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Waste-To-Energy Compendium

Final Report
April 1981

Prepared for:

U.S. Department of Energy

Assistant Secretary for Conservation and
Renewable Energy

Office of Energy from Municipal Waste

Under DOE Contract AC01-76CS20167

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ABSTRACT

This report surveys 35 waste-to-energy recovery projects throughout the United States. Included are nine refuse-derived fuel (RDF) production facilities, six RDF user facilities, two combined RDF production-user facilities, and 18 mass burning facilities with energy recovery. Only those facilities that are fully operational or those in advanced stages of startup and shakedown are surveyed.

Information is provided on processing capacities, operation and maintenance problems,

equipment specifications, capital and operating costs, and the current status of each facility. In addition, process flow schematics are provided for each of the nine RDF production plants and both RDF production-user plants.

Unless otherwise indicated, the data in this report have been updated to October or November, 1980.

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GLOSSARY

Capacity, actual	The real capacity or throughput of a system or equipment over a period of time, as determined by actual operating experience.
Capacity, design	The theoretical capacity or throughput of a system or equipment over a designated period of time, as specified by the manufacturer or designer.
Capacity, peak	The maximum design or actual throughput of a system or equipment over a period of time.
Costs, capital	<p>Unless otherwise indicated, these costs generally include the initial cost of land, construction, equipment, materials, financing, design, and startup. Subsequent costs for plant improvement or repairs after startup generally include only labor, materials, and design.</p> <p>Note: The capital costs reported in this document are subject to variations from site to site, depending on which costs are specifically included or excluded. These variations are best accounted for by contacting each facility directly.</p>
Costs, operating (gross and net)	<p>Gross operating cost (or gross cost) generally includes operations and maintenance, utilities, overhead, and the retirement of all or part of the debt service.</p> <p>Net operating cost (or net cost) is the gross cost less revenues from the sale of RDF, materials and steam, and tipping fees, but not oil entitlement revenues.</p> <p>Note: These costs were supplied directly by each facility, and they are therefore subject to variations in accounting methods from site to site.</p>
Full operation	The date on which the facility either was declared fully operational, achieved full operational throughput, or was determined to be fully operational for the purpose of equipment and system performance acceptance.
Initial startup	The date on which the first quantities of MSW were processed for the purpose of system and equipment shakedown.
Steam price	Given in \$/1000 lb of steam.
Total to date	The value as of mid-November 1980 unless otherwise indicated.
Yield	The percentage by weight of incoming MSW that becomes RDF after processing.

ABBREVIATIONS AND SYMBOLS

avg.	average	M	million, mega-
Btu	British thermal units	min	minute
Btu/day	British thermal units per day	mo	month
Btu/hr	British thermal units per hour	mo/yr	months per year
Btu/lb	British thermal units per pound	MSW	municipal solid waste
d-RDF	dense refuse-derived fuel	MW	megawatt
day/wk	days per week	MWh	megawatt hour
day/yr	days per year	NA	not available
°F	degrees Fahrenheit	ppt	parts per trillion
f.o.b.	free on board	RDF	refuse-derived fuel
ft	foot	sft ³	standard cubic foot
ft ³	cubic foot	ton	ton
ft ³ /min	cubic feet per minute	ton/day	tons per day
gal	gallon	ton-hr	ton-hour
gal/ton	gallons per ton	ton/hr	tons per hour
gr	grain	ton/wk	tons per week
gr/dsft ³	grains per dry standard cubic foot	ton/yr	tons per year
hr	hour	W	watt
hr/day	hours per day	wk	week
hp	horsepower	yd	yard
in.	inch	yd ³	cubic yard
kW	kilowatt	yr	year
lb/ft ³	pounds per cubic foot	≅	approximately equal
lb/hr	pounds per hour	>	greater than
lb/in. ² _g	pounds per square inch, gauge	<	less than
lb/mo	pounds per month	%	percent

WASTE-TO-ENERGY COMPENDIUM

INTRODUCTION

Scope

This report provides the results of a survey on the status of various waste-to-energy recovery projects throughout the United States. Surveyed in this report are three basic resource recovery systems: refuse-derived fuel (RDF) production facilities, refuse-derived fuel user facilities, and municipal solid waste mass-burning facilities with energy recovery. Relevant technical, operational, and economic information on each system is provided in narrative descriptions, process flow schematics, and data summary sheets.

The survey is intended to serve engineers, consultants, designers and planners, plant operations and maintenance personnel, public and private interest groups, and public officials directly involved with solid waste management. It contains current and comprehensive information on various resource recovery projects to assist these groups in planning, designing, implementing, and operating their own facilities.

The report covers only those facilities that are either currently operational (although some may be temporarily inoperative for various reasons) or in advanced stages of startup and shakedown as of spring 1980. Projects under construction at that time were not included because operating and cost data were not yet available. As these projects gain operating time and associated data, they can be included in future updating of this survey.

Approach

Funded in late 1979, this project was originally intended to survey RDF production plants and associated RDF users. However, before the program started, it was decided to expand the survey to include another resource recovery technology in increasingly widespread use throughout the U.S.: mass-burning of municipal waste with energy recovery to generate steam.

The mass-burning technology consists of two basic systems: high excess air waterwall inciner-

ators, and refractory wall incinerators with waste heat recovery boilers; and controlled-air modular incinerators with waste heat boilers.

Once the intent and scope of the project were determined, preliminary questionnaires were developed for each of the three types of systems to be surveyed. Areas of particular importance included MSW processing capacities, operations and manpower scheduling, RDF use, fuel analyses, equipment specifications, economics, operating and maintenance problems, and system modifications. The preliminary drafts were then distributed to selected groups or individuals for their review and comments regarding possible additions, deletions, or corrections. Reviewers included government agencies, plant engineers or superintendents at several operating resource recovery facilities, consulting engineers, and equipment manufacturers. Their comments were evaluated and, as appropriate, incorporated in the final draft questionnaire.

A preliminary listing of the facilities to be surveyed was then developed. In April and May of 1980, a total of 41 questionnaires were sent to 39 individual facilities with a letter describing the program. Four facilities were subsequently removed from the list because they were either closed or no longer recovering energy. Two mass burning facilities, Merrick, N. Y., and Siloam Springs, Arkansas, have been closed indefinitely. A third facility, Blytheville, Arkansas, is no longer recovering heat to generate steam. In addition, the East Bridgewater, Mass., RDF production plant is also closed. This report therefore, contains information from 37 questionnaires representing 35 facilities: nine RDF production facilities, six RDF user facilities, two RDF production-user facilities, and 18 mass burning facilities. The two production-user plants—Akron, Ohio, and Hempstead, N.Y.—burn all RDF produced in dedicated boilers on site.

The response rate from the 39 facilities initially surveyed was approximately 90%. In order to provide information on those sites not responding, and to supplement data provided by those that did, various secondary sources were

consulted. A listing of these references is provided, indicating for which facilities they were consulted.

Organization

For each of the facilities surveyed, a brief narrative description was developed to summarize the system design and equipment, system operation and maintenance problems, basic economics (capital and operating costs and revenues), current status of the facility, and scheduled or anticipated plans in the future. In addition, a standardized two-page data summary sheet was developed to show capacities, test data, equipment specifications, and other fixed and variable data. This format allows for the orderly expansion of data in

the future and facilitates comparative evaluations of data from different technologies and systems.

Draft copies of both the narrative description and data summary sheet were forwarded to the appropriate personnel at each facility in September 1980 for final review and comments, and each was requested to update the information to reflect current operational status. Unless otherwise indicated, the data in this report have been updated to October or November, 1980. For any additional information or clarifications not provided in this report, it is recommended that each facility be contacted directly.

Upon receipt of the final reviews from individual sites, each survey was edited, and the final report was forwarded to DOE.

RDF PRODUCTION FACILITIES

Ames, Iowa

Background

Name—Ames Solid Waste Recovery System

Product—(1) Finely shredded RDF for use as a supplemental fuel with coal; (2) ferrous metals

Owner—City of Ames, Iowa

Operator—City of Ames, Iowa

Designer—Gibbs, Hill, Durham & Richardson, Omaha, Nebraska

Fuel User—City of Ames Municipal Electric Co.

History. The Ames facility, the first fully operational RDF production plant in the U.S., was built as a result of a landfill shortage and the success of the St. Louis-Union Electric project. Construction began in April 1973, and initial processing started in August 1975.

System Description. A flow diagram of the waste recovery system is shown in Figure 2-1, and a system data sheet is presented as Table 2-1. The processing plant has a design capacity of 200 ton/day (during a single shift) with a single 50-ton/hr line. Waste is conveyed from the tipping floor to the primary shredder, where it is reduced to a nominal 6-in. size. Ferrous metals are separated from the primary shredder output, which is then passed through a series of Rader disc screens to further reduce ash content. Material larger than 1-1/2 in. from the disc screens is fed to the secondary shredder, which further reduces the material to a 1-1/2-in. nominal size. The midsize disc screen fraction, from 3/8 to 1-1/2 in., rejoins the secondary shredder product, while the under-size fraction, less than 3/8 in., is disposed of as landfill. An air classifier produces a design light and heavy fraction split of 80/20. The light fraction is conveyed through a cyclone and via a screw conveyor and air lock feeder into a pneumatic transport system, which transports it approximately 600 ft from the processing plant to a storage bin located in the coal yard at the utility site. From there, the RDF is pneumatically fed into the boilers.

The air-classifier heavy fraction passes through an additional ferrous separation step and then enters the nonferrous separation system. This system consists of a four-stage trommel screen and several eddy current separators. The products of this stage are heavy nonferrous metals, aluminum, and a residue for landfilling. (To date, this system has not been operated on a production basis.)

RDF yield as a percentage of incoming waste is reported at 74%. During early operation of the system, severe wear and erosion due to high ash in the RDF plagued the air classification system, air lock feeders and pneumatic line to the RDF storage bin, storage bin floor, and air lock feeders to the boiler. These problems were alleviated by the installation of disc screens. The addition of the disc screens has reduced the ash content of the RDF product but has also reduced yield from the previous average of 84%. A dust suppression and collection system was installed to correct a previously serious dust problem in the plant. Because of problems with spillage and plugging, the plant cannot be operated at the 50-ton/hr design capacity. Current rates average 35 ton/hr.

Economics. Plant costs, including engineering, construction, and startup, totaled \$4.74 M. Costs to retrofit the boilers and construct the storage bin and RDF feed system totaled \$1.714 M. Total capital costs for the Ames system was \$6.45 M. Operating costs per ton were reported to be \$20.27, gross, in 1979.

Present Status. The facility is currently processing an average of 200 ton/day, and delivering roughly 125 to 150 ton/day of RDF to the utility. Ferrous metals are sold to a detinner in Gary, Indiana, and small quantities of baled paper and wood chips are occasionally sold.

Future Plans. The City is studying the feasibility of burning the combustible heavy fraction to recover steam, and it continues to seek additional supplies of waste.

Baltimore County, Maryland

Background

Name—Baltimore County Resource Recovery Facility

Figure 2-1. Ames Solid Waste Recovery System flow diagram.

Table 2-1. Data sheet for Ames Solid Waste Recovery System

Description	Production of RDF and ferrous metals		
Startup Schedule	Initial startup	August 1975	
	Full operation	January 1976	
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk	
	MSW processing	10 hr/day, 5 day/wk	
	Maintenance	8 hr/day, 5 day/wk	
Manpower	Full time	12	
	Per shift		
MSW Processing	Design capacity	50 ton/hr; 200 ton/day	
	Actual capacity	40 ton/hr; 400 ton/day	
	Current through-put	35 ton/hr; 200 ton/day	
	Total to date	178,937 tons (11/80)	
	Total 1979	32,010 tons	
RDF Production	Design capacity	170 ton/day	
	Actual capacity	320 to 340 ton/day	
	Current production	125 to 150 ton/day	
	Total to date		
	Total 1979	23,059 tons	
System Description	Number of lines	One, 50 ton/hr	
	Process	Type & Size	Manufacturer
	Primary shredder	Horizontal shaft; 1000 hp	American Pulverizer
	Ferrous separator	Belt magnet	Dings
	Disc screens	1-1/2 in. and 3/8 in.	Rader
	Secondary shredder	Horizontal; 1000 hp	American Pulverizer
	Air classifier	25,00 ft ³ /min	Rader
	Pneumatic transport	600 ft to storage	

Table 2-1. (continued)

RDF Analysis	Property	Design ^a	Actual ^b
	HHV	4905 Btu/lb	6100 Btu/lb
	Ash	21%	9.6%
	Moisture	22%	18.5%
	Particle Size	90% <1.5 in.	86% <1.5 in.
	Density	5.27 lb/ft ³	2.60 lb/ft ³
	Sulfur	0.34%	0.19%
	Yield (% of input)	85	74

RDF Market History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	Ames Municipal Electric Co.	Until 1999	125 to 150 ton/day		

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metals	Vulcan Materials	≈ 12 ton/day	≈ 12 ton/day	
				78: 2380 tons	\$38/ton
				79: 1559 tons	\$49/ton

Capital Costs	Year	Cost	Item
	1975 & 1978	\$6.45 M	Processing plant; RDF transport, storage, and feed equipment; boiler modifications; engineering startup
	1978	\$0.232 M	Rader disc screens
	1978	\$0.166 M	Dust collection system

Other Costs	Operating, gross	\$20.27/ton
	Tipping fee	\$0.50/car, \$1.00/pickup truck, \$2.00/truck

a. Before disc screen.

b. After disc screen.

Product—(1) Fine and coarse RDF and d-RDF for use as supplemental fuel; (2) ferrous metals; (3) aluminum; (4) glass

Owner—Maryland Environmental Services (MES) and Baltimore County

Operator—Teledyne National Corp.

Designer—Teledyne National Corp.

Fuel User—No long-term contracts for RDF; contract through Fall 1981 with Wright-Patterson AFB, Ohio, for up to 8000 ton/yr of d-RDF

History. The facility was intended as a demonstration plant and was funded by MES and Baltimore County. Teledyne contracted with MES to design, construct, and operate the facility and to locate markets for RDF and other products.

The facility began operating in January 1976 and was fully operational in March 1976. Since no market for RDF is currently available, the RDF produced is disposed of as landfill unless it is required for testing or spot-production. Fourteen hundred tons of RDF were successfully burned at the Lehigh Portland Cement Co., plant in Union Bridge, Maryland in 1979. During the Summer of 1980, 2300 tons of RDF were test-fired in a 310-MW, coal-fired utility boiler of Baltimore Gas and Electric. Data from that test are currently being analyzed.

System Description. A system flow diagram is shown in Figure 2-2, and a system data sheet is presented as Table 2-2. Incoming waste undergoes primary shredding for initial reduction to a 4-in. nominal size, and is then conveyed to a belt magnet for separation of ferrous material. The ferrous material is loaded into open-top trucks for transport to Bethlehem Steel. The remaining material is then either disposed of as landfill or returned to the building for further processing into RDF or d-RDF.

The material is air classified, and the light fraction is passed through a trommel screen with 3/4-in. openings to remove fine glass and grit. The trommel-over material can be shipped as a 4-in. RDF product, or can undergo secondary shredding to produce a 1-in. RDF product. If desired, the secondary shredder output can be densified into d-RDF in either a California Pellet mill or one of two Sprout-Waldron pelletizers. There is also

an eddy current separation system for nonferrous metals and a vibrating table for producing a glass-rich aggregate.

Earlier problems in secondary shredder capacity and product size have been solved with installation of a new shredder. Rapid wear on the dies and rollers continues to be a high maintenance item on the densifiers, and tends to limit overall throughput from these machines.

Economics. Total plant capital cost in 1975 was reported as \$8.4 M. Operating costs are currently \$10.09/ton, excluding financing costs and taxes.

Present Status. The facility is operational and processes 800 ton/day, 6 day/wk. Several thousand tons of d-RDF have been shipped to Wright-Patterson AFB at \$27/ton FOB Baltimore County. Approximately 25 to 30 ton/day of ferrous metals are shipped to Bethlehem Steel at \$33/ton. Production of RDF and d-RDF continues on an intermittent basis as required by Wright-Patterson AFB and local test markets. During the summer of 1980, the aluminum and glass aggregate recovery systems were operating after a long period of inactivity. A market for the glass product in making fiberglass was being explored.

Future Plans. Teledyne and MES continue to seek new markets for their fuel products in the Baltimore area, and several local companies have expressed renewed interest in using the fuel. Construction of a dedicated RDF boiler in Baltimore County, which would burn RDF produced on-site as well as the RDF produced at the existing facility, is being discussed.

Bridgeport, Connecticut

Background

Name—Bridgeport Resources Recovery Facility

Product—(1) ECO-FUEL II for use as a supplemental fuel with coal, oil, or natural gas; (2) ferrous and nonferrous metals

Owner—Connecticut Resources Recovery Authority (CRRRA)

Operator—Combustion Equipment Assoc. (CEA)

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Figure 2-2. Baltimore County Resource Recovery Facility flow diagram.

Designer—CEA; Fletcher-Thompson/Singmaster & Breyer

Fuel User—United Illuminating Co. (UI), Bridgeport, Connecticut

History. In March 1976, CRRA and CEA/OXY (a joint venture of CEA and Occidental Petroleum) signed a contract to design, construct, and operate the resource recovery system, including transfer stations and RDF storage and transport facilities. UI has an agreement with CRRA to purchase fuel at a price tied to its

current fossil fuel cost. The plant processes waste from Bridgeport and eight local municipalities.

Initial startup took place in May 1979, and the first quantities of ECO-FUEL II were burned in November. The Bridgeport facility is actually a second-generation design based on CEA's East Bridgewater, Massachusetts plant.

System Description. A system flow diagram is shown in Figure 2-3, and a system data sheet is presented as Table 2-3. The plant is designed to process 1800 ton/day of MSW and produce

Table 2-2. Data sheet for Baltimore County Resource Recovery Facility

Description	Production of RDF, d-RDF, ferrous metals, aluminum, and glass		
Startup Schedule	Initial startup Full operation	January 1976 March 1976	
Operating Schedule	MSW receiving MSW processing Maintenance	10 hr/day, 6 day/wk 10 hr/day, 6 day/wk 8 hr/day, 5 day/wk	
Manpower	Full time Per shift	55	
MSW Processing	Design capacity Actual capacity Current throughput Total to date Total 1979	1600 ton/day 1200 ton/day 800 ton/day ≈ 536,000 tons 22,036 tons	
RDF Production	Design capacity Actual capacity Current production Total to date Total 1979	Unknown Varies with test needs 5086 tons (RDF & d-RDF) 1482 tons	
System Description	Number of lines	One	
	Process	Type & Size	Manufacturer
	Primary shredder	Horizontal; 55 ton/hr	Tracor
	Ferrous separator	Belt type	Dings
	Air classifier	Vertical	Montgomery
	Trommel	3/4-in. openings	Triple-S
	Secondary shredder	Horizontal; 25 ton/hr	Williams
	Densifier	Pelletizer	CPM, Sprout-Waldron

Table 2-2. (continued)

RDF Analysis	Property	Design	Actual
	HHV	6400 Btu/lb (avg.)	6645 Btu/lb (avg.)
	Ash	12.2%	9.4%
	Moisture	15 to 20%	15 to 20%
	Particle Size	<1 in.	1/2-in. diameter
	Density	3 to 4 lb/ft ³	35 lb/ft ³
	Sulfur	0.26%	0.105%
	Yield (% of input)		

RDF Market History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	Lehigh Portland Cement	1977-1979	Test	1400 tons	
	Baltimore Gas & Electric	1980	Test	2300 tons	
	Wright-Patterson AFB	1979-1981	8000 ton/yr	≅ 3000 tons	\$27/ton (f.o.b. plant)

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metals	Bethlehem Steel	25 to 30 ton/day	25 to 30 ton/day	\$33/ton

Capital Costs	Year	Cost	Item
	1975	\$8.4 M	Total plant capital cost

Other Costs		
	Operating, gross	\$10.09/ton net system cost
	Tipping fee	No charge for county vehicles

INEL-A-17 588

Figure 2-3. Bridgeport Resource Recovery Facility flow diagram.

roughly 880 ton/day of ECO-FUEL II. Two processing lines can handle a peak of 50 ton/hr each (75-ton/hr design), with an aluminum recovery system serving both lines.

Waste from the infeed conveyors enters the primary trommel, after which both the over and under flows are magnetically scalped for ferrous material. The over stream is shredded in a flail mill and returned to the trommel. The trommel under stream is air-classified using preheated gases, with the light fraction being deentrained and dropped into a secondary trommel for further fines removal. Chemical embrittling agents are injected at this point, causing the cellulosic materials to become hard and brittle. Heated steel

balls grind the material to a fine powder in a ball mill, after which the powder is screened to remove remaining textiles, plastics, and aluminum.

The RDF ECO-FUEL II product is air-cooled and pneumatically conveyed to a series of six 300-ton storage silos. The silos discharge into trailers for shipment to the fuel user.

The RDF yield is reported to be approximately 50% by weight. ECO-FUEL II has a HHV of 7800 Btu/lb, a moisture content of 3% to 5%, an ash content of 12% to 15%, and a sulfur content of less than 1%. Approximately five gallons of fuel oil are required to generate process heat for each ton of MSW. Including other energy

Table 2-3. Data sheet for Bridgeport Resource Recovery Facility

Description	Production of ECO-FUEL II, ferrous metals, and nonferrous metals	
Startup Schedule	Initial startup Full operation	May 1979 Not achieved
Operating Schedule	MSW receiving MSW processing Maintenance	8 hr/day, 5 day/wk 24 hr/day, 6 day/wk 24 hr/day, 7 day/wk
Manpower	Full time Per shift	76 Variable
MSW Processing	Design capacity Actual capacity Current throughput Total to date Total 1979	75 ton/hr/line; 1800 ton/hr 50 ton/hr/line; 1800 ton/hr 0—Plant closed indefinitely 11/80 21,592 tons (11/80) 2165 tons
RDF Production	Design capacity Actual capacity Current production Total to date Total 1979	880 ton/day Unknown 0 6791 tons (11/89) 440 tons
System Description	Number of lines	Two, 50 ton/hr (peak)
	Process	Type & Size
	Primary trommel	11-ft diameter; 44 ft long
	Magnetic separator	
	Flail mill (trommel overs)	
	Air classifier	Vertical
		Manufacturer
		CEA/Carter-Day
		Southern Engineering
		Carter-Day

Table 2-3. (continued)

	Process	Type & Size	Manufacturer
	Secondary trommel (embrittlement)	11-ft diameter; 44 ft long	Carter-Day
	Ball mill (grinding)		Kennedy Van Saun
	Screen		Rotex
	300-ton storage silos		

RDF Analysis	Property	Design	Actual
	HHV	7500 to 8000 Btu/lb	7800 Btu/lb
	Ash	<15%	12 to 15%
	Moisture	<5%	3 to 5%
	Particle Size	50% <200 mesh	79% <200 mesh
	Density	25 to 35 lb/ft ³	25 to 35 lb/ft ³
	Sulfur	0.5%	<1.0%
	Yield (% of input)	49	40

RDF Contract History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	United Illuminating	20 years	Variable	6791 tons	\$3.62/M Btu

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metal	Varies	30 to 35 ton/day	0	Market
	Aluminum	Reynolds Aluminum	0	0	Market

Capital Costs	Year	Cost	Item
	1975	\$853 M	Total plant capital cost, including receiving facility at United Illuminating and six transfer stations

Other Costs	Operating	Not available
	Tipping fee	\$20.00/ton

requirements, the total heat input per ton of MSW processed to produce ECO-FUEL II is 1.6 M Btu.

Within several months of startup, dust deflagrations occurred in a fuel silo and bag filter. Damage was minimal since the silos were designed with pressure-relieving doors.

Economics. Total capital cost is reported to be \$53 M, including engineering, boiler modifications and the RDF storage and transport system at UI, site work, and financing costs. No figures are available for operating costs, but the tipping fee is presently \$20/ton.

Present Status. The facility was shut down indefinitely at the end of November 1980, primarily because CEA lacked operating funds. Negotiations were soon underway between CEA and Occidental concerning OXY's financial responsibilities as a partner in the project. In the meantime, CEA continues to operate the transfer stations as part of their agreement with the CRRA.

Before its closing, the plant was operational, processing 500 ton/day of MSW and producing fuel for United Illuminating. Testing continued on various systems and equipment. The utility has burned up to 51% ECO-FUEL II by heat input with good results in their oil-fired boiler at Bridgeport Harbor. Sustained use of ECO-FUEL II at 30% heat input has been achieved. However, since ECO-FUEL II has a sulfur content higher than the state will allow (0.5% maximum), a variance is required when it is burned.

Future Plans. Assuming that operating funds become available and the plant reopens, more MSW will be sought to achieve full-capacity operation and increased deliveries of ECO-FUEL II to UI. Tests are planned to determine the optimal ash content in the fuel for use at UI.

Chicago, Illinois

Background

Name—Southwest Supplementary Fuel Processing Facility

Process—(1) Finely shredded RDF for use as a supplemental boiler fuel; (2) ferrous metals

Owner—City of Chicago, Illinois

Operator—City of Chicago, Illinois

Designer—Ralph M. Parsons Co. and Consoer, Townsend & Assoc.

Fuel User—Commonwealth Edison Co.

History. Facing the need to replace aging plants or upgrade existing incineration facilities to meet emissions standards, the City of Chicago, in 1972, initiated a study to determine workable options. The study recommended the burning of RDF in a utility boiler, an approach similar to that of the St. Louis-Union Electric project. An agreement was negotiated with Commonwealth Edison early in the project for the purchase and firing of RDF at its Crawford Generating Station. Detailed design started in 1973, and construction began in 1974. Initial operations began in April 1977.

System Description. A system flow diagram is shown in Figure 2-4, and a system data sheet is presented as Table 2-4. The plant has a peak design capacity of 1280 ton/day, and an operating capacity of 1000 ton/day over 12 to 14 hours. There are two 80-ton/hr processing lines, which are operated on alternating days to allow for maintenance.

From the tipping floor, refuse is conveyed to the primary shredder for reduction to <8-in. size. The shredder material is then air-classified, and the light fraction from the classifier is deentrained and sent to a secondary shredder for reduction to 1-1/2-in. average size. The RDF is conveyed to a hopper, dropped into an air-lock feeder, and pneumatically conveyed to the boiler site for storage in two Atlas bins. The air-classifier heavy fraction is magnetically separated for ferrous metal recovery, and the rejects are hauled to landfill. Extensive dust control and fire prevention systems are incorporated in the design.

The RDF yield as a percentage of incoming waste is reported to be 70%. Numerous modifications to the facility have been made, including a complete revision of the ferrous recovery system and the addition of air flow adjustment controls to the air-classification system. There continues to be some difficulty in consistently achieving a 1-1/2-in. nominal particle size in the secondary shredder at less than full load. Abrasion has been a major maintenance item in the pneumatic

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Figure 2-4. Chicago Southwest Supplementary Fuel Processing Facility flow diagram.

transport line elbows as well as in the positive displacement air-density separation fan. Jamming and erosion of the rotary air locks and pneumatic line plugging are other problem areas.

Economics. Total capital cost for the RDF plant was approximately \$16 M. Costs to construct the RDF storage and transport system and the boiler modifications at the utility site totaled \$4.5 M. No actual operating and maintenance costs are available.

Present Status. The facility has been off-line since December 31, 1979, and plant management personnel are awaiting funds from the City or other sources to make modifications before processing resumes. Necessary modifications include increasing plant throughput, improving the quality of the fuel product, and reducing maintenance costs and energy consumption.

Prior to shutdown, the plant was operating at up to 50% capacity and had delivered more than 22,000 tons of RDF to Commonwealth Edison.

Future Plans. City officials will review past operating experiences and evaluate future options for the facility. Should funds become available, expected modifications would include: the addition of a rotary screen (trommel) before shredding; installation of a new air classifier; installation of a metering conveyor to the air classifier; modifications to the secondary shredder

to achieve 1-in. particle size; and rebuilding the pneumatic RDF transport system between the plant and Commonwealth Edison.

Lane County, Oregon

Background

Name—Lane County Resource Recovery Facility, Eugene, Oregon

Product—(1) Finely shredded RDF for use as a supplemental boiler fuel; (2) ferrous metals

Owner—Lane County, Oregon

Operator—Western Waste Corporation, Eugene, Oregon

Designer—Allis-Chalmers Corp.

Fuel User—None at present

History. Construction was completed and initial operations began in March 1978. Equipment preacceptance performance testing has continued since that time.

System Description. A system flow diagram is shown in Figure 2-5, and a system data sheet is presented as Table 2-5. The facility has a design capacity of 500 tons per eight-hour day. The

Table 2-4. Data sheet for Southwest (Chicago) Supplementary Fuel Processing Facility

Description	Production of RDF and ferrous metals		
Startup Schedule	Initial startup	April 1977	
	Full operation	Not achieved	
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk	
	MSW processing	12 to 13 hr/day, 5 day/wk	
	Maintenance	3 to 4 hr/day	
Manpower	Full time	37	
	Per shift		
MSW Processing	Design capacity	80 ton/hr; 1280 ton/day (peak)	
	Actual capacity	1000 ton/hr	
	Current throughput	500 to 600 ton/hr (shut down 12/79)	
	Total to date	NA	
	Total 1979		
RDF Production	Design capacity	700 ton/day; 3500 ton/wk	
	Actual capacity	350 ton/day	
	Current production	Not in operation since 12/79	
	Total to date	22,349 tons (12/79)	
	Total 1979	13,528 tons	
System Description	Number of lines	Two, 80 ton/hr each	
	Process	Type & Size	Manufacturer
	Primary shredder	Horizontal shaft	Williams
	Air classifier	Vibrolutriator	Triple-S Dynamics
	Secondary shredder	Vertical shaft	Carborundum
	Ferrous separator		Magnetic Separation, Inc.
	Pneumatic transport of RDF to storage	60 ton/hr	

Table 2-4. (continued)

RDF Analysis	Property	Design	Actual (as received)		
	HHV	6000 Btu/lb	5230 Btu/lb		
	Ash		20.8%		
	Moisture		24.8%		
	Particle Size	85% < 1 in.	1-1/2 in.		
	Density				
	Sulfur		0.3%		
	Yield (% of input)	70	69		

RDF Market History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	Commonwealth Edison Co.	10 years, 3500 tons/wk	Variable	22,349 tons	\$0.30/M Btu

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metals	Magnetic Separation, Inc.	30 ton/day	Variable	39% of No. 1 bundle price

Capital Costs	Year	Cost	Item
	1975	\$16.0 M	Total plant capital cost
	1975	\$4.5 M	RDF receiving and transport system and boiler modifications at utility site

Other Costs	Operating	Not available
	Tipping fee	None—only city trucks accepted

contract between the owner and designer also specifies a minimum recovery rate of 50% by weight of incoming waste, including recovery of at least 90% of all ferrous metals. Waste from the tipping floor is conveyed over a roadway to the primary shredder. The nominal 6- to 8-in. shredder product is conveyed into the vertical air classifier. The light fraction from the air classifier is cyclone-separated and metered to the secondary shredder for final reduction to a 2-in. particle size. The shredded material is conveyed to a hopper for loadout into live bottom transfer trailers and subsequent shipment to an RDF user site.

The air-classified heavy fraction is magnetically scalped for ferrous material recovery. Contract specifications call for the separated ferrous fraction to contain at least 90% ferrous metal, with a maximum of 7% nonferrous metal contaminants.

Problems have been encountered with dust control in the plant. A small baghouse system was installed to vent exhaust air from the primary shredder. A larger baghouse may be installed for bleedoff air from the original closed-loop system. A variable speed conveyor was installed to feed

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Figure 2-5. Lane County Resource Recovery Facility flow diagram.

Table 2-5. Data sheet for Lane County Resource Recovery Facility

Description	Production of RDF and ferrous metals	
Startup Schedule	Initial startup Full operation	March 1978 Currently in shakedown
Operating Schedule	MSW receiving MSW processing Maintenance	8 hr/day, 5 day/wk 8 hr/day, 5 day/wk Variable
Manpower	Full time Per shift	6
MSW Processing	Design capacity Actual capacity Current throughput Total to date Total 1979	62.5 ton/hr; 500 ton/day 427 ton/day (avg. of 43 tests) Variable ≈ 73,500 tons (5/80) 72,200 tons
RDF Production	Design capacity Actual capacity Current production Total to date Total 1979	≈ 250 ton/day 240 ton/day (avg. of 43 tests) Variable Limited quantities Limited quantities

Table 2-5. (continued)

System Description	Number of lines	One, 62.5 ton/hr		
	Process	Type & Size	Manufacturer	
	Primary shredder	Horizontal shaft; 1000 hp	Allis-Chalmers	
	Air classifier	Dual vortex	Allis-Chalmers	
	Secondary shredder	Horizontal shaft; 1000 hp	Allis-Chalmers	
	Ferrous separator	Belt type		

RDF Analysis	Property	Design	Actual
	HHV		
	Ash	<20%	27%
	Moisture	<35%	34%
	Particle Size	90% <2 in.	
	Density		
	Sulfur		
	Yield (% of input)	50	56

RDF Market History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	None to date; negotiations underway with University of Oregon				

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metals	None to date	Limited quantities		

Capital Costs	Year	Cost	Item
	1976	\$2.12 M	Resource recovery system added to original receiving facility
	1978	\$15,000	Variable-speed primary conveyor

Other Costs	Operating	Not available
	Tipping fee	\$1.60/yd ³ for loose commercial waste; \$4.00/yd ³ for compactor trucks

the primary shredder, and modifications were made to the surge bin meter feed to the secondary shredder. A serious primary shredder explosion in November 1979 led to the addition of venting and explosion detection and suppression equipment, and to relocating the operator's console outside the main building.

Economics. Plant capital cost, excluding the central receiving station and the baghouse system, totals \$2.12 M. The baghouse system cost is estimated at \$200,000. Total capital cost, including the central receiving transfer station, is \$4.22 M. No operation and maintenance cost figures are available.

Present Status. The facility is still in the equipment preacceptance phase. Allis-Chalmers must meet all product and operations specifications before the County will accept ownership of the system. To date, the system has not been able to meet the contract specification of 20% ash content in the RDF product. Allis-Chalmers may elect to install a screening device to reduce the ash content to within specification. RDF and ferrous metals are being produced on an intermittent basis, but, no firm markets have been secured.

Future Plans. RDF has been successfully test-fired in wood-burning boilers at the University of Oregon. As a result, verbal agreements between the County and University have been made regarding the sale and purchase of RDF. However, the University is reluctant to sign a long-term contract until the ash content in the fuel is reduced to within acceptable levels.

Madison, Wisconsin

Background

Name—Madison Area Resource Recovery Center

Product—(1) Finely shredded RDF for use as a supplemental boiler fuel; (2) ferrous metals

Owner—City of Madison, Wisconsin

Operator—City of Madison, Wisconsin

Designer—City of Madison, Wisconsin

Fuel User—Madison Gas & Electric Co., (MG&E)

History. The City of Madison has been shredding MSW prior to landfill since 1967. In 1974, the City and MG&E agreed to develop a joint project to process MSW for the production of RDF, and in January 1977 they entered into a 10-yr agreement for the sale and purchase of the fuel. Construction of the processing plant was completed and the first MSW processed in January 1979. The utility began burning RDF in June 1979.

System Description. A system flow diagram is shown in Figure 2-6, and a system data sheet is presented as Table 2-6. The present facility is actually a third generation system, the design of which is based on the City's past operating experience.

The processing plant has a design capacity of 400 ton/day, with a single 50-ton/hr line. In the event of a system breakdown, the processing line can be bypassed and the plant can serve as a transfer station. In addition, the system is designed to allow primary shredding only, or shredding with ferrous recovery, and to bypass the shredded MSW to transfer trucks and landfill. These options allow the City to handle daily waste regardless of the plant's operational status.

Raw waste from the tipping floor is conveyed to the primary shredder (actually a flail mill), which effectively breaks open bags and achieves coarse size reduction. A single-stage drum-type magnetic separator removes ferrous material, which is air-cleaned and densified before shipment. The remaining material is processed in a separator (trommel screen of proprietary design) for removal of most glass, nonferrous metals, and other noncombustibles. The trommel overs are conveyed to a 1250-hp vertical-shaft secondary shredder equipped with a full air-sweep pneumatic takeaway system. This takeaway system also serves as an air classifier designed to remove any remaining heavy noncombustibles and some textiles from the final RDF product. The RDF (90% <3/4 in.) is pneumatically conveyed through a cyclone to stationary packers for shipment to the utility site.

The City has been experimenting with various hammer patterns in the secondary shredder to increase capacity, and has added wear plates to the inner shell to close gaps, more closely control particle size, and reduce material bridging.

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Figure 2-6. Madison Resource Recovery Center flow diagram.

The system design yield of RDF as a percentage of incoming waste is 60%. However, current yield averages approximately 54% and is subject to seasonal variation in waste properties. Ash content averages 12%.

Economics. The processing plant and equipment, site improvements, and engineering cost \$2.83 M. In addition, costs for engineering, construction, and startup of the RDF receiving and feed system at the utility (financed by the City) totaled \$1.06 M. Total capital cost to Madison was \$3.9 M.

Present Status. The facility is currently processing 200 to 250 ton/day of MSW. RDF shipments to MG&E average 120 to 140 ton/day. In addition, approximately 10 ton/day of ferrous metal and small quantities of newsprint are being recovered.

Future Plans. The City is studying the feasibility of installing an aluminum recovery system, which could be operational in 1982. RDF test burns were scheduled for Fall 1980 at the Oscar Meyer plant in Madison under a research grant from the U.S. EPA. Fluff RDF will be cofired with coal in a

Table 2-6. Data sheet for Madison Area Resource Recovery Center

Description		Production of RDF and ferrous metals	
Startup Schedule	Initial startup	January 1979	
	Full operation	August 1979	
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk	
	MSW processing	5 to 7 hr/day, 5 day/wk	
	Maintenance	5 to 7 hr/day	
Manpower	Full time	13	
	Per shift	6 to 7	
MSW Processing	Design capacity	50 ton/hr; 400 ton/day	
	Actual capacity	≅ 50 ton/hr; 400 ton/day	
	Current throughput	≅ 50 ton/hr; 250 ton/day	
	Total to date	≅ 37,500 tons	
	Total 1979	Startup	
RDF Production	Design capacity	240 ton/day (max.)	
	Actual capacity	215 ton/day	
	Current production	120 to 140 ton/day	
	Total to date	20,200 tons (10/80)	
	Total 1979	Startup	
System Description	Number of lines	One, 50 ton/hr	
	Process	Type & Size	Manufacturer
	Primary shredder	Flail type; 300 hp	Local, based on L.A. By-Pro design
	Ferrous separator	Drum magnet	Madison Magnetics
	Trommel	Two-stage	Madison Solid Waste Fuel Co.

Table 2-6. (continued)

	Process	Type & Size	Manufacturer
	Secondary shredder (with air sweep)	Vertical; 1250 hp	Heil Co.
	Transfer trailer to RDF user	Ejector; 75 yd ³	Heil Co. & Steco

RDF Analysis	Property	Design	Actual
	HHV	5000 Btu/lb (wet)	7400 Btu/lb (dry)
	Ash	13%	12%
	Moisture	25%	22%
	Particle Size	95% < 3/4 in.	91% < 3/4 in.
	Density		
	Sulfur		
	Yield (% of input)	59 to 60	54

RDF Market History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	Madison Gas & Electric	Through 1987; 28,000 ton/yr	120 to 140 ton/day	10,200 tons (10/80)	\$1.60/M Btu

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metals	Madison Magnetics	≈ 11 ton/day	10 ton/day	
	Newspaper	Pioneer Paper Corp.	2000 ton/yr	2080 tons	\$20/ton (base)

Capital Costs	Year	Cost	Item
	1978	\$2.84 M	RDF production facility
	1979	\$1.06 M	RDF receiving and feed system at Madison Gas & Electric

Other Costs	Operating	\$20.66/ton, net
	Tipping fee	\$6.75/ton for other than city trucks

traveling grate spreader stoker. EPA is sponsoring the tests and financing all engineering and equipment installation. Oscar Meyer has made no commitment to purchase fuel from Madison.

Milwaukee, Wisconsin

Background

Name—Milwaukee/Americology Resource Recovery Plant

Product—(1) Finely shredded RDF for use as a supplemental boiler fuel; (2) ferrous and nonferrous metals

Owner—Americology Division of American Can Company, Greenwich, Connecticut

Operator—Americology

Designer—American Can Co. and Bechtel, Inc.

Fuel User—Wisconsin Electric Power Co. (WEPCO)

History. In January 1975, the City of Milwaukee and American Can Company signed a 17-yr agreement whereby American Can (through Americology) would finance, design, construct, own, and operate a resource recovery plant and associated transfer stations, and process up to 400,000 ton/yr of MSW and recover paper, ferrous and nonferrous metals, and glass. At the same time, Americology signed a 15-yr contract with WEPCO for the purchase of RDF for use as a supplemental fuel with coal.

Initial plant startup took place in May 1977, and full operational status was achieved in the fall of that year.

System Description. A system flow diagram is shown in Figure 2-7, and a system data sheet is presented as Table 2-7. The plant has a design capacity of 1600 ton/day, with two 50-ton/hr processing lines.

From the plant tipping floor, MSW infeed conveyors to the primary shredders pass picking stations. Newspaper and corrugated paper can be removed at this point, but the primary function of the pickers is to remove hazardous materials from the refuse prior to shredding.

The shredded refuse is conveyed to a zig-zag classifier. The light fraction undergoes secondary shredding to 95% <3/4 in., and ferrous material is removed with a belt magnet. This fraction next passes over a Rader disc screen (added to the original system in 1978) to reduce ash content and to remove oversize material, which is reshredded. The RDF product is then transported 20 miles to WEPCO's Oak Creek plant, where it is stored in an Atlas silo.

The heavy fraction from the classifier undergoes two-stage ferrous separation with belt magnets. Additional processing of the heavy fraction through a trommel screen prepares the material for aluminum and glassy aggregate separation. Due to system and equipment restrictions, the aggregate and aluminum recovery systems have remained inoperable.

The RDF has been averaging 27 to 28% ash (dry) and 20% moisture, with a heating value of 7100 Btu/lb (dry). The quality of the fuel essentially meets contract and design specifications. RDF yield as a percentage of input is running approximately 46%.

In addition to installation of the disc screen, modifications have been made to various conveyors and transfer points, and horsepower of the primary shredders has been increased. After an explosion in December 1978, a steel deflector curtain was erected between the primary shredder and the picking station.

RDF use at WEPCO has been limited by the design characteristics of the suspension-fired units at Oak Creek. Limited ID fan capacity results in lower than anticipated RDF consumption. In addition, marginal sootblowing capacity has further reduced the RDF burn rate. These problems have been accentuated by marginal electrostatic precipitator performance when firing RDF and by limited ash removal capability.

Economics. Initial capital costs for the plan totaled \$18.2 M. In addition, \$4.2 M was spent at the WEPCO site for the RDF receiving and storage facilities, including \$0.8 M for boiler modifications. Addition of the Rader disc screens in 1978 cost \$1.7 M. Net disposal cost for 1979 averages approximately \$22.70/ton; the tipping fee is currently about \$14/ton.

Present Status. A moratorium on burning RDF has been in effect on Unit No. 7 at Oak Creek

Figure 2-7. Milwaukee/Americology Resource Recovery Plant flow diagram.

since September of 1979. In September of 1980, Unit No. 8 at Oak Creek was shut down for annual repairs and the upgrading of its electrostatic precipitators, resulting in the shut-down of the Americology Plant due to a lack of fuel market. Americology is awaiting WEPCO's decision to resume RDF purchases.

When operating, the facility processes MSW at design capacity of <100 ton/hr. Prior to September 1980, the facility operated only 3 day/wk because of limited purchases of RDF by WEPCO.

Future Plans. American Can is considering an expenditure of \$4 M to improve the quality and quantity of the RDF product. Modifications to the air classifier, aluminum recovery system, and glassy aggregate system are contemplated pending the outcome of the RDF marketing problems. In

addition, a test burn using densified RDF in a stoker-type boiler is being planned. The tests should begin in late 1980 or early 1981.

Long-range plans also include construction of a boiler dedicated to burning RDF along with sewage sludge. Steam generated will be sold to industrial customers, thereby eliminating dependence on the utility as the lone fuel customer.

Monroe County, New York

Background

Name—Monroe County Resource Recovery Facility; Rochester, New York

Product—(1) Finely shredded RDF for use as a supplemental boiler fuel; (2) ferrous and nonferrous metals; (3) glass; (4) aluminum

Table 2-7. Data sheet for Milwaukee/Americology Resource Recovery Plant

Description	Production of RDF, ferrous and nonferrous metals, and paper		
Startup Schedule	Initial startup Full operation	May 1977 Fall 1977	
Operating Schedule	MSW receiving	8 hr/day; 5 day/wk	
	MSW processing	8 hr/day; 3 day/wk	
	Maintenance	8 hr/day; 2 day/wk	
Manpower	Full time Per shift	44 25	
MSW Processing	Design capacity	100 ton/hr; 1600 ton/day	
	Actual capacity	> 100 ton/hr; 1600 ton/day	
	Current throughput	0, as of 11/80	
	Total to date	≅ 167,850 tons	
	Total 1979	122,450 tons	
RDF Production	Design capacity	880 ton/day	
	Actual capacity	750 ton/day	
	Current production	0 (11/80)	
	Total to date	131,200 tons	
	Total 1979	56,020 tons	
System Description	Number of lines	Two, 50 ton/hr	
	Process	Type & Size	Manufacturer
	Primary shredder	Horizontal; 1000 hp	Williams
	Disc screens	Two-stage	Rader
	Air classifier	Vertical, zig-zag	Americology
	Secondary shredder	Vertical shaft	Heil Co.
	Ferrous separator	Belt, two-stage	Dings

Table 2-7. (continued)

	Process	Type & Size	Manufacturer
	Trommel		Triple-S Dynamics
	Nonferrous separator	Eddy current	CARPCO

RDF Analysis	Property	Design	Actual
	HHV	5000 to 6000 Btu/lb (wet)	7147 Btu/lb (dry)
	Ash	10 to 20%	27.7%
	Moisture	15 to 25%	29.2%
	Particle Size	90% < 1-1/2 in.	99.5% < 1-1/2 in.
	Density		6.3 lb/ft ³
	Sulfur	< 0.3%	0.28%
	Yield (% of input)	55	46

RDF Market History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	Wisconsin Electric Power Co. (WEPCO)	1977-92	100 ton/day (avg.)	≅ 110,000 tons	\$1.27/M Btu

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metals	Wisconsin Metals & Bethlehem Steel		5860 tons (1980)	\$40/ton

Capital Costs	Year	Cost	Item
	1977	\$18.2 M	Processing plant
	1977	\$ 4.2 M	WEPCO receiving & storage
	1977	\$ 0.8 M	WEPCO boiler modifications
	1978	\$ 1.7 M	Rader disc screens

Other Costs		
	Operating	\$2270/ton, net
	Tipping fee	\$14/ton

Owner—County of Monroe, New York

Operator—Raytheon Service Co., Burlington, Massachusetts

Designer—Raytheon Service Co.

Fuel User—Rochester Gas & Electric Corp. (RG&E) scheduled in 1981

History. The resource recovery program in Monroe County was the outgrowth of a very serious landfill shortage in the early 1970's. Supported by the recommendations of local officials and citizen groups, initial planning began in 1972 and construction started in 1976. Initial startup was in September 1979, with full operations scheduled for early 1981.

System Description. A system flow diagram is shown in Figure 2-8, and a system data sheet is presented as Table 2-8. The facility is designed to handle 2000 ton/day of MSW with two 70-ton/hr

processing lines operating 16 hr/day. There is an array of equipment installed to recover RDF, heavy and light ferrous material, aluminum, heavy nonferrous material, and mixed-color glass.

Infeed conveyors feed raw waste into the primary shredders, which reduce the waste to a maximum 12-in. size. From there, the shredded waste is conveyed to four rotary drum air classifiers. The light fraction is screened on a vibrating screen to remove glass and grit, and then is shredded a second time to a maximum 3/4-in. size. The RDF product is conveyed pneumatically to storage silos for eventual shipment via rail or truck to the utility site.

The heavy fraction undergoes ferrous separation and nonferrous processing. The ferrous fraction passes a differential magnetic separator that separates light and heavy ferrous materials. The light ferrous fraction is shredded and magnetically separated a third time to reduce contaminants.

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Figure 2-8. Monroe County Resource Recovery Facility flow diagram.

Table 2-8. Data sheet for Monroe County Resource Recovery System

Description		Production of RDF, ferrous and nonferrous metals, and glass	
Startup Schedule	Initial startup Full operation	September 1979 In shakedown	
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk	
	MSW processing	16 hr/day, 5 day/wk	
	Maintenance	8 hr/day, 6 day/wk	
Manpower	Full time Per shift	72 27	
MSW Processing	Design capacity	140 ton/hr; 2000 ton/day	
	Actual capacity	Undetermined	
	Current throughput	>200 ton/day	
	Total to date	25,000 tons	
	Total 1979	2000 tons	
RDF Production	Design capacity	1320 ton/day at full capacity	
	Actual capacity	Undetermined	
	Current production	Variable	
	Total to date	200 tons	
	Total 1979	0	
System Description	Number of lines	Two, 70 ton/hr	
	Process	Type & Size	Manufacturer
	Primary shredder	Horizontal; 1000 hp	Newell
	Air classifier	Rotary drum (RODAC); 35 ton/hr	Raytheon
	Secondary shredder (RDF)	Horizontal; 1250 hp	Newell
	Ferrous separator	Belt magnet	Dings
	Trommel screen	Single stage; 3/4 in.	Triple-S Dynamics

Table 2-8. (continued)

	Process	Type & Size	Manufacturer
	Nonferrous separator	Differential sliding board	Raytheon
	Flotation system (glass)		Sprout-Waldron
	Heavy media separator		WEMCO

RDF Analysis	Process	Design	Actual
	HHV	Insufficient data available	
	Ash		
	Moisture		
	Particle Size		
	Density		
	Sulfur		
	Yield (% of input)	66	

RDF Market History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	Rochester Gas & Electric (1981)	20 years; 600 ton/day	None to date		
	Hooker Energy from Waste Facility	RDF being supplied for testing		> 200 tons (1980)	

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous Metals	Vulcan Metals	900 tons	900 tons	
	Aluminum	Reynolds Metals			
	Glass	Owens-Illinois			

Capital Costs	Year	Cost	Item
	1974-80	\$50 M	Processing plant
	1977-81	\$12 M	RDF receiving facility at Rochester Gas & Electric

Other Costs	Operating	Undetermined
	Tipping fee	Undetermined

The nonferrous heavy fraction is trommeled, and the undersize fraction (<3/4 in. glass, ceramics, etc.) passes to a residue recovery module for separation of mixed-color glass cullet and a sand residue through froth flotation. The trommel oversize material (heavy combustibles, nonferrous metals) undergoes secondary shredding and air classification in a small aspirator-type classifier. The light fraction is returned to the vibrating screen. The secondary air-classifier heavy fraction undergoes magnetic separation and nonferrous metal recovery with a sliding board nonferrous metal separator. The resulting nonferrous metals are separated into aluminum and heavy nonferrous products with a heavy media separator.

Since little operating time has been accumulated to date, only minor modifications have been made to certain equipment. Additional safety measures and explosion prevention are planned for the primary shredder, and an emergency power generator will provide backup electrical power.

RDF yield is estimated to be 66% by weight of incoming refuse, or 1320 tons of RDF per day at full design capacity.

Economics. Total capital cost for the resource recovery facility is reported to be \$50 M. RDF handling, storage, and feed facilities at the RG&E Russell Station will cost \$12 M. No operation or maintenance costs are available.

Present Status. The processing facility is currently in the system and equipment shakedown and performance acceptance phase. MSW is processed on a regular basis at a reduced throughput of roughly 200 ton/day. Construction continues at the RG&E site, and those facilities should be ready in late 1981. The county is continuing to seek additional markets for the remaining RDF product (RG&E will be able to use only half of the full production output). Also, additional quantities of MSW are being sought from surrounding municipalities to allow full-capacity operation in the future.

Future Plans. The county and Raytheon are considering the addition of RDF densification equipment, as well as construction of a dedicated boiler, to burn any remaining RDF and combustible fractions. Several potential steam customers have been identified in the area.

Tacoma, Washington

Background

Name—Tacoma Resource Recovery System

Product—(1) Coarsely shredded RDF for use as a supplemental boiler fuel; (2) ferrous metals

Owner—City of Tacoma, Washington

Operator—City of Tacoma, Washington

Designer—Boeing Engineering and Construction, Seattle, Washington

Fuel User—None at present

History. The City has operated a waste-shred-to-landfill facility since 1972. Landfill restrictions and siting problems prompted Tacoma to initiate planning for a resource recovery system in 1974, with construction beginning in April 1977. Initial startup took place in October 1978, and the system became fully operational in June 1979.

System Description. A system flow diagram is shown in Figure 2-9, and a system data sheet is presented as Table 2-9. The resource recovery system was added to the back end of the original shredder. The facility was designed to handle 750 ton/day, with a single 100-ton/hr processing line. The actual operating capacity is reported to be 550 ton/day.

Waste is conveyed 100 ft from the tipping floor to the primary shredder, which reduces the material to a 4-in. size. From there, it is conveyed to a Boeing horizontal "aerodynamic" air classifier of proprietary design. The light material flows into a settling chamber that serves as surge storage, and is then conveyed to a loadout building, where traveling conveyors load transfer trailers. The air-classified heavy fraction is magnetically separated, and the ferrous fraction is loaded into trucks. The remaining material is landfilled.

The plant has an extensive fire control system, with sprinklers covering all conveyors. Some problems experienced with spillage from the conveyors should be eliminated with additional coverings.

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Figure 2-9. Tacoma Resource Recovery System flow diagram.

Table 2-9. Data sheet for Tacoma Resource Recovery System

Description	Production of RDF and ferrous metals	
Startup Schedule	Initial startup	October 1978
	Full operation	June 1979
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	7 hr/day, 5 day/wk
	Maintenance	4 to 6 hr/day
Manpower	Full time	8
	Per shift	5
MSW Processing	Design capacity	100 ton/hr; 750 ton/day
	Actual capacity	80 ton/hr; 550 ton/day
	Current throughput	Variable, depending on test needs
	Total to date	1300 tons (5/80)
	Total 1979	600 tons

Table 2.9. (continued)

RDF Production	Design capacity Actual capacity Current production Total to date Total 1979	300 ton/day Undetermined Variable, depending on test needs 900 tons 400 tons			
System Description	Number of lines	One, 100 ton/hr			
	Process	Type & Size	Manufacturer		
	Primary shredder	Horizontal shaft; 800 hp	Williams		
	Air classifier	Horizontal	Boeing		
	RDF settling and storage chamber				
	Ferrous separator	Belt magnet	Eriez		
RDF Analysis	Property	Design	Actual		
	HHV Ash Moisture Particle Size Density Sulfur Yield (% of input)	Insufficient data available			
RDF Market History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	None—limited testing with local wood products industries				
Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metals	None	30 ton/day (estimate)		\$20/ton (estimate)
Capital Costs	Year	Cost	Item		
	1978	\$3.0 M	Total Facility Cost		
Other Costs	Operating	\$6.00/ton, gross (present estimate)			
	Tipping fee	\$10.00/ton			

Economics. Total capital cost of the facility, less the cost of the existing shredder equipment, is reported to be \$3 M. Operating costs are estimated to be roughly \$6/ton gross, with a \$10/ton tipping fee.

Present Status. The plant is operational, but the system is only operated to produce test quantities of RDF for prospective customers,

primarily local wood products companies. Several three-hour tests at 80 ton/hr have been completed. The City is attempting to secure markets for both the RDF and ferrous products.

Future Plans. The City is investigating the feasibility of installing RDF densification equipment to improve product handling characteristics and increase its marketability.

RDF USER FACILITIES

Ames, Iowa

Background

Name—Ames Municipal Electric Co.

Process—Combustion of RDF with pulverized coal in a 33-MW suspension-fired boiler

RDF Producer—Ames Solid Waste Recovery System

History. The Ames processing facility began operations in August 1975, and the utility began burning RDF to supplement coal shortly thereafter. Initially, because of problems with unburned material in the large, suspension-fired unit, RDF was burned in two smaller, coal-fired traveling grate spreader stoker units. With the addition of a bottom dumping burning grate in 1978, the suspension-fired unit now handles approximately 20% RDF by heat input. RDF is burned in the two stoker boilers only when the main boiler is undergoing maintenance.

RDF Combustion System Description. A system data sheet is presented as Table 3-1. RDF is burned along with pulverized coal in a 22-MW tangentially-fired Combustion Engineering boiler. Designated Unit No. 7, it is rated at 360,000 lb/hr steam flow at 900 lb/in.²g and 900°F. A burning grate was installed in 1978 to allow complete combustion of all RDF and to reduce ash handling problems. This unit employs a wet bottom ash system and a pneumatic fly ash system. Particulate emissions are controlled with an electrostatic precipitator.

RDF from the processing plant is pneumatically conveyed 600 ft to a 500-ton Atlas storage bin next to the utility. Sweep buckets on the bin floor move material onto four variable-speed infeed conveyors. A fluffing roll and scalping roll then condition the material, after which it passes through an airlock feeder and into an 8-in. pneumatic transport line that feeds the boiler. Interchangeable elbows and transition pieces allow RDF to be fed to any of the three boilers on site.

RDF is fed into the furnace through nozzles located in each of the four corners between the

two elevations of coal nozzles. Most material burns in suspension, with final combustion of larger material on the grates. RDF is burned at 20% by heat input, or at a rate of approximately 9 ton/hr.

Since the addition of disc screens in the processing plant, few operational problems have been reported other than normal wear in various RDF transport and handling systems.

Economics. Costs in 1975 to install the storage bin, RDF transport system, and feed nozzles totaled \$1.6 M. Installation of dump grates in 1978 cost \$114,000. The utility is currently paying \$36/ton (\$1.77/M Btu) for Wyoming coal and \$13.95/ton (\$1.14/M Btu) for RDF.

Present Status. The utility is currently accepting all RDF produced by the Ames processing plant, about 125 to 150 ton/day. RDF is fired 24 hr/day, 7 day/wk, although feeding is discontinued at certain intervals to shed slag from the furnace tubes.

Wright-Patterson Air Force Base, Ohio

Background

Name—Wright-Patterson AFB Heating Plant

Process—Combustion testing of densified refuse-derived fuel (d-RDF) with coal in a stoker boiler

d-RDF Producer—Baltimore Co. Resource Recovery Plant (Teledyne)

History. The current tests using d-RDF at Wright-Patterson AFB (WPAFB) are part of an overall effort by the Department of Defense to reduce oil consumption and fuel costs. In 1975, 50 tons of d-RDF produced by Blank-Clawson Co. of Franklin, Ohio were successfully burned at the base. Construction of six new coal-fired boilers began in 1978, and at that time WPAFB attempted to procure d-RDF under a 10-yr contract. However, no local producer submitted a bid, and a contract was let in early 1979 to Teledyne National in Cockeysville, Maryland for

Table 3-1. Data sheet for Ames, Iowa Municipal Electric Co.

Description	Combustion of RDF with pulverized coal in a 33-MW boiler			
RDF Producer	Ames Solid Waste Recovery System			
Startup schedule	Initial RDF use	Fall 1975		
	Full operation	May 1978		
RDF Deliveries		Quantity	Price	
	Contract	125 to 150 ton/day	\$13.95/ton (\$1.14/M Btu)	
	Actual			
	Total to date			
	Total 1979	23,059 tons	\$12.30/ton (\$1.00/M Btu)	
Combustion System	Units burning RDF	One, Unit No. 7		
	Manufacturer	Combustion Engineering (1968)		
	Size	33 MW		
	Type	Tangentially fired, suspension burning		
	Primary fuel	Pulverized coal (Iowa and Western)		
	Ash removal system	Wet bottom ash system; hydraulic fly ash system		
	Emissions control	Electrostatic precipitator		
	RDF boiler modifications	Pneumatic RDF feed nozzles (4); bottom dump burning grate		
Steam Production		lb/hr	lb/in. ² g	°F
	Design	360,000	900	900
	Actual with RDF	360,000	900	900

Table 3-1. (continued)

RDF Handling System	Storage	500-ton Atlas storage bin	
	Metering	Variable-speed infeed conveyor; fluffing and scalping rolls	
	Transport	Air lock; 8-in.-diameter pneumatic line	
	Furnace feed	Pneumatic nozzles between the two coal nozzle elevations	
	Furnace firing	Suspension and bottom grate burning	

RDF Use		Design	Actual
	Heat input, %	20	20
	Rate of use	8.7 ton/hr	9 ton/hr

Fuel Analysis		Primary Fuel	RDF
	Type	Western coal	Fluff RDF
	HHV	10.150 Btu/lb	6000 Btu/lb
	Ash	9.74%	9.6%
	Moisture	16.6%	18.5%
	Particle size		86% < 1-1/2 in.
	Density		2.6 lb/ft ³
	Sulfur	2.79%	0.19%
	Price	≅ \$36/ton (\$1.77/M Btu)	\$1.14/M Btu

Emissions Data	Test Date	Type	Results	Standard
	Late 1978	Particulates	0.53 lb/M Btu (20% RDF)	

Costs	Year	Cost	Item
	1975	\$1.6 M	Boiler modification; RDF storage, transport, and feed system
	1978	\$114,000	Furnace dump burning grates

20,000 tons over 2-1/2 yrs. As of August 1980, only 1050 tons had been burned in an existing boiler.

RDF Combustion System Description. A system data sheet is presented as Table 3-2.

Although the new fuel receiving, blending, and storage system is available and has been used, the d-RDF has been cofired with double-screened coal in an existing Babcock & Wilcox traveling-grate spreader-stoker boiler. The boiler is rated at 100 M Btu/hr, producing high-temperature hot

Table 3-2. Data sheet for Wright-Patterson Air Force Base, Ohio

Description	Combustion testing of d-RDF in a spreader stoker boiler		
RDF Producer	Baltimore County Resource Recovery Facility		
Startup schedule	Initial RDF use	1975 (100 tons of d-RDF)	
	Full operation	Testing in May 1980	
RDF Deliveries		Quantity	Price
	Contract	20,000 tons (1979-91)	\$27/ton, f.o.b. Baltimore
	Actual	Variable	\$27/ton
	Total to date	1262 tons	
	Total 1979	800 tons	
Combustion System	Units burning RDF	One	
	Manufacturer	Babcock & Wilcox (1959)	
	Size	100 M Btu/hr	
	Type	Traveling grate spreader stoker	
	Primary fuel	Stoker coal	
	Ash removal system	Pneumatic	
	Emissions control	Two-field electrostatic precipitator	
	RDF boiler modifications	None	

Table 3-2. (continued)

Steam Production		lb/hr	lb/in. ² g	°F
	Design	100 M Btu/hr	435	450
	Actual with RDF	Not determined		
RDF Handling System				
	Storage	Covered silos		
	Metering	Blended with coal from silos on a volume basis		
	Transport	Conveyors to boiler feed hopper		
	Furnace feed	Mechanical spreader stokers		
	Furnace firing	Bulk of the d-RDF burns on the grate		
RDF Use		Design	Actual	
	Heat input, %			
	Rate of use	1:1 coal/d-RDF (by vol.)		
Fuel Analysis		Primary Fuel	RDF	
	Type	Bituminous coal	d-RDF	
	HHV		7850 to 9800 Btu/lb	
	Ash		8.4 to 21.5%	
	Moisture		8.4 to 23.3%	
	Particle size		2.8 to 27.2%	
	Density		<1/4 in, 23.5 to 37.0 lb/ft ³	
	Sulfur Price	\$2.25/M Btu	\$5 to \$6/M Btu	
Emissions Data		Type	Results	Standard
	Test Date			
	Scheduled for 1/5/81 to 1/23/81	Particulates		
Costs		Year	Cost	Item
	NA			

water. A two-field electrostatic precipitator was installed on the unit in 1977.

D-RDF from Teledyne, delivered by truck to the base, is unloaded to a storage hopper. A belt conveyor moves the fuel to a covered silo. Coal and d-RDF are blended on a 1:1 ratio by volume as they are fed onto the same conveyor belt from separate silos, and the blend is then transported back to storage or to the boilers.

Initial test burns resulted in excessive slagging on the back refractory wall due to high pellet trajectories. Adjustments to the spreader stokers corrected the problem. The high fines and moisture content of the d-RDF pellets, caused by deterioration during shipment, have created handling and storage problems, but these have been eliminated with harder pellets of lower moisture content. Segregation of the coal and d-RDF does not appear to be a problem during transport and feeding.

Limited emissions testing has been performed, and particulate loadings are reported to be within existing state and federal levels.

Economics. The Air Force is paying \$27/ton for d-RDF from Teledyne. However, with trucking costs included, this increases to \$82.26/ton, or roughly \$5 to \$6/M Btu. The coal costs for the base are \$55 to \$64/ton, or \$2.20 to \$2.25/M Btu.

Present Status. The base is currently receiving shipments of d-RDF from Teledyne, but in small quantities. Limited testing is performed with the available fuel, and involves primarily visual observations of boiler performance and operations, as well as of fuel handling and feeding systems.

Future Plans. Extensive testing for a 12-mo period is scheduled for 1981, and will be funded by the Department of Defense. The Air Force is also attempting to locate companies willing to produce d-RDF locally under contract.

Bridgeport, Connecticut

Background

Name—United Illuminating Co., New Haven, Connecticut; Bridgeport Harbor Station

Process—Combustion of ECO-FUEL II with No. 6 fuel oil in an 87-MW cyclone-furnace steam generator

RDF Producer—Bridgeport Resources Recovery Facility

History. United Illuminating Co. (UI) signed a contract with the Connecticut Resources Recovery Authority for the purchase of ECO-FUEL II at a price based on the utility's cost for fuel oil, less discounts related to the quantity of fuel used and other factors. The first quantities of ECO-FUEL II were burned at the Bridgeport Harbor Station in November 1979.

RDF Combustion System Description. A system data sheet is presented as Table 3-3. The ECO-FUEL II is burned in Unit No. 1, an 87-MW Babcock & Wilcox slagging-type, pressurized, cyclone-furnace boiler. Rated at 625,000 lb/hr steam flow, 1520 lb/in.²g, and 1000°F, the unit was originally designed to burn coal but was converted to No. 6 heavy fuel oil about 15 yr ago. It is equipped with Research-Cottrell electrostatic precipitators for particulate emissions control. The bottom ash slag removal system, a hydraulic sluice type, was upgraded to handle additional quantities of slag when burning the RDF. The fly ash removal system utilizes a dry vacuum system.

Trailers from the Bridgeport Resources Recovery Facility deliver ECO-FUEL II to the utility site, where it is unloaded and pneumatically conveyed to three 200-ton storage silos. From the silos, a gravimetric screw-type metering and feed system controls the flow of RDF into pneumatic lines for transport to the boiler. The fuel is injected into three cyclone burners via the primary air lines, and is burned along with oil in the burners.

Initial reports indicate no appreciable problems with corrosion, erosion, or excessive plugging in the gas passes when burning the ECO-FUEL II. A stack gas monitor was installed to determine gaseous sulfur emissions. The state-issued boiler operating permit was based on the burning of low-sulfur oil (<0.5%), with allowable emissions of 0.55 lb/M Btu of SO₂.

Economics. Costs for the RDF fuel receiving equipment, storage silos, weigh-feeders to meter

Table 3-3. Data sheet for United Illuminating Co., Bridgeport Harbor Station

Description	Combustion of ECO-FUEL II with oil in an 87-MW boiler		
RDF Producer	Bridgeport Resource Recovery Facility		
Startup schedule	Initial RDF use Full operation	November 1979 Currently testing	
RDF Deliveries		Quantity	Price
	Contract		
	Actual	Variable	\$56.47/ton; \$3.62/M Btu (1980 avg.)
	Total to date	>6800 tons	
	Total 1979	440 tons	
Combustion System	Units burning RDF	One, Unit No. 1	
	Manufacturer	Babcock & Wilcox (1957)	
	Size	87 MW	
	Type	Pressurized, cyclone furnace	
	Primary fuel	No. 6 fuel oil (coal, originally)	
	Ash removal system	Bottom ash— hydraulic sluice; fly ash—dry pneumatic	
	Emissions control	Electrostatic precipitators	
	RDF boiler modifications	Upgrading of bottom ash removal system	
Steam Production		lb/hr	lb/in. ² g °F
	Design	625,000	1520 1000
	Actual with RDF	625,000	1520 1000

Table 3-3. (continued)

RDF Handling System	Storage	Three 200-ton silos		
	Metering	Gravimetric, screw-type meter system		
	Transport	Airlock, pneumatic line		
	Furnace feed	Pneumatic injection into three cyclone burners		
	Furnace firing	Cocombustion with oil in cyclone burners		
<hr/>				
RDF Use		Design	Actual	
	Heat input, %	40	51 (max)	
	Rate of use			
<hr/>				
Fuel Analysis		Primary Fuel	RDF	
	Type	No. 6 fuel oil	ECO-FUEL II	
	HHV	18,250 Btu/lb	7500 to 8000 Btu/lb	
	Ash	0.08%	12 to 15%	
	Moisture	<2.0%	3 to 5%	
	Particle size	NA	79% <200 mesh	
	Density	NA	25 to 35 lb/ft ³	
	Sulfur	<0.5%	0.8 to 1.4%	
	Price		\$3.62/M.Btu	
<hr/>				
Emissions Data	Test Date	Type	Results	Standard
	No data available			
<hr/>				
Costs	Year	Cost	Item	
	1979	>\$1.5 M	RDF receiving, storage, transport, and feed system; boiler modifications	

the fuel, and modifications to ash handling equipment are estimated to be in excess of \$1.5 M. As of August 1980, UI was paying \$56.47/ton of ECO-FUEL II, or \$3.62/M Btu.

Present Status. The unit has successfully burned up to 51% ECO-FUEL II by heat input, with sustained rates of over 30%. The goal has been stated to be roughly 40%.

Shipments of RDF to the utility were discontinued in November 1980 due to the closing of the Bridgeport production plant for an indefinite period of time. Prior to closing, deliveries of ECO-FUEL II were sporadic, although UI gladly accepted all it could get. Initial stack testing indicated that the unit was within the existing standards for emissions of both particulates and NO_x . However, the utility was operating under a variance because the ECO-FUEL II exceeds the standard of 0.5% sulfur content in the fuel source.

Future Plans. United Illuminating plans to increase their use of ECO-FUEL II as soon as deliveries from the production plant resume. The utility plans to monitor and test stack conditions at various firing rates. Eventually, modifications to a second unit at Bridgeport Harbor may be made to increase RDF use and reduce the utility's use of fuel oil.

Chicago, Illinois

Background

Name—Commonwealth Edison Co., Crawford Generating Station

Process—Combustion of RDF with pulverized coal in two suspension-fired utility boilers

RDF Producer—Southwest Supplementary Fuel Processing Facility

History. In 1973, Commonwealth Edison signed a contract with the City of Chicago for the purchase of RDF. RDF was first fired regularly as a supplementary fuel with coal at the Crawford Station in October 1978. However, deliveries of RDF to the utility were discontinued in December 1979 after closure of the Southwest Processing Plant.

RDF Combustion System Description. A system data sheet is presented as Table 3-4. RDF is burned in suspension in two Combustion Engineering tangentially-fired pulverized coal boilers with twin furnaces. Unit No. 7, constructed in 1958, is rated at 200 MW and 1.3 M lb/hr steam flow. Unit No. 8, constructed in 1961, is rated at 325 MW and 2.2 M lb/hr. The units were designed to burn high-sulfur (4.6%) Illinois coal with 15% ash. There are tilting tangential coal nozzles at four elevations in each furnace.

A hydraulic sluice bottom ash system removes and transports the ash to a series of hydro-bins for dewatering. Electrostatic precipitators control particulate emissions. These units were modified with new automatic voltage controls and an SO_3 flue gas conditioning system when the units were converted to low-sulfur western coals.

RDF from the processing plant is pneumatically conveyed to either a 60,000 ft³ or 90,000 ft³ Atlas storage silo on Commonwealth Edison property, feeding Units No. 7 and No. 8, respectively. Revolving sweeps on the silo floors move material onto variable-speed drag conveyors and then to a fragmentizer (for delumping) before the RDF is dropped into four airlocks and pneumatically fed to the boilers. The pneumatic lines are designed to feed 20 ton/hr to Unit No. 7 and 40 ton/hr to Unit No. 8. RDF is injected into each furnace section of the boiler above the uppermost coal parts in two opposite corners (four nozzles per unit). Two RDF feed lines per furnace can supply 10% of the total unit heat input.

Experiments by Commonwealth Edison with RDF nozzle locations indicate that the most effective combustion is achieved by locating the nozzles high in the furnace and directing RDF down into the main fireball. This minimizes ash removal problems due to large unburned materials. With the present furnace configuration, particle sizes of 100% < 1 in. are recommended to prevent severe bottom ash problems.

Although the utility has burned only 14,000 tons of RDF, there are no indications of excessive slagging or evidence of increased corrosion.

Initial stack testing of Unit No. 7 in Fall 1978 indicated particulate loadings to be well within current federal standards. Test results also

Table 3-4. Data sheet for Commonwealth Edison Co., Crawford Generating Station

Description	Combustion of RDF with pulverized coal in two utility boilers		
RDF Producer	Southwest-Supplementary Fuel Processing Facility		
Startup schedule	Initial RDF use Full operation	October 1978 Not achieved; processing plant closed 12/79	
RDF Deliveries		Quantity	Price
	Contract	700 ton/day; 3500 ton/wk	
	Actual	Variable; ≅ 200 ton/day	\$0.30/M Btu
	Total to date	22,349 tons	\$0.30/M Btu
	Total 1979	10,500 tons	
Combustion System	Units burning RDF	Two, Unit Nos. 7 and 8	
	Manufacturer	Combustion Engineering	
	Size	No. 7: 200 MW No. 8: 325 MW	
	Type	Suspension fired tangentially; divided furnace	
	Primary fuel	Pulverized coal	
	Ash removal system	Hydraulic bottom ash system; pneumatic fly ash system	
	Emissions control	Four-field electrostatic precipitators	
	RDF boiler modifications	Four RDF nozzles located above upper coal nozzle	

Table 3-4. (continued)

Steam Production		lb/hr	lb/in. ² _g	°F
	Design	No. 7: 1.3 M	2400	1000 to 1050
		No. 8: 2.2 M	2400	1000 to 1050
	Actual with RDF ^a	No. 7: 1.3 M	2100	1000 to 1050
		No. 8: 2.2 M	2100	1000 to 1050
RDF Handling System	Storage	Two Atlas storage silos, 90,000 and 60,000 ft ³		
	Metering	Variable speed drag conveyor with fluff rolls		
	Transport	Airlock to 2500 ft ³ /min pneumatic line		
	Furnace feed	Pneumatic, with four RDF nozzles in opposite corners		
	Furnace firing	Suspension burning		
RDF Use		Design	Actual	
	Heat input, %	Nos. 7 & 8: 10	5 to 7	
	Rate of use	No. 7: 20 ton/hr No. 8: 40 ton/hr	≅ 10 ton/hr 20 to 25 ton/hr	
Fuel Analysis		Primary Fuel	RDF	
	Type	Western coal	Fluff	
	HHV	9460 Btu/lb	5230 Btu/lb	
	Ash	< 10%	20.8%	
	Moisture	23.3%	24.8%	
	Particle size		1/2 in. (estimate)	
	Density			
	Sulfur	0.6%	0.3%	
Price	\$1.45/M Btu (1978)	\$0.30/M Btu (1978)		
Emissions Data	Test Date	Type	Results	Standard
	Fall 1978	Particulates	0.09 lb/M Btu	0.10 lb/M Btu
Costs	Year	Cost	Item	
	1975	\$4.5 M	RDF storage, transport, and feed system; boiler modifications	

a. Actual pressure does not vary with use of RDF along with coal.

indicated a 10% reduction in electrostatic precipitation efficiency when firing RDF, but this can be reduced to 2% with optimum SO₃ injection into the flue gas stream.

Economics. Capital costs to construct the RDF receiving, storage, and transport system, including modifications to the boilers, totaled approximately \$4.5 M. In 1979, the utility was paying \$0.30/M Btu for the RDF and \$1.45/M Btu for western coal.

Present Status. RDF is not currently being burned by Commonwealth Edison because of the continued shutdown of the Southwest Processing Plant.

Future Plans. Should the processing plant resume operations, the utility plans to resume purchases of RDF and has agreed to pay \$1.30/M Btu for the fuel. Modifications to the Atlas storage silos, bottom ash sluice system, and RDF handling and feeding systems are planned. In addition, dump grates would be installed in the furnaces to increase RDF burnout and reduce bottom ash removal problems.

Madison, Wisconsin

Background

Name—Madison Gas & Electric Co., Blount Street Station

Process—Combustion of RDF with pulverized coal in two 50-MW suspension-fired boilers

RDF Producer—Madison Area Resource Recovery Center

History. The City of Madison and Madison Gas & Electric (MG&E) jointly developed an energy-from-waste project in 1974. In order to determine the optimum particle size and RDF burnout rate, two short tests of 5000 lb each were conducted. These tests proved that RDF could be burned effectively in the Blount St. units, and agreements were signed to supply and purchase fuel. MG&E began burning RDF on a regular basis in June 1979.

RDF Combustion System Description. A system data sheet is presented as Table 3-5. RDF is burned along with coal in two 50-MW Babcock &

Wilcox front-wall suspension-fired pulverized-coal boilers. Designated Units No. 8 and 9, they are rated at 425,000 lb/hr steam flow, 1250 lb/in.²g, and 950°F each. Both boilers are equipped with mechanical collectors and electrostatic precipitators for particulate emissions control. Bottom ash is collected in a dry ash pit and removed with a dry vacuum system.

Several modifications were required to the original boilers. Drop grates were installed above the ash pits at the boiler neck to maximize burnout of RDF and prevent clinkering in the ash pit. Two new fans were installed on each unit to supply overfire and underfire air to the grates. Three-fourths-inch RDF is pneumatically injected into the furnace via two air-cooled nozzles located in the front wall between the two lowest coal nozzle elevations (there are three elevations of coal nozzles, two nozzles per elevation). No modifications to the boiler controls were necessary. RDF is fed through a system independent of the primary fuel control system and is assumed to be a constant fuel input. However, several start permissives must be satisfied before RDF can be used: (1) the boiler load must be >60%; (2) both coal pulverizers must be in service, with the feeders on automatic; (3) the underfire and overfire air fans must be on; and (4) the ignition gas must be on.

RDF from the Madison Resource Recovery Center is delivered in transfer trailers and deposited in one of two 18-ton surge and storage bins in the RDF receiving building. Each bin serves one boiler. Two twin variable-speed augers feed RDF onto individual conveyors that discharge material into a feed chute with two delumpers and an air-lock feeder. RDF is pneumatically transported to the boilers and blow directly into the furnace.

Excessive dust generation at transfer points has been a problem. Since the variable speed augers provide only minimal feedrate control, fine adjustment of feedrate is not possible.

RDF is burning well in suspension at an average firing rate of 15% by heat input. An estimated 30% burns in suspension, the remainder on the dump grates. No serious problems with ash handling or air-preheater plugging is reported. The boilers, which do not slag naturally on coal, have shown no tendency to slag on RDF and coal. Some clinker formations are reported above the

Table 3-5. Data sheet for Madison Gas & Electric Co., Blount Street Station

Description	Combustion of RDF with pulverized coal in two 50-MW boilers		
RDF Producer	Madison Area Resource Recovery Center		
Startup schedule	Initial RDF use	June 1979	
	Full operation	1980	
RDF Deliveries		Quantity	Price
	Contract	28,000 ton/yr	
	Actual	120 to 140 ton/day	\$1.60/M Btu
	Total to date	10,200 tons (10/80)	
	Total 1979	1514 tons	
Combustion System	Units burning RDF	Two, Unit Nos. 8 and 9	
	Manufacturer	Babcock & Wilcox	
	Size	50 MW	
	Type	Frontwall suspension fired	
	Primary fuel	Pulverized coal	
	Ash removal system	Dry vacuum bottom ash system; pneumatic fly ash system	
	Emissions control	Mechanical collectors and electrostatic precipitator	
	RDF boiler modifications	Dump-type burning grates; over- and under-fire air fans; two RDF nozzles	
Steam Production		lb/hr	lb/in. ² g °F
	Design	425,000	1500 950
	Actual with RDF	425,000	1250 950

Table 3-5. (continued)

RDF Handling Storage	Storage	Two 18-ton storage bins	
	Metering	Twin variable speed augers	
	Transport	Airlock feeder and pneumatic transport	
	Furnace feed	Two pneumatic RDF nozzles between lowest coal nozzles	
	Furnace firing	Suspension—30%; burning grates—70%	

RDF Use		Design	Actual
	Heat input, %	20	11 to 15
	Rate of use	10 ton/hr	6 to 7 ton/hr/unit

Fuel Analysis		Primary Fuel	RDF
	Type	Midwest Bitum. Coal	Fluff (wet)
	HHV	12,500 Btu/lb	6100 Btu/lb
	Ash		10.25%
	Moisture		18.6%
	Particle size		91% < 3/4 in.
	Density		
	Sulfur	3.5%	0.17%
	Price	≅ 1.55/M Btu	\$1.60/M Btu

Emissions Data	Test Date	Type	Results	Standard
	Scheduled in the future			

Costs	Year	Cost	Item
	1979	\$1.06 M	RDF receiving, storage, feed, and transport system (cost to city)
	1979	\$0.5 M	Boiler modification—burning grates, fans, RDF nozzles

grate at the furnace throat, and are removed by lowering the grate and rodding the clinker from an access door. By slowing the RDF feedrate to the boiler and dumping the grates immediately after sootblowing, clinker formations can be minimized. Stack outlet temperatures have increased 30°F because the underfire air fans do not use, but rather displace, preheated forced draft fan air. This loss of heat results in a loss in efficiency of about 1-1/2%. Induced draft fan capacity is also reduced somewhat. No emissions testing has been performed, but no visible emissions are reported.

Economics. Capital costs for the RDF receiving, storage, metering, and transport system (including startup, engineering, improvements, etc.) were \$1.06 M and were paid for by the City. Modifications to the boilers, including drop grates, RDF piping, fans, and startup were \$0.5 M and were financed by MG&E.

Present Status. The utility is receiving approximately 120 to 140 ton/day of RDF, and fires 10 to 12 hr/day, 5 day/wk. As of July 1980, MG&E was paying \$1.60/M Btu for RDF.

Future Plans. Additional performance and stack testing is scheduled in the future. There are currently no plans to increase RDF use by the utility.

Milwaukee, Wisconsin

Background

Name—Wisconsin Electric Power Co. (WEPCO), Oak Creek Power Plant

Process—Combustion of RDF with pulverized coal in two 310-MW suspension-fired boilers

RDF Producer—Americology Resource Recovery Plant

History. WEPCO has a 15-yr contract (signed in 1975) with Americology for the purchase of RDF as a supplemental fuel with coal for use in their Oak Creek plant. The Oak Creek plant is located 20 miles from the Americology plant. RDF was first fired by the utility in March 1977, and more than 110,000 tons have been burned since that time.

RDF Combustion System Description. A system data sheet is presented as Table 3-6. Two boilers, Units No. 7 and 8, were modified to fire RDF. Built in 1965 and 1967 by Combustion Engineering, they are tangentially fired, balanced draft, pulverized-coal burning boilers rated at 310 MW each. Five elevations of coal nozzles are located in each corner. Bottom ash is removed with a hydraulic system, and fly ash with a pneumatic system.

The only modifications to the boilers involved installation of four RDF nozzles per unit, one in each corner above the uppermost elevation of coal nozzles.

RDF from the Americology plant is discharged from transfer trailers into a receiving building at WEPCO and pneumatically conveyed into a single 640-ton Atlas storage silo. Sweeps at the base of the silo move material to four airlocks into the pneumatic transport lines to the boilers. Diverting valves allow the lines to feed either Unit No. 7 or No. 8. Localized erosion in the pneumatic lines, particularly at 90-degree elbows, has been a problem.

RDF is injected directly into the furnace at an average rate of 15 to 25 ton/hr, or 8 to 12% by heat input. An increase in slagging of the waterwalls and superheater pendants has been reported. Prior to RDF burning, the units averaged 10 deslaggings per month to shed accumulated slag. With RDF, that number now averages 12 per month. Notable increases in bridging are reported over the ash pit and between steam tube pendant assemblies. Load restrictions due to marginal ID fan capacity have also resulted when burning RDF. WEPCO states that a load drop of one MW per ton/hr of RDF can be expected. RDF firing is discontinued at peak load demand.

Increased quantities of bottom ash from unburned RDF and wall slag have caused additional operating and maintenance problems. The presence of floating debris (wood, plastic) has caused plugging and other problems in the dewatering bins and water treatment facilities. While they do increase maintenance, these problems are not a major cause of unit downtime.

No conclusive data is available on air emissions. Preliminary testing indicates a reduction in NO_x

Table 3-6. Data sheet for Wisconsin Electric Power Company

Description	Combustion of RDF with coal in two 310-MW boilers		
RDF Producer	Americology Resource Recovery Plant		
Startup schedule	Initial RDF use Full operation	March 1977 Not achieved	
RDF Deliveries		Quantity	Price
	Contract		Coal equivalent less added costs
	Actual	As requested	
	Total to date	>110,000 tons	
	Total 1979	30,600 tons	\$1.27/M Btu
Combustion System	Units burning RDF	Two, Unit Nos. 7 and 8	
	Manufacturer	Combustion Engineering, Inc.	
	Size	310 MW	
	Type	Pulverized coal, suspension-fired tangentially	
	Primary fuel	Midwestern and western bituminous coal	
	Ash removal system	Wet bottom ash system; pneumatic fly ash system	
	Emissions control	Electrostatic precipitator	
	RDF boiler modification	Installation of four RDF nozzles	
Steam Production		lb/hr	lb/in. ² _g
	Design	No. 7: 2.0 M No. 8: 1.9 M	2520 2400
			1000 to 1050 1000 to 1050
	Actual with RDF	No. 7: 1.9 M No. 8: 1.9 M	2400 2400
			1000 to 1050 1000 to 1050

Table 3-6. (continued)

RDF Handling System	Storage	640-ton Atlas bin	
	Metering	Variable speed conveyors	
	Transport	Pneumatic from storage	
	Furnace feed	Pneumatic nozzle	
	Furnace firing	Suspension	

RDF Use		Design	Actual
	Heat input, %	15 to 20	8 to 12
	Rate of use	30 to 40 ton/hr	15 to 25 ton/hr

Fuel Analysis		Primary Fuel	RDF
	Type	Bituminous coal	Fluff
	HHV	11,300 Btu/lb	5060 Btu/lb
	Ash	10.7%	28%
	Moisture	10.8%	29%
	Particle size		90% <3/4 in.
	Density		6.3 lb/ft ³
	Sulfur		0.28%
	Price	\$1.29/M Btu (1979)	\$1.27/M Btu (1979)

Emissions Data	Test Date	Type	Results	Standard
	No data available			

Costs	Year	Cost	Item
	1977	\$4.2 M	RDF receiving, storage, and feed system
	1977	\$0.61 M	Boiler modifications—RDF feed nozzles

emissions by 15%, an increase in chloride emissions, and no discernible effect on SO₂ emissions. Particulate loading did increase, however, indicating the probability of reduced precipitator performance.

Economics. Capital costs to construct the RDF receiving, storage, metering, and feed system at WEPCO totaled \$4.2 M. In addition, modifications to the boilers totaled \$615,000. In 1979, WEPCO paid an average of \$12.52/ton for RDF (\$1.27/M Btu). The price is based on the equivalent cost for coal. Fuel payments reflected the amortized costs for the RDF handling, transport, and fuel feed systems, boiler modifications, and increased operating costs to WEPCO.

Present Status. The units went offline in September 1980 for installation of new electrostatic precipitator control systems. One unit is currently back online, but the decision to resume RDF firing has not been made, and the situation is being evaluated by WEPCO officials. Prior to the shutdown, purchases of RDF by WEPCO were less than anticipated due to operating and maintenance problems associated with slagging, ash removal, and particulate emissions control.

Future Plans. WEPCO is not as yet committed to the full-scale use of RDF in its boilers. Discussions continue between WEPCO and Americology regarding conditions for future purchases of fuel.

RDF PRODUCTION-USER FACILITIES

Akron, Ohio

Background

Name—Akron Recycle Energy System

Product—(1) Shredded RDF for onsite use in 100%-RDF-fired dedicated boilers to produce steam and electricity; (2) ferrous metals

Owner—City of Akron, Ohio

Operator—Teledyne National; Northridge, California

Designer—Glaus, Pyle, Schomer, Burns & DeHaven; Akron, Ohio

Fuel or Energy User—Onsite combustion of RDF; steam sold to B. F. Goodrich, University of Akron, and downtown heating and cooling loop

History. The Recycle Energy System was designed to produce steam and small quantities of electricity from 1000 ton/day of municipal waste. Contracts for construction of the processing system, boiler plant, and steam distributing system were awarded in December 1976. Construction began in March 1977 and was completed by the spring of 1979. Initial MSW processing started in June of 1979, and the first firing of the boilers with RDF occurred July 3, 1979. The first quantities of steam were delivered to B. F. Goodrich on July 19, 1979, and full operational status was achieved in September 1980.

MSW Processing System Description. A system flow diagram is shown in Figure 4-1, and a system data sheet is presented as Table 4-1. The MSW processing system, with two, 60-ton/hr (peak) processing lines operating 14 hr/day, has a peak capacity of 1200 ton/day and a design capacity of 1000 ton/day.

Incoming refuse trucks dump directly into an 1800-ton storage pit. Waste is moved from the pit onto the shredder infeed lines by means of two hydraulic multiram positive displacement loading lines. The rams discharge into a surge bin that feeds the horizontal hammermill primary shredders. A remotely operated grapple crane removes oversized and potentially hazardous materials

before the shredding operation. The primary shredders produce a minus-5-in. product (i.e., <5 in. in size).

Shredded material is then air-classified in a vibrating air density separator. A 70/30 light-heavy split is the desired product ratio. The heavy fraction is magnetically separated; ferrous material is conveyed to trailers for shipment, and the residue is disposed of as landfill. The air-classified light material is drawn off into a cyclone separator and dropped into a 2100-ton, double-sided, Miller-Hofft storage bin. A pair of dual screw augers feed material to the center and onto a conveyor that moves RDF to a metering and surge bin. A series of three flight conveyors in the metering bin distribute the RDF into three air locks, which then feed it into pneumatic transport lines to the boiler area.

A number of problems have been encountered during startup. Most of these involve material handling and transport. There have been bridging and flow rate control problems in the operation of the metering bin. The installation of an air cannon to break up and aerate the RDF and the addition of pressure-sensing lines should alleviate the problems. Excessive pneumatic line plugging, due primarily to unshredded plastic bottles, required installation of additional grate bars in the shredders. Excessive wear in the pneumatic lines because of inorganic fines remains a problem. Bridging of waste in the receiving pits above the ram feeders has also been experienced. A reduction in the carrying capacity of the Miller-Hofft augers because of entangled rags was eliminated by the installation of a dog-house that permits cleaning of the augers at least once per day.

RDF Combustion System Description. A system data sheet is presented as Table 4-2. The combustion system includes three Babcock & Wilcox semisuspension, traveling grate, spreader-stoker boilers rated at 126,000 lb/hr burning 100% RDF. No. 2 fuel oil is used as the backup fuel and can supply 100% of the rated load if RDF is not available. At full load, each boiler is designed to burn 300 ton/day of RDF.

RDF from the pneumatic lines is deentrained and gravity-fed to each boiler through four air-swept spouts. Rotary dampers distribute the fuel from front to back and side to side. An estimated

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Figure 4-1. Akron Recycle Energy System flow diagram.

30 to 40% of the RDF burns in suspension. Remaining combustion occurs on the grate, and burnout is reported to be quite good.

Furnace conditions are said to be good, with no appreciable slag accumulations. Sootblowers are operated once per day. No emissions data are currently available, but stack appearance is generally good.

A four-field electrostatic precipitator is included for particulate emissions control. Following the precipitator, a regenerative air heater reduces flue gas temperatures to 325°F and supplies 340°F combustion air to the furnace. In the original design, a waste heat economizer was installed to heat water for building heating and to cool the stack gases. However, this system was subject to ash plugging and was later removed.

A steam coil air heater at the forced draft fan outlet maintains air heater metal temperatures in

cold weather. Originally, this fan was supplied with recirculated RDF transport air, which resulted in some plugging due to dust buildups at the fan inlet. The fan now draws air directly from the interior of the building.

The plant has two 2000-kW turbine generators to furnish about one-third of in-house electrical requirements.

Saturated steam reduced from 560 to 125 lb/in.²g is distributed to an existing Ohio Edison steam system with condensate return. New distribution lines carry steam at 560 lb/in.²g to the B. F. Goodrich complex adjacent to the plant, to the University of Akron 1-1/2 miles away, and to Akron City Hospital two miles away. One hundred percent condensate return is provided.

Economics. Total capital cost to date for the entire system is reported to be \$55 M. Included in that figure are roughly \$8.5 M for the steam

Table 4-1. Data sheet for Akron Recycle Energy System, RDF Production

Description	Production of RDF for onsite combustion, and of ferrous metals		
Startup Schedule	Initial startup Full operation	June 1979 September 1980	
Operating Schedule	MSW receiving MSW processing Maintenance	8 hr/day, 5 day/wk 20 hr/day, 5 day/wk 5 day/wk	
Manpower	Full time Per shift	83 24	
MSW Processing	Design capacity Actual capacity Current throughput Total to date Total 1979	60 ton/hr; 1200 ton/day 1000 ton/day 600 ton/day 72,125 tons (9/80) Startup	
RDF Production	Design capacity Actual capacity Current production Total to date Total 1979	700 ton/day 700 to 800 ton/ day 420 to 480 ton/ day 54,000 tons	
System Description	Number of lines	Two, 60 ton/hr each	
	Process	Type & Size	Manufacturer
	Primary shredder	Horizontal shaft; 1500 hp	American
	Air classifier	Vibrolutriator	Triple-S Dynamics
	Pneumatic transport of RDF to storage	2100 tons	Miller-Hofft
	Ferrous separator	Drum-type magnet	

Table 4-1. (continued)

RDF Analysis	Property	Design	Actual
	HHV	5500 to 6500 Btu/lb	5500 to 7000 Btu/lb
	Ash		15%
	Moisture	40%	25%
	Particle Size	80% at 2 in.	95% < 3 in.
	Density	5 lb/ft ³	5 lb/ft ³
	Sulfur		0.14%
	Yield (% of input)	70	87

History RDF Market	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	Onsite combustion of all RDF produced				

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metals	None to date	691 tons		

Capital Costs	Year	Cost	Item
	1976-78	\$56 M	Total facility capital cost (includes \$8.5 M for steam generators and \$3.4 M for new steam lines)

Other Costs	Operating	Not fully determined
	Tipping fee	\$6.00/ton

generation system, \$3.4 M for the steam distribution lines, \$12 M for financing the project, and indirect costs of \$17 M for engineering, startup, legal fees, spare parts, etc. No definitive data on operating costs are currently available.

The City receives a tipping fee of \$6 for each ton of refuse deposited.

Present Status. The Akron plant processes an average 600 ton/day of waste, 20 hr/day,

5 day/wk. Steam sales to the various customers average roughly \$4/1000 lb of steam. The facility was certified in September 1980 as meeting minimum design requirements of 1000 ton/day of refuse and 378,000 lb/hr steam production. With the shutdown of the old Ohio Edison steam plant in late summer, the Akron facility now supplies 100% of the steam system requirements.

Future Plans. Akron officials continue to seek increases in waste flow so as to consistently reach

Table 4-2. Data sheet for Akron Recycle Energy System, RDF Use

Description	Combustion of RDF in three dedicated boilers to generate steam and electricity		
RDF Producer	Onsite production		
Startup schedule	Initial RDF use	July 1979	
	Full operation	September 1980	
RDF Deliveries		Quantity	Price
	Contract	300 ton/day/ boiler	
	Actual	420 to 480 ton/ day (11/80)	
	Total to date	54,000 tons (9/80)	
	Total 1979	Startup	
Combustion System	Units burning RDF	Three	
	Manufacturer	Babcock & Wilcox	
	Size	126,000 lb/ hr/unit steam; 4 MW electricity	
	Type	Semisuspension, traveling-grate stokers	
	Primary fuel	100% RDF (<4-in.); No. 2 oil backup	
	Ash removal system	Bottom ash—dry hopper; fly ash—screw with water spray	
	Emissions control	Four-field elec- trostatic precipitators	
	RDF boiler modifications	None required— dedicated units	
Steam Production		lb/hr	lb/in. ² _g
	Design	126,000/unit	560
	Actual with RDF	126,000/unit	560
			°F
			479
			490

Table 4-2. (continued)

RDF Handling System	Storage	2100-ton Miller-Hofft bin	
	Metering	Meter and surge bin; variable speed flight conveyor	
	Transport	Airlock to 8-in. pneumatic line to boilers	
	Furnace feed	Gravity feed through four air-swept distributors	
	Furnace firing	Semisuspension; 30 to 40% burns in suspension	

RDF Use		Design	Actual
	Heat input, %	100	100
	Rate of use	300 ton/day/unit	225 ton/day/unit (avg.)

Fuel Analysis		Primary Fuel	RDF
	Type	2-in. RDF	Same
	HHV	5900 to 6300 Btu/lb	Same
	Ash	10%	Same
	Moisture	19%	Same
	Particle size	80% at 2 in.	Same
	Density	5 lb/ft ³	Same
	Sulfur	0.14%	Same
	Price	NA	Same

Emissions Data	Test Date	Type	Results	Standard
	None to date			

Costs	Year	Cost	Item
	1976-78	\$56 M	Total facility capital cost (includes \$8.5 M for steam generators and \$3.4 M for new steam lines)

the 1000 ton/day capacity. Unit performance testing is scheduled for late 1980. There are plans to install a four-section superheater in one of the boilers to evaluate corrosion. Each section will consist of differing alloys and will be equipped with individual steam flow control valves to regulate steam and metal temperatures. The use of air-cooled probes to evaluate the corrosion incidence of various metals in the lower and upper furnace is also being considered.

Modifications to reduce plant maintenance and bring the system to full design capacity are planned for 1981. The air-classification system will be eliminated and replaced with a disc-screen unit. The existing pneumatic RDF transport to storage will be replaced by a mechanical conveyor system.

Hempstead, New York

Background

Name—Hempstead Resources Recovery Corporation

Product—(1) Wet-pulp RDF for combustion in dedicated boilers to generate steam and electricity; (2) ferrous metals; (3) aluminum; (4) color-sorted glass

Owner—Hempstead Resources Recovery Corporation (HRRC)

Operator—HRRC

Designer—Parsons & Whittemore, Inc. and Black Clawson Fibreclaim, Inc. (a subsidiary of Parsons & Whittemore)

Fuel or Energy User—Onsite combustion of RDF to generate steam and electricity for export to Long Island Lighting Co. (LILCO)

History. In 1974, the HRRC (a subsidiary of Parsons & Whittemore) signed an agreement with the Town of Hempstead to design, construct, and operate a facility to handle 11,000 ton/wk of MSW with a maximum of 3% residue by volume.

Design of the Hempstead plant was based on experience gained by Black Clawson at its prototype plant in Franklin, Ohio, which was the first to utilize the Hydrasposal process. Initial

operation and testing of the Hempstead facility began in August 1978, and the facility has since undergone numerous modifications to improve performance and reduce maintenance.

System Description. An RDF production system flow diagram is shown in Figure 4-2, and system data sheets for RDF production and use are presented as Tables 4-3 and 4-4. The Hydrasposal process involves the wet separation of municipal refuse into portions that can be recycled and portions that can be burned to generate steam and electric power.

Refuse is delivered to the plant and unloaded into a pit with a capacity of more than 4000 tons. From there, MSW is conveyed into a trommel screen and fed into three 20-ft-diameter pulpers (hydrapulpers), where refuse is disintegrated and removed as water slurry. Disintegration of the MSW is attained through the action of high-speed rotors.

Oversized and heavy objects are ejected from the hydrapulpers and pass under a magnet for removal of ferrous metals. The slurry is pumped to hydrocyclones for separation of combustible and noncombustible materials by centrifugal action. Glass, aluminum, and some ferrous material is ejected and floated to remove any remaining organics, and then jigged to separate metals and glass. Ferrous metals and aluminum are recovered. The glass is dried and optically sorted into flint, amber, and green product.

The combustible portion is dewatered in presses and mechanically conveyed to fuel storage, where it is blended further. From storage, the RDF is weighed, metered, and gravity-fed into the furnaces of two power boilers through five air-swept spouts located 6 ft above the burning grates. At full load, each unit burns approximately 40 ton/hr of RDF, of which 60 to 80% is reported to burn in suspension. The boilers are identical Stirling (B&W) units—semisuspension-fired, traveling grate, spreader-stokers with an output of 200,000 lb/hr of superheated steam. The steam drives two turbogenerators (owned by LILCO), each capable of generating electric power at a rate of 480 MWh per day. Of the total 40-MW capacity, roughly 20% is used onsite, with the remaining 80% exported to LILCO. Particulate emissions are controlled with a bank of cyclones followed by electrostatic precipitators.

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Figure 4-2. Hempstead Resource Recovery Corporation flow diagram.

Testing by the EPA indicated that TCDD's (dioxins) were present in the boiler flue gas in concentrations ranging from 3 to 10 ppt (parts per trillion) with the 2, 3, 7, 8-TCDD possibly present in trace amounts of 0.3 ppt. Further testing is planned since both the number of samples and the sampling procedure were in question.

The plant has undergone numerous design and structural modifications since startup. The trommel screens were installed in mid-1980 to reduce wear in the hydrapulpers. RDF from the drying presses was originally transported to the storage bunker pneumatically, but this system was replaced with mechanical conveyors because of high wear in the pneumatic line elbows. Bridge cranes were once used to move RDF to the boiler feed hoppers, but method has been replaced by the current belt conveyor system. A new boiler ash-handling system was installed, and a new air scrubbing system was installed to reduce serious odor and dust problems within the plant.

Economics. Total capital cost of the original facility was reported to be \$130 M. Modifications since 1978 total \$10 M. No operating costs are available.

Present Status. The Hempstead plant is currently closed down and has been since March 10, 1980. The Town of Hempstead and HRRC have agreed to keep the plant closed until the U.S. EPA establishes uniform standards for testing TCDD's. During this time, plant personnel continue to make modifications and adjust equipment in hopes of improving product output and quality. Prior to its closing, the plant was processing roughly 1200 ton/day, 5-1/2 day/wk, and generating electricity for sale to LILCO.

Future Plans. The facility will resume operations as soon as the aforementioned problems are resolved. Plant throughput will be increased to full capacity as soon as possible.

Table 4-3. Data sheet for Hempstead Resources Recovery Corporation, RDF Production

Description	Production of RDF for onsite combustion, and of ferrous metals, aluminum, and color-sorted glass		
Startup Schedule	Initial startup	August and September 1978	
	Full operation	Not yet achieved	
Operating Schedule	MSW receiving	8 hr/day, 5-1/2 day/wk	
	MSW processing	24 hr/day, 7 day/wk	
	Maintenance		
Manpower	Full time	To be determined (previously 190)	
	Per shift		
MSW Processing	Design capacity	2000 ton/day; 11,000 ton/wk	
	Actual capacity	To be determined	
	Current throughput	Plant closed (previously 1200 ton/day)	
	Total to date Total 1979		
RDF Production	Design capacity	1100 ton/day	
	Actual capacity	To be determined	
	Current production	Plant currently closed	
	Total to date Total 1979		
System Description	Number of lines	Three	
	Process	Type & Size	Manufacturer
	Trommel		
	Hydrapulpers (3)	20-ft diameter; 1200 hp	
	Ferrous separator		
	Hydrocyclone		
	Spiral & disc press		
	RDF dryers		

Table 4-3. (continued)

	Process	Type & Size	Manufacturer
	RDF storage	Concrete bin	
	Glass jig		
	Nonferrous separator	Eddy current	

RDF Analysis	Property	Design	Actual
	HHV	8030 Btu/lb (dry)	8140 Btu/lb (dry)
	Ash	6%	8 to 10%
	Moisture	50%	≅ 50%
	Particle Size	Fluff	Fluff
	Density	22 lb/ft ³	≅ 22 lb/ft ³
	Sulfur	0.1%	0.09%
	Yield (% of input)	55	Unknown

RDF Market History	Customer	Contract Period and Quantity	Quantity Delivered	Total Delivered	Price
	Onsite use in dedicated boilers				

Other Products	Product	Customer	Produced	Delivered	Price
	Ferrous metals	Local			
	Aluminum	Reynolds Metals, Alcoa			
	Glass	Glass Containers Corp.			
	Electricity	LILCO	40 MW	≅ 32 MW	To be established

Capital Costs	Year	Cost	Item
	1976	\$100 M	Initial plant capital cost
	1978-80	\$10 M	Modifications since startup

Other Costs		
	Operating	NA
	Tipping fee	NA

Table 4-4. Data sheet for Hempstead Resources Recovery Corporation, RDF Use

Description	Combustion of 100% RDF to generate steam and electricity			
RDF Producer	Onsite production			
Startup schedule	Initial RDF use Full operation	September 1980 Not achieved		
RDF Deliveries		Quantity	Price	
	Contract	Design: 1100 tpd		
	Actual			
	Total to date			
	Total 1979			
Combustion System	Units burning RDF	Two		
	Manufacturer	Fives-Cail Babcock, France		
	Size	20 MW/unit		
	Type	Sterling two-drum, semisuspension traveling grate stoker		
	Primary fuel	RDF		
	Ash removal system	Drag conveyor with silo for mixed ashes		
	Emissions control	Mechanical cyclones, electrostatic precipitators		
	RDF boiler modifications	Dedicated boilers designed to fire 100% RDF		
Steam Production		lb/hr	lb/in. ² g	°F
	Design	191,400/unit	625	750
	Actual with RDF	To be determined		

Table 4-4. (continued)

RDF Handling System	Storage	10,000-ton concrete fuel storage bin	
	Metering	Weigh scales and metering drums	
	Transport	Conveyors from storage to boiler hoppers	
	Furnace feed	Gravity feed; five air-swept spouts 6 in. above grate	
	Furnace firing	Semisuspension; 60 to 80% burns in suspension	

RDF Use		Design	Actual
	Heat input, %	100	100
	Rate of use	39 ton/hr	Not determined

Fuel Analysis		Primary Fuel	RDF
	Type	RDF	Same
	HHV	8140 Btu/lb (dry)	Same
	Ash	8%	Same
	Moisture	50%	Same
	Particle size	Fluff	Same
	Density	22 lb/ft ³	Same
	Sulfur	0.09%	Same
	Price	NA	Same

Emissions Data	Test Date	Type	Results	Standard
	4/30 & 5/1/79	Particulates	20.67 lb/hr	75.52 lb/hr

Costs	Year	Cost	Item
	1976	\$100 M	Initial plant capital cost
	1978-80	\$10 M	Modification since startup

MASS BURNING FACILITIES WITH ENERGY RECOVERY

Baltimore, Maryland

Background

Name—Baltimore Pyrolysis Plant

Process—Incineration of shredded MSW in a starved-air rotary kiln with waste heat recovery to generate steam

Owner—City of Baltimore

Operator—City of Baltimore

System Designer—Monsanto Enviro-Chem Systems

Energy User—Baltimore Gas and Electric Co. (BG&E)

History. The Baltimore Pyrolysis Plant began operations in February 1975 as a 1000-ton/day pyrolytic conversion system with heat recovery. The system used was based on the Monsanto Landgard Process. The original pyrolysis never worked. Problems included excessive equipment wear, pluggages in the refuse pit, unstable kiln processing, refractory failures, excessive slagging, and particulate emissions.

The City took over the facility and made modifications to the original system in 1978-79. Shredded refuse storage was discontinued, and the processing rate was changed to match the kiln firing rate. A new gas purifier was installed to produce fly ash instead of slag. Higher temperature refractory was installed in the rotary kiln. The original wet scrubber system was replaced with electrostatic precipitators and ID fans for each boiler, and a new 220-ft exhaust stack was added. The labor-intensive kiln residue processing facility for ferrous metals recovery was eliminated. The plant reopened in May 1979 and is operating and generating steam. The modified plant has a design capacity of approximately 600 ton/day.

System Description. A system data sheet is presented as Table 5-1. Refuse from the tipping floor is shredded and then fed into the rotary pyrolytic kiln combustion chamber at a rate of 25 ton/hr by two independent ram feeders. Supplemental fuel (No. 2 oil) is used for startup

and to keep the 20-ft-diameter, 100-ft-long kiln warm when refuse is not available. Ash from the thermal reduction process, estimated to be 25% of incoming waste, is discharged at the end of the kiln into a water trough and conveyed to trucks for disposal as landfill. Pyrolytic gases from the kiln pass to a secondary chamber (gas purifier), where the combustion process is completed with the addition of secondary air and supplemental heat when necessary. Hot gases then enter two water-tube, drum-type waste heat boilers rated at 125,000 lb/hr each. Steam is transported one mile to the BG&E station for use in district heating and cooling.

Refractory replacement continues to be a significant maintenance item, and is required in the kiln at a cost of \$500,000 after each 300,000 tons of waste are burned. The asbestos seals around the kiln ends require replacement every five to seven days. Chain replacements on the ash removal conveyor are required periodically.

Economics. Total capital cost, including the latest modifications, is reported to be \$29.5 M. Gross operating cost over an 8-mo operating period in 1979 was \$12.87/ton of waste processed. BG&E is currently paying roughly \$2.80/1,000 lb of steam.

Present Status. The plant is operating and processes 600 ton/day, 5 day/wk. Steam deliveries to BG&E average 80,000 lb/hr. Fuel oil is used to keep the kiln warm over the weekends.

Future Plans. The City is studying the feasibility of a redundant or second rotary kiln to allow continued processing of waste if one kiln is inoperative. Alternatively, the installation of a grate-type refractory to replace the original kiln is being considered.

New York City, New York

Background

Name—Betts Avenue Incinerator, Woodside, New York, New York

Process—Combustion of unprocessed MSW in refractory incinerators with waste heat boilers to generate steam

Table 5-1. Data sheet for Baltimore Pyrolysis Plant

Description	Combustion of shredded MSW in a starved-air kiln with waste heat recovery to generate steam	
Startup Schedule	Initial startup Full operation	February 1975 May 1979, after major modifica- tion
Operating Schedule	MSW receiving MSW processing Maintenance	8 hr/day, 5 day/wk 24 hr/day, 5 day/wk
Manpower	Full time Per shift	50 8
MSW Processing	Design capacity Actual capacity Current throughput Total to date Total 1979	1000 ton/day (original plant design) 600 ton/day (after 1978-79 changes) 600 ton/day 103,000 t (6/79 to 6/80)
Combustion System	Number of units Manufacturer Type Capacity per unit, design Capacity per unit, actual Grate type MSW storage and feed Ash removal	One kiln, two waste heat boilers Kiln: Kennedy Van Saun Boilers: Erie City Kiln: Rotary Boilers: Water- tube, drum-type 40 ton/hr; 1000 ton/day (original system) 25 ton/hr; 600 ton/day (present system) Not applicable (refractory lined kiln) Tipping pit; MSW shredding; con- veyor to kiln Water trough; drag chain con- veyor

Table 5-1. (continued)

	Emissions control	Two electrostatic precipitators			
	Supplemental fuel	No. 2 fuel oil, 7 to 10 gal/ton of waste			
	Residue (% of input)	25, by weight			
Energy Recovery System	System type	Two waste heat boilers			
	Condensate return	No			
	Steam production	lb/hr	lb/in. ² g	°F	
	Design	125,000	330	426	
	Actual	100,000	350	430	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Baltimore Gas & Electric			75,000 to 80,000	\$2.80/1000 lb
Other Products					
Emissions Data	Test Date	Type	Results	Standard	
	October 1979	Particulates	0.03 gr/dsft ³		
Capital Costs	Year	Cost	Item		
	1977	\$20.6 M	Total cost before shutdown in 1977		
	1979	\$9.0 M	Modifications to original system		
Other Costs	Operating	\$12.87/ton, gross (operation and maintenance, 8 months of 1979)			
	Tipping fee				

Owner—City of New York, New York

Operator—New York City Department of Sanitation

Energy User—Plant and several adjacent City facilities for heating and industrial processes

System Manufacturer—Combustion Engineering (incinerator)

History. The facility began full operations in 1953 using four refractory-lined furnaces with no heat recovery. In 1965, the plant was rehabilitated with the installation of a waste heat recovery system using two waste heat boilers and waste heat ducts installed across the four furnace outlets. The facility has been generating steam for use by the City since that time.

System Description. A system data sheet is presented as Table 5-2. The facility has a design capacity of 1000 ton/day of MSW generating 150,000 lb/hr of steam. Four refractory-wall furnaces with traveling grates incinerate 42 ton/hr of MSW each. MSW is fed by an overhead crane into continuous gravity-feed hoppers. The MSW storage pit has a capacity of 600 to 1000 tons. Ash is dropped into a water-quench tank and removed via a drag conveyor. A small oil-fired auxiliary boiler is available for standby use in the event the waste heat recovery system is inoperable.

Problems have been encountered with refractory damage caused by excess radiant heat. The traveling grate surfaces have shown signs of oxidation. In 1979, several modifications to correct these problems were initiated, including: new furnace linings and interior configuration modifications to increase the combustion efficiency; new Illinois rolling grates to replace the worn originals; addition of four new electrostatic precipitators for particulate emissions control.

Economics. The original plant cost \$7 M in 1953. Additional modifications in 1957 totaled \$2 M. Installation of the waste heat recovery-steam generation system cost \$5 M in 1965. The capital investment for the latest modifications in 1979 are estimated to be \$18 M. A \$5.15 tipping fee is currently assessed. Income from DOE oil entitlements was \$0.5 M in 1979.

Present Status. The plant is processing 500 ton/day, 6 day/wk, but capacity will be

increased once the electrostatic precipitators are installed and operational. Steam is generated for approximately 6 mo/yr at roughly 35,000 lb/hr (20 M lb/mo) steam flow.

Future Plans. Capacity will be increased as modifications are completed, and steam will be generated year-round. Emissions testing will be conducted when the electrostatic precipitators are operational.

Braintree, Massachusetts

Background

Name—Braintree Thermal Waste Reduction Center

Process—Combustion of unprocessed MSW in a waterwall furnace to generate steam

Owner—City of Braintree, Massachusetts

Operator—City of Braintree, Massachusetts

Designer—Camp, Dresser & McKee, Inc.

Energy User—Weymouth Art & Leather Co.

History. The Braintree facility began operations in March 1971, and was the first municipal incinerator in the U.S. to be designed and constructed with electrostatic precipitators. The plant was closed in May 1976 for failure to meet new state and federal emissions standards. Subsequent modifications resulted in the reopening of the plant in early 1978, and it has been in regular operation since that time.

System Description. A system data sheet is presented as Table 5-3. The facility has an operating capacity of 384 ton/day using two waterwall furnaces, and it can generate 60,000 lb/hr of steam at 250 lb/in.²g and 400°F. The plant closing in 1976 revealed several problems. The electrostatic precipitators and economizer tubes were found to be corroding badly due to repeated startups and shutdowns. Modifications included rebuilding the two precipitators and reworking the internal baffling system to modify gas flow. The plant currently meets state standards for particulate emissions.

Table 5-2. Data sheet for Betts Avenue Incinerator, Woodside, New York City

Description	Refractory furnace combustion of MSW with waste heat recovery for steam generation.	
Startup Schedule	Initial startup	1953
	Full operation	Fall 1965
Operating Schedule	MSW receiving	8 hr/day, 6 day/wk
	MSW processing	24 hr/day, 6 day/wk
	Maintenance	
Manpower	Full time	100
	Per shift	20
MSW Processing	Design capacity	1000 ton/day
	Actual capacity	1000 ton/day
	Current throughput	500 ton/day
	Total to date	
	Total 1979	115,000 tons
Combustion System	Number of units	Four
	Manufacturer	Combustion Engineering
	Type	Refractory lined furnaces with chain grates
	Capacity, Design per unit	250 ton/day
	Actual	250 ton/day
	Grate type	Illinois rolling grates, newly installed
	MSW storage and feed	800-ton pit; overhead crane; gravity feed
	Ash removal	Water trough and drag conveyors
	Emissions control	Electrostatic precipitators
	Supplemental fuel	No. 6 fuel oil, in auxiliary boiler

Table 5-2. (continued)

	Residue (% of input)	25 to 30, by weight			
Energy Recovery System	System type	Two waste heat recovery boilers			
	Condensate return	Yes			
	Steam production	lb/hr	lb/in. ² g	°F	
	Design	75,000/boiler	125	saturated	
	Actual	≅35,000 (total)	125	saturated	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Onsite, for heating and processes			20 M lb/mo, 6 mo/yr (winter)	
Other Products					
Emissions Data	Test Date	Type	Results	Standard	
	NA				
Capital Costs	Year	Cost	Item		
	1953	\$ 7.0 M	Initial plant capital cost		
	1957	\$ 2.0 M	Additional modifications		
	1965	\$ 5.0 M	Waste heat recovery system		
	1979	\$18.0 M	Electrostatic precipitators, roll- ing grates, furnace modifications		
Other Costs	Operating	NA			
	Tipping fee	\$5.15/yd ³			

Table 5-3. Data sheet for Braintree Thermal Waste Reduction Center

Description	Waterwall combustion of MSW to generate steam	
Startup Schedule	Initial startup	
	Full operation	March 1971
Operating Schedule	MSW receiving	
	MSW processing	24 hr/day, 7 day/wk
	Maintenance	
Manpower	Full time	NA
	Per shift	
MSW Processing	Design capacity	240 ton/day
	Actual capacity	384 ton/day
	Current throughput	250 ton/day
	Total to date	NA
	Total 1979	
Combustion System	Number of units	Two
	Manufacturer	NA
	Type	Waterwall furnace with economizer
	Capacity per unit	Design Actual
		120 ton/day 192 ton/day
	Grate type	Riley traveling grate
	MSW storage and feed	Pit; grapple feeder to hoppers
	Ash removal	
	Emissions control	Electrostatic precipitators
	Supplemental fuel	
	Residue (% of input)	

Table 5-3. (continued)

Energy Recovery System	System type	Waterwall with economizer		
	Condensate return	Yes, 100%		
	Steam production	lb/hr	lb/in. ² g	°F
	Design	60,000	250	400
	Actual	40,000	250	400

Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Weymouth Art & Leather Co.			20,000	

Other Products

Emissions Data	Test Date	Type	Results	Standard
	August 1978	Particulates	Within standard	0.10 gr/dsft ³

Capital Costs	Year	Cost	Item
	1971	\$2.85 M	Initial plant capital cost
	1977	\$0.5 M	Modifications to electrostatic precipitators and furnace

Other Costs	Operating	NA
	Tipping fee	NA

Economics. Capital cost of the original facility in 1971 totaled \$2.85 M. Modifications installed in 1977 to meet emissions standards cost approximately \$500,000.

Present Status. The plant is operating and processes 250 ton/day, 24 hr/day, 7 day/wk, generating roughly 40,000 lb/hr of steam. Sales to Weymouth Art & Leather average 20,000 lb/hr. The unsold portion is condensed.

Chicago, Illinois (NW)

Background

Name—Chicago Northwest Waste-to-Energy Facility

Process—Combustion of unprocessed MSW in four waterwall incinerators for steam production

Owner—City of Chicago, Illinois

Operator—City of Chicago, Illinois

Designer—Metcalf and Eddy, Inc.

Energy User—From 20 to 25% is used onsite and in an adjacent City garage to drive turbines and produce hot water. Approximately 33% of steam production will be used by the Brach Candy Co. in late 1980.

History. This facility, which became fully operational in January 1971, is the largest mass-burning thermal-processing plant in North America. It has been in continuous operation since its startup in September 1970.

System Description. A system data sheet is presented as Table 5-4. The facility has a design capacity of 1600 ton/day using utilizing four 400-ton/day Martin reverse reciprocating grate furnaces. Waste from a 10,000-yd³ pit is charged into hoppers by three overhead cranes. Residence time in the furnace is estimated to be 40 min. Three of the four units are operated at one time to allow for maintenance, and each has a normal continuous steam capacity of 110,000 lb/hr. Electrostatic precipitators control particulate emissions to within existing federal standards.

Economics. Total capital costs for the facility in 1970 are reported to have been \$23 M. Current operating costs are \$18/ton, gross (operation and maintenance). No tipping fee is charged. The City had received \$1.7 M from DOE oil entitlements as of April 1980.

Scalping of the residue for ferrous metals has been done intermittently although no permanent market exists.

Present Status. The facility is operating and processes approximately 1200 ton/day. Construction of a new steam line was recently completed to supply process steam to Brach Candy Co. under a long-term contract.

Future Plans. Steam deliveries to Brach Candy are expected to begin in the first quarter of 1981. Approximately one-third of the plant's steam output will be used by Brach.

Hampton, Virginia

Background

Name—NASA-Hampton Refuse-Fired Steam Generating Facility

Process—Combustion of unprocessed waste to produce steam for the NASA-Langley Research Center

Owner—City of Hampton, Virginia, and NASA

Operator—City of Hampton, Virginia

Designer—NASA and J. M. Kenith Co.

Energy User—NASA-Langley Research Center

History. The project was developed as a joint venture between the City of Hampton and NASA, and is intended to demonstrate the feasibility of using 200 ton/day of MSW to generate energy, thereby saving fuel oil and reducing landfill requirements. Seventy percent of the capital cost was funded by Hampton and 30% by the federal government. Initial plant startup took place in the summer of 1980. Approximately 175 ton/day of MSW is expected from the City, and 25 ton/day from various federal installations.

System Description. A system data sheet is presented as Table 5-5. MSW with bulky items removed is charged into hoppers by an overhead bridge crane, which feeds two 100-ton/day Keeler waterwall furnaces with Detroit Stoker reciprocating grates. The unit is equipped with an economizer section as well as electrostatic precipitators. Bottom ash is discharged into a water-filled trough with chain conveyors for ash removal.

Since the system only recently began operations, little operational or test data are available.

Economics. Total capital cost to date for the plant is \$10.4 M. Tipping fees will initially be set at \$4.70/ton. The Langley Research Center will purchase steam at \$5.22/1000 lb.

Present Status. The plant was declared fully operational on November 1, 1980, although the quantities of waste through the facility continue to be variable on a daily basis. Actual maximum capacity is reported to be 230 ton/day. Operations are expected to be 24 hr/day, 7 day/wk.

Table 5-4. Data sheet for Chicago Northwest Waste-to-Energy Facility

Description	Waterwall combustion of MSW to generate steam	
Startup Schedule	Initial startup	September 1970
	Full operation	January 1971
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	24 hr/day, 7 day/wk
	Maintenance	
Manpower	Full time	77
	Per shift	
MSW Processing	Design capacity	1600 ton/day
	Actual capacity	1600 ton/day
	Current	1200 ton/day
	throughput	(3 to 4 units)
	Total to date	3.014 M tons (12/79)
	Total 1979	298,184 tons
Combustion System	Number of units	Four
	Manufacturer	Martin/U.O.P.
	Type	Waterwall
	Capacity } Design	400 ton/day
	per unit } Actual	400 ton/day
	Grate type	Martin reverse reciprocating
	MSW storage and feed	2800-ton pit; three overhead cranes; ram feeders
	Ash removal	Water trough; drag conveyor
	Emissions control	Electrostatic precipitators
	Supplemental fuel	Natural gas (ignition only)
	Residue (% of input)	28, avg. by weight

Table 5-4. (continued)

Energy Recovery System	System type	Waterwall			
	Condensate return	In-house: yes; Brach Candy: no (1981)			
	Steam production	lb/hr	lb/in. ² _g	°F	
	Design	135,000/unit	275	414	
	Actual	110,000	275	414	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Onsite use: turbine drives, heating and cooling			60,000 to 90,000	
	Brach Candy Co.	Start 1981	≅ 110,000		
Other Products	Ferrous metals recovery from ash, intermittent				
Emissions Data	Test Date	Type	Results	Standard	
		Particulates	0.05 gr/dsft ³	0.08 gr/dsft ³	
Capital Costs	Year	Cost	Item		
	1970	\$23 M	Total plant capital cost		
Other Costs	Operating	\$18/ton, gross (operation and maintenance only)			
	Tipping fee	None			

Table 5-5. Data Sheet for NASA/Hampton Refuse-Fired Steam Generating Facility

Description	Waterwall combustion of MSW to generate steam	
Startup Schedule	Initial startup	July 1980
	Full operation	November 1980
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	24 hr/day, 7 day/wk
	Maintenance	8 hr/day, 5 day/wk
Manpower	Full time	27
	Per shift	5
MSW Processing	Design capacity	200 ton/day
	Actual capacity	200 ton/day
	Current throughput	Limited quantities
	Total to date	
	Total 1979	0
Combustion System	Number of units	Two
	Manufacturer	E. Keeler Co.
	Type	Waterwall with economizer
	Capacity per unit	Design Actual
		100 ton/day 115 ton/day
	Grate type	Detroit stoker, reciprocating
	MSW storage and feed	700-ton pit; overhead crane to hoppers
	Ash removal	Water trough with chain conveyors
	Emissions control	Electrostatic precipitators
	Supplemental fuel	None
	Residue (% of input)	10 to 15 (by volume, estimated)

Table 5-5. (continued)

Energy Recovery System	System type	Waterwall with economizer			
	Condensate return	Yes, 100%			
	<u>Steam production</u>	<u>lb/hr</u>	<u>lb/in.²g</u>	<u>°F</u>	
	Design	33,000/unit	400	saturated	
	Actual	33,000/unit	400	saturated	
Steam Delivery	<u>Customer</u>	<u>Contract Period</u>	<u>Contract Quantity, lb/hr</u>	<u>Quantity Delivered, lb/hr</u>	<u>Price</u>
	NASA/Langley Research Center			55,000 (estimated)	\$5.22/1000 lb
Other Products					
Emissions Data	<u>Test Date</u>	<u>Type</u>	<u>Results</u>	<u>Standard</u>	
		Particulates	Design: 0.05 gr/dsft ³	0.08 gr/dsft ³	
Capital Costs	<u>Year</u>	<u>Cost</u>	<u>Item</u>		
	1980	\$10.4 M	Total facility capital cost		
Other Costs	Operating	NA			
	Tipping fee	\$4.70/ton			

Future Plans. Performance and operational data will be developed now that the system is fully operational.

Harrisburg, Pennsylvania

Background

Name—Harrisburg Steam Generating Facility

Process—Codisposal of unprocessed MSW and sewage sludge in a waterwall furnace to generate steam

Owner—City of Harrisburg, Pennsylvania

Operator—City of Harrisburg, Pennsylvania

Designer—Gannett, Fleming, Corrdry and Carpenter, Inc.

Energy User—Steam is used in-plant for sludge drying, bulky waste shredding, and heating buildings, and is sold to Pennsylvania Power and Light for district heating

History. The date of initial startup was October 1972, and the plant has been operational

since March 1973. To date, only MSW has been processed. Startup and testing of the sewage sludge drying and feed system began in late summer 1980.

System Description. A system data sheet is presented as Table 5-6. Each of the two Martin waterwall units has a design capacity of 15 ton/hr.

The plant is operated 24 hr/day, 7 day/wk. Overhead cranes with grapples feed the furnaces. The residence time on the Martin reverse reciprocating grates is 30 min. Ash content varies from 30 to 35% by weight. Approximately 150,000 lb/hr of steam is produced at 525°F and 260 lb/in.²g. Both units are equipped with electrostatic precipitators. During initial operation of the

Table 5-6. Data sheet for Harrisburg Steam Generating Facility

Description	Cocombustion of MSW and sewage sludge to generate steam	
Startup Schedule	Initial startup	October 1972 (sludge system, late 1980)
	Full operation	March 1973
Operating Schedule	MSW receiving	8 hr/day, 5 days/wk
	MSW processing	24 hr/day, 7 days/wk
	Maintenance	
Manpower	Full time Per shift	65
MSW Processing	Design capacity	720 ton/day
	Actual capacity	720 ton/day
	Current throughput	550 ton/day
	Total to date	980,000 tons (9/80)
	Total 1979	142,000 tons
Combustion System	Number of units	Two
	Manufacturer	Martin/U.O.P.
	Type	Waterwall
	Capacity per unit, design	15 ton/hr; 360 ton/day
	Capacity per unit, actual	15 ton/hr; 360 ton/day
	Grate type	Martin reverse reciprocating
	MSW storage and feed	5000-yd ³ pit; overhead crane to feed hopper
	Ash removal	Water trough; belt conveyor

Table 5-6. (continued)

	Emissions control	Electrostatic precipitators			
	Supplemental fuel	None			
	Residue (% of input)	30 to 35 (by weight)			
Energy Recovery System	System type	Waterwall			
	Condensate return	No			
	Steam production	lb/hr	lb/in. ² _g	°F	
	Design	180,000	260	525	
	Actual	180,000	260	525	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Pennsylvania Power & Light			186 M lb (1/80 to 8/80)	≅ \$4.11/1000 lb
Other Products	Ferrous metals, approximately 15 ton/day				
Emissions Data	Test Date	Type	Results	Standard	
	April 1978	Particulates	0.08 gr/dsft ³	0.10 gr/dsft ³	
	June 1980	Particulates	0.09 gr/dsft ³	0.10 gr/dsft ³	
Capital Costs	Year	Cost	Item		
	1968	\$8.3 M	Initial plant capital cost		
	1977	\$3.4 M	New steam line		
	1976	\$4.4 M	New sludge processing system		
Other Costs	Operating	\$14.00 to \$14.50/ton gross (operation and maintenance, amortization)			
	Tipping fee	\$10.80 to \$12.80 (depending on source)			

plant, several sections of superheater tubing were replaced because of excessive sootblowing. A change in operations and tube material to T22 has eliminated the problem. Emissions testing in April 1978 showed particulate loadings to be within the state limit of 0.10 gr/dsft³.

Economics. Initial capital cost of the incinerator in 1968 was \$8.3 M. The new steam main installed in 1977 cost \$3.4 M. Total expenditures through 1979 after modifications were \$19.3 M. Gross operating costs are reported to be \$14.50/ton (average for 1979, includes amortization of capital), and a \$10.80 to \$12.80/ton tipping fee is assessed, depending on the source. As of June 1980, \$1 M of DOE entitlements had been received.

Present Status. The plant is operating 7 day/wk, processing roughly 550 ton/day of MSW. A portable screen was set up at the ash pile located adjacent to the plant to screen the ash for recovery of salable ferrous materials. The sewage sludge drying system, 75% funded by EPA, is in the startup phase and should be operating by late 1980. It will produce 35 ton/day of sludge (at 15% moisture) for codisposal in the incinerator.

Future Plans. The City will attempt to increase MSW deliveries to meet the full capacity of 720 ton/day.

Nashville, Tennessee

Background

Name—Nashville Thermal Transfer Corporation

Process—Combustion of unprocessed MSW in waterwall incinerators to produce steam for district heating and cooling

Owner—Nashville Thermal Transfer Corp.

Operator—Nashville Thermal Transfer Corp.

Designer—I. C. Thomasson Associates, Nashville, Tennessee

Energy User—29 local private and public facilities, including the state capital

System Manufacturer—Babcock & Wilcox—boiler; Detroit Stoker Co.—grate system

History. Nashville Thermal Transfer is a nonprofit corporation established by the City in 1970 to provide district heating and cooling for various government and private buildings. They have the authority to issue bonds, and are responsible for operating and maintaining the incinerator facility. The plant began initial operations in June 1974 and was fully operational in October 1974. It has provided six years of continuing service since that time.

System Description. A system data sheet is presented as Table 5-7. The facility has two waterwall incinerators with reciprocating grate stokers, and each was originally rated at 360 ton/day. Recent modifications have increased the rated capacity to 530 ton/day per unit. The present design output is 250,000 lb/hr of steam total at 400 lb/in.²g and 600°F. Steam is used to drive turbines for pumps and two compressors for production of 14,000 tons of chilled water. The reduced-pressure steam at 150 lb/in.²g and 365°F enters the steam distribution system to provide district heating.

Waste from the storage pit is loaded by an overhead crane into feed hoppers, where hydraulic rams charge waste onto a series of four reciprocating grates. Ash residue is water-quenched and loaded into trucks for disposal as landfill. Residue is estimated to be 22% by weight of incoming waste. Combustion gases from the furnace pass through a dust collector and four-field electrostatic precipitators for particulate removal. Emissions are reported to be 0.01 gr/dsft³ (corrected to 12% CO₂), well below the 0.08 standard.

Initially, several problems plagued the system. The low-energy scrubbers failed to limit emissions of particulates to within allowable levels and were replaced with two electrostatic precipitators in 1976 and 1977. Severe tube wastage due to corrosion in several waterwall and superheater sections has necessitated regular replacement of tubes. In addition, silicon carbide refractory was added to protect the lower waterwall tubes, and overfire air was increased and underfire air rezoned. Hydraulic ram MSW feeders were added in 1979 to replace the original gravity feed system.

Economics. The facility cost in 1974, including engineering, financing, and other expenses, was \$12.5 M. Construction of the new steam distribution system totaled \$4 M. Modifications in

Table 5-7. Data sheet for Nashville Thermal Transfer Corp.

Description	Waterwall combustion of MSW to generate steam	
Startup Schedule	Initial startup	June 1974
	Full operation	October 1974
Operating Schedule	MSW receiving	8 hr/day, 4 day/wk
	MSW processing	24 hr/day, 7 day/wk, 365 day/yr
	Maintenance	Day shift
Manpower	Full time	37
	Per shift	4
MSW Processing	Design capacity	720 ton/day (original design)
	Actual capacity	1060 ton/day (present configuration)
	Current throughput	400 ton/day
	Total to date	> 700,000 tons
	Total 1979	134,000 tons
Combustion System	Number of units	Two
	Manufacturer	Babcock & Wilcox
	Type	Waterwall, with superheater and economizer
	Capacity per unit, design	360 ton/day (original system)
	Capacity per unit, actual	530 ton/day (modified system)
	Grate type	Detroit reciprocating
	MSW storage and feed	Pit; overhead crane; hoppers; hydraulic rams
	Ash removal	Water quench; siftings removal system
	Emissions control	Four-field elec- trostatic precipitators

Table 5-7. (continued)

	Supplemental fuel	No. 2 fuel oil; natural gas			
	Residue (% of input)	22, by weight; 10, by volume			
Energy Recovery System	System type	Waterwall, superheater, economizer			
	Condensate return	Yes			
	Steam production	lb/hr	lb/in. ² g	°F	
	Design	109,000/unit	400	600	
	Actual	125,000/unit	400	600	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	District heating & cooling loop	30 years		100,000	\$6.00/1000 lb
Other Products	Chilled water: 14,000 tons at 41°F (\$0.08/ton-hr)				
Emissions Data	Test Date	Type	Results	Standard	
		Particulates	0.0068 to 0.0103 gr/dsft ³	0.08 gr/dsft ³	
Capital Costs	Year	Cost	Item		
	1974	\$12.5 M	Total plant cost		
	1974	\$4.0 M	Steam distribution system		
	1976	\$8.0 M	Installation of electrostatic precipitators; boiler modifica- tions		
Other Costs	Operating	\$17.70/ton, gross (operation and maintenance only; 1979)			
	Tipping fee	\$9.00/ton (1979)			

1976-77, including installation of the electrostatic precipitators, cost \$8 M. Operating costs in 1979 were reported to be \$17.70/ton (operation and maintenance), with a \$9/ton tipping fee. Steam sale revenues presently average \$0.08/ton/hr.

Present Status. The plant is fully operational, processing 400 ton/day, 7 day/wk. Total output of steam is roughly 100,000 lb/hr. MSW routinely provides greater than 90% of the total fuel input, but a backup oil and natural gas steam generator is available for standby service should the incinerators be inoperable.

Norfolk, Virginia (Naval Station)

Background

Name—Salvage Fuel Boiler Plant, Norfolk, Virginia

Process—Combustion of unprocessed MSW in a waterwall furnace to produce steam

Owner—U.S. Navy Public Works Center, Norfolk, Virginia

Operator—U.S. Navy Public Works Center, Norfolk, Virginia

Designer—Metcalf and Eddy, Inc.

Energy User—Naval Station, for onsite use

History. Fully operational in May 1967, the facility employed the first waterwall incinerator in the U.S. It has undergone numerous modifications since that time.

System Description. A system data sheet is presented as Table 5-8. The plant contains two Foster Wheeler waterwall furnaces, each having a capacity of 180 ton/day. Clamshell buckets pick the refuse and feed the furnaces. Residence time on the Detroit reciprocating stokers is about 30 min, with the average furnace temperature being 1400°F. Approximately 20% by weight of the input is discharged as residue. Forty thousand lb/hr of saturated steam at 225 lb/in.²g is produced. Some problems with excessive grate wear have been reported, and several tube sections required replacement in 1978. The furnaces are equipped with electrostatic precipitators.

Modifications to the precipitators to meet state standards for particulates appear to have been successful.

Economics. Original plant costs, not including land, were \$2.2 M in 1967. The plant's gross operating cost in 1978 was \$29.63/ton (operations and maintenance only).

Since 1968, an additional \$2.12 M have been invested in electrostatic precipitators (\$1 M), an automatic sifting removal system (\$0.12 M), a shredding and ferrous materials recovery facility (\$0.8 M), and retubing (\$0.2 M).

Present Status. The plant is currently processing 140 ton/day on one unit, 7 day/wk. It has been operating regularly since its initial startup.

Oceanside, New York

Background

Name—Oceanside Disposal Plant

Process—Combustion of unprocessed MSW in two waterwall furnaces to generate steam and electricity

Owner—Town of Hempstead, New York

Operator—Town of Hempstead, New York

Energy User—Onsite generation of electricity and steam for saltwater conversion processes

History. In 1965, three refractory-lined incinerators with a combined capacity of 750 ton/day began operations at Oceanside. Two of the units, each rated at 300 ton/day, were equipped with waste heat boilers and wetted-cyclone mechanical dust collectors for particulate emissions control. Shortly after startup, the boilers began to experience severe, rapid tube wastage and failures. In 1970, one of the 300-ton/day units underwent modifications that included installation of an electrostatic precipitator to meet the latest emissions standard. The refractory furnace was replaced with silicon-carbide-coated waterwall tubes, and the convection section was enlarged to reduce gas velocities by one-half. Heat transfer surface was increased 50%. These modifications, completed in 1974, essentially eliminated the earlier problems of

Table 5-8. Data sheet for Navy Salvage Fuel Boiler Plant, Norfolk, Virginia

Description	Waterwall combustion of MSW to generate steam	
Startup Schedule	Initial startup	January 1967
	Full operation	May 1967
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	24 hr/day, 7 day/wk
	Maintenance	
Manpower	Full time	21
	Per shift	5
MSW Processing	Design capacity	360 ton/day
	Actual capacity	360 ton/day
	Current throughput	140 ton/day
	Total to date	
	Total 1979	
Combustion System	Number of units	Two
	Manufacturer	Foster Wheeler
	Type	Waterwall furnace
	Capacity Design per unit	180 ton/day
	Actual	140 ton/day (one unit operated per week)
	Grate type	Detroit reciprocating stoker
	MSW storage and feed	700-ton pit; clam-shell buckets to feed hoppers
	Ash removal	Water trough; drag conveyor
	Emissions control	Electrostatic precipitators
	Supplemental fuel	No. 6 fuel oil
	Residue (% of input)	.20

Table 5-8. (continued)

Energy Recovery System	System type	Waterwall			
	Condensate return	No			
	Steam production	lb/hr	lb/in. ² g	°F	
	Design	50,000/unit	275	Saturated	
	Actual	40,000/unit	275	Saturated	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Naval station			40,000	
Other Products					
Emissions Data	Test Date	Type	Results	Standard	
		Particulates	0.052 gr/dsft ³	0.14 gr/dsft ³	
Capital Costs	Year	Cost	Item		
	1967	\$2.2 M	Initial plant cost		
	1968	\$0.12 M	Automatic siftings removal system		
	1975	\$1.0 M	Electrostatic precipitators		
	1975	\$0.8 M	Shredder (not operating)		
	1979	\$0.2 M	Modifications to electrostatic precipitators		
Other Costs	Operating	\$29.63/ton, gross (operation and maintenance only)			
	Tipping fee	NA			

wastage, slagging, and high emissions. Accordingly, the second 300-ton/day unit was modified in 1977. An electrostatic precipitator was also added to the 150-ton/day unit, but no heat recovery. The facility has been operational since that time.

System Description. A system data sheet is presented as Table 5-9. Unprocessed waste is fed into charging hoppers with overhead cranes for

continuous gravity feed into the furnaces. Combustion takes place on a series of Flynn & Emrick rocking stoker grates. A siftings conveyor removes material to the residue conveyors, where the remaining grate ash is removed for disposal as landfill.

One hundred thousand lb/hr of steam at 500 lb/in.²g and saturation temperature are generated in each unit. Two 1250-kW turbine

Table 5-9. Data sheet for Oceanside Disposal Plant

Description	Waterwall combustion of MSW to generate steam and electricity	
Startup Schedule	Initial startup Full operation	1965 ^a 1974 and 1977 ^b
Operating Schedule	MSW receiving MSW processing Maintenance	 24 hr/day, 7 day/wk
Manpower	Full time Per shift	100 12
MSW Processing	Design capacity Actual capacity Current throughput Total to date Total 1979	750 ton/day 750 ton/day 450 ton/day 2.025 M tons (7/80) 135,000 tons
Combustion System	Number of units Manufacturer Type Capacity Design per unit } Actual Grate type MSW storage and feed Ash removal	Two (with energy recovery) Erie Welded waterwall 300 ton/day 225 ton/day, avg. Flynn & Emrich; continuous rocker type Pit; overhead crane grapple to hoppers Undergrate ash conveyor

Table 5-9. (continued)

	Emissions control	Two-field electrostatic precipitator			
	Supplemental fuel				
	Residue (% of input)	21			
Energy Recovery System	System type	Waterwall			
	Condensate return	Yes, from onsite processes			
	Steam production	lb/hr	lb/in. ² g	°F	
	Design	100,000/unit	500	467	
	Actual	60,000	500	saturated	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Onsite use by two 1250-kW turbine-generators			\$35,000 lb/hr each	
Other Products	Fresh water, from saltwater conversion units				
Emissions Data	Test Date	Type	Results	Standard	
	March 1975	Particulates	0.045 gr/dsft ³	0.08 gr/dsft ³	
	June 1977	Particulates	0.03 gr/dsft ³	0.08 gr/dsft ³	
Capital Costs	Year	Cost	Item		
	1965	\$5.7 M	Plant cost		
	1965	\$2.3 M	Site work		
	1972-79	\$9.8 M	Modifications: electrostatic precipitators, two waterwall furnaces, other plant improvements		
Other Costs	Operating	NA			
	Tipping fee	\$15.50/ton			

a. Original design included three refractory incinerators of 300-, 300-, and 150-ton/day capacity.

b. Waterwall furnaces installed in the two 300-ton/day incinerators.

generators use 35,000 lb/hr each, and provide all plant lighting, heat, and power. Saltwater conversion units condense the steam before return to the boilers and produce fresh water for various plant processes. A sodium hypochlorite generation system is included to retard mussel growth in the desalination units and douse the fly ash lagoons where coliform counts were high.

Economics. The initial plant cost was \$5.7 M in 1965, plus \$2.3 M for site work. Capital investment for the modifications in 1974 and 1977 totaled \$9.8 M. The tipping fee is currently \$15.50/ton.

Present Status. The plant is operational, processing 450 ton/day, 7 day/wk. Steam generation is roughly 60,000 lb/hr for each unit. Emissions are well within state and federal standards.

Portsmouth, Virginia (Naval Shipyard)

Background

Name—Norfolk Naval Shipyard Refuse Boiler, Portsmouth, Virginia

Process—Combustion of unprocessed MSW in two waterwall incinerators to produce steam

Owner—Norfolk Naval Shipyard, U.S. Navy

Operator—Public Works Department, Norfolk Naval Shipyard

Designer—Day & Zimmerman, Inc.

Energy User—Naval Shipyard for onsite use in hotel service and industrial steam for dockside ships

History. The date of initial startup was January 1977, and the plant was fully operational in August 1977.

System Description. A system data sheet is presented as Table 5-10. Shipyard wastes and some MSW from the City of Norfolk is fed to two Keeler water-tube boilers having a capacity of 80 ton/day each. They are equipped with Detroit reciprocating grates. Residue averages 10% by weight, with a combustion efficiency of 68%. The

two units are operated on alternate weeks to allow for maintenance. Steam is produced at the rate of 30,000 lb/hr at 350°F and 200 lb/in.²g.

Occasional problems with breakdowns of the single loading crane have resulted in downtime or use of No. 6 fuel oil to maintain load. The plant is also having difficulty meeting the state standard of 0.08 gr/dsft³ for particulate emissions.

Economics. Total capital costs are reported to be \$4.3 M. A \$3.54/ton tipping fee is assessed.

Present Status. The plant is currently processing an average of 70 ton/day, 5 day/wk. Corrective measures are underway to reduce emissions to within acceptable levels.

Future Plans. Additional quantities of waste are being sought to increase to full capacity.

Saugus, Massachusetts

Background

Name—Refuse Energy Systems Co. (RESCO) Boston North Shore Project

Process—Combustion of unprocessed MSW in two waterwall furnaces to generate high-temperature and high-pressure steam

Owner—Wheelabrator-Frye; De Matteo Construction Co.

Operator—RESCO

System Manufacturer—Wheelabrator-Frye; Von Roll, Ltd.

Energy User—General Electric Co. (GE), Lynn Massachusetts

History. In response to a serious landfill problem in the early 1970's, De Matteo and Wheelabrator-Frye formed RESCO in 1973 to construct a waste-to-energy system for the production of steam for sale to a nearby GE manufacturing facility. Financing was through tax-exempt industrial development bonds issued by the Town of Saugus and backed by revenues from the facility. A 14.5-yr contract was signed with GE for the purchase of steam on a noninterruptible basis. Construction began in 1973, initial

Table 5-10. Data sheet for Norfolk Naval Shipyard Refuse Boiler, Portsmouth, Virginia

Description	Waterwall combustion of MSW to generate steam	
Startup Schedule	Initial startup	January 1977
	Full operation	August 1977
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	24 hr/day, 5 day/wk
	Maintenance	16 hr/day
Manpower	Full time	20
	Per shift	6 to 8
MSW Processing	Design capacity	160 ton/day
	Actual capacity	160 ton/day
	Current throughput	70 ton/day
	Total to date	35,000 tons
	Total 1979	20,800 tons
Combustion System	Number of units	Two
	Manufacturer	E. Keeler Co.
	Type	Waterwall
	Capacity } Design	80 ton/hr
	per unit } Actual	70 ton/hr (alternating weeks)
	Grate type	Detroit stoker reciprocating
	MSW storage and feed	Pit; overhead crane grapple
	Ash removal	Quench trough; drag conveyor
	Emissions control	Electrostatic precipitators
	Supplemental fuel	No. 2 fuel oil (backup fuel)
	Residue (% of input)	10

Table 5-10. (continued)

Energy Recovery System	System type	Waterwall			
	Condensate return				
	<u>Steam production</u>	<u>lb/hr</u>	<u>lb/in.²g</u>	<u>°F</u>	
	Design	30,000/unit	125	350	
	Actual	30,000/unit	200	350	
Steam Delivery	<u>Customer</u>	<u>Contract Period</u>	<u>Contract Quantity, lb/hr</u>	<u>Quantity Delivered, lb/hr</u>	<u>Price</u>
	Naval Shipyard: onsite use for hotel service and shipside processes		30,000		
Other Products					
Emissions Data	<u>Test Date</u>	<u>Type</u>	<u>Results</u>	<u>Standard</u>	
	NA	Particulates	Out of compliance	0.08 gr/dsft ³	
Capital Costs	<u>Year</u>	<u>Cost</u>	<u>Item</u>		
	1977	\$4.3 M	Total facility capital cost		
Other Costs	Operating	NA			
	Tipping fee	\$3.54/ton for city of Norfolk MSW			

startup was September 1975, and the first deliveries of steam were in November 1975. The facility has operated continuously since that time.

System Description. A system data sheet is presented as Table 5-11. The system uses two Von Roll/Wheelabrator-Frye waterwall furnaces with reciprocating grates. Each has a design capacity of 750 ton/day and can generate 185,000 lb/hr steam at 675 lb/in.²g and 875°F. Total system capacity averages 1200 ton/day.

Waste from a 6000-ton storage pit is fed by overhead cranes into two gravity-feed furnace hoppers. Two auxiliary oil-fired boilers onsite allow the plant to supply the minimum required steam flow to GE should the incinerators be inoperable. On an annual basis, municipal waste supplies more than 95% of all available heat input into the system for the generation of steam.

Bottom ash and fly ash are combined, water-quenched, and processed through two single-stage

Table 5-11. Data sheet for Resco-Boston North Short Project

Description	Waterwall combustion to generate steam; ferrous metal recovery	
Startup Schedule	Initial startup	September 1975
	Full operation	December 1975
Operating Schedule	MSW receiving	8 hr/day, 5-1/2 day/wk
	MSW processing	24 hr/day, 7 day/wk
	Maintenance	Continuous
Manpower	Full time	55
	Per shift	9 to 20
MSW Processing	Design capacity	1500 ton/day
	Actual capacity	1200 ton/day
	Current throughput	1200 ton/day
	Total to date	1.6 M tons(6/80)
	Total 1979	
Combustion System	Number of units	Two
	Manufacturer	Von Roll/ Wheelabrator-Frye
	Type	Waterwall furnace, with superheater and economizer
	Capacity-Design per unit } Actual	750 ton/day 600 ton/day
	Grate type	Von Roll inclined, reciprocating grates
	MSW storage and feed	6000-ton pit; overhead crane to feed hopper
	Ash removal	Water quenched; trommel (3-in.); ferrous separator
	Emissions control	Two-field electrostatic precipitators

Table 5-11. (continued)

	Supplemental fuel	Fuel oil (100% standby capacity)			
	Residue (% of input)	15 to 20			
Energy Recovery System	System type	Waterwall, superheater, economizer			
	Condensate return				
	Steam production	lb/hr	lb/in. ² g	°F	
	Design	185,000/unit	.675	875	
	Actual	125,000 to 150,000/unit	625	725 to 825	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	General Electric	14.5 years	≅ 228,000, noninter-ruptible (2 billion lb/yr)		
Other Products	Ferrous scrap:	60 to 90 ton/day			
Emissions Data	Test Date	Type	Results	Standard	
	Spring 1980	Particulates	0.025 gr/dsft ³	0.05 gr/dsft ³	
Capital Costs	Year	Cost	Item		
	1975	\$38.3 M	Total initial capital cost		
	1975-80	\$14 M	Additional capital expenses for modifications		
Other Costs	Operating	NA			
	Tipping fee	\$15.47/ton for municipalities			

trommels and a magnet for recovery of ferrous metals. Particulate emissions are reported to be well within the state standard.

A utility bridge was constructed across the Saugus River to link the plant with GE and to transport steam, condensate, and electricity.

Initially, a shredder was installed at the plant to shred bulky waste. Because of high operating and maintenance costs, however, its use was discontinued after a fire in 1976. Shortly after startup, the superheater section began to corrode and was replaced with a new section having a modified configuration and using a special alloy. A special mechanical rapping device removes ash from the boiler tubes. No additional corrosion problems have been reported. Modifications to the furnace air flow distribution system and boiler convection sections were completed to improve efficiency and increase system availability.

Economics. Total capital costs, including land, financing, and startup, were \$38.3 M in 1975. Since that time, additional modifications and expenses have totaled roughly \$14 M. Total capital investment to date is \$53 M. The present tipping fee at the plant is \$15.47/ton for municipalities. No data on operating costs are available.

Present Status. The plant is fully operational, processing approximately 1200 ton/day, 7 day/wk. Steam is delivered to GE 24 hr/day and averages 225,000 to 250,000 lb/hr. The steam is used to generate electricity and to test turbines and other process machinery. Low-pressure extraction steam is returned to RESCO for drive turbines and feedwater heating. GE also supplies all electrical power to RESCO. Roughly 60 to 90 ton/day of ferrous scrap is sold to a local dealer.

Waukesha, Wisconsin

Background

Name—Waukesha Municipal Incinerator

Process—Combustion of unprocessed MSW in two refractory incinerators with heat recovery for steam generation

Owner—City of Waukesha, Wisconsin

Operator—City of Waukesha, Wisconsin

Designer—Danohue & Assoc.—incinerator; Sanders & Thomas—heat recovery system

Energy User—10% onsite, 40% to a local industry, and 50% to a new sewage treatment plant

System Manufacturer—Affiliated Incinerator Corp., Detroit Stoker

History. The facility began operations in May 1971 using two refractory wall furnaces with wet scrubbers rated at 175 ton/day each. No heat recovery was included. In 1979, a waste heat recovery boiler and electrostatic precipitator were installed common to both furnaces. The electrostatic precipitator replaced the wet scrubber for particulate emissions control.

System Description. A system data sheet is presented as Table 5-12. Waste from the refuse pit is fed to each furnace by an overhead crane, which charges a gravity-feed hopper to the furnace. A series of Detroit Stoker reciprocating grates moves the material through the furnace, after which ash is deposited in a water trough and removed by a drag chain conveyor.

Due to limitations in the capacity of the waste heat boiler and the electrostatic precipitator, only one furnace is operated 24 hr/day, 5 day/wk, with the other unit on standby.

Economics. The original facility was constructed in 1971 at a cost \$1.7 M. The total cost of installing the waste heat boiler and the electrostatic precipitator in 1979 was \$3.9 M. No operating costs are available.

Present Status. The facility is operational, processing 120 ton/day, 5 day/wk. Steam is currently being sold to a local industry. Construction of the new sewage treatment plant is scheduled for completion in July 1981. Steam to the new plant will drive a 1000-kW turbine generator as well as provide heat for the buildings and digestors.

Crossville, Tennessee

Background

Name—Environmental Services Corporation, Crossville, Tennessee

Table 5-12. Data sheet for Waukesha Municipal Incinerator

Description		Combustion of MSW in refractory furnaces with a waste-heat boiler
Startup Schedule	Initial startup	May 1971 (initial system)
	Full operation	1979 (steam generation system)
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	24 hr/day, 5 day/wk
	Maintenance	
Manpower	Full time	13
	Per shift	3 to 7
MSW Processing	Design capacity	350 ton/day (no heat recovery)
	Actual capacity	175 ton/day (with heat recovery)
	Current throughput	120 ton/day
	Total to date	NA
Total 1979		
Combustion System	Number of units	Two furnaces, one waste-heat boiler
	Manufacturer	Affiliated Incinerator
	Type	Refractory-lined furnaces
	Capacity per unit, design	175 ton/day/furnace; 350 ton/day, total system
	Capacity per unit, actual	175 ton/day, total system
	Grate type	Detroit stoker reciprocating
	MSW storage and feed	1800-yd ³ pit; overhead crane; gravity feed
	Ash removal	Water trough; drag conveyor

Table 5-12. (continued)

	Emissions control	Electrostatic precipitator			
	Supplemental fuel				
	Residue (% of input)	10, by volume			
<hr/>					
Energy Recovery System	System type	Waste heat recovery boiler			
	Condensate return				
	Steam production	lb/hr	lb/in. ² g	°F	
	Design	35,000	425		
	Actual	25,000	425	440	
<hr/>					
Steam Delivery			Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Customer	Contract Period			
	Sewage plant			40% of output	
	Onsite use			10% of output	
	Local industry	20 years	10,000		
<hr/>					
Other Products					
<hr/>					
Emissions Data	Test Date	Type	Results	Standard	
	NA				
<hr/>					
Capital Costs	Year	Cost	Item		
	1971	\$1.7 M	Initial plant cost		
	1979	\$3.9 M	Waste heat boiler; electrostatic precipitators; steam lines		
<hr/>					
Other Costs	Operating	NA			
	Tipping fee	\$7.00/ton			

Process—Combustion of shredded MSW in two modular incinerators to generate steam

Owner—Crossville Rubber Products, Inc.

Operator—Environmental Services Corp.

Energy User—Crossville Rubber Products, Inc.

System Manufacturer—Environmental Control Products, Inc.

History. After default during equipment delivery by the original contractor, Farrier/Smokatrol, Environmental Control Products equipment was installed in 1978. Extensive modifications were required to accommodate the waste, which contains large amounts of glass, and rubber from the Crossville Rubber plant. The facility has been operating on a part-time basis since January 1978.

System Description. A system data sheet is presented as Table 5-13. All waste is shredded

Table 5-13. Data sheet for Environmental Services Corp., Crossville, Tennessee

Description	Combustion of shredded MSW in modular incinerators to generate steam	
Startup Schedule	Initial startup	January 1978
Full operation	Est. January 1981	
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	24 hr/day, 5 day/wk
	Maintenance	
Manpower	Full time	8
	Per shift	2 to 3
MSW Processing	Design capacity	60 ton/day
	Actual capacity	62 ton/day
	Current throughput	60 ton/day
	Total to date	7800 tons (9/80)
	Total 1979	0
Combustion System	Number of units	Two
	Manufacturer	Environmental Control Products, Inc.
	Type	Modular; Model No. 25 TES
	Capacity } Design	30 ton/day
	per unit } Actual	>30 ton/day
	Grate type	Refractory high-temperature brick hearth

Table 5-13. (continued)

	MSW storage and feed	70-ton floor; front-end loader to hopper			
	Ash removal	Water trough; automatic drag conveyor			
	Emissions control	NA			
	Supplemental fuel	Natural gas			
	Residue (% of input)	10, approx.			
Energy Recovery System	System type	York-Shipley fire tube boiler			
	Condensate return	No			
	Steam production	lb/hr	lb/in. ² g	°F	
	Design	15,300	150	saturated	
	Actual	10,000	150	saturated	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Crossville Rubber Products		10,000	7000 (estimated)	
Other Products					
Emissions Data	Test Date	Type	Results	Standard	
Capital Costs	Year	Cost	Item		
	1978	\$0.735 M	Total facility capital cost		
	1980	\$0.190 M	Improvements		
Other Costs	Operating	NA			
	Tipping fee	NA			

prior to incineration. The system uses two 30-ton/day Environmental Control Products two-chamber modular units. Material is charged into infeed hoppers with a small front-end loader, and ash is automatically deposited in a wet ash conveyor system for disposal. The units employ electronic ignitors rather than continuously burning pilot lights. Two York-Shipley fire-tube boilers generate 10,000 lb/hr of steam.

Extensive modifications included: new feeder ram, fuel and air modulation controls, modified underfire air source, replacement of refractory with brick linings, and the use of vertical MSW charging doors. These modifications were intended to eliminate clinkering and glass fusion problems.

Economics. Total capital costs in 1978 were \$735,000. No data are available regarding operating costs.

Present Status. The plant is operational, processing roughly 60 ton/day, 5 day/wk. Steam sales to Crossville Rubber average 10,000 lb/hr.

Future Plans. Equipment performance and emissions testing will be conducted. Discussions are underway concerning cogeneration at the site.

Genesee Township, Michigan

Background

Name—Solid Waste Disposal Center, Flint, Michigan

Process—Combustion of unprocessed MSW in modular incinerators to generate steam

Owner—Township of Genesee, Michigan

Operator—Township of Genesee, Michigan

Energy User—Undetermined

System Manufacturer—Consumat Systems, Inc.

History. The facility is located in an industrial park with existing steam and electrical distribution lines. Full operational status of the plant was achieved in May 1980.

System Description. A system data sheet is presented as Table 5-14. The facility has a design capacity of 100 ton/day using two 50-ton/day, controlled-air, two-chamber modular incinerators. Waste feeding and ash removal systems both operate automatically. Three hundred tons of waste can be stored on the tipping floor. The waste heat boilers have a design steam output of 30,000 lb/hr.

Since the facility has been fully operational only a short time, little operating data is available. Preliminary emissions tests indicate that particulate loadings are within acceptable levels.

Economics. The total capital cost, including land and site development, is \$2.01 M. Initial operating and maintenance costs are reported to be \$18.00/ton, gross, and a \$20.75/ton tipping fee is assessed.

Present Status. Plant operation has been temporarily interrupted by a lack of steam customers. Negotiations are underway with several local industries at an adjacent industrial park.

Future Plans. The Township is considering installing electrical generation capability as part of a cogeneration system.

Groveton, New Hampshire

Background

Name—Groveton Paper Company, Groveton, New Hampshire

Process—Combustion of mill waste and MSW in a modular incinerator to generate steam

Owner—Groveton Paper Co.; Diamond International Corp.

Operator—Groveton Paper Co.

Energy User—In-house use of steam for various manufacturing processes

System Manufacturer—Environmental Control Products, Inc.—incinerator; Eclipse Boiler—boiler unit

Table 5-14. Data sheet for Genesee Solid Waste Disposal Center

Description	Combustion of MSW in modular incinerators to generate steam	
Startup Schedule	Initial startup	February 1980
	Full operation	May 1980
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	24 hr/day, 5 day/wk
	Maintenance	
Manpower	Full time	9
	Per shift	2 to 4
MSW Processing	Design capacity	100 ton/day
	Actual capacity	100 ton/day
	Current throughput	100 ton/day
	Total to date	800 tons (5/80)
	Total 1979	0
Combustion System	Number of units	Two
	Manufacturer	Consumal Systems, Inc.
	Type	C-2000 modular
	Capacity } Design	50 ton/day
	per unit } Actual	50 ton/day
	Grate type	Refractory; ash rams
	MSW storage and feed	300-ton floor; front-end loader, ram feeder
	Ash removal	Automatic ram; water trough; drag conveyor
	Emissions control	NA
	Supplemental fuel	Natural gas (10 M Btu/day)
	Residue (% of input)	25 to 35, by weight

Table 5-14. (continued)

Energy Recovery System	System type	Waste heat recovery boiler			
	Condensate return	Yes			
	Steam production	lb/hr	lb/in. ² g	°F	
	Design	30,000	275	450	
	Actual				
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Undetermined				
Other Products	Cogeneration system in planning phase				
Emissions Data	Test Date	Type	Results	Standard	
	NA				
Capital Costs	Year	Cost	Item		
	1979	\$2.01 M	Total plant capital cost		
Other Costs	Operating	\$18.00/ton, gross (operation and maintenance)			
	Tipping fee	\$20.75/ton			

History. The facility began operations to dispose of mill waste in October 1975. At the present time, the system burns mill waste 5-1/2 day/wk, and all of Groveton's municipal waste 2 nights per week, 8 hours per night.

System Description. A system data sheet is presented as Table 5-15. The incinerator is a two-chamber, starved-air modular system using No. 2 fuel oil for ignition. It is rated at 25 ton/day. A dry ash conveyor system is used to remove ash.

The fire tube boiler has a design steam output of 6000 lb/hr. The major maintenance item is the constant repairs to the chamber refractory linings.

Economics. Total capital costs in 1975 were \$0.25 M. No operating costs are available.

Present Status. The plant is operational, processing roughly 12 ton/day of waste, 5-1/2 day/wk. Plant personnel indicate that the primary function of the system is to dispose of waste, not necessarily to recover energy.

Table 5-15. Data sheet for Groveton Paper Co.

Description	Combustion of mill waste and MSW in a modular incinerator to generate steam	
Startup Schedule	Initial startup Full operation	October 1975
Operating Schedule	MSW receiving MSW processing Maintenance	2 day/wk 2 night/wk (mill waste: 5 day/wk)
Manpower	Full time Per shift	3 1
MSW Processing	Design capacity Actual capacity Current throughput Total to date Total 1979	25 ton/day 25 ton/day 12 ton/day NA
Combustion System	Number of units Manufacturer Type Capacity } Design per unit } Actual Grate type MSW storage and feed Ash removal Emissions control Supplemental fuel Residue (% of input)	One Environmental Control Products Modular; 2500-T 25 ton/day 12 ton/day Refractory Tipping floor; batch feed Dry ash conveyor to bin NA No. 2 fuel oil NA

Table 5-15: (continued)

Energy Recovery System:	System type	Eclipse fire tube boiler		
	Condensate return:	Yes		
	<u>Steam production:</u>	<u>lb/hr</u>	<u>lb/in.²g</u>	<u>°F</u>
	Design	6000	125	saturated
	Actual	2500	125	saturated
Steam Delivery	<u>Customer</u>	<u>Contract Period</u>	<u>Contract Quantity, lb/hr</u>	<u>Quantity Delivered, lb/hr</u>
	Onsite use by Groveton Paper			2500
Other Products				
Emissions Data	<u>Test Date</u>	<u>Type</u>	<u>Results</u>	<u>Standard</u>
	NA			
Capital Costs	<u>Year</u>	<u>Cost</u>	<u>Item</u>	
1975	\$250,000	Total capital cost		
Other Costs	Operating	NA		
	Tipping fee	NA		

North Little Rock, Arkansas

Background

Name—North Shore Energy Plant

Process—Combustion of unprocessed MSW in a modular incinerator to generate steam

Owner—City of North Little Rock, Arkansas

Operator—Consumat Systems, Inc. (formerly the City)

Energy User—Koppers Co., Inc., for use in industrial processes

Systems Manufacturer—Consumat Systems, Inc.

History: The North Little Rock energy plant was one of the first U.S. systems to combust MSW in modular incinerators to generate steam. The facility was fully operational in September 1977. Because of poor operating and maintenance procedures by the City, the plant had severe difficulty operating at capacity and fulfilling its steam commitments to Koppers. As a result, in 1980 the City contracted with Consumat to operate the facility on a permanent basis.

System Description. A system data sheet is presented as Table 5-16. The facility has a design capacity of 100 ton/day, using two-chamber or starved-air modular combustion systems. Four 25-ton/day primary combustion chambers are fed MSW by individual automatic hydraulic ram feeders. Ash is removed to a water-filled trough by

a continuous ash discharge ram. Waste reduction is approximately 95% by volume and 62% by weight. Two waste heat recovery boilers generate 10,000 lb/hr of steam each (design).

In addition to routine maintenance, problems were encountered with freezups of the ash

Table 5-16. Data sheet for Little Rock North Shore Energy Plant

Description Combustion of MSW in modular incinerators to generate steam		
Startup Schedule	Initial startup	Spring 1977
	Full operation	September 1977
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	24 hr/day, 5 day/wk
	Maintenance	
Manpower	Full time	11
	Per shift	3 to 5
MSW Processing	Design capacity	100 ton/day
	Actual capacity	100 ton/day
	Current throughput	90 to 110 ton/day
	Total to date	NA
	Total 1979	
Combustion System	Number of units	Four (two waste heat recovery boilers)
	Manufacturer	Consumat Systems, Inc.
	Type	CS-1200
	Capacity } Design	25 ton/day
	per unit } Actual	> 25 ton/day
	Grate type	Refractory ash rams
	MSW storage and feed	Tipping floor; front-end loaders; ram feeder

Table 5-16. (continued)

	Ash removal	Water trough; drag conveyor		
	Emissions control			
	Supplemental fuel	Natural gas		
	Residue (% of input)	35, by weight		
Energy Recovery System	System type	Two waste heat recovery boilers		
	Condensate return	Partial		
	Steam production	lb/hr	lb/in. ² g	°F
	Design	20,000	150	saturated
	Actual	20,000	130	saturated
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr
	Koppers Co., Inc.		15,000	≅ 12,000
Price				
NA				
Other Products				
Emissions Data	Test Date	Type	Results	Standard
	NA	Particulates	0.065 to 0.15 gr/dsft ³	
Capital Costs	Year	Cost	Item	
	1977	\$1.53 M	Total initial plant cost	
Other Costs	Operating	1978: \$20.45/ ton, gross Fall 1980: \$12.00/ton, gross		
	Tipping fee	\$1.25/yd ³ for non-city-owned vehicles		

removal system in cold weather and binding of the conveyor drive by large, solid objects. These difficulties have been corrected by Consumat. Particulate emissions are reported to be within the state standard.

Economics. Total plant capital costs in 1977 were \$1.53 M, including land and planning. Operation and maintenance costs in 1978 were reported to be \$20.45/ton, gross, while the City was still operating the facility. Present operating costs under Consumat are reported to be roughly \$12/ton gross. A \$1.25 tipping fee is assessed non-city-owned vehicles.

Present Status. The plant is fully operational under Consumat management, and processing up to 100 ton/day, 24 hr/day, 5 day/wk. Steam sales to Koppers average 12,000 lb/hr, although the steam plant is capable of producing at the design rate of 20,000 lb/hr.

Osceola, Arkansas

Background

Name—Osceola Waste-to-Energy Facility

Process—Combustion of unprocessed MSW in two modular incinerators to generate steam

Owner—City of Osceola, Arkansas

Operator—City of Osceola, Arkansas

Energy User—Crompton Mills, Inc., for industrial uses

System Manufacturer—Consumat Systems, Inc.

History. Two new 25-ton/day modular systems went into operation in January 1980. Prior to that, the City had operated two 12.5-ton/day units, which were subsequently replaced. A contract with Crompton Mills for 10,000 lb/hr of steam was also negotiated.

System Description. A system data sheet is presented as Table 5-17. The design capacity is 50 ton/day, with two controlled-air, two-chamber modular incinerators. The plant tipping floor has a 100-ton storage capacity. Waste is charged into an automatic ram loader, where it is burned in the primary chamber. Ash is discharged into a quench tank and removed to a truck with a drag-chain

conveyor. Unburned material from the primary chamber passes up into a secondary chamber for complete combustion with secondary air, and the flue gases then pass to a waste heat boiler rated at 10,000 lb/hr of steam.

Several underfire air tubes required replacement after a loss of cooling water in the ram feeder cooling system. The use of steam sootblowers was discontinued, although cooling air may be required to prevent tube warpage. Some slagging due to glass and particulate buildups in the secondary chamber has been noted.

Economics. Total capital cost in 1979 was \$1.2 M, including financing and ancillary equipment. A \$3.50/ton tipping fee is assessed. In May 1980, the price of steam paid by Crompton Mills was \$3.67/M Btu. This price is tied to the cost of No. 6 fuel oil or natural gas.

Present Status. The plant is operating 5 day/wk, processing approximately 40 ton/day. Incoming waste is relatively dry because it is bagged, and some quantities of high-Btu-content industrial waste are consumed. Approximately 9600 lb/hr of steam are delivered to the mill.

Future Plans. A study is underway to determine the feasibility of selling the ash residue.

Salem, Virginia

Background

Name—Salem Waste Disposal - Energy Recovery Plant

Process—Combustion of MSW in modular incinerators to generate steam

Owner—City of Salem, Virginia

Operator—City of Salem, Virginia

Energy User—Mohawk Rubber Co.

System Manufacturer—Consumat Systems, Inc.

History. Because of problems in siting a new landfill in the mid-70's, the City initiated a study to determine the most feasible method of disposal, and selected incineration in modular units with steam recovery. Construction began in 1977,

Table 5-17. Data sheet for Osceola Waste-to-Energy Facility

Description Combustion of MSW in modular incinerators to generate steam		
Startup Schedule	Initial startup	January 1980
	Full operation	January 1980
Operating Schedule	MSW receiving	8 hr/day, 5 day/wk
	MSW processing	24 hr/day, 5 day/wk
	Maintenance	1 1/2 day/wk (Saturday)
Manpower	Full time	11
	Per shift	2 to 4
MSW Processing	Design capacity	50 ton/day
	Actual capacity	50 ton/day
	Current throughput	40 ton/day
	Total to date	2100 tons(4/80)
	Total 1979	0
Combustion System	Number of units	Two, 25 ton/day/unit
	Manufacturer	Consumat Systems, Inc.
	Type	CS-1200; modular incinerator with heat recovery
	Capacity, design	50 ton/day (total for two units)
	Capacity, actual	40 ton/day (total for two units)
	Grate type	Refractory with ash rams
	MSW storage and feed	Tipping floor; front-end loaders; ram feeder
	Ash removal	Automatic ram; water trough; drag conveyor to truck
	Emissions control	NA

Table 5-17. (continued)

	Supplemental fuel	Natural gas			
	Residue (% of input)	35, by weight			
Energy Recovery System	System type	Vierson Co. waste heat boiler			
	Condensate return	No			
	Steam production	lb/hr	lb/in. ² _g	°F	
	Design	10,000	150	saturated	
	Actual	9600	125	saturated	
Steam Delivery	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Crompton Mills			9600	\$3.67/M Btu (≅ \$4.37/ 1000 lb)
Other Products					
Emissions Data	Test Date	Type	Results	Standard	
Capital Costs	Year	Cost	Item		
	1970	\$1.20 M	Total capital cost		
Other Costs	Operating	NA			
	Tipping fee	\$3.50/ton			

and the first quantity of waste was burned in October 1978. Full operations began in December 1978.

System Description. A system data sheet is presented as Table 5-18. The facility has a design capacity of 100 ton/day using two dual Consumat two-chamber, controlled-air incinerators. Four primary combustion chambers handle 25 ton/day

each, with two secondary chambers common to a pair of primary chambers. Natural gas is used for ignition and supplemental fuel. Each ton of waste requires approximately 250,000 to 350,000 Btu of natural gas.

Waste from the tipping floor is charged directly into automatic loading hoppers, where hydraulic ram feeders push waste into the primary chamber.

Table 5-18. Data sheet for Salem Waste Disposal-Energy Recovery Plant

Description	Combustion of MSW in modular incinerators to generate steam	
Startup Schedule	Initial startup Full operation	October 1978 December 1978
Operating Schedule	MSW receiving MSW processing Maintenance	8 hr/day; 5 day/wk 24 hr/day, 5 day/wk 1 day/wk
Manpower	Full time Per shift	12 3 to 6
MSW Processing	Design capacity Actual capacity Current throughput Total to date Total 1979	100 ton/day 100 ton/day 90 to 100 ton/day 25,394 tons(6/80) 14,661 tons
Combustion System	Number of units Manufacturer Type Capacity per unit, design Capacity per unit, actual Grate type MSW storage and feed Ash removal Emissions control	Two Consumat Systems, Inc. Dual CS-1200 50 ton/day (two 25-ton/day chambers) 50 ton/day Refractory ash rams Tipping floors; front-end loader; ram feeder Automatic ram; water trough; drag conveyor NA

Table 5-18. (continued)

	Supplemental fuel	Natural gas (250,000 to 350,000 Btu/ton)			
	Residue (% of input)	40, by weight			
Energy Recovery System	System type	Two waste heat boilers			
	Condensate return	No			
	Steam production	lb/hr	lb/in. ² _g	°F	
	Design	20,000	250	saturated	
	Actual	12,000 to 14,000	235	saturated	
Steam Delivery					
	Customer	Contract Period	Contract Quantity, lb/hr	Quantity Delivered, lb/hr	Price
	Mohawk Rubber Co.	20 years	15,000	12,000 to 14,000	\$3.08/1000 lb (1/80 to 6/80)
Other Products	Ferrous and nonferrous metals (11/80)				
Emissions Data	Test Date	Type	Results	Standard	
	February 1979	Particulates	0.105 gr/dsft ³	0.08 gr/dsft ³	
	June 1979	Particulates	0.122 gr/dsft ³	0.08 gr/dsft ³	
	August 1980	Particulates	0.09 gr/dsft ³	0.08 gr/dsft ³	
Capital Costs	Year	Cost	Item		
	1977	\$1.902 M	Total plant capital cost		
Other Costs	Operating	\$7.45/ton, net; \$17.12/ton, gross			
	Tipping fee	\$4.75/ton (private haulers)			

Automatic ash rams eject ash material into a water trough, where a drag chain removes it to waiting trucks. Waste reduction is 95% by volume and 60% by weight. A waste heat boiler located after the secondary chamber generates 10,000 lb/hr per unit. A steam line transports the steam 1/4-mile away to the Mohawk Rubber plant. No condensate return is provided. The major operating and maintenance problem has been the ash removal conveyor system. Large, solid pieces tend to jam in the flights and cause stoppages. Since only one conveyor serves all four primary chambers, the entire system must be shut down unless repairs are made within one or two hours.

The system has been unable to meet the state emissions standard of 0.08 gr/dsft³. Modifications to the ash rams and underfire air systems have helped. As part of weekly maintenance, the boiler sections must be thoroughly cleaned to remove fly ash buildup.

Economics. Capital costs for the facility, including engineering, planning, and site work, totaled \$1.9 M in 1977. Net operating costs through June 1980 averaged \$7.45/ton processed. A \$4.75/ton tipping fee is assessed private haulers. Steam sales to Mohawk from January 1980 to June 1980 averaged \$3.08 per 1000 lb.

Present Status. The plant is operational, processing 90 to 100 ton/day, 24 hr/day, 5 day/wk, and delivered an average of 12,000 to 14,000 lb/hr of steam to Mohawk. Reynolds Metal Company installed a refuse processing system at the facility to recover ferrous and nonferrous cans. The system, which was to be operational by the end of November 1980, includes a trommel screen, magnetic separator, nonferrous separator, air knife, and compactor.

Future Plans. Discussions are underway with state officials regarding air emissions from the plant. Air-pollution control equipment may be required unless a variance is granted.

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