AD-A147 680   A FIELD INVESTIGATION AND FACILITY REVIEW OF EIGHT MODULAR STARVED-AIR HEAT RECOVERY INCINERATOR SYSTEMS (U) SCS ENGINEERS LONG BEACH CA T J CHANG ET AL.   1/1

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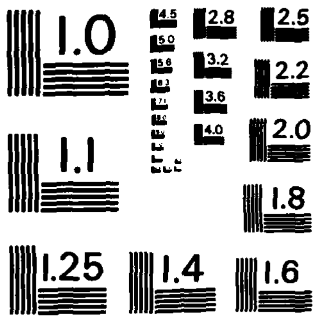

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AD-A147 680

CR 85.001

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

Sponsored by
NAVAL FACILITIES ENGINEERING COMMAND

A FIELD INVESTIGATION AND FACILITY REVIEW OF EIGHT MODULAR STARVED-AIR HEAT RECOVERY INCINERATOR SYSTEMS

October 1984

An investigation conducted by:
SCS Engineers, Inc.
Long Beach, CA

Approved for public release; distribution is unlimited.

METRIC CONVERSION FACTORS

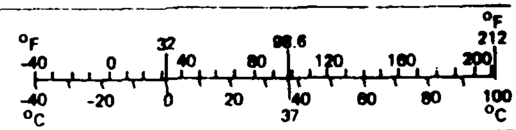
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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HRI, solid waste, modular HRI, energy recovery

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The goal of this project was to verify and augment the technical and cost data on modular incinerators that have been obtained in a previous study. Eight modular starved-air heat recovery incinerator (HRI) facilities ranging from 20 to 110 tons per day were visited. The equipment, facility layout, and operations were observed and photographed. Supervisors,

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operators, and maintenance personnel were interviewed at length about their experience with the HRI equipment and supporting facilities. To aid in the future development of design guidelines for HRI facilities, an emphasis was placed on documenting operational problems and the modifications involved in solving these problems. Where available, cost information for labor, modifications, spare parts, and consumables (utilities, chemicals, ash disposal, pest control) were obtained.

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ACKNOWLEDGMENTS

SCS Engineers wishes to acknowledge the cooperation and assistance provided by the following plant personnel:

- Bill Morgenroth at K.W. Muth Company.
- Doyle Calhoun at Cassia County.
- Merle Clement at Rolscreen.
- John Watson at Government of Ontario.
- Richard Rugg at Lamprey Regional Solid Waste Cooperative.
- Bill Seiver at Corning Glass Works.
- Jim Fender at City of Salem, Virginia.
- Rich Robertson and Marty LeVelle at Lockheed.

Our sincere thanks is also extended to Ms. Mary Lingua, Mr. Don Brunner, and Mr. Jerry Zimmerle of the Navy Civil Engineering Laboratory for their assistance during the project.

CONTENTS

INTRODUCTION

After a preliminary literature review[1] of modular heat recovery incinerator (HRI) facilities, the Naval Civil Engineering Laboratory selected eight facilities for further consideration. SCS Engineers was selected to conduct a facility review of the following HRI installations:

- K.W. Muth in Sheboygan, Wisconsin.
- Cassia County in Heyburn, Idaho.
- Rolscreen in Pella, Iowa.
- Government of Ontario in Toronto, Ontario.
- Lamprey Regional Solid Waste Cooperative in Durham, New Hampshire.
- Corning Glass Works in Corning, New York.
- City of Salem in Salem, Virginia.
- Lockheed in Sunnyvale, California.

Incineration equipment was furnished by Consumat Systems at six facilities; Kelley Company, one facility; and Sunbeam Comtro, one facility.

The purpose of the facility reviews was to:

- Verify and augment the findings of the literature survey.
- Inspect and observe each facility in operation and obtain photographs and equipment layouts.
- Interview supervisors, operators, and maintenance personnel about their experiences with the equipment and supporting facilities.

The data from the facility reviews was to be used to compile HRI system life cycle costs and to provide information for design of future HRI facilities.

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[1] Tuck, J.; Glaub, J.; Savage, G., A Survey of Capital, Operating and Maintenance Costs for Starved-Air Heat Recovery Incinerators, Cal Recovery Systems, Inc., July 1982.

DATA COLLECTION

Methodology

A detailed field survey form was developed to streamline data collection in the field. Technical and cost data from the literature review was entered on the survey forms, to be verified at the site. To ensure completeness of data, the forms listed various categories of equipment; capital, operating, and maintenance costs; completed and planned modifications; facility shortcomings and problems.

At each site, plant personnel including supervisors, operators, and maintenance staff were interviewed at length. Cooperation and responsiveness was excellent at all facilities. Access to the facilities was generally not restricted, and cameras were allowed at all except one facility which burns classified documents.

Data Availability

The availability of various types of data varied greatly. Readily available information included quantity of refuse and steam; fuel characteristics; operating schedule; technical comments on various types of equipment; problem areas; completed and planned modifications; and capital costs.

Some data was difficult or impossible to obtain and/or subject to much interpretation. For example, some facilities share operators or maintenance personnel with a boiler plant, so it is difficult to determine how many people really staff the incinerator facility. At other locations, incinerator operators also sort or handle the waste. Job titles and labor classifications are poorly defined. Labor rates were extremely difficult to obtain, but vary greatly across the country, as might be expected.

Operating and maintenance costs were particularly difficult to obtain. Either the data simply did not exist, or operators and supervisors did not have access to the data. In many instances, the incinerator is considered a part of the overall heating plant; hence, costs for items such as boiler feedwater chemicals, electricity, auxiliary fuels (gas or oil), and wages for operators and maintenance staff accrue to the heating plant account and are not available for the incinerator facility alone. The cost of paint, tools, chemicals, and rodent control are often considered insignificant and hence not accounted for.

Most equipment nameplates were obscured by dirt or situated in dimly lit, inaccessible locations, making horsepower and other useful data difficult to obtain. While free access to the plants were permitted, the amount of time to inspect the facility was limited by the availability of operators to act as guides and by general safety considerations.

For this report, certain common words are assigned specific meanings:

- "They" refers to one or more incinerator facility personnel, including supervisors, operators, and maintenance technicians.
- "Reported" or "reportedly" means they (defined above) told us something we could not readily verify during our site visit. Whether reported items were fact or opinion could not usually be verified either.

COMMON PROBLEMS AND MODIFICATIONS

The numerous equipment and operational problems common to most of the facilities visited are summarized below. Some solutions, suggested by plant personnel, and actual equipment modifications are also described. Note that while various problems are mentioned in some of the individual Facility Reviews, the intention is not to single out these facilities nor to imply that the problems occurred only at those plants.

Feed and Ash Rams

Malfunction of these systems generally occurs when the rams are snagged on the refuse or drag refuse across the refractory floor, causing excessive refractory wear. As a majority of the installations have required replacement of refractory in the primary chamber, usually within two or three years of the original installation, this type of problem appears to be inherent in the design of modular incinerators.

Boilers

Slagging of boiler tubes and accumulation of particulate matter on the exterior surface of watertubes or interior surface of firetubes is a major problem with HRI facilities. Boiler tubes with solid or serrated fins experience worse fouling than bare tubes, as might be expected. Tube spacing is often considered to be too dense. The problem is accentuated by sootblowing systems which either are inadequately sized or operate too infrequently. Some plants wash the soot off boiler tubes with high pressure water, but report poor drainage and inconvenient access to boiler compartments.

Boiler tube scaling occurs less frequently, but feedwater treatment is still a problem at some facilities. Other common boiler problems include poor water circulation, warped tubes, or warped boiler access doors.

Ash Systems

Ash is an exceedingly difficult material to handle due to its high temperature and abrasive nature. Components such as chains, pins, and bearings require almost constant repair or replacement. Most operators prefer to have one ash conveyor for each incinerator. This prevents an ash system breakdown from shutting down all the incinerators. Several operators recommended dropping ash only onto moving conveyors to prevent stretching the chain.

Instrumentation

Instrumentation is generally considered to be inadequate. A majority of operators would prefer (or have already installed) more temperature sensors, draft gauges, and air flow sensors. More instrumentation of the type generally found on large power boilers would aid the operators greatly in running their equipment more effectively. At a number of plants, instruments were hard to read because of their location. A central instrument panel is preferable. At some plants, the instrument panel is located near the feed door, and dust from the refuse has short-circuited electrical contacts.

Seals and Gaskets

Leakage of air into the incinerator causes loss of combustion efficiency at numerous plants. Blowback, or discharge of ash and burning particles through feed hoppers and access doors, is common.

Air Systems

Better control over the quantity of combustion air is desirable. Damper systems to throttle fans are often ineffective. Bypassed air from throttled fans is often blown into the room, contributing to dust problems. Air leaks are common around equipment access doors.

Shakedown Period

The reported shakedown period for HRI systems varied from 2 months to several years, and some systems still do not operate at design capacity. Lengthy shakedown periods generally appear to be caused by continuing problems with feed and ash rams, ash conveyors, and boilers, as discussed above.

Tipping Floor

At the majority of facilities, the tipping floor was considered to be inadequate in size. It should be mentioned, however, that at several facilities this factor was beyond the designer's control, as insufficient land was available to build a properly-sized facility. This may be indicative of the priority assigned to the facility by management.

Waste Characteristics

Most of the facilities visited encounter a fairly wide variety of wastes and have learned to handle them. Most facilities now either exclude certain types of waste, presort waste to a greater extent, or are resigned to an occasional shutdown due to problems caused by burning a difficult waste.

Operator Training

The education and experience of operating and maintenance personnel varies greatly. It is generally agreed that more comprehensive and in-depth training programs are required to help plant personnel understand the many facets of modular incineration, including waste selection, boiler operation, and pollution control.

Especially in industrial waste facilities, an in-house education program is essential to gain the cooperation of those who put waste into the system. Source separation appears to be the best way to prevent problem wastes from entering the system.

FACILITY: K.W. MUTH CO.
2021 North Avenue
Sheboygan, Wisconsin 53081

CONTACT: Bill Morgenroth
Plant Engineer
(414) 458-9181

OWNER: K.W. Muth Co.

OPERATOR: K.W. Muth Co.

INCINERATOR DATA:

Manufacturer: Kelley Company, Inc.
6720 North Teutonia Avenue
Milwaukee, Wisconsin 53209
(414) 352-1000
Attention: Roy D. Miller

Units: 2 each: Kelley Model 1280 pyrolytic incinerator with Kelley Model 72 automatic feeder and York-Shipley waste heat boiler.

Design Capacity: 1,000 lb/hr (each incinerator)

Fuel Characteristics:

Main feedstock:

- Manufacturing wastes from automobile components--plastic, fiber, trim, cardboard, and wood waste (hardboard, particle board, and plywood).

Secondary feedstock:

- Insulation, miscellaneous packaging materials, and cafeteria wastes.

Date Installed: July 1976

Heat Recovery: 6,000 lb/hr of 100 psi steam

Operation: They operate both incinerators 5 days/week, 24 hours/day during the winter. During the summer, operation is based on process steam demand. One unit at a time is shut down for major maintenance during the summer. Some wastes are stored during the summer months to insure that winter heating demands can be met.

They have 3 operators, 1 maintenance person, and 1 supervisor. The maintenance and supervisory personnel are shared with the production facility.

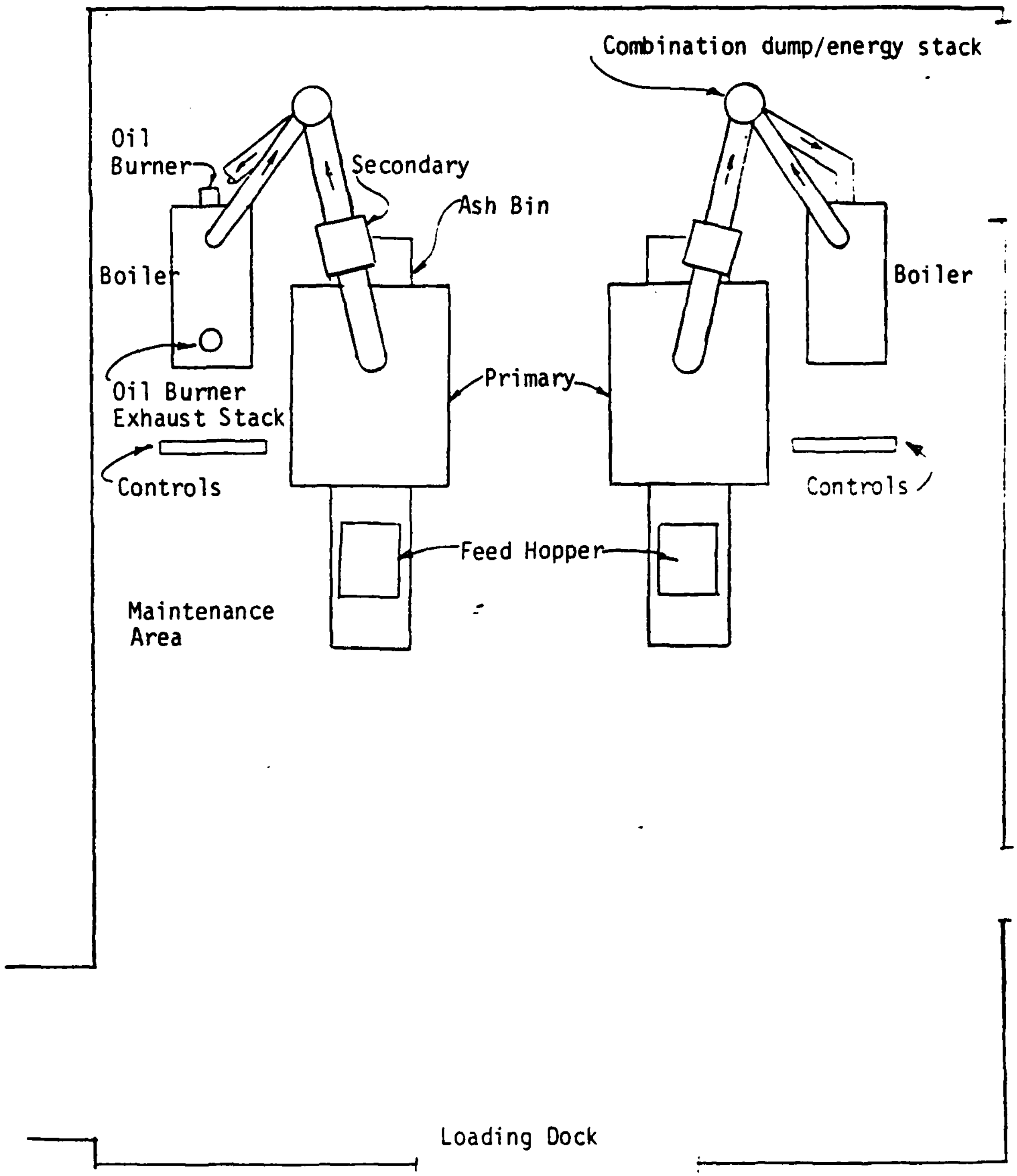
Capital Costs: $260,000 (1976) plus $45,000 for the building.

Operating and Maintenance Costs: O&M costs are approximately $80,000 per year, with about 56% of that for labor and 44% for consumables. The consumables include $10,000-$20,000 per year for spare parts for major maintenance on the incinerator and boiler. Costs are not specifically assigned to the incinerator facility by their accounting department, so accurate costs are difficult to obtain.

FACILITY DESCRIPTION:

A metal building houses the incinerators and a loading dock/waste handling area. The two incinerators and two boilers are installed in a pit at one end of the approximately 100' by 100' loading dock/waste handling area.

Wheeled bins towed by forklift are used to collect and store the waste. The bins (about 3' x 3' x 5' long) are stored both in the yard and the loading dock area. Non-putrescible manufacturing waste is accumulated during the summer for use during the winter heating season. The waste is dropped from the bins into the feeder hopper. When the hopper is full, a vertical charging door between the feeder and the incinerator opens and a hydraulic ram pushes waste into the primary chamber. The primary chamber burns waste at 1,200 to 1,300°F under oxygen-lean conditions with a reported volume reduction of 90% or better. This pyrolysis process generates a combustible gas which rises out of the primary chamber into a horizontal duct where secondary combustion takes place. It is



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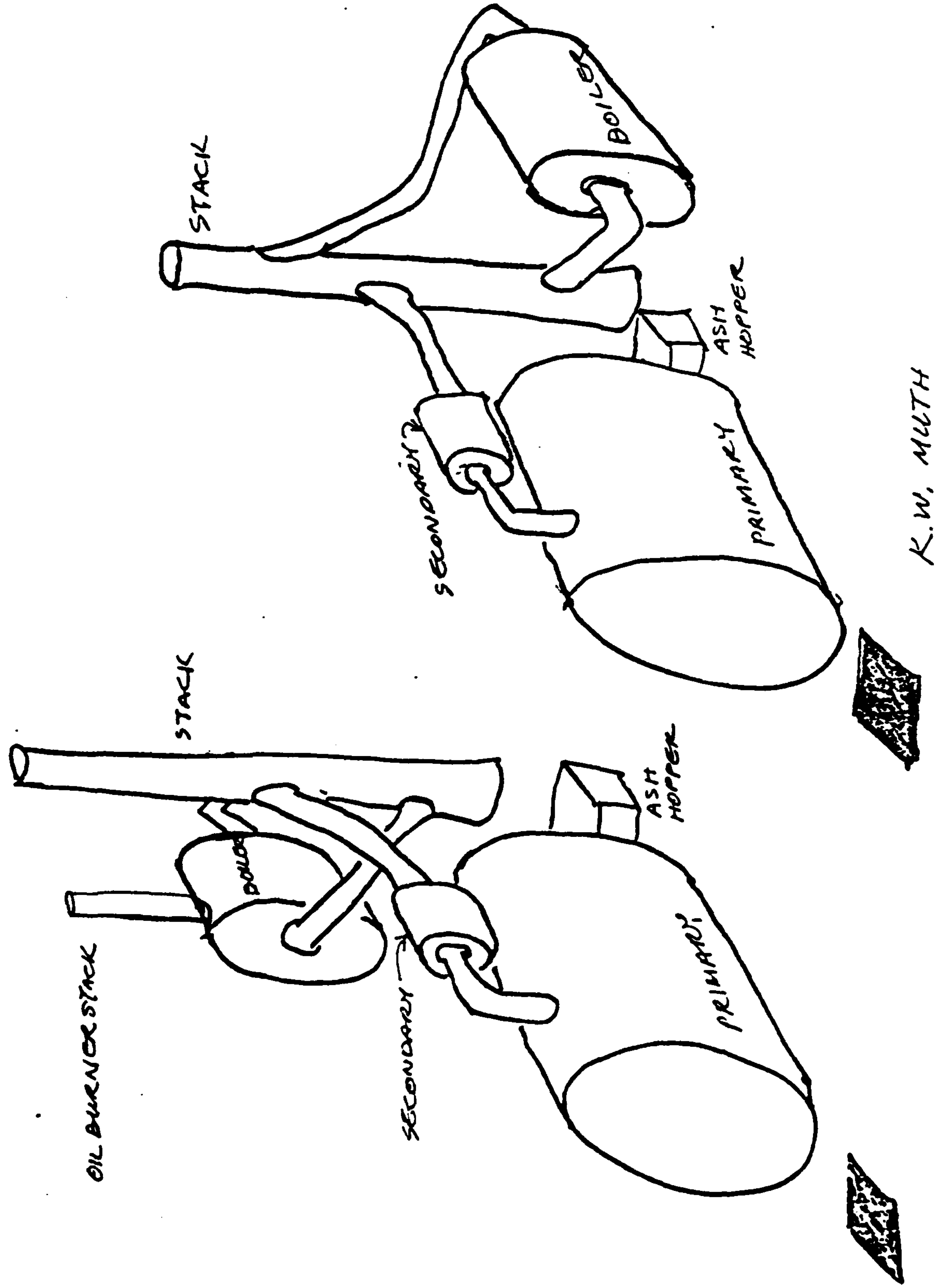
K.W. Muth


STACK
BOILER
ASH HOPPER
SECONDARY
PRIMARY
K.W. MUTH
STACK
ASH HOPPER
PRIMARY
SECONDARY
OIL BURNER STACK

ignited in a collar-shaped zone of the duct by a small pilot burner. Flue gases then pass into a York-Shipley waste heat boiler to produce 100 psig steam. The steam is used for process heating and building space heating.

To maintain building temperatures on winter weekends when the incinerator is not operating, a fuel oil burner in Boiler No. 863 is fired. Flue gases exit via an auxiliary stack on that boiler. Boiler No. 864 does not have an oil burner.

The incinerator was operating at the time of our visit. Air is supplied by a 5 hp. blower at 5 inches water column to the tuyeres (underfire air inlets in the primary chamber) and to the secondary chamber. The primary chamber temperature is sensed by thermocouples and maintained at 1,200 to 1,300^{o}F by intermittent water sprays.

A hydraulic ram pushes ash out of the primary chamber into an ash hopper cooled by water sprays. Ash is then lifted out of the hopper by a small overhead crane and dropped into dumpsters for disposal. The ash handling operation is very labor-intensive. Fortunately, the quantity of ash is low due to the high combustible content of Muth's present waste stream.

Major maintenance was being performed on Incinerator/Boiler No. 863 during our site visit. The primary work involved the annual replacement of refractory located in the feeder and ash transfer ram areas of the incinerator. Each incinerator is shut down for major maintenance at a different time during the summer when steam demand is low.

The plant operator reported that the incinerator operates within the environmental standards for air emissions developed by the Department of Natural Resources, State of Wisconsin.

PROBLEMS AND MODIFICATIONS:

A continuing problem is the yearly replacement of refractory in the loading and ash handling areas of the incinerator. Refractory wear is caused by the operation of the loading and ash rams. Because of the company's commitment to burning waste as their primary fuel source, they consider refractory replacement to be just another part of their routine heating expenses. They feel the same way about the admittedly labor-intensive ash handling operation.

FACILITY: CASSIA COUNTY, IDAHO
Thermal Reduction Co.
P.O. Box 548
Heyburn, Idaho 83336

CONTACT: Doyle Cahoon
Plant Manager
(208) 678-3510

OWNER: Cassia County, Idaho

OPERATOR: Wilder Construction, Thermal Reduction Division, turnkey operator for first year of operation before turning over operation to Cassia County.

INCINERATOR DATA:

Manufacturer: Consumat Systems, Inc.
P.O. Box 9379
Richmond, Virginia 23227
(804) 746-4120

Units: Dual Model CS-1200 (two primary chambers, one secondary chamber, one waste heat boiler)

Design Capacity: 4,200 lb waste/hr

Actual Capacity (as operated): Peaks in excess of 50 tons/day.

Fuel Characteristics: Primarily municipal solid wastes with some industrial wastes (i.e. cardboard and packaging waste) from food processing plant.

Date Installed: November 1, 1981

Routine Operation: January 1, 1982

Heat Recovery: 9,840 lb/hour of 150 psi saturated steam supplied to Simplot, an agricultural product processing plant.

Operation: Three shifts, 5.5 days/week, 52 weeks/year.

Capital Costs: Total capital cost $1,400,000 (1981)

Operating and Maintenance Costs:

Consumables--

Electricity:	$950/month
Water:	$175/month
Auxiliary Fuel:	17,167 cu. ft/day natural gas 9.2 gallons/day diesel 18.7 gallons/day gasoline
Chemicals:	About $3,500/year

Labor--

1 - Plant Manager
1 - Asst. Plant Manager/Plant Operator
2 - Plant Operators
4 - Bobcat operators and cleanup

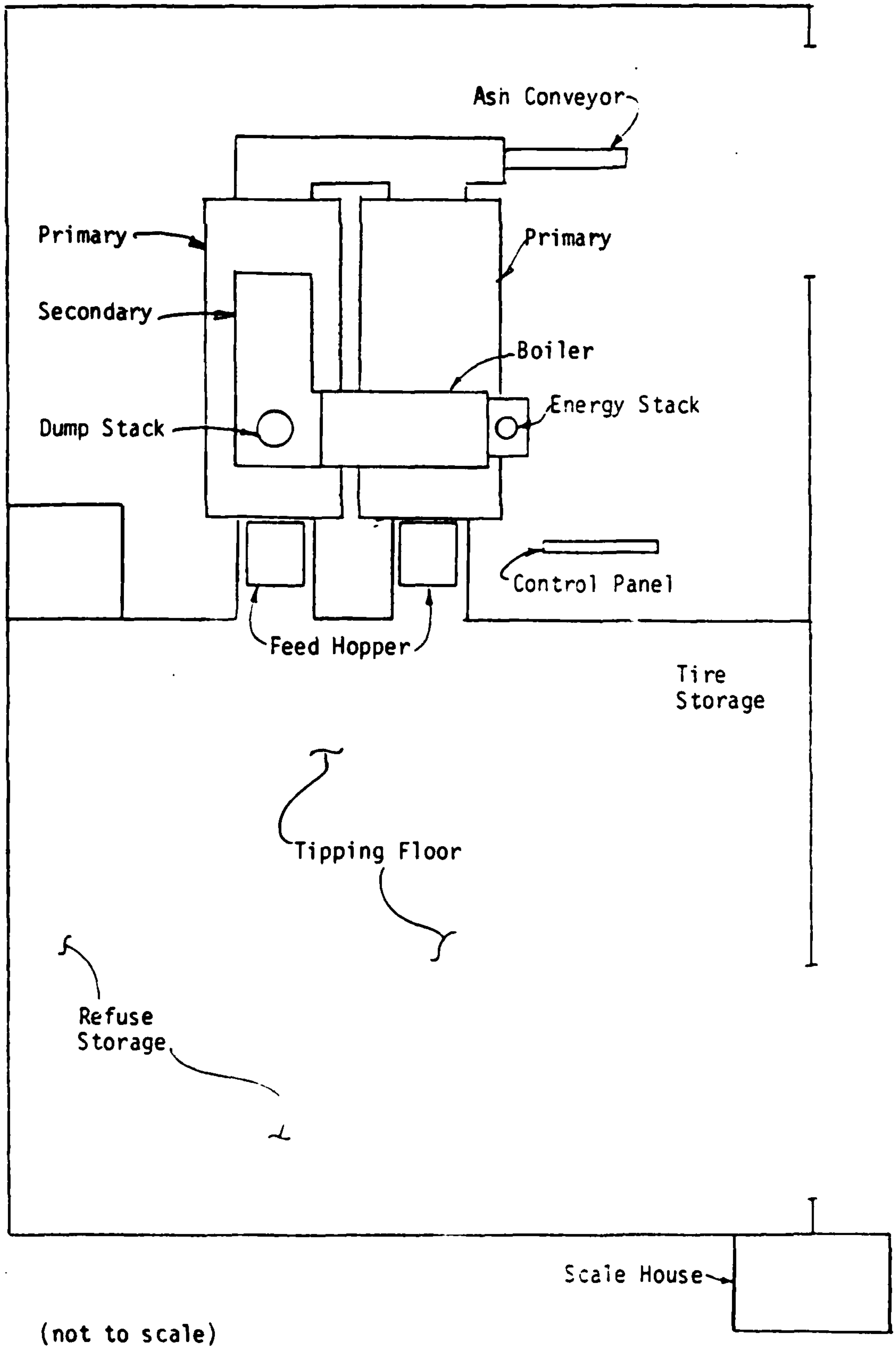
Spare Parts: $20,000 starting inventory. Major parts include:

- 1 Hydraulic pump assembly
- 2 Underfire water cooled air tube transfer rams
- 1 Dialatrol heat recovery control

FACILITY DESCRIPTION:

The incinerator system is a Consumat CS-1200 Dual System employing two primary chambers with separate automatic feeders to supply pyrolysis gases to a single secondary combustion chamber. The primary chambers are operated at 1,200 to 1,300°F with the secondary chamber at 1,800°F. Hot flue gases exit the back of the secondary chamber into a waste heat boiler perpendicular to the chamber. The boiler has 7 rows of tubes and cools the flue gases down to about 475°F. The operations stack has an economizer which preheats boiler feedwater from 200° up to 235° while lowering the flue gas to about 410°.

Single-pass boiler feedwater (no condensate is returned) is produced from city water by ion exchange process. Feedwater flows to the deaerator and is preheated with steam to 200°, then boosted by the stack economizer to 235°. The 9,840 lb/hr of 150 psi steam is sold to Simplot, the potato processing plant located across the street.



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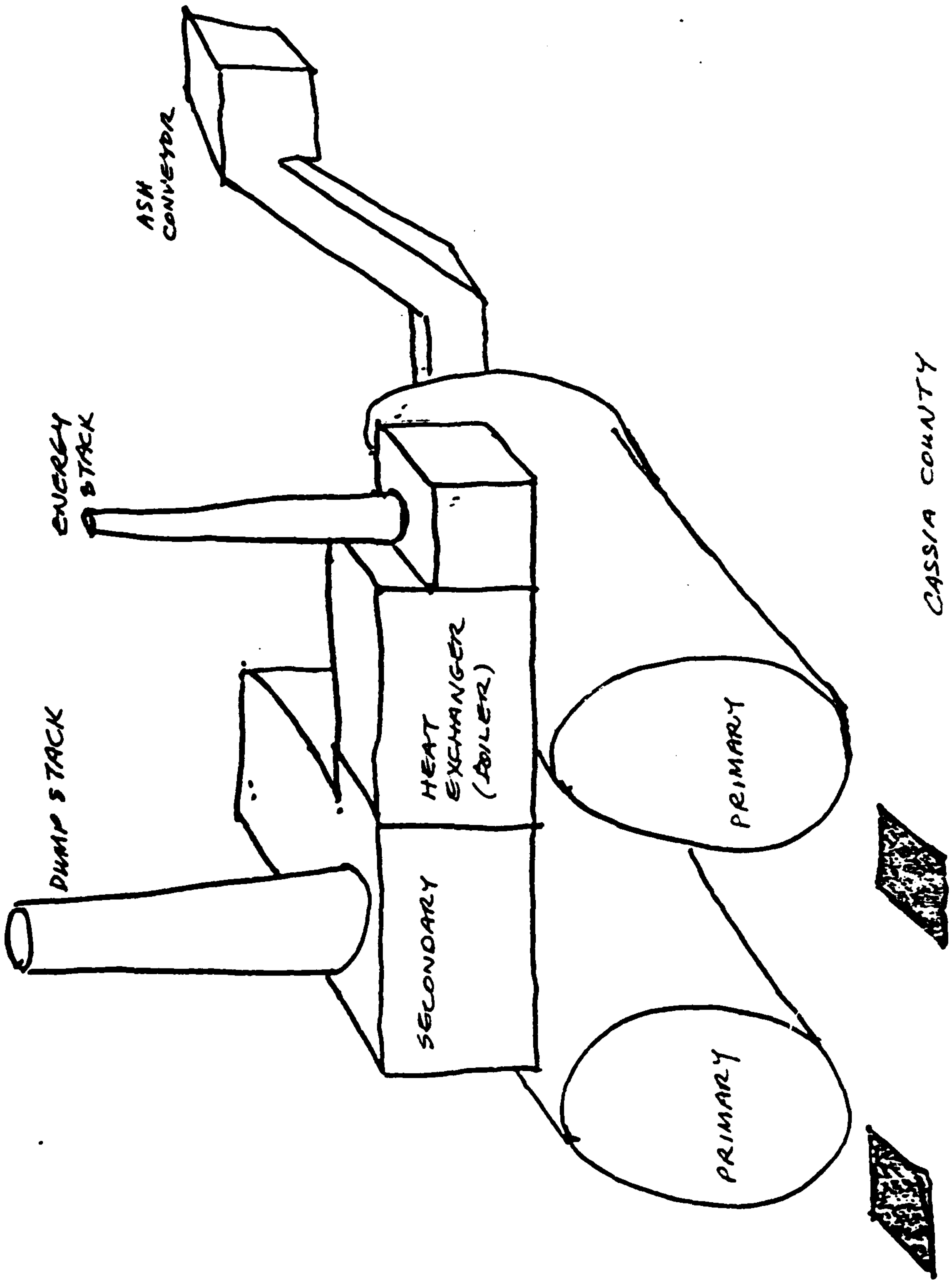
CASSIA COUNTY, IDAHO


DUMP STACK
ENERGY STACK
ASH CONVEYOR
SECONDARY
HEAT EXCHANGER (BOILER)
PRIMARY
PRIMARY
CASSIA COUNTY

The ash handling system consists of an ash slurry (quench) tank and ash conveyor. The conveyor's steel flights move the ash up out of the quench tank and into a hopper, where it is discharged into one of two dump trucks and hauled to the landfill.

The tipping floor and incinerators are housed in a metal building. A DPT 500 scale weighs the garbage trucks and ash dump trucks. A 6 foot high concrete wall rings the 80' by 80' (approximate) tipping floor. As the metal wall appears undamaged, the concrete wall apparently is high enough to protect the metal wall. The facility can unload one truck at a time. A single Clark 743 Bobcat loader is used to feed waste into the incinerators. A standby Bobcat is kept on hand as this location is remote from repair services.

On the day shift, a "scavenger" under contract with the County separates out and hauls away recyclable items. Both the scavenger and the Bobcat operator separate out bulky wastes and metal wastes of value. Tires are fed into the incinerators about every third load.

PROBLEMS AND MODIFICATIONS:

1) Potato picking rods occasionally jam the ash conveyor. To locate and remove the rods, the ash sump must be drained using a vacuum truck at $135 per visit because the plant's double diaphragm ash slurry pumps do not operate effectively on ash slurry.

2) The downcomer on the first and second boiler tube bank (nearest the secondary chamber) is being enlarged from 2 to 3 inch diameter. The modification is intended to increase feedwater flow in the tubes, to reduce buildup of sodium deposits in the tubes, and to promote better heat transfer.

Unlike the other water tube boilers in this review, the tubes in the seven tube banks of this boiler are all bare (i.e. they have no fins or other extended heat transfer surfaces. Notably, there is no reported problem with particulates clogging or coating the exterior of these tubes.

3) A change in the user's steam pressure requirement has caused some problems with boiler feedwater pumps. The original pumps were replaced as being inadequate for the 275 psi steam which Simplot required. Two new Worthington feedwater pumps rated at 375 psi were then installed. These pumps are being throttled back because Simplot now requires only 150 psi steam.

4) The concrete slab on which the incinerator system rests was installed level, preventing wash water from flowing to the drain. Drain channels had to be chipped into the floor to correct this situation.

5) Brown smoke from soot-blowing operations and black smoke from over-feeding the incinerators has reportedly caused problems with the neighbors. The day of our visit, the air emissions were minimal. However, conversations with the original site developers suggest that the facility is having trouble with air quality. This is corroborated by local press reports. Part of this problem may be due to unrealistic local expectations that with an incinerator facility, garbage goes in, steam and clean ash come out, and no smoke is ever visible. The air quality situation remains controversial.

No written information on air quality requirements, permits, or test data was made available to us.

MISCELLANEOUS:

1) The system reduces the waste by 49% (weight basis). About 9,840 lbs/hr of 150 psi steam are produced from 2 tons/hr of waste.

2) Maintenance appears to be excellent. Maintenance procedures are well documented. They feel that 8 people are required to operate the facility properly.

3) Despite the aforementioned shortcomings, the facility seemed to operate well during our site visit. This appears to be largely due to the expertise of the Plant Manager.

FACILITY: ROLSCREEN
102 Main Street
Pella, Iowa 50219

CONTACT: Merle Clement
Maintenance Supervisor

Ken Nollen
Plant Engineer
(515) 628-1000

OWNER: Rolscreen

OPERATOR: Rolscreen

INCINERATOR DATA:

Manufacturer: Consumat Systems, Inc.
P. O. Box 9379
Richmond, Virginia 23227
(804) 746-4120

Unit: One Model CS-1200

Design Capacity: 2,000 lb waste/hr

Actual Capacity (as currently operated): 36 tons/week

Fuel Characteristics:

Industrial wastes - primarily cardboard, waste paper, and wood wastes.

Date Installed: October 1979

Routine Operation: December 1979

Heat Recovery: 4,000 lb/hr of 50 psi steam

Operation: Presently they run 2 shifts/day, 3 days/week, using two operators. Previously they ran 3 shifts/day, 5 days/week, with four operators.

Capital Costs; Total capital $600,000 (1979), with $350,000 for equipment and $250,000 for the building.

Operating and Maintenance Costs: Annual labor costs were approximately $80,000 for four operators. They presently have only two operators due to slower business conditions and lower than expected steam output.

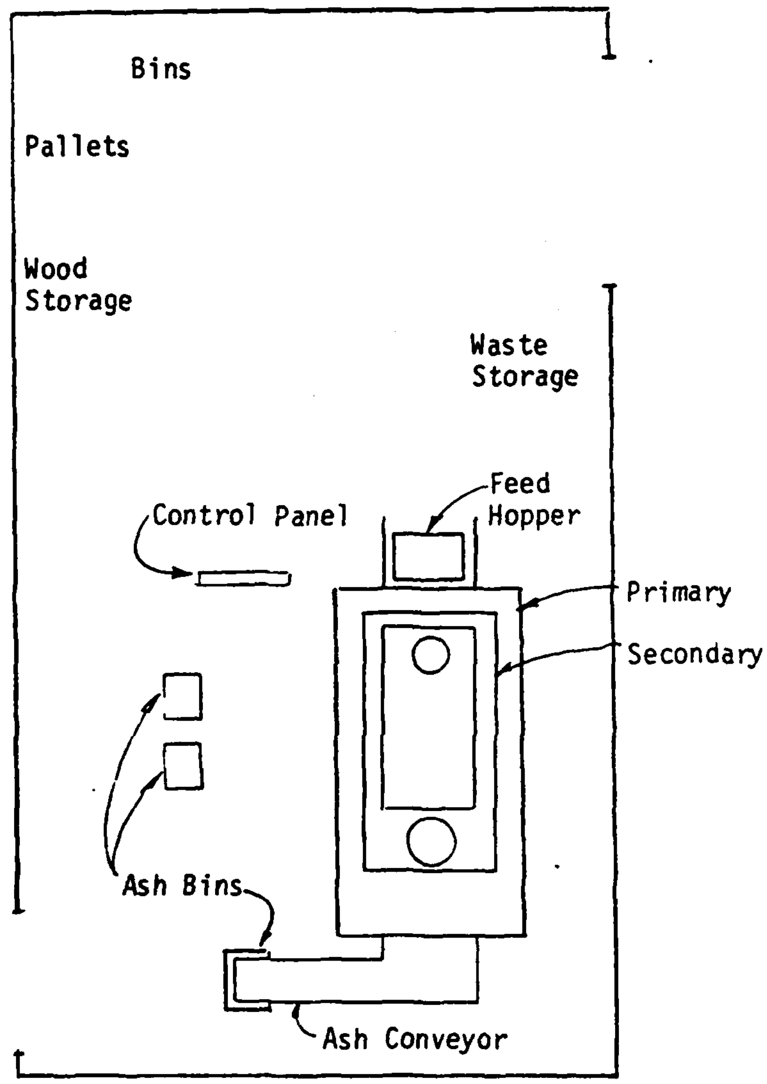
Costs for consumables such as electricity, water, and auxiliary fuel are mingled with those items used by other parts of the heating plant, and hence are not available separately for the incinerator facility.

FACILITY DESCRIPTION:

The waste handling and incinerator building is located away from the main plant steam boilers. The building has high ceilings to allow roll-off type waste disposal trucks to pick up roll-off containers holding noncombustible items such as glass and metal from their manufacturing operation. The 60' by 60' loading area floor is enclosed in a heated building with large doors that accommodate roll-off containers. There was a brown sooty appearance to the incinerator area, possibly from "blowback" around the loading door seals.

Wastes are stored on the loading area floor before being pushed into the loading hopper by a propane-powered Northwestern Motor Company loader. The Consumat-designed hydraulic loading ram system operated well during our site visit, with little "blowback" from the furnace. Transfer rams move the waste through the primary chamber to the ash handling system. The rams contain underfire air tubes, but these are not water-cooled and have created maintenance problems. The ash handling system lifts wet ash up a 45^{o} incline and drops it into dumpsters.

The secondary chamber has both oil and natural gas burners. It is maintained at $1{,}700^{o}F$. Flue gases pass from the secondary into a heat exchanger with 4 banks of 2-inch diameter tubes.



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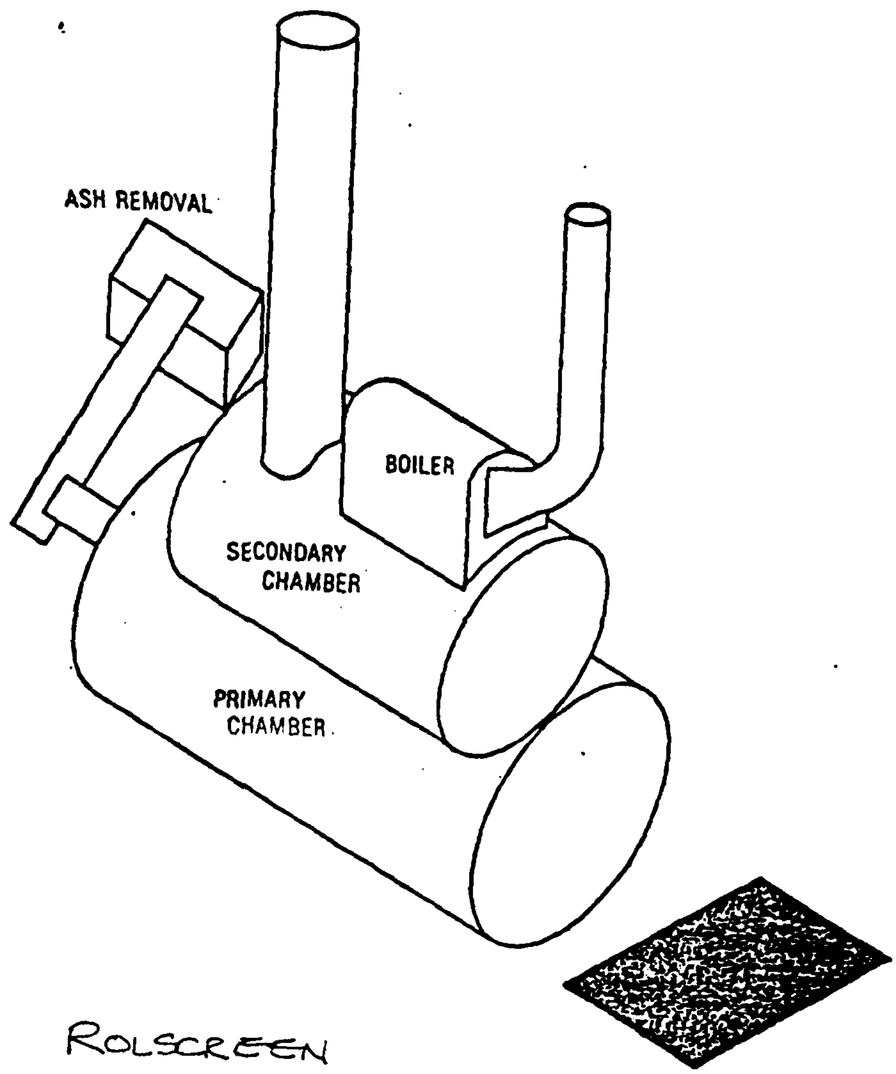
ROLSCREEN



ROLSCREEN

A liquid waste burner is located on the primary chamber for combustion of liquids such as non-halogenated waste fluids from plant equipment and lift trucks.

While they do not weigh their wastes or ash, they estimate that the incinerator has been processing about 36 tons per week, producing about 3 tons of dry ash and 4,000 lb/hr of steam per week.

PROBLEMS AND MODIFICATIONS:

1) To minimize slagging and particulate accumulation on the exterior of the heat exchanger tubes, the tubes were treated with anti-slagging chemicals. They did not mention how effective this modification was.
2) A blower modification, the nature of which was not reported, was made at the manufacturer's expense.
3) The refractory was replaced in the first year at the manufacturer's expense. The problem was created by excessive temperatures in the primary chamber caused by burning dry waste with very high combustible content. They are presently lowering the heat content of the waste by wetting it down before burning.
4) The entrance to the primary chamber just "downstream" of the loading hopper was widened to allow easier transport of waste and prevent the loading door from hanging up on the waste.
5) Operating personnel expressed concern that the equipment did not meet the intended energy recovery goals and that more maintenance was required than had been expected.

FACILITY: GOVERNMENT OF ONTARIO
Ontario Centre for Resource Recovery
4375 Chesswood Drive
Downsview, Ontario M3J2C2
(416) 636-8015

CONTACT: John Watson
(416) 636-0770

OWNER: Ministry of the Environment
Government of Ontario

OPERATOR: Browning-Ferris Industries, Ltd.
Resource Recovery Division
35 Vanley Crescent
Downsview, Ontario M3JM2B7

INCINERATOR DATA:

Manufacturer: Consumat Systems, Inc.
P.O. Box 9379
Richmond, VA 23227
(804) 746-4120

Unit: One Model C760A

Design Capacity: 2,200 lb/hr

Actual Capacity (as operated): 800 to 900 lb/hr

Fuel Characteristics: Fluff RDF containing newsprint, mixed paper, plastic, and finely ground organic particles from food wastes (see FACILITY DESCRIPTION). Waste is obtained from private haulers and the City of North York.

Date Installed: Late 1976

Routine Operation: They did not achieve heat recovery until the early part (winter) of 1982. Shakedown period was about 5 years.

Heat Recovery: 340 gpm of 230 deg. F hot water.

Operation: They operate 8 hrs/day, 5 days/week, 50 weeks/year. They have one operator. Maintenance is performed at night by the maintenance crew which serves the whole resource recovery facility. Routine maintenance takes about 4 hours/week; major maintenance takes about 10 days/year.

Capital Costs: It was thought that the overall facility cost between $9 and $15 million (Canadian). However, actual capital costs can only be obtained from the Ontario Ministry of the Environment (the owner). Because this is one of the few C760A models in existence and the incinerator system is only a small part of the overall resource recovery facility, capital costs are not likely to be of much use.

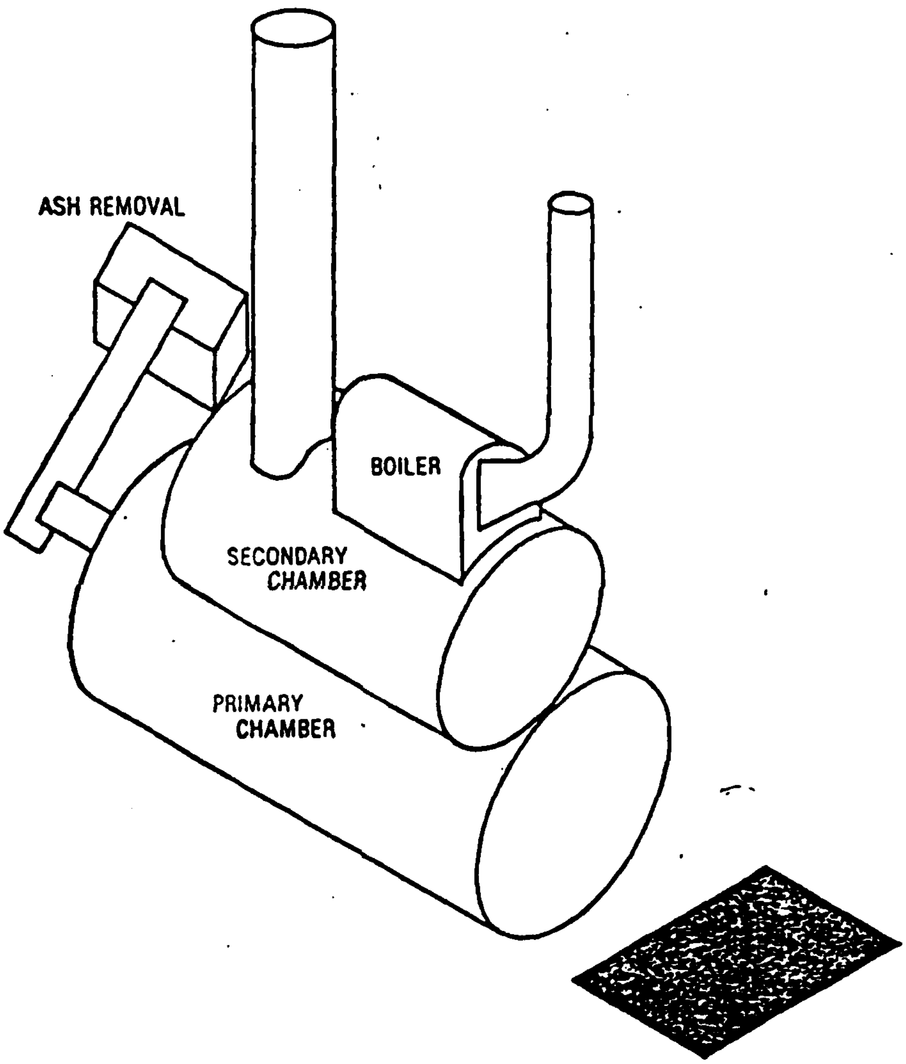
Operating and Maintenance Costs: It presently costs about $30.39 Canadian to make a ton of RDF. Labor to operate and maintain the incinerator runs $17/hour Canadian.

Spare Parts: They have had numerous problems with the hydraulic system, especially the solenoid valves, so they keep these in stock. In general, though, they do not carry a lot of spare parts.

FACILITY DESCRIPTION:

The incinerator system is just one part of an experimental resource recovery center owned by the Ministry of the Environment. The facility receives municipal solid waste from private haulers and the City of North York. Cardboard and newspaper are removed and baled for recycling. The rest of the waste is shredded to 6-inch size by a thousand horsepower shredder. A two-stage air classifier removes paper and plastic; this fluff RDF is one component of the incinerator fuel.

Heavy material, including metals, glass, and food wastes is conveyed to an electromagnetic separator which removes ferrous material which is then shredded and stored for shipping. The remaining material is conveyed to a revolving (trommel) screen where crushed glass and ceramics fall through three-quarter-inch openings



GOVERNMENT
OF
ONTARIO

Note: Control panel is located in a control room on the same level as the secondary chamber. Tipping floor is in another building.

to an air classifier which cleans off any residual organic material. This glass-rich fraction is lifted to a storage bin for market investigation and shipping.

Oversize material from the revolving screen is ground fine and any remaining organic material is conveyed to storage in a hundred-ton bin. This material is either composted or combined with the fluff RDF and burned.

The tipping floor is 125 feet by 110 feet and is apparently adequately sized. The facility can handle up to 1,000 tons in an 8 hour day. The incinerator is located in a separate building and receives only RDF from a storage bin.

At the time of our visit, the incinerator was not operating as modifications were being made to the boiler.

The incinerator is an early model in the Consumat line and differs from the units at Durham, New Hampshire. For instance, it lacks air tubes in the ram. Primary chamber air enters through a single slot on the bottom centerline of the furnace rather than through several smaller side ports. The primary chamber is operated at 1,200 deg. F and the secondary at 1,500 to 1,600 deg. F.

The heat-exchanger is a Riley-Beaird boiler with finned water tubes. The facility also has 8 Raypak hot water boilers. Early 1982 is the first period that the incinerator's boiler has run reliably enough to displace any of the Raypak boilers.

PROBLEMS AND MODIFICATIONS:

Unlike other incinerator facilities which we visited, this one has reportedly received little technical support from the equipment manufacturer.

Problems:

1) The original heat recovery package lacked a "block valve" (damper). Consequently, the flue gases took the path of least resistance and bypassed the boiler. A new block valve was added in October 1981, costing $21,000 Canadian.

2) The space between the boiler's water tubes used to plug every day or two with particulates. Since the original soot blower only cleaned the top portion of the tubes, fly ash built up below. A new soot blower and larger compressor costing $8,000 Canadian* were installed, and the system has operated satisfactorily since. This system provides 35 cfm at 150 psi and operates 2 minutes on, 2 minutes off.

3) Unlike newer Consumat models, this unit has only one feed ram. Although the specific problem with the ram was not mentioned, they did report spending about $800 Canadian* to relocate the driving mechanism from the bottom to the side of the ram.

4) The heat exchanger access doors have warped. This appears to be a typical problem with this manufacturer's equipment.

5) Combustion air control is considered to be poor. Although there is a damper on inlet to the constant speed combustion air fan, it only modulates about 5 degrees. The unit leaks a lot of air, particularly at the burner. It has reportedly never operated under starved air conditions.

6) There have been problems with particulates accumulating on the outside of the tubes in the original boiler. The tubes were placed quite close

*At the time of the site visit, $1 Canadian was equal to about $.80 U.S.

together and were difficult to clean. They are adding spacer plates between successive tube banks to increase the separation from about 3 inches to 10 or 11 inches. This modification will cost about $1,500 Canadian. The tightly-spaced fins on the tubes (4 fins per inch) have also contributed to tube clogging. Besides being a maintenance problem, clogged tubes contributed to poor boiler performance, preventing reliable heat recovery until early in 1982. They reportedly have not received much technical support from the boiler manufacturer.

7) The burners are reportedly unpredictable. The operator is also unsure why they should run continuously, since he feels that the combustion should be self-sustaining.

8) Their waste burnout is reportedly poor. The Ministry of the Environment requires a rate of waste throughput which is equivalent to charging the incinerator every 12 minutes. At this rate, only 55 percent of the combustibles are burned.

9) The day of our visit, there was some garbage odor, but this is actually produced by the RDF facility. The incinerator was not operating that day.

10) The boiler has a water spray to clean the outside of the tubes. To prevent the spray water from running all over the floor, they installed a metal catch pan.

PLANNED FUTURE MODIFICATIONS:

They will replace the ram's drive mechanism with a rack and pinion drive located underneath the ram. This is expected to cost about $1,500 Canadian.

MISCELLANEOUS:

1) The Ministry of the Environment has tested the incinerator's air emissions. Information on emission requirements and plant compliance may be available from Mr. Ron Lyons, Plant Manager, 35 Vanley Crescent, Downsview, Ontario M3JM2B7.

2) The instrumentation is apparently the manufacturer's standard package. The instrumentation is reportedly adequate and they have not had much trouble with it.

FACILITY: LAMPREY REGIONAL SOLID WASTE COOPERATIVE
1 Lamprey Way
Durham, New Hampshire 03284

CONTACT: Richard Rugg
(603) 868-1068

OWNER: Lamprey Regional Solid Waste Cooperative

OPERATOR: Lamprey Regional Solid Waste Cooperative

INCINERATOR DATA:

Manufacturer: Consumat Systems
P. O. Box 9379
Richmond, Virginia 23227
(804) 747-4120

Unit: Three Model CS-1600 incinerators with 2 heat recovery boilers

Design Capacity: Each 3,000 lb/hr, total 9,000 lb/hr

Actual Capacity (as operated): 7,500 lb/hr

Fuel Characteristics:

- Municipal solid waste from 13 surrounding towns
- Selected wastes including oily wastes, oil-spill cleanup debris, confidential records, and marijuana.
- They do not accept brush, construction materials, or inorganics in large quantities.

Date Installed: August 1980

Heat Recovery: 150-190 psi saturated steam. Output for week of September 6-12, 1982 was 1,029,020 lbs of steam. This is a low output for them since the University was in summer session and steam demand was low; excess flue gases were vented.

Operation: They operate 24 hours/day, 7 days/week, 52 weeks/year. They apparently operate two daily 12 hour shifts using 1 foreman, 1 operator, 1 truck driver, and 1 cleanup person. Two mechanics work 8 hours/day, 40 hours/week. In addition to the daily maintenance, major maintenance takes about 10 days/year.

Shakedown Period: Approximately 2½ months - they began hiring personnel in August 1980 and first produced steam November 10, 1980.

Capital Costs (1981): $3,300,000 total. $1,500,000 of this was for equipment and $1,800,000 for the building and site utilities.

Operating Costs: They have an outstanding record keeping system which makes their operating and maintenance costs, waste tonnages, and steam production readily available.

Sample Data (All Numbers Rounded)

	1st qtr 1982	2nd qtr 1982
Incinerators Operated (hours)	3,800	3,900
Boilers Operated (hours)	3,500	2,400
Waste Burned (tons)	8,050	8,660
Quenched (wet) Ash (tons)	4,700	4,700
Electricity Used (kwh)	415,000	292,000
Water Used (cu ft)	68,000	22,000

- Electricity costs them $.06/kwh, and they use more than $100,000 worth per year.
- Water costs about $150 per quarter, and is used for domestic purposes and washdown. As they receive treated boiler feedwater from the University, their chemical use is minimal.

With a 1982 budget of $521,500 and an expected through-put of 31,500 tons, this is equal to about $17/ton for operating and maintenance expenses, exclusive of debt service and depreciation.

Their 1981 budgeted tipping fee was $10/ton and for 1982 it is $15/ton.

Revenues: The Cooperative's revenue is derived from several sources:

- Sale of steam to the University of New Hampshire at a price 20% less than the calculated cost of producing steam using oil. The price of steam is adjusted periodically to reflect current oil prices.
- Destruction of special wastes such as oily wastes, oil spill cleanup debris, confidential records, and marijuana, all on request.
- Tipping fees and miscellaneous hauling and disposal services.

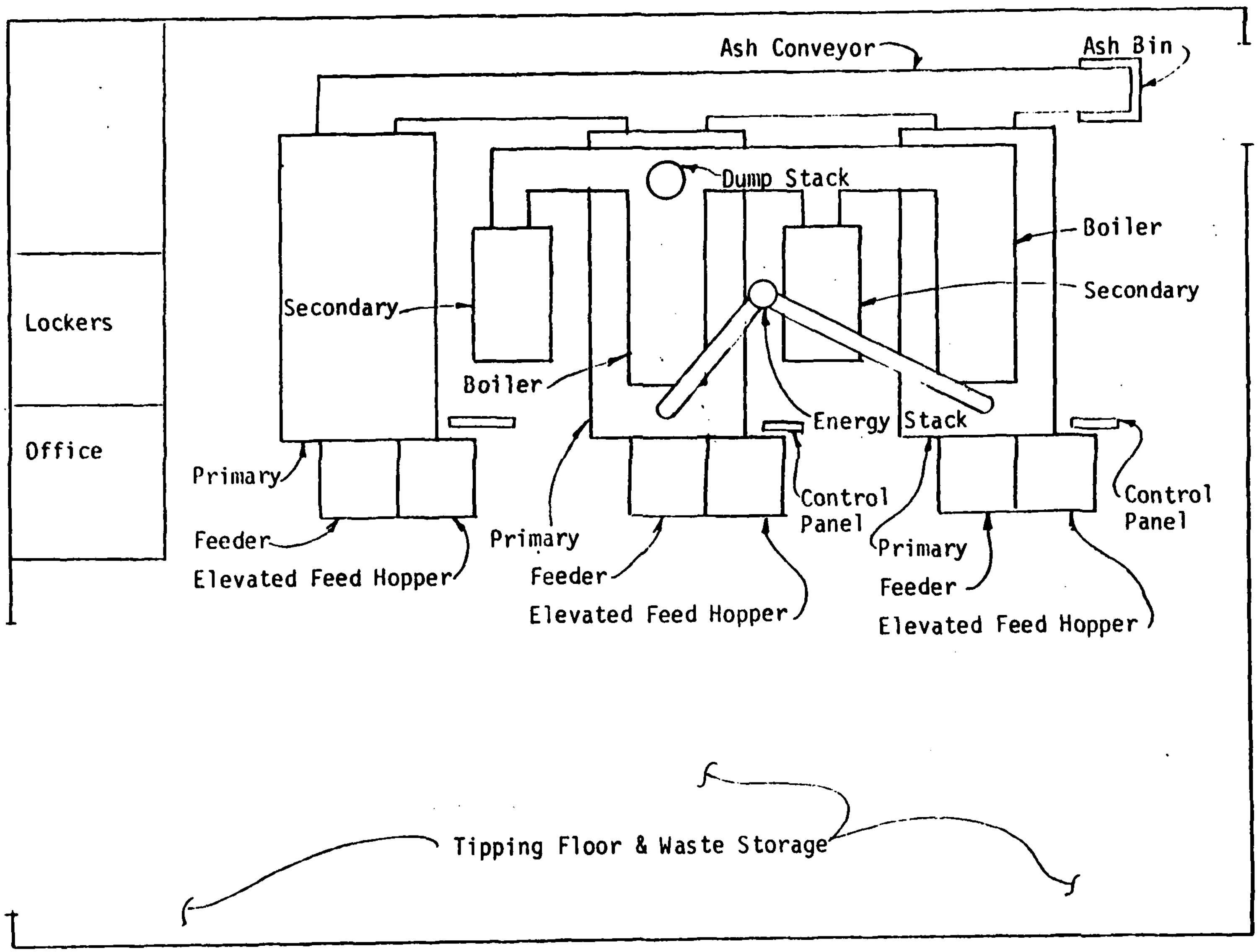
Spare Parts: The Cooperative keeps about $40,000 to $50,000 worth of inventory due to their remote location, since there are no stocking distributors nearby. They will probably join with other local Consumat users, such as Pease Air Force Base in Portsmouth, N.H., to maintain a common inventory.

FACILITY DESCRIPTION:

The incinerator facility is owned and operated by the Lamprey Regional Solid Waste Cooperative, a consortium of 13 municipalities which have organized to provide for the disposal of solid waste generated within their boundaries.

The three incinerators and the two heat recovery boilers are housed in a metal building on the University of New Hampshire campus, adjacent to the University's boiler plant. The incinerators are operated to keep pace with the flow of solid waste received. Steam is produced to match the University's load, which is considerably higher during the academic year than in the summer months.

The tipping floor is about 45' x 110'. This is considered to be inadequate, but sufficient land was not available to build a facility with an adequate tipping



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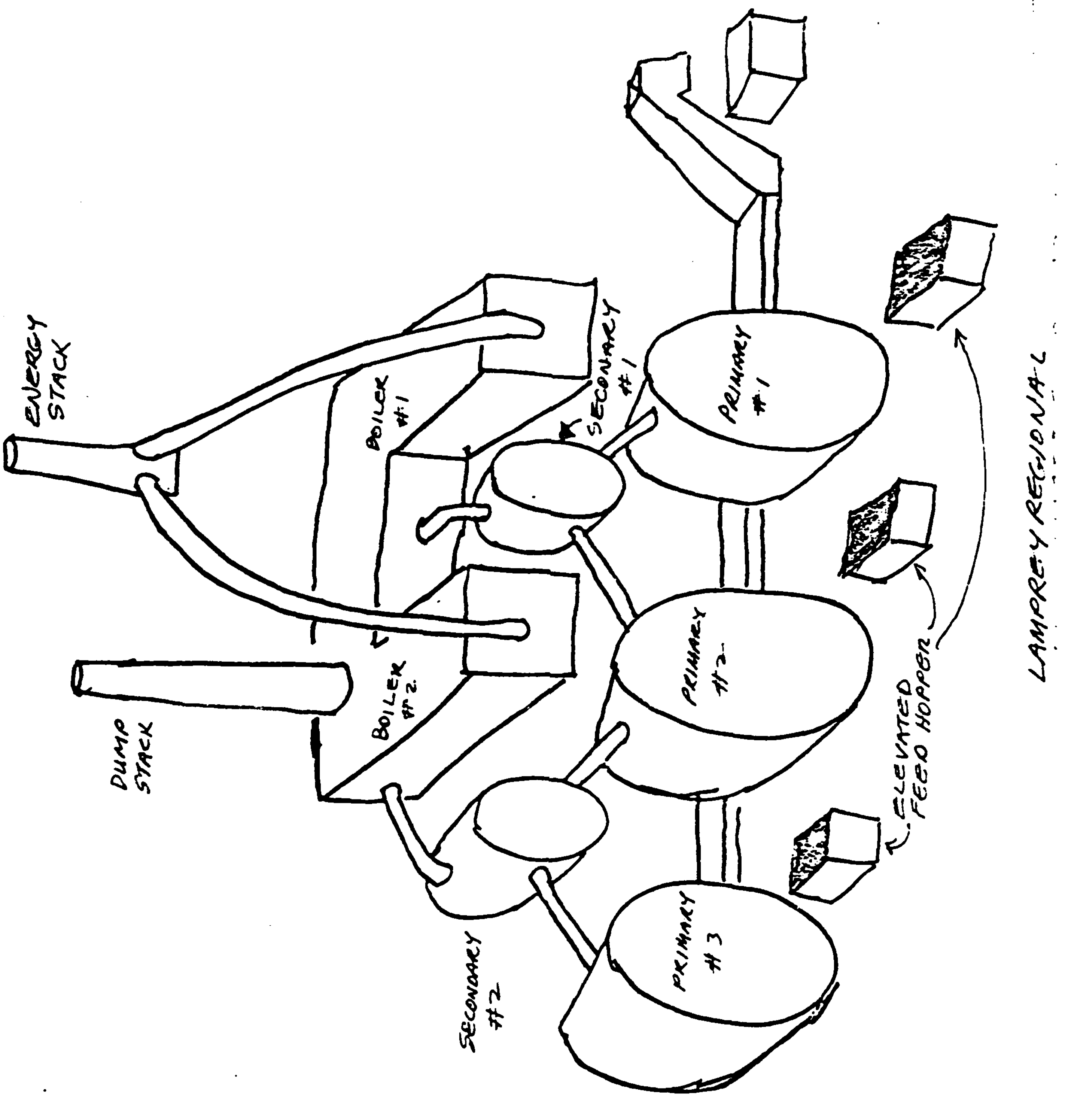
LAMPREY REGIONAL SOLID WASTE COOPERATIVE


ENERGY STACK
DUMP STACK
BOILER #1
BOILER #2
SECONDARY #1
SECONDARY #2
PRIMARY #1
PRIMARY #2
PRIMARY #3
ELEVATED FEED HOPPER
LAMPREY REGIONAL

floor.

These particular incinerators require the refuse to be lifted up by a front end loader equipped with a special side-dump type bucket, then dropped into an elevated hopper. While this has the advantage of fluffing the waste, it is not as convenient as another Consumat design which involves pushing the waste across the floor until it drops into the loading pit where a hydraulic ram feeds it into the furnace. Furthermore, the newer design allows use of a small skid-steer tractor rather than a large front end loader.

The primary chamber is maintained within a range of 1150 to 1375 deg F. (operators reported different temperatures within this range) by controlling the mass of refuse being burned at any particular time. The operator is signalled by a large lighted panel to feed a LIGHT, NORMAL, or HEAVY load of refuse, which in turn causes the primary chamber temperature to increase, remain constant, or decrease. They operate on a 7.5 minute charge cycle. If the primary chamber overheats say to 1500 deg, a water spray comes on to cool it. If the temperature continues to rise, the underfire air is shut off automatically.

The secondary chamber is maintained at about 1700 deg F by modulating a damper on the constant speed combustion air fan to that chamber. If the temperature falls, the auxiliary fuel (propane) burner comes on.

Each heat recovery boiler was designed to use the flue gases from two of the incinerators to produce steam, leaving the other incinerator and boiler as backup. The boilers are water tube type manufactured by the Vierson Company of Michigan. The first bank of tubes are bare, the middle ones have fins, and the last banks have serrated fins.

In the winter the two boilers base-load the University's boiler system, running full-bore all the time. In the summer months when steam demand is lower, the induced draft fan (see below) is modulated based on steam header pressure (i.e., steam demand). In the summer they run only one incinerator and one boiler. They leave the dump stack open so that natural convection takes some of the flue gas out, the rest being pulled through the boiler by the induced draft fan. In the winter the dump stack is closed to force flue gases through the boilers.

The boilers were designed to use the 1600 to 1800 deg F. flue gases to produce 5,000 pounds of 190 psi saturated steam per ton of refuse with a 4,500 Btu/lb heating value. They have not run any tests of either boiler efficiency or refuse heating value, so they are unable to verify whether the design criteria have been met. During their best 3 months of operation, they estimated that they were producing about 4,000 pounds of steam per ton of refuse, after adjusting for boiler blow-down and other losses. At other times the steam production may have been as low as 3,500 pounds of steam per ton. They have reportedly produced as much as 30,000 pounds of steam per hour, which either implies that the boiler was conservatively rated, or that they were feeding refuse in excess of the 4.5 tons per hour design rating.

An induced draft fan pulls flue gas out of the boiler and into a cyclone to remove particulates. The flue gas is then exhausted up the plant (energy) stack.

PROBLEMS AND MODIFICATION:

1) The equipment is covered with dust and ash because they are unable to wash down the facility. While the Consumat equipment was furnished with watertight electrical connections, the plant wiring (e.g. fluorescent lights and outlets) were not watertight. They are currently rewiring various parts of the facility, so they may then wash down with hoses.

2) The steel guillotine doors on the inlets to both boilers warped due to the heat. They have been replaced with doors made of non-warping "Fiberfax" material mounted on stainless steel rods. Consumat paid for this modification.

3) Lamprey has "taped shut" the barometric dampers on the stacks so they can "run harder" if they want. It is not clear what benefits resulted from this modification, nor what if any problems it may have caused.

4) The refractory floor of the primary chamber scrapes on the bottom of the feed rams, and vice-versa. One theory is that the front and back sections of the incinerator were not properly aligned during installation. Another theory holds that cans and other debris hang up beneath the rams or the ¼-inch steel wipers, which tend to warp. Consumat modified the rams by adding stainless steel plates on the refractory and rollers on the underside of the rams. They think that only use of a tough, castable refractory will work, and they are currently experimenting with this alternative.

5) They have had several problems with their boiler tubes. First, as at most facilities, there has been severe deposition of ash on fins of the boiler tubes. This may in part be attributed to the fact that their sootblowers operate once every 1.5 hours, which is relatively infrequent. They have been cleaning the exterior of the tubes with a high pressure water hose, although they would prefer to use compressed air or a broom. Second, they have had buckling of some of the tubes due to thermal expansion. This was apparently caused by a small fin welded to some of the tubes. Designed to turn the flue gases upward along the vertical length of the tubes, it also acted to stiffen the tubes. When the tubes expanded during incineration, they were unable to bend slightly, and

buckled instead. Third, they have had internal clogging of the middle boiler tubes with white and black colored deposits. Since the first and last modules of boiler tubes have about the same blowdown content as the steam drum, it appears that most of the water is evaporating from the middle set of tubes. The University boiler plant, which provides treated feedwater, does not think it is a feedwater problem. Consumat is reportedly having this type of boiler probem at other locations.

6) At Lamprey the waste is lifted up about 10 feet and dropped into elevated feed hoppers, rather than pushed into sunken hoppers as on newer Consumat (and other manufacturer's) units. Although it is acknowledged that the present setup is less desirable, it would have cost an additional $500,000 to use sunken hoppers, as the building would have required a significantly different foundation, because of undesirable soil conditions. Use of the elevated hoppers requires special side-dump buckets which are not as "accurate" as pushing refuse into sunken hoppers. It also increases the amount of dust in the facility. Lamprey claims that two advantages of the system are that they can pile the waste higher than if they used skid-steer tractors, and that they can fluff the waste and sift through it for large metal objects more easily.

7) Several people at Lamprey feel that each incinerator should have its own ash conveyor. With only one conveyor there is no backup and all three incinerators must be shut down if there is a conveyor problem. The single conveyor is about 75 feet long and removing blockages requires draining about 5,000 gallons of water and shoveling out the ash.

8) Lamprey plans to modify the ash conveyor controls so that the conveyor is moving when the ash hits it. They would also modify the controls

so that the conveyor runs on demand, which would be less frequently than it does now.

9) Lamprey would prefer pneumatic damper controllers instead of electric because they react more quickly.

10) Lamprey reports that in 1.5 years of operation (at about 30,000 tons/year) they have had to divert less than 100 tons of waste because of equipment problems.

11) Both units #1 and #2 were modified in August 1982 with new floors, new refractory and firebrick, and replacement of warped boiler guillotine doors, and warped and plugged boiler tubes.

12) There appeared to be an accumulation of slag on the refractory in the secondary chamber. This may be evidence of a high rate of particulate carryover, possibly caused by excessive gas velocity resulting from over-firing the primary or having too much air in the primary (non-starved-air condition).

13) Combustion air to the secondary chamber is preheated by flowing through a shroud covering the primary chamber. Ash and dust which leak out around the loading ram accumulate on the outside of the primary and are entrained in this combustion air. Because the fan is constant speed and the throttling damper does not appear to effectively cut the flow, the combustion air not required by the secondary is blown out into the room. This reportedly accounts for a large amount of the dust and ash which is visible on the equipment.

14) The building was initially designed as closed system; odors would be minimized by drawing combustion air in through the louvers. However, the doors are often open to allow refuse deliveries which occur quite frequently. The building as operated does not allow optimal odor control nor preheating of combustion air to the primary.

15) The primary chamber has water-cooled tubes on the outside, designed to keep the primary chamber, the underfire air tubes, and the rams relatively cool, thus preventing warpage and slagging. The original water tubes had underfire air tubes inside them, with water filling the annular space between them. However, heat warpage caused short circuiting of the water. One of the Lamprey engineers designed a triple wall tube with the water entering in the middle tubes and returning in the outer tube; this seemed to solve the problem.

16) There is some debate as to whether auxiliary fuel is used only for startup, burndown, and the pilots, or whether the secondary burner runs constantly to keep down emissions. It appeared that the burner fan for the secondary was running constantly. If the burner runs constantly, this would adversely affect auxiliary fuel usage.

17) Consumat paid for replacing the bottom part of the cyclones (no mention was made of the reason for the modification).

18) Temperature limits in the primary and secondary chambers are set to yield the best emissions results, rather than for optimum boiler efficiency.

MISCELLANEOUS:

1) Each incinerator is rated at 36 tons/day (tpd). Because this is below the regulatory limit of 50 tpd, they are allowed an emissions rate of 0.2 grains/sdcf rather than 0.08 grains.

2) They have done some tests for toxicity and leachate on the ash, and it has passed the EPA requirements. The ash is not considered hazardous; it is approved as secondary cover material in the state of New Hampshire and is trucked to the Newmarket landfill.

3) They reported that the lead content of the ash seemed a bit high, but it is evidently not a problem. Their lead content is reportedly lower than the ash from the Saugus, Massachusetts incinerator facility.

FUTURE MODIFICATION:

Lamprey is planning to install a steam turbine to generate electricity. They expect to spend about $300,000 with a payback period of 2 years. This is in large part due to their expected $80,000 annual savings in electrical demand charges.

FACILITY: CORNING GLASS WORKS
Main Plant
Building 50-3
Corning, New York 14831

CONTACT: William L. Seiver
Engineering Department Supervisor
(607) 974-7920

OWNER: Corning Glass Works

OPERATOR: Corning Glass Works

INCINERATOR DATA:

Manufacturer: Comtro Division
Sunbeam Equipment Corporation
180 Mercer Street
Meadville, PA 16335
Attention: Edward J. Donley

Unit: One Model A-50

Design Capacity: 2,000 lb/hr

Actual Capacity: 1,400 lb/hr

Fuel Characteristics:

Main feedstock

- Industrial plant waste from the Glass Works, including wooden pallets, cardboard, paper, glass waste, 15-20 percent cafeteria waste, and occasional plastic containers.
- RDF: Baled leftovers from the Rochester, New York, RDF manufacturing facility, consisting of lighter fractions of municipal waste.

Secondary feedstock

- Miscellaneous wastes from local haulers, as selected by the Glass Works.

Date Installed: December 1981

Heat Recovery: 7,500 lb/hr of 200 psi steam, with condensate return at 165-170 deg. F.

Operation: They operate 13 hrs/day, 5 days/week. Maintenance takes about 4 hours/week. They have a morning shift Saturday, then are shut down the rest of Saturday and Sunday. Monday morning they clean the facility and receive waste. Monday afternoon they begin burning again.

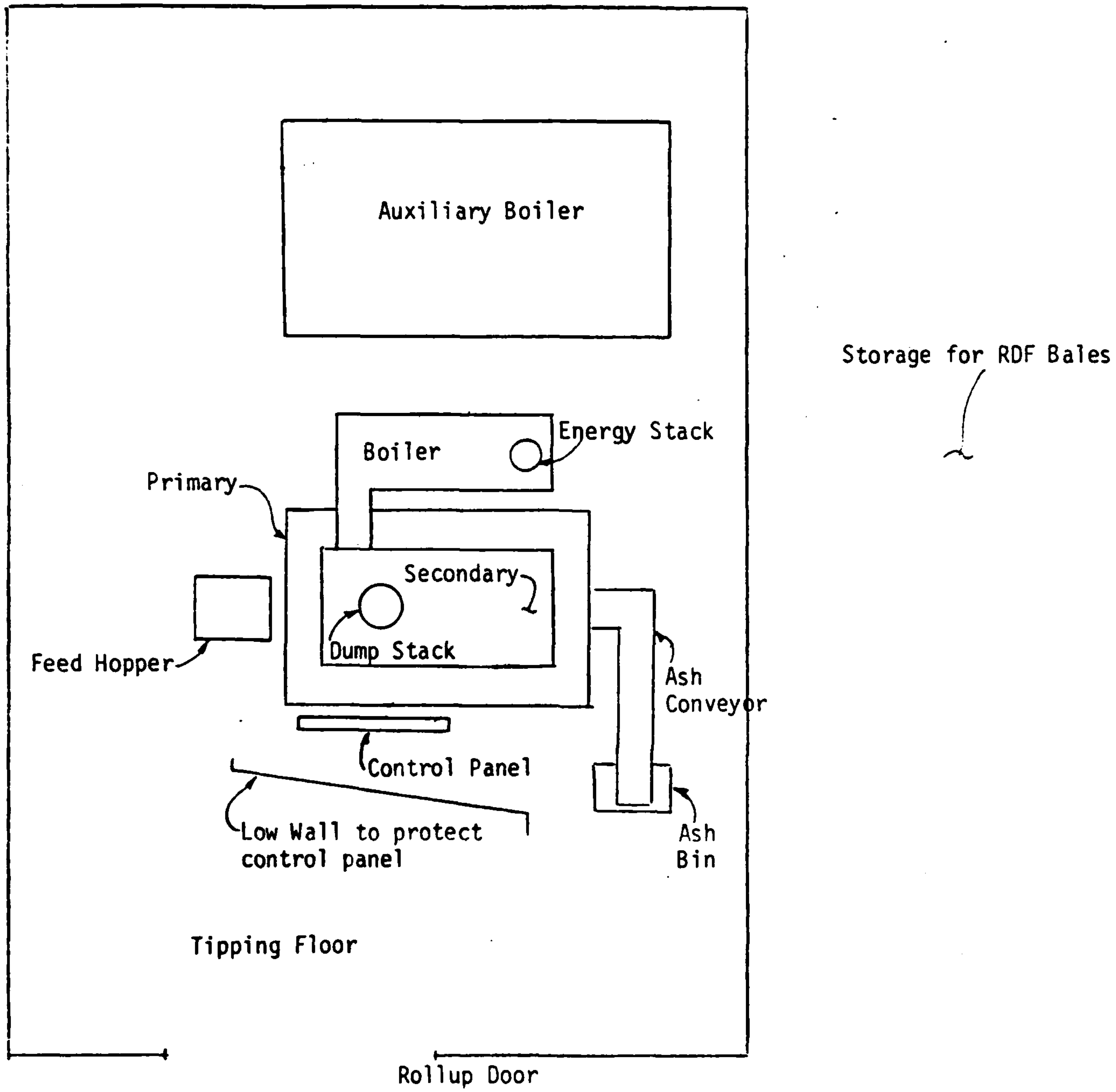
They have 3 operators, 2 maintenance personnel (on a shared basis with the main boiler plant), and 0.4 full-time supervisor. The skill level varies greatly.

Capital Costs: (1981 basis) $1,500,000 total, of which $1,350,000 was for equipment and $150,000 for the building and site utilities. They estimate that the total capital cost to date is about $2,000,000.

Operating and Maintenance Costs: Costs are not available because their accounting system does not separate costs for the incinerator facility from costs for the boiler plant yet. In addition, they cannot yet meter natural gas usage as auxiliary fuel for the incinerator. They did note that they had budgeted 1700 cfh for the primary burner and 2500 cfh for the secondary. The burners are rated 90,000 cfd (about 3.75 million Btu/hr) total on high-fire.

FACILITY DESCRIPTION:

The incinerator is housed in a metal building across the railroad tracks from the main boiler plant. At the time of our visit, waste consisting of baled RDF from Rochester and some plant waste including plastic containers was stockpiled adjacent to the building. Some slight odor from the RDF was noticeable. The RDF is being used to supplement the in-plant waste, which is



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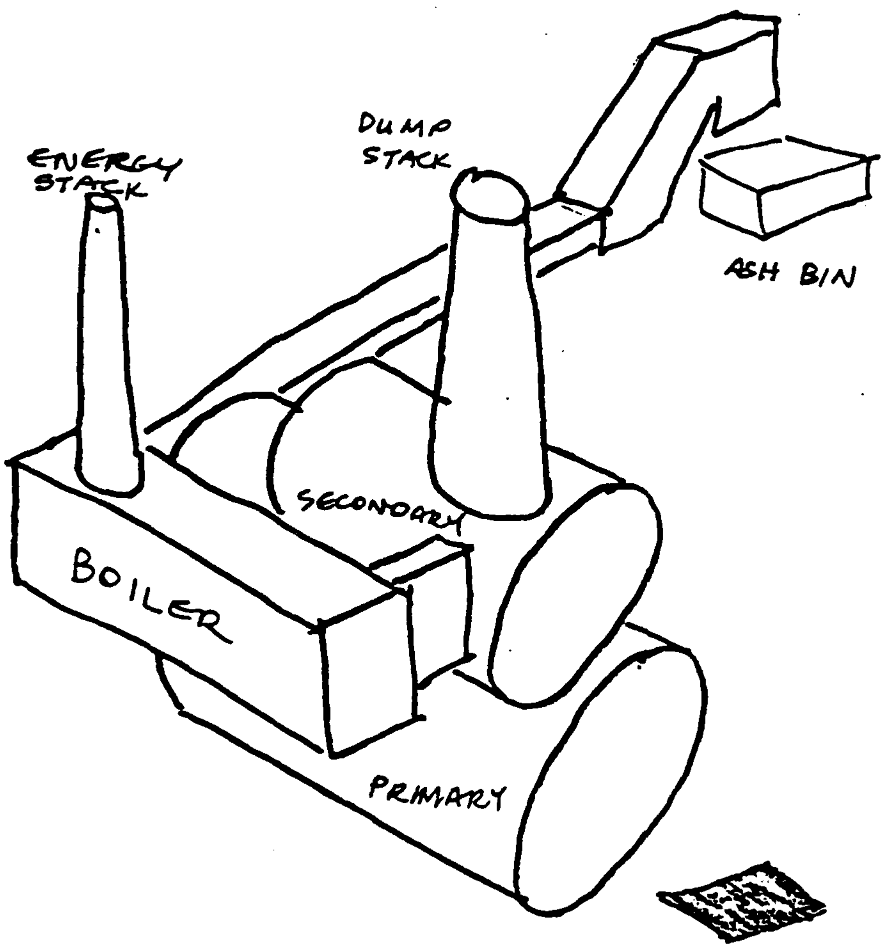
CORNING GLASS



CORNING GLASS WORKS

inadequate since the plant is not running at full capacity due to the general state of the economy.

The Corning staff reports that the 36' x 33' tipping floor is too small; they may enlarge it by 40 feet towards the rollup door. They would enlarge it further, but they lack the space. At present, the waste piles up about 6 to 8 feet high on the tipping floor.

The waste bales are broken open and fluffed by dropping, using a four tire Waldron 5000 loader with a clawed front bucket. This enables the operator to get more even-sized loads. The waste is dropped down into the three yard loading hopper, the top of which is level with the floor. The hopper reportedly holds a draft well and has little "blowback" from the furnace.

Numerous modifications have been made to the furnace, which now has a water-cooled refractory hearth of a proprietary design. The staff feels that the incinerator will now operaté satisfactorily. The primary chamber burner was destroyed in an accidental fire, so they now light the primary chamber waste with a match. Oftentimes, the load will self-ignite from the residual heat in the primary chamber.

Under-fire, over-fire, and secondary chamber air is provided by the same constant speed fan; hence, all combustion air goes either to the primary or the secondary chamber as controlled by dampers. The fan is capable of between 2 and 9 inches of water column. The secondary chamber has a burner which is continually fired, automatically, on a Hi-Lo basis. Natural gas is the auxiliary fuel and is metered at the main boiler plant only. However, a separate gas meter for the incinerator facility is on order. The incinerator is operated with the primary at 1500 deg. F and the secondary at 1700.

The heat recovery boiler is a Model 5 HIR, manufactured by Eclipse Lookout Co., Chattanooga, Tennessee. It is rated at 10,091 lb/hr of steam, entering gas temperature of 1800 deg. F, leaving gas temperature 515 deg. F, 6006 scfm flue gas, equivalent 1585 sq. ft. heating surface. They have been getting good quality steam. Because it is a firetube type boiler, however, they have had problems with particulate accummulation on the (inside) surfaces of the heat transfer tubes. Water treatment is provided by the main boiler plant.

Although the State's environmental agency has allowed them to burn, the facility has reportedly not been tested for air emissions. They reportedly get some puffs of smoke when the unit is loaded, and occasionally a big black cloud. There is a pneumatic controller on the dump stack, with a time delay to prevent the stack from opening up on surges. The stack damper is counter-weighted.

Ash is disposed of at Corning Glass's own landfill. There is an internal, cost-center type charge for this disposal.

PROBLEMS AND MODIFICATIONS:

The Corning facility has experienced difficulties common to most of the incinerator facilities visited. Most of the problems listed below have already been solved, or were constraints beyond the control of the equipment manufacturer and/or the facility designer in the first place. Most importantly, the Glass Works staff emphasize that the equipment manufacturer has given them very good technical support and in most cases the manufacturer paid for equipment modifications.

1) The waste is moved through the incinerator in about 3.5 hours by the combined action of a loading ram and two stepped internal plows (rams)

which push the waste forward and tumble it to promote complete burnout. A programmable controller automatically cycles the three rams in sequence. The length of time a particular ram is extended, as well as its position relative to the other rams, can be varied. After experimenting with various settings, they reportedly can obtain better than 50% volume reduction. However, some partially burned material was noted in the ash stored in a dumpster outside.

2) They have had some relatively minor problems with their waste stream. They believe that they are receiving the heavy combustible stream from the Rochester RDF plant, as it appears to contain large amounts of ash and grit. This obviously is not a high quality fuel. They also had a fire due to self-ignition of a one-ton bale of RDF. When they first began accepting in-plant waste, they received large amounts (up to 40% of the waste stream) of reject glassware and glass fragments which turned to jelly in the furnace. Contact with the relatively cool mechanism caused the glass to solidify and tear out the refractory as the plow was retracted. An education program for plant personnel has remedied that problem.

3) The dump stack bearings seized up, but this has been remedied by the simple addition of grease slots.

4) As previously noted, the primary burner was destroyed accidentally in a fire. They elected not to spend $1,400 to replace it, since the primary chamber either self-ignites or can easily be match-lighted.

5) They have had numerous problems with the wiring (the exact nature of which was not specified).

6) The layout of the facility was constrained by lack of space to put the building itself, and this is reflected in a tipping floor that they recognize is too small. In addition, the ash conveyor was made quite steep (60 degrees from the horizontal) to conserve space. They feel that this has caused operational problems with the conveyor, including frequent breakage of shear pins, bushings, and chains. Another consequence of inadequate space is that the controls are too near the loading area. A metal wall topped with plexiglass has been erected to protect the controls from the trash handling vehicles. However, the close proximity to the trash has resulted in dust contaminating the electrical contacts of the control panel. A containment wall angled toward the hopper would aid in directing trash into the hopper.

7) The gasket on the ash discharge chute burned up and leaked. They deleted the bolts and instead welded the chute to the chamber.

8) The front-loading door seal, originally made of spring steel, leaked air badly. Others either burned up or were torn off in the course of normal operation. Their present seal made of 1/8 inch "red rubber" surrounded by fiberglass reportedly works well.

PLANNED FUTURE MODIFICATIONS:

They are in the process of building an intake plenum surrounding the boiler stack to preheat combustion air. This will allow them to use outside air directly, rather than room air which contains dust and can clog part of the proprietary combustion air system. It should also increase efficiency and prevent cold winter combustion air from entering through building louvers and freezing pipes.

FACILITY: SOLID WASTE DISPOSAL ENERGY RECOVERY PLANT
1300 Indiana St.
Salem, Virginia

CONTACT: Jim Fender
(703) 375-3052

OWNER: City of Salem, Virginia

OPERATOR: City of Salem, Virginia

INCINERATOR DATA:

Manufacturer: Consumat Systems
P.O. Box 9379
Richmond, Virginia 23227
(804) 746-4120

Unit: Two Dual CS-1200 incinerators. Each dual incinerator has 2 primary chambers, 1 secondary chamber, 1 boiler, and 1 ash conveyor.

Design Capacity: Each unit 4,200 lbs/hr, total 8,400 lbs/hr (total 100 tons/day)

Actual Capacity (as operated): 105 tons/day peak loading

Fuel Characteristics:

- Municipal solid waste from Roanoke County and the City of Salem.
- Commercial solid waste
- Aluminum, ferrous metals, and glass are removed from the wastes prior to loading the refuse into the incinerator.

Date Installed: October 1978

Heat Recovery: 250 psi saturated steam. System is designed to produce 480,000 pounds per day (20,000 pounds per hour) of steam for sale to the Mohawk Tire Company. When demand is low, the excess flue gases are vented.

Operation: The city operates the facility 24 hours per day, 5 days per week. Solid waste is received 8 hours per day. The facility personnel work on three 8 hour shifts. Three equipment operators, 1 weigh master, 1 supervisor, and 1 superintendent are on the first shift (day shift). Two equipment operators, a utility worker, and a foreman/boiler mechanic are present on the next 2 shifts. Maintenance is performed on the incinerators and facility during the weekend.

Shakedown Period: The facility was completed in October 1978 and by November of the same year, steam was being delivered to the customer. Full capacity operation was reached in December 1978.

Capital Costs (1978): The system cost $1,900,000. This included planning, engineering, legal, and construction but did not include acquisition of the 2.2 acre site the facility is situated on. Financing was mainly by general municipal bonds.

Operating Costs: The Salem facility operators maintain fairly good records for operation and maintenance costs. Records are kept on the following operational costs:

- Electricity: about $.05083 per kwh; there is no demand charge.
  - Winter max: $5,000 per month (max kwh = 98,000)
  - Summer max: $3,700 per month (max kwh = 70,000, range = 40,000 kwh to 70,000 kwh)
- Water: 80,000 gpd (no information on costs)
- Auxiliary fuel: $1,000 per month (oil or gas can be used, costs will vary accordingly).
- Chemicals: $1,700 every 8 months for salts for water softening
- Tools: $1,500 per year
- Labor: The facility has a base pay budget of $220,000 and fringe benefit budget of $43,000 for 1982 (16 employees).
- Ash disposal: $6,500 per year (however, 63 percent of this was spent during the first 3 months of the year).

Revenues: The facility generates revenue from the following sources:

- Sale of steam to Mohawk Tire Company: Steam is sold at a price between $4.40 to $5.50 per 1000 pounds depending on what type of fuel Mohawk Tire Company is using to generate its own steam. The lower price is associated with natural gas, while the higher price is associated with oil.
- Tipping fee: A tipping fee of $7.00 per ton is charged to all private haulers and $6.00 per ton for commercial haulers. Private citizens can dispose of their wastes without paying a tipping fee, as long as the quantities are small.

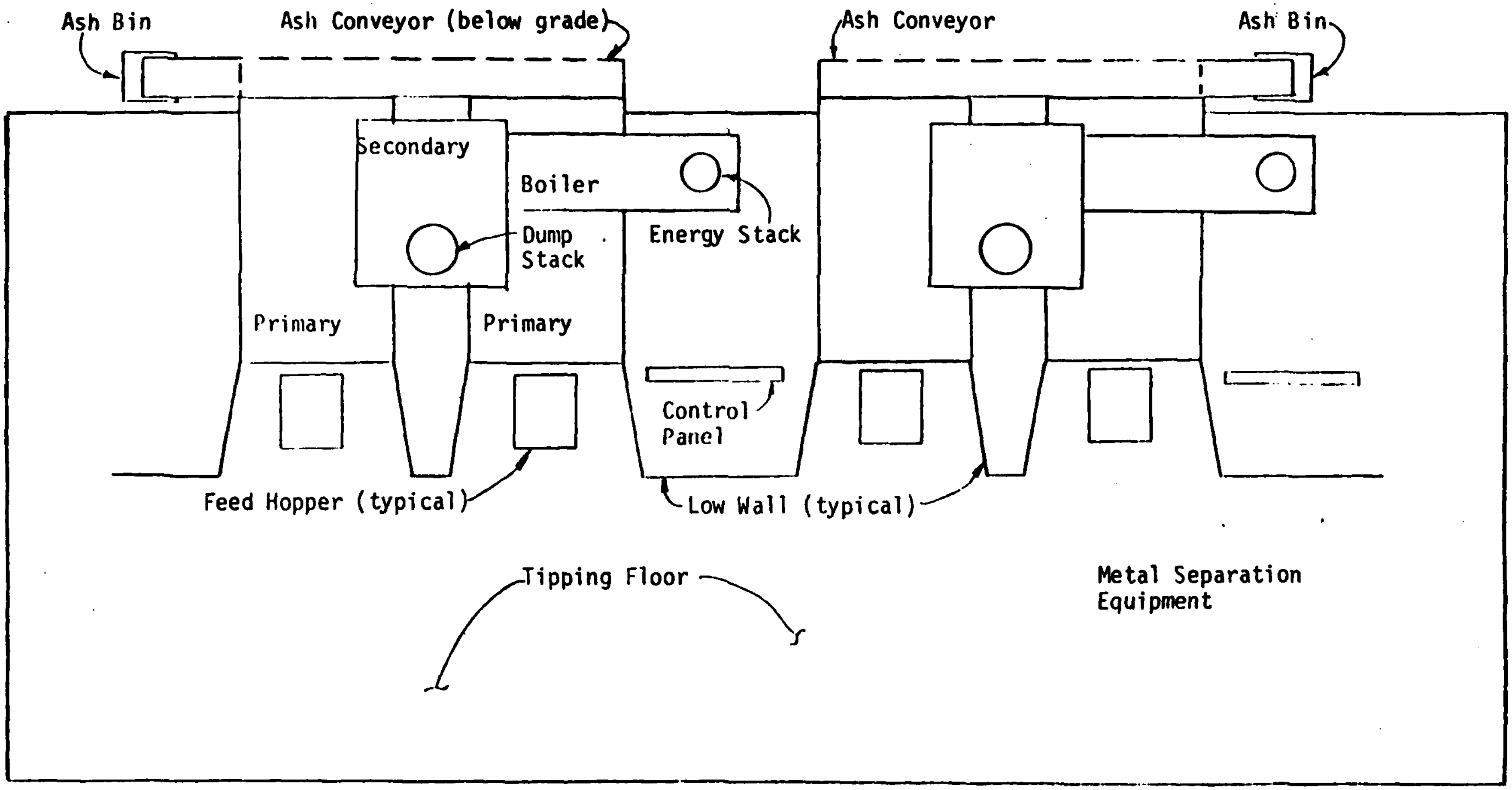
Spare Parts: The facility does not maintain an inventory of spare parts. They are located close enough to the manufacturer (Richmond, VA) to obtain parts as needed.

FACILITY DESCRIPTION:

The facility is owned and operated by the City of Salem. Refuse is received from the City of Salem, Roanoke County, and commercial establishments. The facility is located adjacent to the Mohawk Tire Company, who have contracted with the City to purchase approximately 7 million pounds of steam per month.

The incinerator and boiler system is located in a 15,600 square foot pre-engineered building. The building has one entrance for vehicle entrance and exit. A sloped ramp leads up to the entrance of the building.

The tipping floor is 120 feet long by 80 feet wide. Approximately one-third of this space is no longer available since a metals separator has been installed in the building. The supervisor for the facility feels that the tipping floor is not adequately sized, and was inadequate even before the metals recovery system was installed.



SALEM

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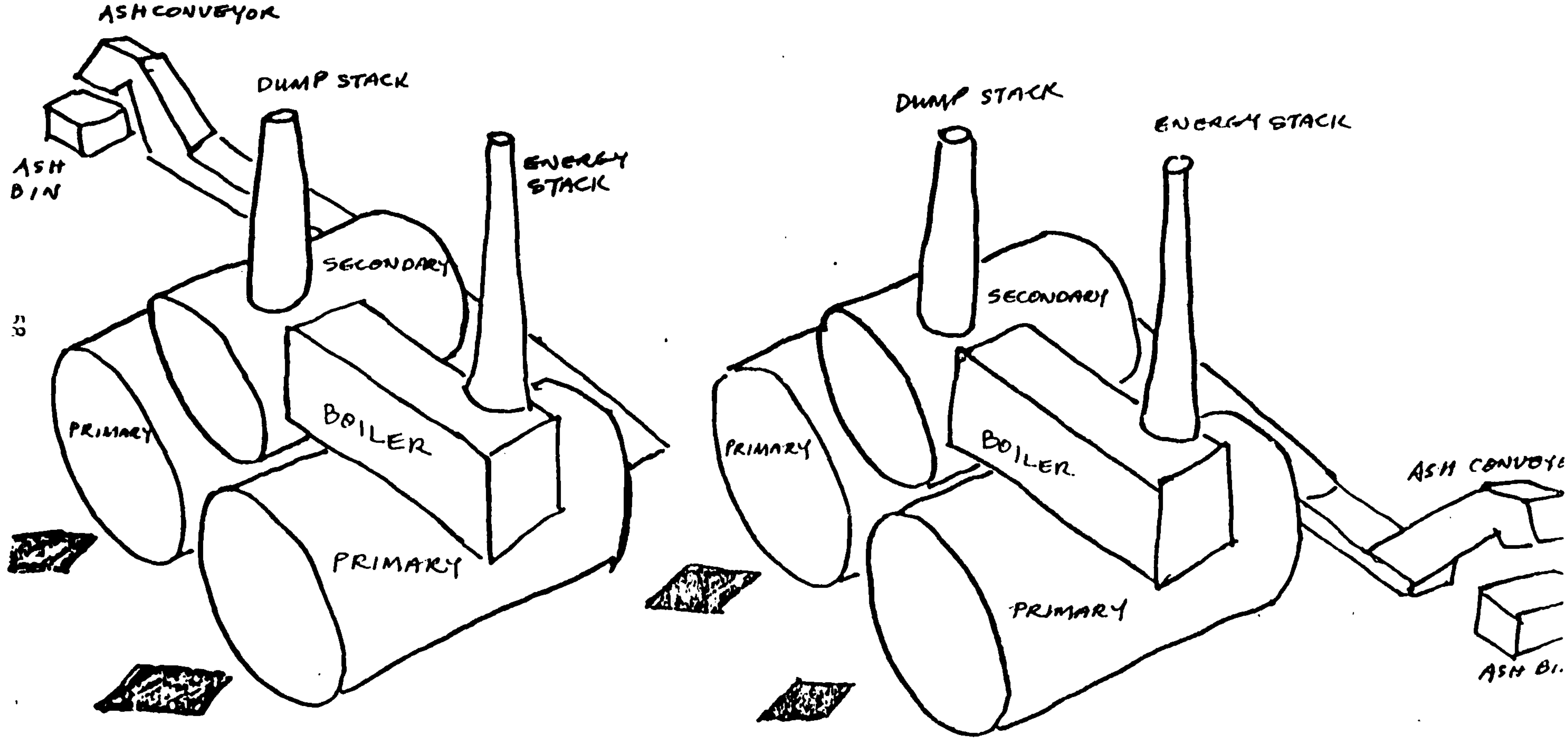

ASHCONVEYOR
ASH BIN
DUMP STACK
ENERGY STACK
SECONDARY
BOILER
PRIMARY
PRIMARY
DUMP STACK
ENERGY STACK
SECONDARY
BOILER
PRIMARY
PRIMARY

SALEM

Refuse is dumped directly on the tipping floor from the refuse hauling trucks. Tires and bulky metal objects are manually separated from the waste piles. The metal separation equipment is operated only part-time and separates steel with a magnet and aluminum with an eddy-current linear motor. Small front-end loaders (2 skidsteer type and one articulated type) are used to load the four refuse hoppers which feed the incinerators. The refuse is automatically loaded into the incinerator chamber through a ram system.

The boiler is equipped with an automatic soot blowing system. A blower header supplies high pressure air to six positions along the vertical boiler tubes. The blower system operates on a 2-hour cycle, with incremental sootblows every 15 minutes of each cycle. The boiler tubes originally had serrated fins, but these have been replaced with solid, non-serrated fins to decrease particulate buildup and subsequent decrease in heat transfer.

Ash is automatically ejected from the primary combustion chamber into a water-filled trough where a drag conveyor transports the settled ash to disposal trucks. The facility was originally designed with one conveyor belt. A second conveyor best was installed during the summer of 1982. Each primary combustion chamber is now served by a separate conveyor system.

The water tube boilers are designed to produce a total of 20,000 pounds of saturated steam per hour at a pressure of 250 psi. Current steam production ranges from 14,000 to 18,000 pounds per hour. The City has a contract with Mohawk Tire Company to buy at least 7 million pounds of steam during a 20-day period. The Salem facility met its contract for the first time in 4 years in September 1982. Incinerator downtime has precluded successfully meeting the contract in the past.

The facility has no special air pollution control devices. Air quality coming from the incinerators stacks meets the State of Virginia Air Pollution standards of .08 grains/sdcf.

PROBLEMS AND MODIFICATIONS:

1) The facility has encountered two problems with its ash handling system: ash dispersal and conveyor belt breakdown. Both of these problems have been resolved in 1982. The ash dispersal problem was resolved by installing hoods over the ash removal ports to force the material into the water troughs (a water spray system was a part of the original design).

   The original design had just one conveyor belt spanning the entire distance between the two units. Any problem with the conveyor system would shut down both incinerators. The conveyor belt was apparently too long; the conveyor system was difficult to align resulting in undesirable stresses on the sprockets and motor. A second conveyor belt system was installed, so that each unit's primary combustion chambers are served by a separate conveyor belt system. The facility has not experienced complete shutdown of the system due to conveyor belt malfunctioning since the new conveyor belt was installed. The ash handling modifications were completed during the summer of 1982 at a cost of approximately $45,000.

2) The facility experienced problems with leaks in the feedwater pipes, mainly due to external corrosion. They previously used the feedwater as cooling water for the rams and air tubes, thus preheating the feedwater. The high temperatures and aggressive atmosphere caused corrosion of the pipes. They then switched to an air-cooled ram system. The

feedwater is now preheated only in the oxygen eliminator (deaerator) tank using boiler blowdown, and they have had no further problems with the feedwater system. Cost information for installing the closed loop cooling system was not available.

3) The feedwater pumps have given the operators substantial problems, mostly due to bearing failure. The pumps were evidently not sturdy enough for the intended use. The pump manufacturer, after much discussion, agreed to rework the two feedwater pumps at no charge to Salem. The pump manufacturer installed heavier duty shafts and power frames. The supervisor is now satisfied with the pumps.

4) The incinerators were completely overhauled during the first half of 1982. The overhaul included rebuilding damaged refractory, installing 12 new incinerator access doors, replacing and repairing various pipes, fittings and valves, and replacing the boiler tubes. The cost for the overhaul was $47,000 for each incinerator unit, for a total of almost $100,000.

5) They would like a more effective soot blower system, as the boiler tubes at present have to be manually washed every week with water. The boiler tube compartment is reportedly not designed for safe human access. The boiler drainage system reportedly should be redesigned to facilitate washdown.

6) Boiler water circulation is reportedly unsatisfactory. While scaling has not been a critical problem, they plan to clean the boiler tubes with acid annually beginning in 1984.

7) The operators think that more attention should have been given to the design and location of the incinerator controls. Many of the pressure

and temperature gauges are in inaccessible locations. A centralized control panel with all the pressure and temperature gauges easily accessible would be preferred. However, the present controls for the incinerator do work and appear adequate.

FUTURE MODIFICATIONS:

At the present time, the incinerators are shut down every Friday night and allowed to cool until Sunday morning. Maintenance on the system can therefore only take place on Sunday. This period is too brief to perform routine maintenance. The facility supervisor hopes to install a third incinerator unit in the next few years. The building was originally designed to house three units. The additional unit would permit a continuous maintenance program on the incinerators. The duty cycle for each unit would be two weeks operating, one week shut down. This would greatly increase system reliability.

FACILITY: LOCKHEED
1111 Lockheed Way
Building 103
Sunnyvale, California 94086

CONTACT: Rich Robertson
Incinerator Supervisor
(408) 742-9533/742-8104

OWNER: Lockheed Missiles & Space Company, Inc.

OPERATOR: Lockheed Missiles & Space Company, Inc.

INCINERATOR DATA:

Manufacturer: Consumat Systems, Inc.
P.O. Box 9379
Richmond, Virginia 23227
(804) 746-4120

Unit: One Model CS-1200

Design Capacity: 2,100 lb waste/hr

Actual Capacity (as operated): 2,200 lb/hr

Fuel Characteristics:

- At present -- industrial park waste, including mixed paper, newsprint, plastics, cardboard, plastic garbage bags, and classified documents.

Date Installed: October 1980

Heat Recovery: 120 psi saturated steam. They have no steam meter, hence no record of steam output.

Operation: They receive waste 5 days/week. They burn 24 hours/day, 7 days/week, 40 weeks/year. The incinerator operator also tends the chillers and boilers located in the same building. Maintenance is performed as required and takes about 60 days/year.

Day shift crew: 1 operator
3 workers on the baling machine
1 supervisor (4 hours/day)

Swing shift crew: 1 operator

Night shift crew: 1 operator

Weekend crew: 1 operator per shift

Shakedown Period: Eight to nine months.

Capital Costs: The incineration equipment cost $700,000 (1980). The building utilities and other equipment (absorption chiller, boiler, etc.) housed in the building cost $1,840,000.

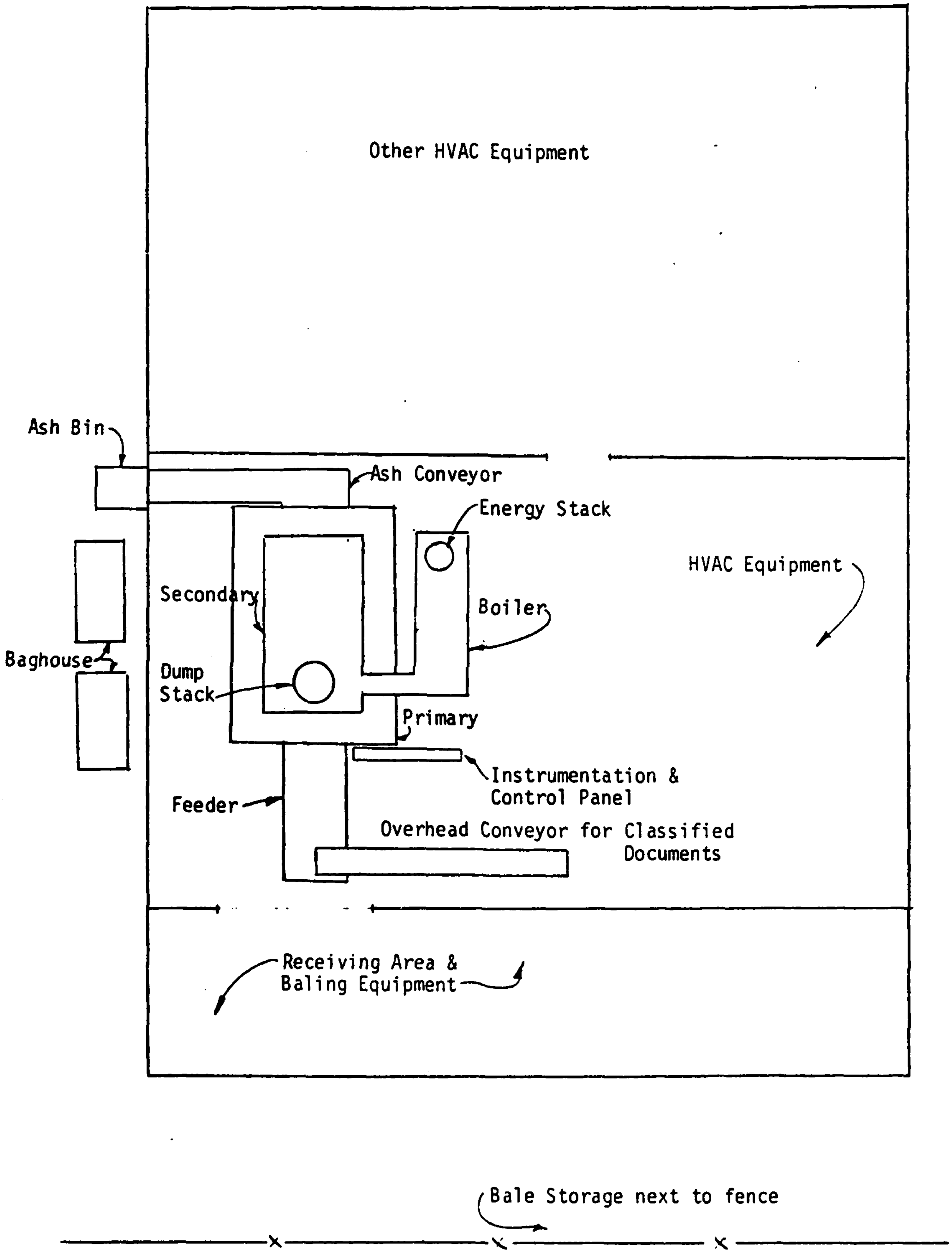
Operating and Maintenance Costs: These figures include all HVAC equipment in the building, as well as the incinerator facility.

Electricity	$4.20/hour
Water	2.5 gallons/hour
Auxiliary fuel	$6.90/hour
Chemicals	$2.83/24 hours
Pest control	$80/week
Tools, paint, etc.	$10,000/year
Ash disposal	$17.91/day
Labor	$1,000/day

FACILITY DESCRIPTION

Waste is received 5 days a week and is immediately compacted into 500 pound bales approximately 3' by 3' by 4' in size. Since the waste is stacked in a fenced area outside the building, baling keeps the area looking neat. As local rainfall is only about 14 inches a year, the bales are not covered. The baling equipment was not being operated during our site visit. They suspect that baling reduces the efficiency of waste burnout, since the waste is not well fluffed.

Waste is fed through a typical Consumat design hydraulic ram and hopper system. In addition, they have a special overhead conveyor belt system for dropping classified documents into the hopper. The primary chamber is maintained at 1,550^{o}F by throttling the supply air fan. The secondary chamber is maintained at 1,750^{o}F. Air to the secondary is preheated by being drawn through a heat



LOCKHEED

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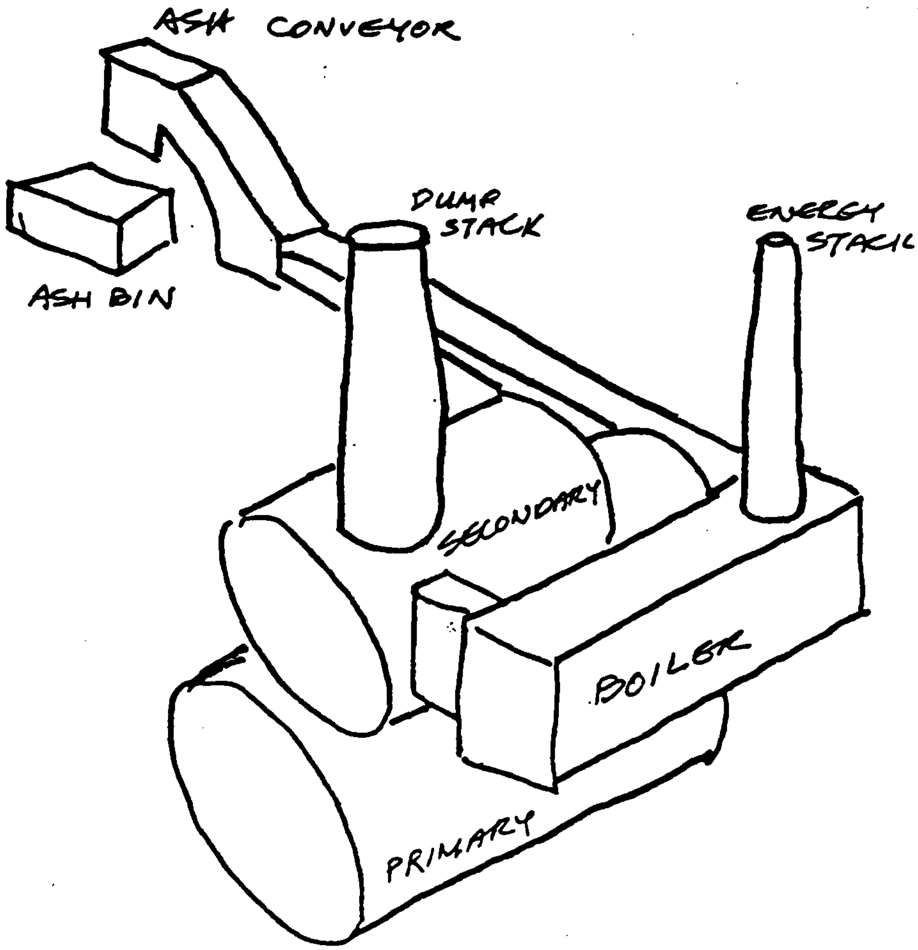
ASH CONVEYOR
ASH BIN
DUMP STACK
ENERGY STACK
SECONDARY
BOILER
PRIMARY

LOCKHEED

exchanger shroud surrounding the primary. To avoid the problem encountered at other facilities with excess, dust-laden air being blown out into the room when the secondary air fan is throttled back, they have installed a bypass stack to vent the air above the roof. The auxiliary burner in the secondary chamber is fired to maintain chamber temperatures of 1,750^{0}F. While the burner fan appears to operate 60-70% of the time, gas input to the burner is not constant, being continually adjusted by a modulating motor.

Flue gases enter the Maxim (Riley-Beaird) boiler at a reported temperature of about 1,500^{0}F. The first two tube banks are bare (no fins). The third bank has fins spaced about 3 per inch. The last two tube banks have serrated fins. Each tube bank has its own blowdown connection. The water treatment works well and they have no scaling problems. The boiler has a steam drum, but no mud drum. A 50 hp, constant speed induced-draft (ID) fan pulls flue gases out of the boiler at about 400-450^{0} and blows them to an economizer located outside the building. The economizer raises the temperature of the boiler feedwater by about 25^{o}. Flue gases are cleaned up in a baghouse before being vented.

They have found that if ash falls on a stationary conveyor chain, the chain tends to "hang up". The chain also stretches. They have remedied this problem by running the chain all the time, so that ash always falls on a moving chain.

PROBLEMS AND MODIFICATIONS:

1) The baghouses had to be replaced after two years due to severe external corrosion. They believe the problem began when the bolted seams of the baghouse expanded when heated, allowing corrosive gases to leak out and condense on the outside of the baghouses. The high plastic content in their waste stream produces a good deal of corrosive gas.

They feel that all-welded construction and heavy insulation of the baghouses will prevent leakage and condensation of corrosive gases, respectively.

2) The ash ram is not supported out to its fully extended position, and hence tends to "drop down" at the end and rake refuse back across the hearth as it is being retracted. This has caused refractory wear, but they have not had to replace the refractory yet. The operator reports that the Consumat incinerator at the Amway plant has similar problems.

3) Sometimes the ram wiper gets blocked off by the refuse, and combustion air in the primary flows back under the ram and out through the loading door ("blowback").

4) They experience a buildup of 8 to 12 inches of soft, fine dust in the secondary chamber. This requires the unit to be shut down for 4 hours on the night shift to scrape out the dust.

5) They have lowered the gas velocity (to decrease particulate entrainment) by slowing down the ID fan from its original setting.

6) They added sootblowers on the first tube bank in the boiler to improve particulate removal.

7) The sootblowers which use 120 psi compressed air can blow ash out through leaky gaskets and into the room. They installed roof-mounted power ventilators to provide adequate air changes to keep the room air relatively clean.

8) They added a low draft sensor to prevent explosive and/or dusty gases from leaking back into the room. If a low draft condition (.07 vs. a normal .2 reading) is sensed, the dump stack is opened after a 20 second time delay, venting the system to the outdoors.

9) The ID fan had bearing problems and its control damper functions poorly.

10) Minor shortcomings of the facility include:

   a) A crane or other lifting device would be helpful in removing the 50 hp ID fan for repairs.

   b) More room in the ash pit for easier maintenance is desirable.

   c) The ID fan vibrates the platform grating excessively. The fan should either be tied more firmly to the structure or should have vibration isolators installed.

   d) Boiler and incinerator doors have warped.

11) When their waste stream contained more organics than at present, they did have some problem with rodents. They now try to exclude organics.

MISCELLANEOUS:

1) The waste burnout looked quite good. The facility was also very clean.

2) They have not run any tests on thermal efficiency of the unit.

3) They charge a small tipping fee; however, the refusal disposal service is mainly a public relations measure.

4) Their water treatment works well and they have no scaling problems.

5) While there is not a definite problem with heavy metals in the ash at present, pending California legislation may change this situation. Lockheed is considering using a magnet to separate ferrous metals, as well as source separation (e.g. bins marked "Paper" and "Other").

6) They furnished us an excerpt from an emissions test report which indicates that their particulate emission is less than 0.008 grains/sdcf, far below the Bay Area Air Pollution Control District standard of 0.15 grains. Their NO_x emission was tested at 87 ppm versus a standard of 300 ppm, and their SO_x was 152 versus a standard of 300 ppm.

APPENDIX

TABLE A

EQUIPMENT DATA SUMMARY FOR STARVED-AIR HEAT RECOVERY INCINERATOR SYSTEMS

Owner[a]	Location	Fuel[b]	Type of Heat Recovery	Year Installed	Total Design Capacity lb/hr	Total Capacity As-Operated lb/hr	Mfr.[c]	No.	Model	Capital Cost ($1000s) Eqpt.	Capital Cost ($1000s) Facility
K.W. Muth	Sheboygan, WI	Ind. (W,C,P,F)	Steam 100#	1976	2,000	No data	Kel	2	1280	260	45
Cassia County	Heyburn, ID	MSW, Ind.	Steam 150#	1981	4,200	4,200+	CSI	1	Dual CS-1200	--1,400--	
Rolscreen	Pella, IA	Ind. (P,W)	Steam 50#	1979	2,100	1,500	CSI	1	CS-1200	350	250
Gov't of Ontario	Toronto, Ontario	RDF (P, Pl)	Hot Water 230 F.	1976	2,200	850	CSI	1	C760A	--d--	
Lamprey Regional Solid Waste Cooperative	Durham, NH	MSW	Steam 150#	1980	9,000	7,500	CSI	3	CS-1600	1,500	1,800
Corning Glass Works	Corning, NY	RDF & Ind (P, W,M)	Steam 200#	1981	2,000	1,400	Com	1	A-50	1,350	150
City of Salem	Salem, VA	MSW	Steam 250#	1978	8,400	8,800	CSI	2	Dual CS-1200	--1,900--	
Lockheed Missiles & Space Co.	Sunnyvale, CA	Ind. (P,M)	Steam 120#	1980	2,100	2,200	CSI	1	CS-1200	700	e

[a] All facilities owner-operated except:
- Cassia County - operated by Thermal Reduction Div. of Wilder Construction
- Government of Ontario - operated by Browning-Ferris Industries

[b] Abbreviations for fuel types:

MSW - municipal solid waste
RDF - refuse derived fuel
Ind. - industrial/commercial plant waste
C - corrugated paper
F - food
M - metals
P - newsprint and mixed paper
Pl - plastic
W - wood

[c] Manufacturers:

Kel - Kelley Co.
CSI - Consumat Systems Inc.
Com - Sunbeam/Comtro

[d] $9 to 15 million (Canadian) for entire resource recovery facility, including RDF and composting plants.

[e] Building and HVAC equipment - $1,840,000.

TABLE B

O&M DATA SUMMARY FOR STARVED-AIR HEAT RECOVERY INCINERATOR SYSTEMS

Owner	Design Capacity lb/hr	No. of Operating Personnel/Day: Supervisors	No. of Operating Personnel/Day: Operators	No. of Operating Personnel/Day: Maintenance	Operating Schedule: Hours per Day	Operating Schedule: Days per Week	Operating Schedule: Weeks per Year	Maintenance Schedule: Hours per Week	Maintenance Schedule: Days per Year[c]	System Modifications[d]: Completed	System Modifications[d]: Proposed
K.W. Muth	2,000	1	3	1	24	5	51	AR[b]	AR	R	
Cassia County	4,200	2	6		24	5.5	52	AR	AR	BT,P	
Rolscreen	2,100		2		16	3		AR	AR	AS,B, FE,R	
Ontario	2,200	a	1	a	8	5	50	4	10	ATR,BT, D,SB,R	ATR
Lamprey	9,000	1	8	2	24	7	52	80	10	AP,BT, C,FE, FR,R,S	ARS, CG
Corning	2,000	.4	3	2[a]	13	5		4	AR	ARS,ATR, FE,R, S,WCH	APR TF
Salem	8,400	2	10	2	24	5		AR	AR	ARS,BT, FE,FP, FR,FS, P,R	I
Lockheed	2,100	.5	6	a	24	7	40	AR	60	ARS,B, BH, C, SB,TF	ATR,FS, R

[a]Shared with rest of facility.

[b]As required.

[c]In addition to weekly maintenance.

[d]Abbreviations:

AP - air pollution equipment modification
APR - air preheater installation
ARS - ash removal system/controls modification
AS - anti-slagging chemical utilization
ATR - ash transfer ram modification
B - blower modification or replacement
BH - baghouse installation/replacement
BT - boiler or blow-down modification/tube replacement
C - installation or modification of air/steam/temperature controls
CG - cogeneration facility installation
D - damper installation
FE - feed entry or guillotine door modification
FP - feedwater preheater installation
FR - modification of feed ram (may include water cooling system)
FS - feedwater system modification
I - additional incinerator installation
IN - addition of insulation
LI - addition of liquid injection
P - pump modification (deaerator, sump, and/or feedwater)
R - refractory replacement
S - stack modification
SB - soot blower replacement
SM - steam vent muffler added
TF - tipping floor modification

TABLE C

RECURRING ANNUAL O&M EXPENDITURES FOR STARVED-AIR HEAT RECOVERY INCINERATOR SYSTEMS ($)[a]

Owner	Design Capacity lb/hr	Labor	Elect. Power	Water/ Sewer	Aux. Fuels[b]	Chem-icals[c]	Residue Disposal	Spare Parts	Tools, Paint, Pest Control	Total O&M
K.W. Muth	2,000	45,000	[i]		5,000		[i]	15,000		80,000
Cassia County	4,200		11,400	2,100		3,500		20,000[e]		
Rolscreen	2,100	80,000								
Ontario	2,200	32,000 (39,000 Canadian)								
Lamprey	9,000		100,000	600		[i]		45,000[e]		521,507[d]
Corning[g]	2,000									
Salem	8,400	220,000	50,000		12,000	1,700	6,500		1,500	
Lockheed[f]	2,100	280,000	28,000	[i]	46,000	800	5,000		13,000	

[a] Estimated 1982 dollars; excludes interest and depreciation.

[b] Includes fuel for burners and front-end loaders.

[c] Includes chemicals for water treatment and control of slagging.

[d] 1982 budget estimate.

[e] Value of inventory

[f] Based on 6,720 hr/yr operation. Includes HVAC plant operation.

[g] No figures available for incinerator facility.

[i] Insignificant.

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