/A	440	N/A	46200	5400	87
Norfolk Naval Station	VA	360	N/A	N/A	N/A	N/A	N/A	N/A	40000	N/A	67
North Andover	MA	1500	32	38	0.84	550	N/A	N/A	344000	5500	85
North Hempstead	NY	990	17	21	0.81	N/A	N/A	N/A	N/A	N/A	
Northwest Waste-To-Energy Facility	IL	1600	N/A	N/A	N/A	N/A	N/A	N/A	330000	N/A	70
Oklahoma City	OK	820	10	22	0.46	N/A	N/A	N/A	240000	5200	85
Olmstead County	MN	200	2	3	0.75	N/A	293	N/A	50000	5500	87
Onondaga County	NY	990	32	38	0.84	640	N/A	N/A	311646	6000	
Oyster Bay	NY	1000	27	31	0.87	N/A	N/A	N/A	248000	6000	
Pasco County	FL	1050	29	31	0.94	550	650	0.85	270900	4800	
Passaic County	NJ	1434	37	45	0.83	625	753	0.83	445620	5500	
Pinellas County (Wheelabrator)	FL	3150	56	62	0.90	430	N/A	N/A	750000	4000	83
Portland	ME	500	10	14	0.74	N/A	500	N/A	120000	5000	88
Preston (Southeastern Connecticut)	CT	600	16	18	0.89	520	N/A	N/A	144000	5000	
Quonset Point	RI	710	18	21	0.86	455	N/A	N/A	182000	4750	
S.E. Resource Recovery Facility (SERRF)	CA	1380	30	36	0.83	540	N/A	N/A	351000	4800	88
S.W. Resource Recovery Facility (BRESCO)	MD	2250	34	60	0.57	350	400	0.88	441000	5100	85
Saugus	MA	1500	40	50	0.80	550	N/A	N/A	340000	4500	75
Savannah	GA	500	N/A	N/A	N/A	N/A	N/A	N/A	120000	N/A	87
Spokane	WA	800	22	26	0.85	497	N/A	N/A	222600	N/A	

N/A = Not Available

FACILITY	ST	DESIGN CAPACITY (TPD)	NET PWR OUTPUT (MW)	GROSS PWR OUTPUT (MW)	RATIO NET/GROSS PWR OUTPUT	NET KWH PER TON PROCESSED	GROSS KWH PER TON PROCESSED	RATIO NET/GROSS KWH/TON	POUNDS PER HOUR STEAM	BTUs PER POUND	STARTUP YEAR
Stanislaus County Res. Recovery Facility	CA	800	17	23	0.76	450	N/A	N/A	201000	4750	89
Sturgis	MI	560	11	13	0.85	N/A	N/A	N/A	100000	6000	
Union County	NJ	1440	39	44	0.89	567	670	0.85	360000	5400	
University City Res. Recovery Facility	NC	235	4	5	0.75	395	476	0.83	50000	4500	89
Walter B. Hall Res. Recovery Facility	OK	1125	15	17	0.88	530	600	0.88	240000	5000	86
Warren County	NJ	400	11	14	0.78	482	N/A	N/A	112000	4650	88
Washington/Warren Counties	NY	400	11	13	0.85	N/A	N/A	N/A	115000	5500	
Wayne County	NC	300	4	5	0.85	N/A	N/A	N/A	36000	N/A	
West Pottsgrove Recycling/R.R. Facility	PA	1500	40	45	0.89	N/A	N/A	N/A	336000	5200	
Westchester	NY	2250	56	60	0.93	590	N/A	N/A	504000	4800	84
NUMERICAL AVERAGE OF NON-ZERO VALUES		1138	27	32	0.83	526	577	0.87	291520	5065	
STANDARD DEVIATION		754	20	22	0.10	74	115	0.03	199429	450	
				PROCESS: MB - Modular							
Agawam/Springfield	MA	360	7	9	0.83	390	N/A	N/A	85500	4200	88
Barron County	WI	80	0	0	0.26	N/A	N/A	N/A	16500	4750	86
Batesville	AR	100	N/A	N/A	N/A	N/A	N/A	N/A	6200	N/A	81
Bellingham	WA	100	1	2	0.67	350	N/A	N/A	23000	4500	86
Beto 1 Unit (Texas Dept. of Corrections)	TX	25	N/A	N/A	N/A	N/A	N/A	N/A	7000	N/A	80
Cassia County	ID	50	N/A	N/A	N/A	N/A	N/A	N/A	9000	N/A	82
Cattaraugus County R-T-E Facility	NY	112	N/A	N/A	N/A	N/A	N/A	N/A	26000	N/A	83
Center	TX	40	N/A	N/A	N/A	N/A	N/A	N/A	9000	N/A	86
City of Carthage/Panola County	TX	40	N/A	N/A	N/A	N/A	N/A	N/A	2500	N/A	86
Cleburne	TX	115	1	1	0.77	N/A	N/A	N/A	18000	4500	86
Collegeville	MN	50	N/A	N/A	N/A	N/A	N/A	N/A	11000	N/A	81
Dyersburg	TN	100	N/A	N/A	N/A	N/A	N/A	N/A	20000	N/A	80
Eau Claire County	WI	150	3	3	0.91	263	323	0.81	37000	5000	
Elk River R.R. Authority (TERRA)	TN	200	N/A	N/A	N/A	N/A	N/A	N/A	50000	N/A	
Energy Gen. Facility at Pigeon Point	DE	600	11	13	0.79	532	N/A	N/A	152000	5500	87
Fergus Falls	MN	94	N/A	N/A	N/A	N/A	N/A	N/A	30000	N/A	88
Fort Dix	NJ	80	N/A	N/A	N/A	N/A	N/A	N/A	12000	N/A	86
Fort Leonard Wood	MO	75	N/A	N/A	N/A	N/A	N/A	N/A	8740	N/A	82
Fort Lewis (U.S. Army)	WA	120	N/A	N/A	N/A	N/A	N/A	N/A	42000	N/A	
Gatesville (Texas Dept. of Corrections)	TX	13	N/A	N/A	N/A	N/A	N/A	N/A	3000	N/A	80
Hampton	SC	270	N/A	N/A	N/A	N/A	N/A	N/A	45000	N/A	85
Harford County	MD	360	N/A	N/A	N/A	N/A	N/A	N/A	75000	N/A	88
Harrisonburg	VA	100	N/A	N/A	N/A	N/A	N/A	N/A	17000	N/A	82

N/A = Not Available

FACILITY	ST	DESIGN CAPACITY (TPD)	NET PWR OUTPUT (MW)	GROSS PWR OUTPUT (MW)	RATIO NET/GROSS PWR OUTPUT	NET KWH PER TON PROCESSED	GROSS KWH PER TON PROCESSED	RATIO NET/GROSS KWH/TON	POUNDS PER HOUR STEAM	BTUs PER POUND	STARTUP YEAR
Key West	FL	150	2	3	0.85	300	N/A	N/A	42740	5000	86
Lamprey Regional Solid Waste Cooperative	NH	108	N/A	N/A	N/A	N/A	N/A	N/A	20000	N/A	80
Lassen Community College	CA	100	1	2	0.78	N/A	N/A	N/A	24000	6500	84
Lewis County	TN	50	N/A	N/A	N/A	N/A	N/A	N/A	14000	N/A	88
Long Beach	NY	200	3	5	0.67	N/A	N/A	N/A	58000	5000	88
Manchester	NH	560	13	14	0.89	425	N/A	N/A	20000	4500	
Mayport Naval Station	FL	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	79
Miami	OK	108	N/A	N/A	N/A	N/A	N/A	N/A	23000	N/A	82
Miami International Airport	FL	60	N/A	N/A	N/A	N/A	N/A	N/A	15000	N/A	83
Muskegon County	MI	180	2	3	0.82	373	N/A	N/A	34000	N/A	
New Hanover County	NC	100	2	4	0.50	N/A	N/A	N/A	54000	N/A	84
North Slope Borough/Prudhoe Bay	AK	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	81
Oneida County	NY	200	1	2	0.55	N/A	N/A	N/A	26000	N/A	85
Osceola	AR	50	N/A	N/A	N/A	N/A	N/A	N/A	10000	N/A	80
Oswego County	NY	200	1	4	0.28	275	N/A	N/A	45000	5000	86
Park County	MT	75	N/A	N/A	N/A	N/A	N/A	N/A	13000	N/A	82
Pascagoula	MS	150	N/A	N/A	N/A	N/A	N/A	N/A	24000	N/A	85
Perham	MN	116	N/A	N/A	N/A	N/A	N/A	N/A	23000	N/A	86
Pittsfield	MA	240	N/A	N/A	N/A	N/A	N/A	N/A	50000	N/A	81
Polk County	MN	80	N/A	N/A	N/A	N/A	N/A	N/A	21000	N/A	88
Pope-Douglas W-T-E Facility	MN	80	N/A	N/A	N/A	N/A	N/A	N/A	11000	N/A	87
Red Wing	MN	72	N/A	N/A	N/A	N/A	N/A	N/A	15000	N/A	82
Richard Asphalt	MN	57	N/A	N/A	N/A	N/A	N/A	N/A	13500	N/A	82
Rutland	VT	240	6	7	0.86	470	N/A	N/A	40000	N/A	88
Salem	VA	100	N/A	N/A	N/A	N/A	N/A	N/A	14000	N/A	78
St. Croix County	WI	115	1	1	0.58	85	110	0.77	23500	5000	89
Tuscaloosa Energy Recovery Facility	AL	300	N/A	N/A	N/A	N/A	N/A	N/A	55880	N/A	84
Wallingford	CT	420	9	11	0.85	384	500	0.77	105000	4850	89
Waxahachie	TX	50	N/A	N/A	N/A	N/A	N/A	N/A	15000	N/A	82
Westmoreland County	PA	50	N/A	N/A	N/A	N/A	N/A	N/A	10000	4500	88
Windham	CT	108	2	2	0.86	N/A	150	N/A	16800	5000	81
NUMERICAL AVERAGE OF NON-ZERO VALUES		143	4	5	0.71	350	271	0.78	29651	4920	
STANDARD DEVIATION		122	4	4	0.19	114	155	0.02	27108	525	
			PROCESS: MB - Rotary Combustor								
Auburn (New Plant)	ME	200	4	5	0.76	N/A	N/A	N/A	113800	5200	
Delaware County Regional R.R. Project	PA	2688	80	90	0.89	600	N/A	N/A	664972	5200	

N/A = Not Available

FACILITY	ST	DESIGN CAPACITY (TPD)	NET PWR OUTPUT (MW)	GROSS PWR OUTPUT (MW)	RATIO NET/GROSS PWR OUTPUT	NET KWH PER TON PROCESSED	GROSS KWH PER TON PROCESSED	RATIO NET/GROSS KWH/TON	POUNDS PER HOUR STEAM	BTUs PER POUND	STARTUP YEAR
Dutchess County	NY	506	9	10	0.92	140	320	0.44	110000	N/A	88
Falls Township (Technochem)	PA	70	0	1	0.47	130	275	0.47	16000	4500	
Galax	VA	56	N/A	N/A	N/A	N/A	N/A	N/A	12000	N/A	86
Gaston County/Westinghouse R.R. Center	NC	440	6	7	0.81	550	N/A	N/A	N/A	N/A	
MacArthur Energy Recovery Facility	NY	518	8	12	0.70	370	N/A	N/A	118000	4450	89
Mercer County	NJ	975	32	36	0.89	560	655	0.85	314500	5000	
Monmouth County	NJ	1700	57	63	0.90	N/A	N/A	N/A	N/A	4950	
Monroe County	IN	500	9	11	0.85	N/A	N/A	N/A	110000	N/A	
Montgomery County (North)	OH	300	6	6	0.95	523	550	0.95	72000	5000	88
Montgomery County (South)	OH	900	18	19	0.95	482	507	0.95	240000	5000	
Oakland County	MI	2000	54	62	0.87	645	N/A	N/A	600000	5200	
San Juan Resource Recovery Facility	PR	1040	22	27	0.81	510	N/A	N/A	254000	4500	
Sangamon County	IL	450	6	8	0.75	380	N/A	N/A	90000	N/A	
Skagit County	WA	178	2	2	0.85	345	N/A	N/A	40000	4500	88
Sumner County	TN	200	0	1	0.86	N/A	N/A	N/A	50000	N/A	81
Waukesha County (New Plant)	WI	600	N/A	N/A	N/A	N/A	N/A	N/A	200000	5500	
Westinghouse/Bay Resource Mgmt. Center	FL	510	10	12	0.83	432	480	0.90	136000	4600	87
York County	PA	1344	30	35	0.86	540	N/A	N/A	330000	4500	89
NUMERICAL AVERAGE OF NON-ZERO VALUES		759	20	23	0.83	443	465	0.76	192848	4864	
STANDARD DEVIATION		680	22	25	0.11	151	131	0.22	181052	336	
			PROCESS: MB - Sludge Co-Disposal								
Glen Cove	NY	250	1	3	0.40	N/A	N/A	N/A	40000	5000	83
Huntsville	AL	690	N/A	N/A	N/A	N/A	N/A	N/A	172000	N/A	90
Indianapolis Resource Recovery Facility	IN	2362	N/A	N/A	N/A	N/A	N/A	N/A	500000	N/A	88
Sitka	AK	24	N/A	N/A	N/A	N/A	N/A	N/A	5200	N/A	85
NUMERICAL AVERAGE OF NON-ZERO VALUES		832	1	3	0.40	0	0	0.00	179300	5000	
STANDARD DEVIATION		916	0	0	0.00	0	0	0.00	195331	0	

N/A = Not Available

Document Control Page	1. NREL Report No.	2. NTIS Accession No.	3. Recipient's Accession No.
	NREL/TP-431-4988C	DE92016433	

4. Title and Subtitle

Data Summary of Municipal Solid Waste Management Alternatives. Volume III: Appendix A—Mass Burn Technologies

5. Publication Date
October 1992

6.

7. Author(s)
SRI International

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

SRI International
333 Ravenswood Ave.
Menlo Park, CA 94025-3493

10. Project/Task/Work Unit No.
WM21.1010

11. Contract (C) or Grant (G) No.

(C) RF-1-11003

(G)

12. Sponsoring Organization Name and Address

National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401

13. Type of Report & Period Covered
Subcontract Report

14.

15. Supplementary Notes
NREL Technical Monitor: Bimleshwar Gupta and Philip Shepherd (303) 231-1760

16. Abstract (Limit: 200 words)

The overall objective of the study in this report was to gather data on waste management technologies to allow comparison of various alternatives for managing municipal solid waste (MSW). The specific objectives of the study were to:

1. Compile detailed data for existing waste management technologies on costs, environmental releases, energy requirements and production, and coproducts such as recycled materials and compost.
2. Identify missing information necessary to make energy, economic, and environmental comparisons of various MSW management technologies, and define needed research that could enhance the usefulness of the technology.
3. Develop a data base that can be used to identify the technology that best meets specific criteria defined by a user of the data base.

Volume I contains the report text. Volume II contains supporting exhibits. Volumes III through X are appendices, each addressing a specific MSW management technology. Volumes XI and XII contain project bibliographies.

17. Document Analysis

a. Descriptors
municipal waste; waste to energy; resource recovery; recycling

b. Identifiers/Open-Ended Terms

c. UC Categories
249

18. Availability Statement
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

19. No. of Pages
150

20. Price
A08

Form No. 0069E (6-30-87)