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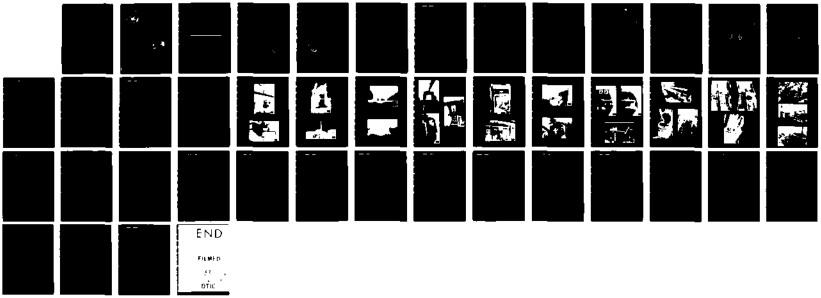

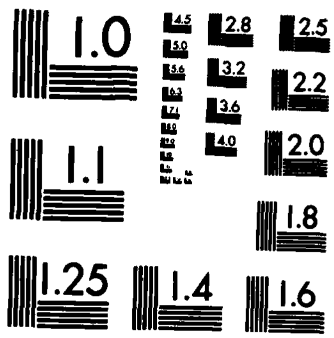

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CR 83.016

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

Sponsored by
CHIEF OF NAVAL MATERIAL
NAVAL FACILITIES ENGINEERING COMMAND

PRELIMINARY OPERATING ASSESSMENT ADVANCED HEAT RECOVERY INCINERATOR SITE TWO: BASIC ENVIRONMENTAL ENGINEERING, INC.

March 1983

An Investigation Conducted by
SANDERS & THOMAS, INC.
Consulting Engineers
Pottstown, Pennsylvania

N68305-80-C-0060

METRIC CONVERSION FACTORS

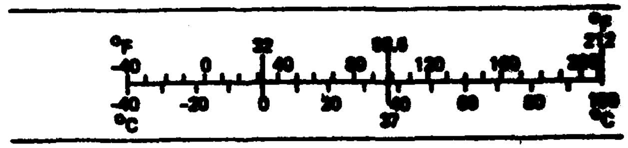
Approximate Conversions to Metric Measures

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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Energy conversion; incinerators; energy recovery; solid waste

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

This brief evaluation of a Basic Environmental Engineering, Inc. heat recovery incinerator (HRI) documents and describes several innovative features not found in most other modular HRI's this small. These features and subsystems include: waterwall primary combustion chamber; pulsed hearths for burning material transport; multiple zone control of secondary combustion; ash —

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) removal subsystem with no moving linkages under water; and partial integrated digital controls. The system start-up experience, also well documented, may be considered typical or better than average for many modular HRI's in the last few years.

For further information, contact P. L. Stone, A/V 360-5925 or FTS 799-5925/5974 or commercial (805) 982-5925/5974.

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ACKNOWLEDGEMENTS

Sanders & Thomas, Inc. gratefully acknowledges the assistance and willing cooperation of the following people whose contributions helped make this report possible:

St. John's University

Fr. Gordon Tavis, Treasurer
Fr. James Tingerthall, Assistant Treasurer
Daniel L. Weber, Chief Engineer

Civil Engineering Laboratory

Philip L. Stone

I. Introduction

Observations and evaluation of a Basic Environmental Engineering, Inc. heat recovery incinerator (HRI) were conducted during the week of June 28, 1982, at St. John's Abbey and University in Collegeville, Minnesota. This examination of the unit's operation followed a maintenance shutdown of the incinerator during which the original refractory brick on both the upper and lower hearths was replaced with castable refractory in addition to installation of more effective air seals around the hearths to minimize air leakage.

Additional types of heat recovery incinerator technologies will be evaluated in future tasks to provide assessments of a variety of technologies possibly suitable for use by the United States Navy in satisfying its requirement for small scale heat recovery incinerators.

II. Background

In 1857, Benedictine monks who had served settlers in the Minnesota Territory received the charter for what is today St. John's University, a college of the liberal arts and sciences located west of St. Cloud. Approximately 2,000 students attend classes taught by a staff composed of 103 lay instructors and 48 Benedictine monks. Associated with the University is St. John's Abbey, a monastic community of 300, of whom over half work in education, publishing, research, arts, crafts and services at Collegeville. Benedictine monastic foundations from St. John's have been established at other locations within the United States, Canada, Central America and Asia.

Steam generated at the boilerhouse is used primarily for heating and generation of electricity for use at both the University and Abbey. Additional uses of steam are in food preparation, laundry and tailoring activities. Four (4) spreader stoker-fired boilers using Wyoming bituminous coal and one (1) No. 6 fuel oil-fired package boiler were in service prior to construction of the Basic HRI. Consideration of construction and operation of a heat recovery incinerator was prompted by both economics and conservation. A cheaper fuel was desired, and the need to conserve existing fuels was recognized. Disposal of University and municipal solid wastes was not a primary intention, although the operation of St. John's incinerator does assist in the disposal of municipal solid wastes from the City of St. Cloud and a few industrial sources in addition to the disposal of the University and Abbey solid wastes.

III. Description/Operation of the Facility

St. John's heat recovery incinerator facility was constructed from October, 1980 to October, 1981, during which a 3-month suspension of construction occurred due to labor difficulties. The facility completed initial dryout and shakedown and became operational in December, 1981. Longest continuous operating period for the unit has been 33 days during February and March, 1982. This investigation followed a seven-week period of modifications to the hearths and seals. Figure 1 shows the general layout of St. John's HRI. Photographs 1, 2, and 4, found at the end of this section, present various views of the incinerator and facility.

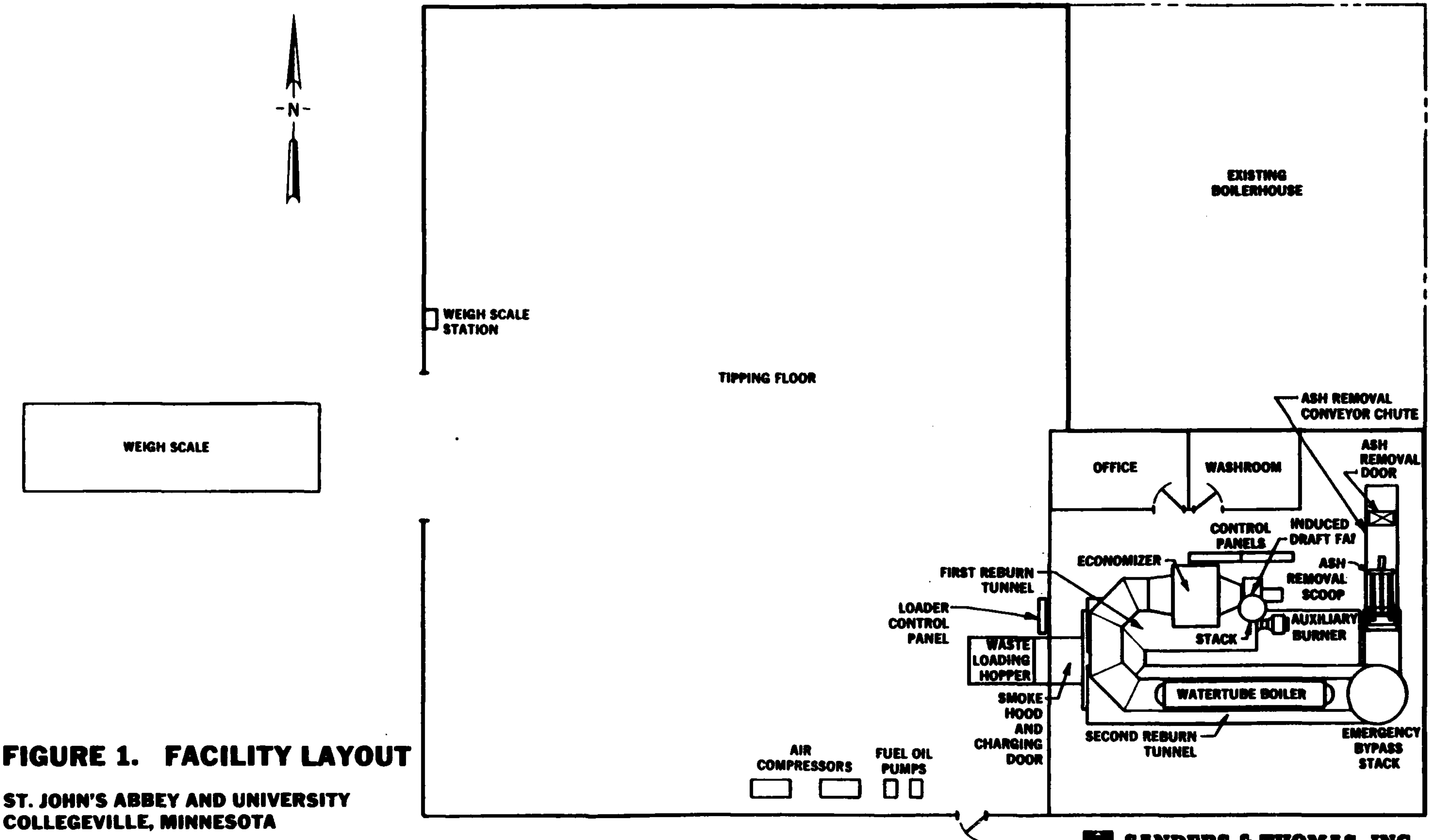

FIGURE 1. FACILITY LAYOUT

ST. JOHN'S ABBEY AND UNIVERSITY
COLLEGEVILLE, MINNESOTA

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Refuse collection trucks are weighed on an in-ground scale located outside the HRI building. Truck tare weight is prerecorded. Gross, tare and load weights are printed out at the weigh scale station located within the building adjacent to the truck door. The incinerator operator is responsible for weighing incoming trucks. Refuse is unloaded onto the tipping floor and pushed into temporary storage piles by front-end loader. Oversize, bulky items and other unprocessable items are segregated, and loaded back into the refuse truck for final landfill disposal. If the delivering refuse truck has departed, the bulky items are stockpiled and removed by another truck or by the hauler who removes incinerator residues.

The Model 3000 Basic Incinerator is rated at 24,000,000 BTU/hr. heat input with an estimated maximum steam production capacity of 18,000 lbs./hr. This equates to a maximum charge rate of 60 tons of municipal solid waste per day based on an average heating value of 4500 BTU/lb. Figure 2 shows the incinerator and waste heat recovery equipment layout.

Figure 3 shows typical instrumentation and control components and their locations for the Basic unit. More than one component may be situated at an indicated location.

A front-end loader pushes waste into a loader hopper, generally filling it one-half to three quarters full. The hopper is 5½' wide by 7½' long by 3½' deep. After is is loaded, its pneumatically-actuated cover is closed, the refractory-faced charging door retracted up into the smoke hood, and an electrically-driven, rack-and-pinion advances a ram, pushing trash into the furnace section. When operated in the full mode, the outer periphery of the ram stops at the furnace end of the hopper

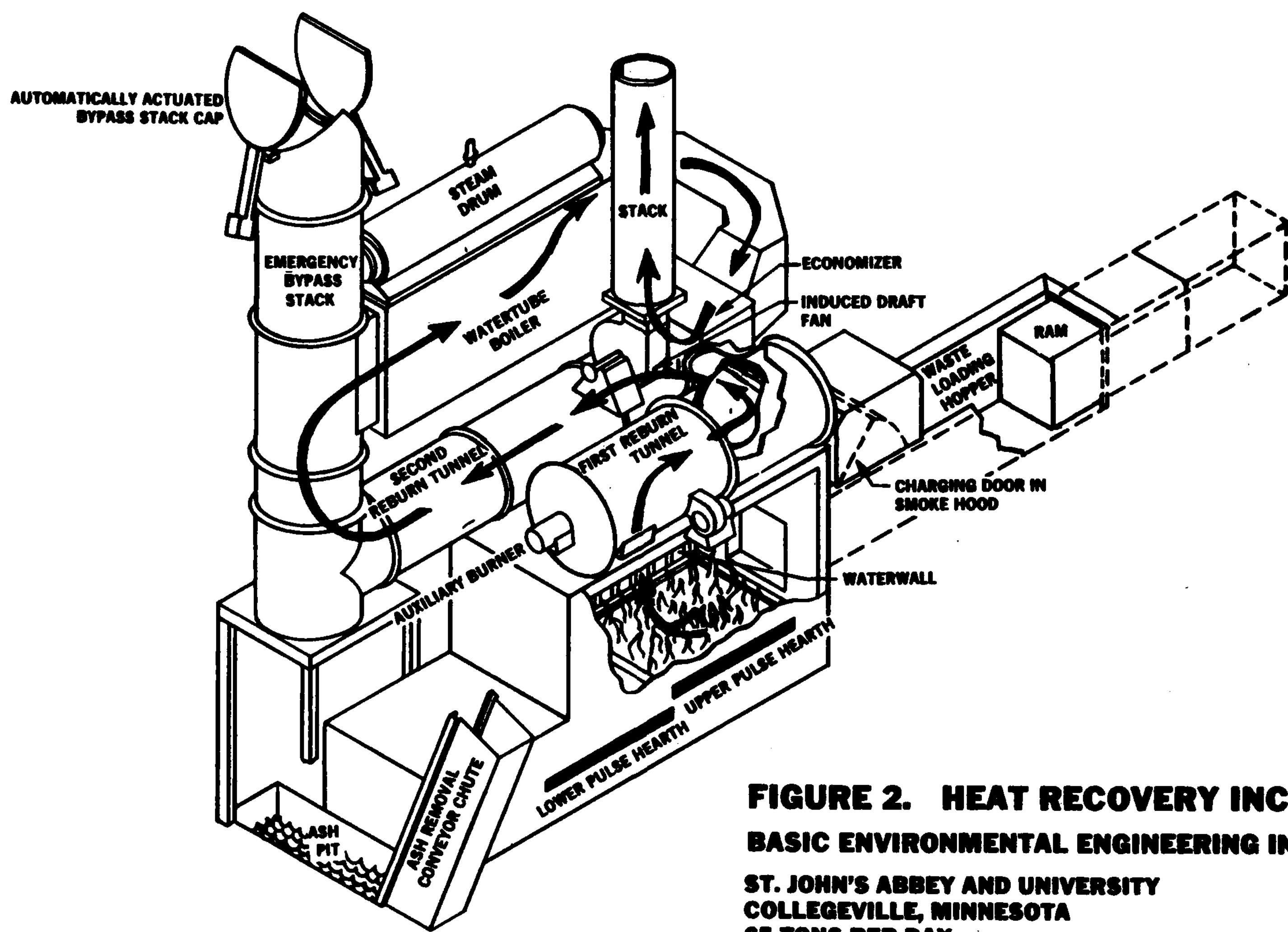

FIGURE 2. HEAT RECOVERY INCINERATOR

BASIC ENVIRONMENTAL ENGINEERING INC.

ST. JOHN'S ABBEY AND UNIVERSITY
COLLEGEVILLE, MINNESOTA
65 TONS PER DAY

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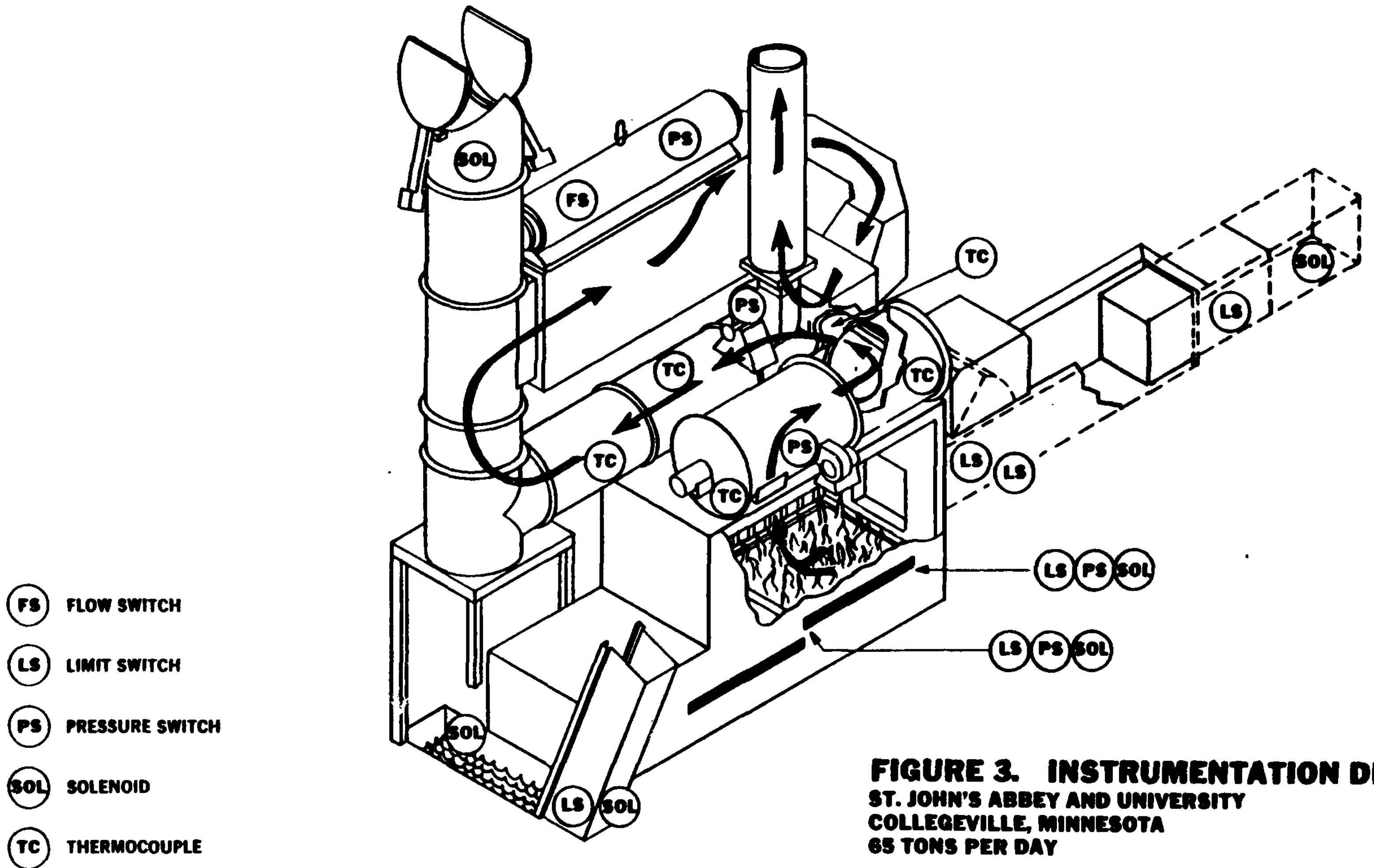

FIGURE 3. INSTRUMENTATION DIAGRAM
ST. JOHN'S ABBEY AND UNIVERSITY
COLLEGEVILLE, MINNESOTA
65 TONS PER DAY

SANDERS & THOMAS, INC.
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while the inner face continues to move, extending into the waterwall furnace. This mode of operation is used to level a high pile of burning trash within the incinerator and is employed infrequently. Normal mode of operation, in which the ram stops at the entry to the furnace, is usually used.

Photographs 5 thru 9, and 12 show interior views of the radiant chamber and pulse hearths.

The furnace section of the Basic unit is a waterwall radiant chamber having 430 square feet of heat transfer surface. Waste is moved, as it burns, through the furnace section by the action of the upper and lower pulse hearths. These hearths are externally suspended, moving refractory floors with integral underfire air jets as shown in Photographs 10 and 11. The floors are pulsed or jogged by rapid expansion of double convolute air bags and stopped abruptly by impact with rubber bumpers. This acceleration/deceleration cycle advances the burning waste and agitates the waste to promote combustion. Photographs 17, 18 and 19 show details of the air bag pulsing system. Residue falls off the lower hearth into a pit filled with water to both quench the residue and to prevent gases from escaping the furnace. A continuous automatic ash removal system collects the quenched residue and deposits it into containers for landfill disposal. Table III-1 indicates the automatic steps in the residue removal sequence and times required to complete an entire cycle.

Off-gases from the radiant chamber flow through two reburn tunnels arranged in series, wherein the gas temperature is elevated by firing auxiliary No. 2 fuel oil at a maximum rate of 37 gph, to insure complete combustion of the volatile matter. After leaving the second reburn tunnel,

TABLE III-1

RESIDUE REMOVAL SEQUENCE

Heat Recovery Incinerator
St. John's Abbey and University
Collegeville, Minnesota

	Description of Actions	Total Time Elapsed
1.	From start position with hoist at top of ash removal conveyor, scoop indexed out, and chute door closed, hoist begins downward travel.	0
2.	Hoist stops at bottom of ash removal conveyor with scoop totally submerged. Scoop indexes in to pick up residue.	1 minute, 10 seconds
3.	Scoop completes indexing hoist starts up.	1 minute, 25 seconds
4.	Hoist stops at top of conveyor, ash chute door opens, scoop indexes out and releases residue.	3 minutes, 40 seconds
5.	Chute door closes.	4 minutes
6.	Hoist starts down.	4 minutes, 10 seconds

the gases pass into the emergency bypass stack, shown on Photograph 3. If the bypass stack caps are closed, the gases are directed thru the boiler convection section, which has 2,618 square feet of heating surface, the economizer, induced draft fan and discharged to atmosphere. No air pollution control devices are installed. A final air emissions compliance test has yet to be conducted by the Minnesota Pollution Control Agency to determine compliance with the .08 gr/dscf at 12% CO_2 incinerator standard prior to issuance of a final operating permit.

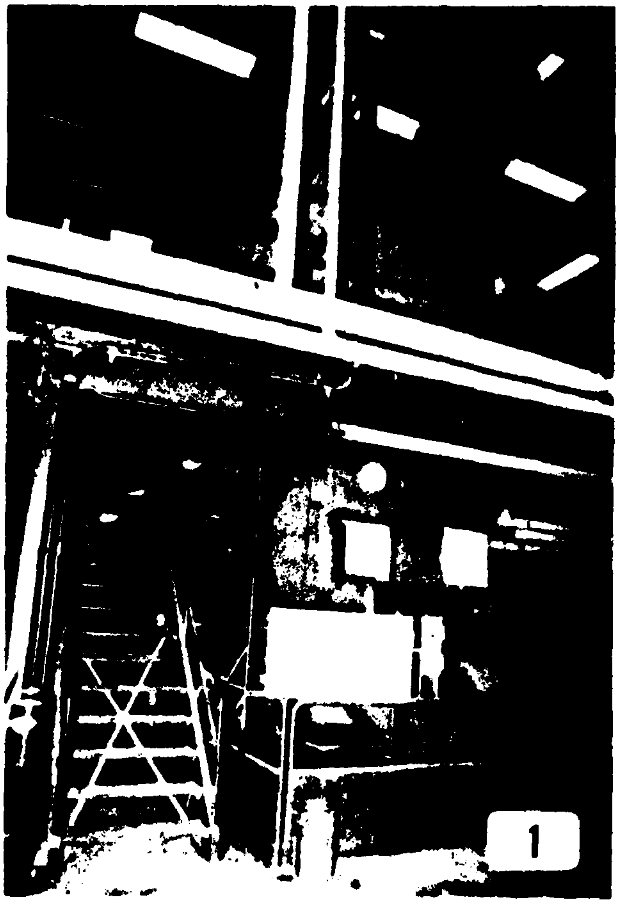
During startup and shutdown, or upon loss of power or boiler feed-water, the emergency stack caps open automatically, allowing the combustion gases to bypass the convection section, economizer and induced draft fan and discharge directly to atmosphere.

St. John's operates their heat recovery incinerator with a single operator per shift whose responsibilities include:

- Charging of furnace - feeds proper quantity and mixture of waste on a schedule that insures desired steam production rate.
- Incoming waste acceptance - weighing and evaluation of acceptability of waste.
- Monitoring of facility operations - recording of data, adjustment of equipment.
- Removal of residue - includes supervising removal from facility of incinerator residue and unacceptable wastes.
- General housekeeping.
- Clearing of floating residue and scum from incinerator pit.

A boiler operator, whose primary duties are the operation of the coal-fired boilers and generating turbines, also monitors the steam production of the heat recovery incinerator's boiler and its contribution to boilerhouse steam production.

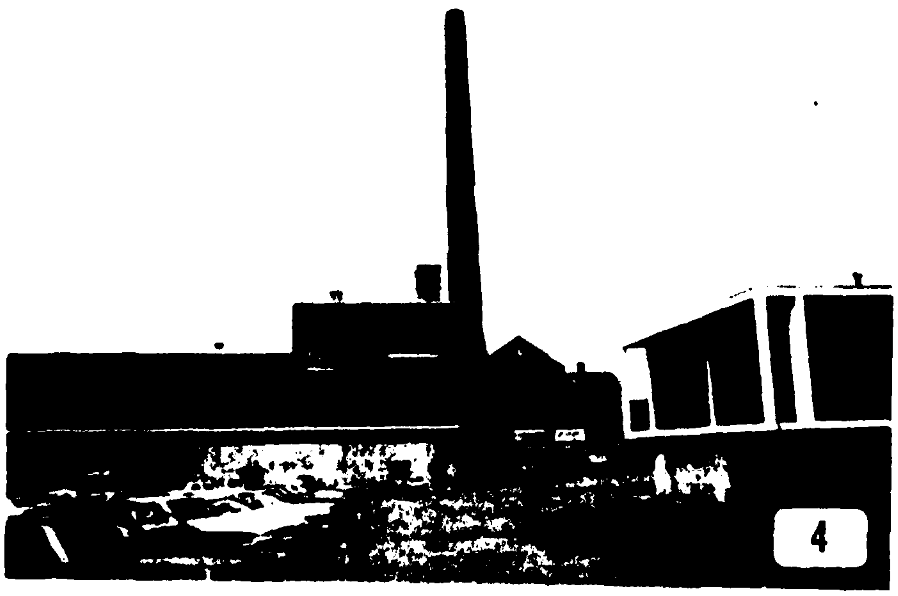
During the day shift, the boilerhouse supervisor is usually available to assist the operator when necessary. Major or specialized repairs such as replacement of the hearth floors are performed by contractors.



Photograph 1: Basic heat recovery incinerator.

Photograph 2: Basic heat recovery incinerator.

Photograph 3: Emergency bypass stack and automatically actuated caps.

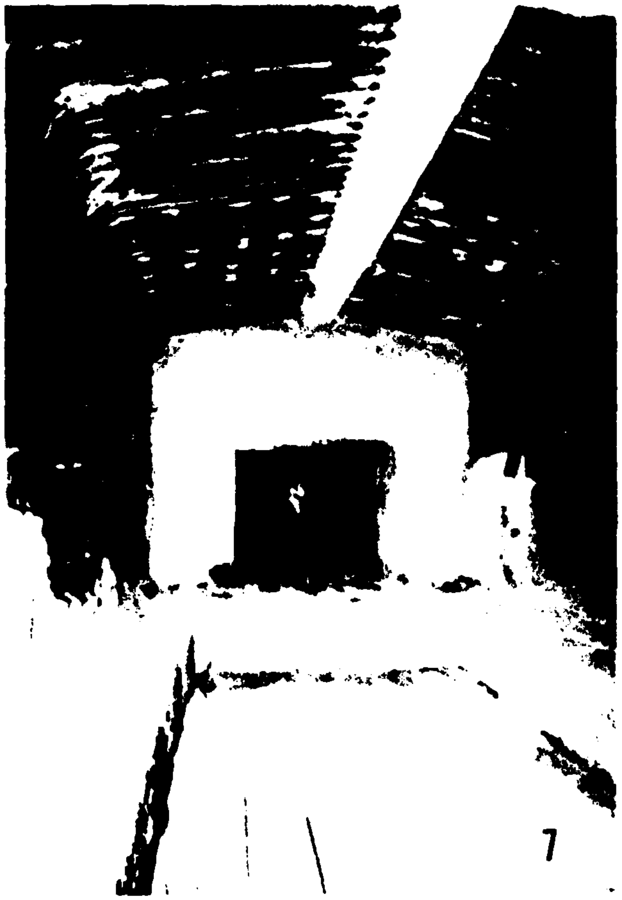


Photograph 4: View of heat recovery incinerator addition to boilerhouse.

Photograph 5: Interior of radiant chamber facing waste loading hopper.

6

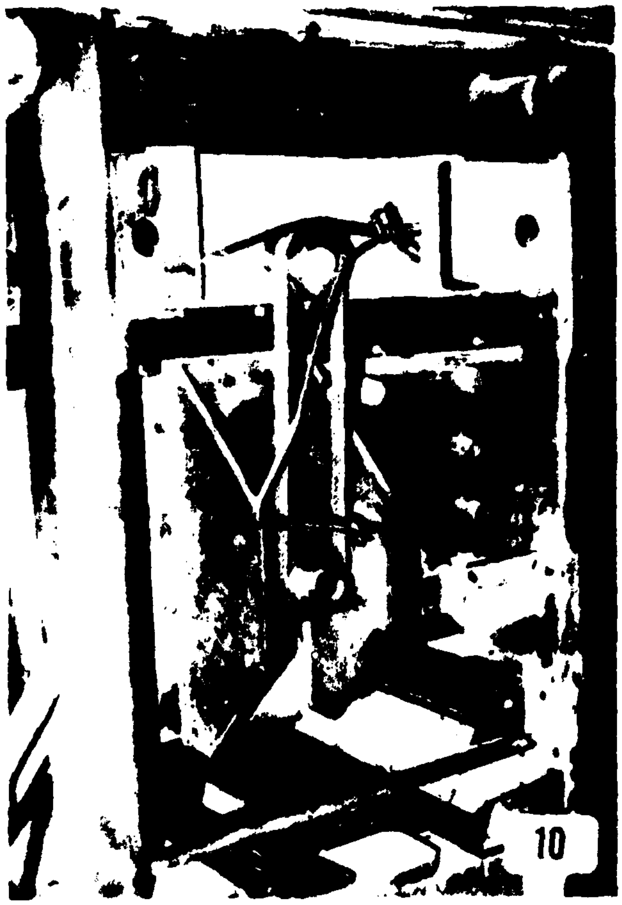
Photograph 6: Interior of radiant chamber facing lower pulse hearth and ash pit.



Photograph 7. Interior of radiant chamber facing waste loading hopper.

Photograph 8. Combustion gas outlet from radiant chamber to first reburn tunnel.

Photograph 9. Clearance at end of upper pulse hearth.

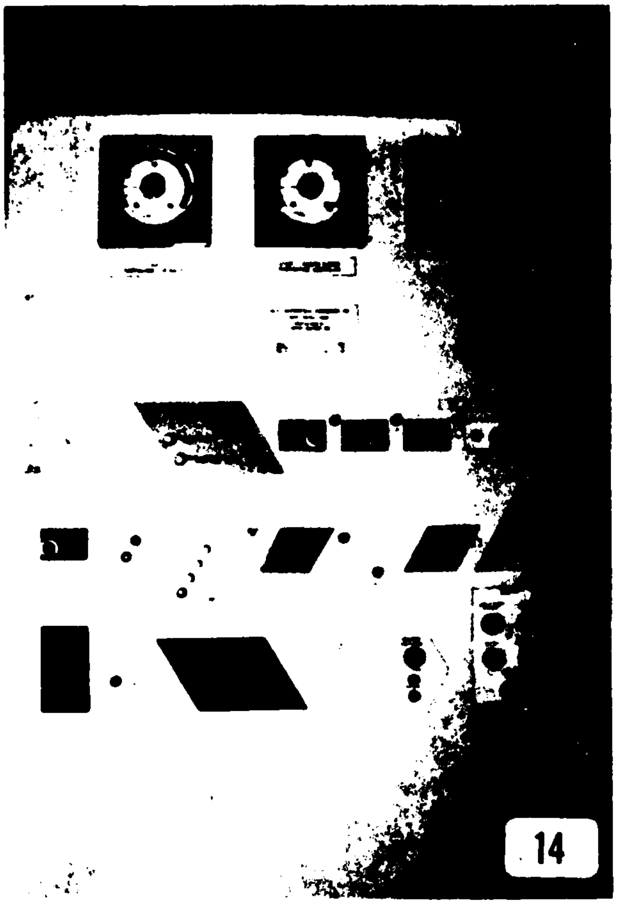


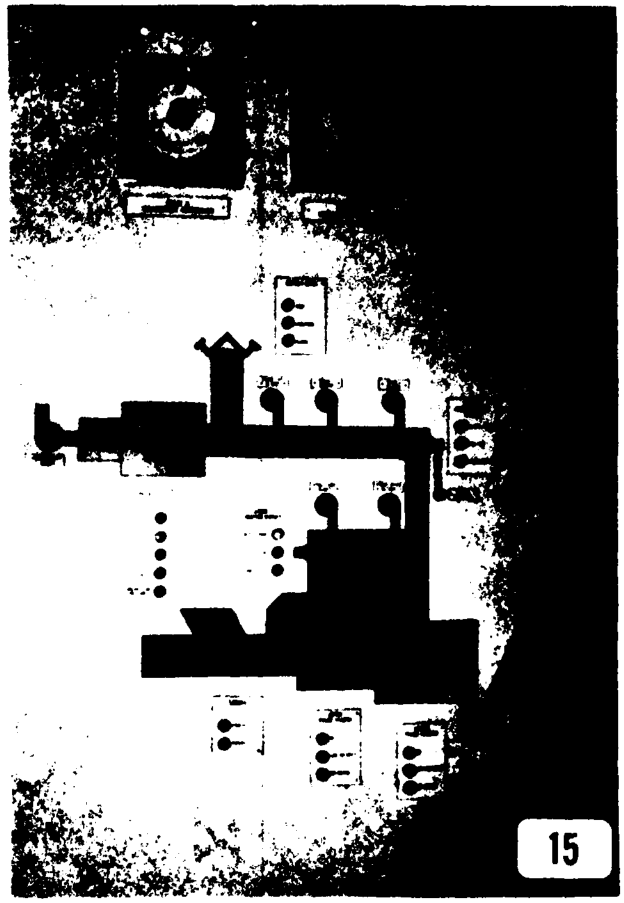
Photograph 10: Hearth cable suspension detail.

Photograph 11: Exterior view of hearths with combustion air supply and plenum visible.

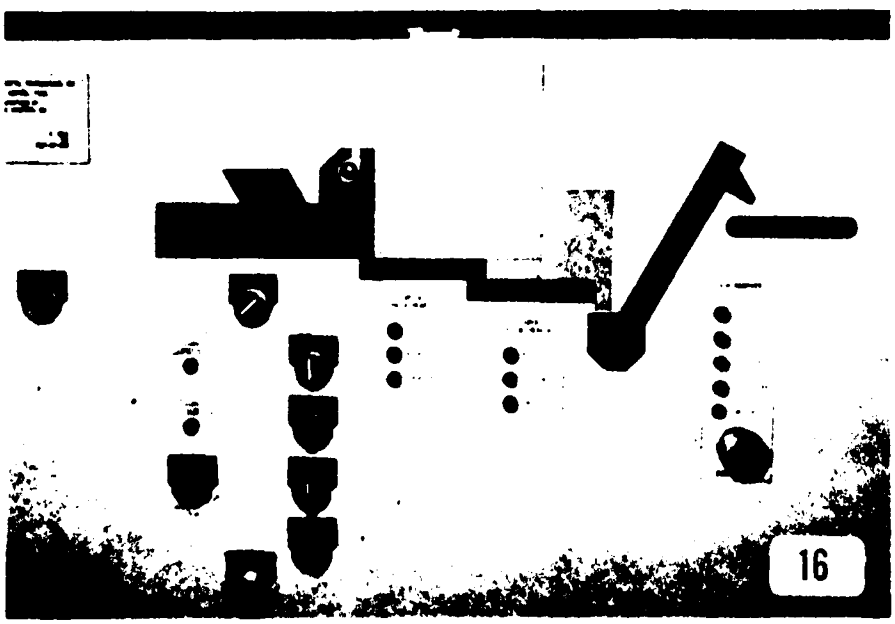
Photograph 12. Interior view of radiant section from rear access door.

Photograph 13. Rear access door and pressure -- relief mechanism.

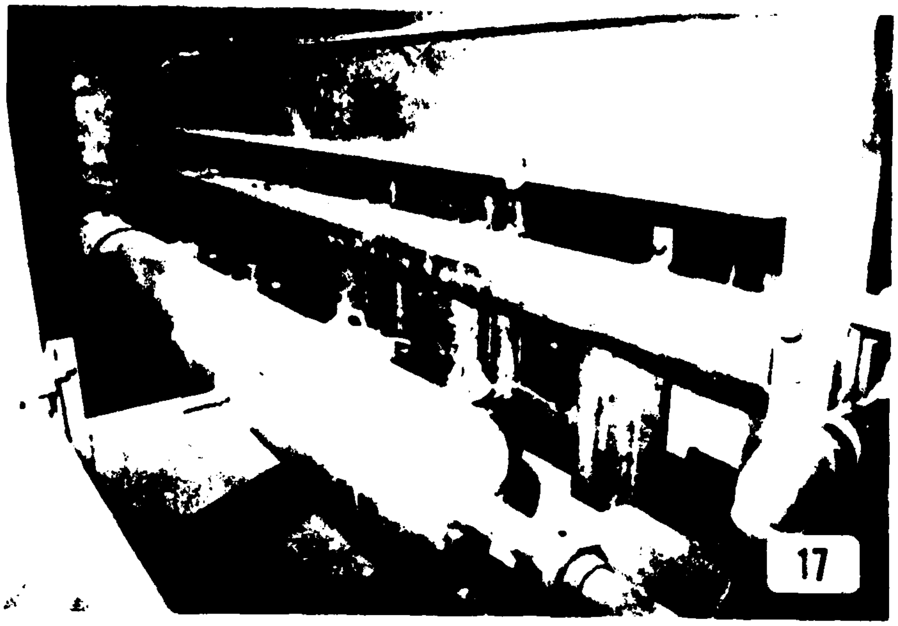




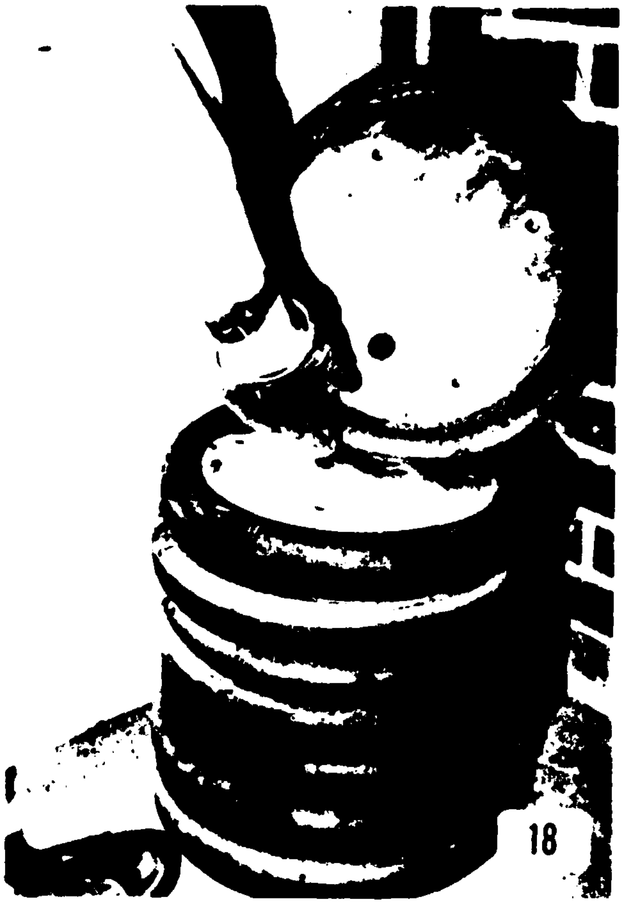
Photograph 14 and 15. Main control panels located on upper level.



Photograph 16. Loader control panel adjacent to waste loading hopper.



Photograph 17. Compressed air reservoir for upper hearth pulsing.



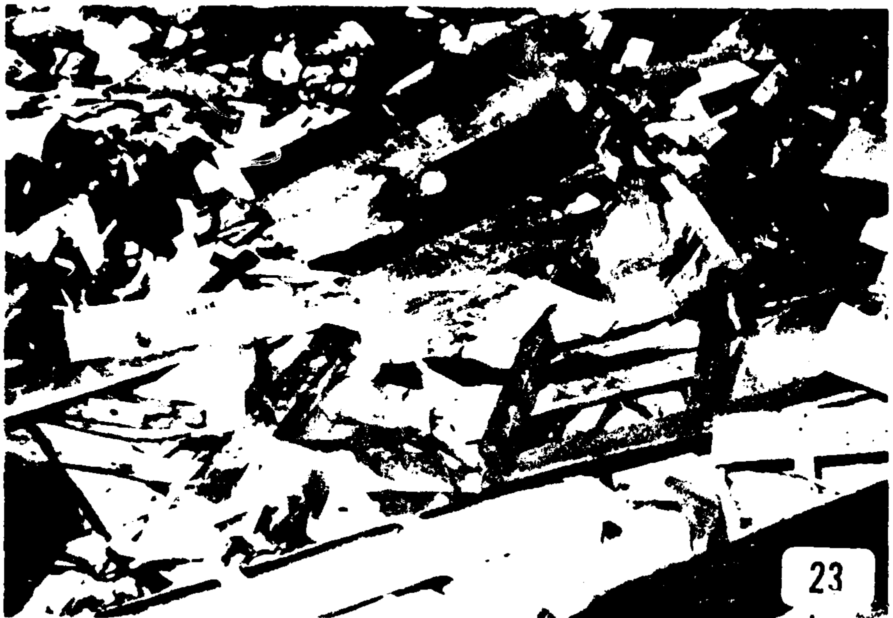
Photograph 18. Spare air bags.

Photograph 19. View of air bags and rubber bumpers on upper hearth.

Photograph 20. Ash scoop hoist at top of ash removal conveyor, ash chute door open, and scoop indexing outward.

Photograph 21. Ash scoop hoist approaching top of conveyor.

Photograph 22. Ash scoop emerging from ash pit with residue.



Photograph 23. Typical industrial waste, as received.

Photograph 24. Oversize, bulky waste which are rejected.

Photograph 25. View of tipping floor.

IV. Capital Costs

Actual construction costs for the facility are shown below in Table IV-1. Approximately 60% of the total cost was furnished by a 40-year, 3% interest rate Federal Department of Education loan while the remainder was financed by internal funds.

Table IV-1

Heat Recovery Incinerator Costs (1980)

Item	Cost
Coal Bunker Contract	$ 36,816*
Building & Erection Contract	1,271,670
Electrical Subcontract	51,980
Steam Condensers	125,000
Basic Equipment	618,758
Freight (Basic Equipment)	18,100
Engineering	213,000
Legal	19,640
Interest	9,763
Government Expense	1,200
Other	9,903
TOTAL	$2,375,860

* Refers to relocation of coal storage pile.

Uninstalled cost for a complete Model 3000 Heat Recovery Incinerator has been estimated to be $1,400,000 in 1982 dollars. Installation costs for this equipment are estimated at $250,000.

V. Solid Waste/Residues

Stearns County, Minnesota, Within which St. John's is located, does not direct or control waste flow within its boundaries. The heat recovery facility, therefore, must compete with landfills with their tipping fee to attract sufficient waste to operate the heat recovery incinerator. This fee is currently set at $2.15 per cubic yard ($8-9 per ton, depending on compaction). Residential solid waste from the City of St. Cloud is delivered to the facility by both municipal and private haulers. Campus waste constitutes 4 to 5 tons per day of the total waste stream when classes are in session. Three manufacturing companies in the vicinity also deliver non-hazardous industrial waste to St. John's for incineration. This industrial waste stream mainly consists of paper, cardboard, packing materials and wooden pallets. Some rigid plastic scraps from moulding operations and fiberglass insulation trimmings are also found in this waste.

Unacceptable oversize waste and incinerator residues are transported to several landfills which are within a 25-mile radius of St. John's. A privately-owned transfer station is operating in St. Cloud. Stearns County is currently investigating the feasibility of a county-owned, private contractor-operated landfill.

VI. Available Operating Data

Facility personnel record waste received and residue removed quantities by weight through the use of the weigh scale and also by volume by estimation of the compaction of the waste within the known holding capacity of the truck. Table VI-1 summarizes this data for January through May, 1982. An uncompacted waste equivalence of 5 yds/ton was assumed for all incoming deliveries for this table. Outgoing residue volumes are based on estimates by drivers and operating personnel. Average daily delivery, residue removal, and feed rates are calculated in addition to volume and weight reductions. Over the five-month period, 84.9% volume and 57% weight reductions were realized by incineration. Table VI-2 shows the daily steam production for the heat recovery incinerator. Average daily steam production was 214,999 pounds/day.

Representative flue gas temperatures taken at various points throughout the heat recovery incinerator system are noted in Table VI-3. These temperatures were recorded during steady state operation of the incinerator when no startups or shutdowns were performed. The thermocouple locations of the five stages with reference to the flue gas path are as follows:

Stage	Location
1	Furnace exit to first reburn tunnel
2B	Near end of first reburn tunnel prior to crossover to second tunnel
2	Crossover
3	Downstream of entry to second reburn tunnel
3-1/2	Second reburn tunnel exit to bypass stack

These locations are also indicated on Figure 3.

TABLE VI-1

SUMMARY OF AVAILABLE 1982 OPERATING DATA

Heat Recovery Incinerator
St. John's Abbey and University
Collegeville, Minnesota

Month	No. of Delivery Days	Total Waste Delivered* Tons (Yds)	Average Daily Delivery Tons/Day (Yds/Day)	No. of Residue Removal Days	Total Residue Removed** Tons (Yds)	Average Daily Removal Tons/Day (Yds/Day)	No. of Operating Days	Average Daily Feed Tons/Day (Yds/Day)	Volume Reduction	Weight Reduction
January	10	300.1 (1500.5)	30 (150.1)	10	165.6 (295)	16.6 (29.5)	11	27.3 (136.4)	80.3%	44.8%
February	19	681.9 (3409.5)	35.9 (179.5)	21	270.0 (495.5)	12.9 (23.6)	21	32.5 (162.4)	85.5%	60.4%
March	24	993.2 (4966)	41.4 (206.9)	24	364.9 (644)	15.2 (26.8)	27	36.8 (183.9)	87.0%	63.3%
April	22	899.6 (4498)	40.9 (204.5)	22	381.6 (633)	17.3 (28.8)	25	36 (179.9)	85.9%	57.6%
May	7	289.4 (1447)	41.3 (206.7)	10	192.6 (328)	19.3 (32.8)	10	28.9 (144.7)	77.3%	33.5%
Five Month Total or Average	92	3164.2 (15,821)	34.3 (172)	87	1374.4 (2395.5)	15.8 (27.5)	94	33.7 (168.3)	84.9%	56.6%

*5 yds/ton Uncompacted Waste Assumed

**St. John's yds/ton Estimates Used

TABLE VI-2

SUMMARY OF AVAILABLE 1982 DAILY STEAM PRODUCTION

Heat Recovery Incinerator
St. John's Abbey and University
Collegeville, Minnesota

Pounds of Steam Per Day

Day	January	February	March	April	May
1	---	---	193,200	254,440	253,700
2	---	---	293,500	273,280	250,140
3	---	---	292,160	284,180	264,900
4	---	---	300,780	280,900	239,900
5	---	---	259,260	106,180	218,760
6	---	---	298,040	---	190,520
7	---	---	234,440	---	155,000
8	---	191,740	144,020	---	91,680
9	---	224,560	273,900	---	246,580
10	---	260,480	276,500	---	56,780
11	125,520	198,360	303,000	26,780	---
12	232,520	261,000	1,880	203,800	---
13	242,500	238,820	---	282,320	---
14	259,640	186,940	---	47,880	---
15	155,020	256,120	242,980	236,040	---
16	---	254,360	17,940	231,880	---
17	153,740	141,580	---	216,460	---
18	227,500	258,940	---	208,860	---
19	223,060	283,920	31,600	259,040	---
20	245,570	283,820	250,520	78,100	---
21	246,200	276,600	214,660	252,720	---
22	109,260	220,500	181,460	278,900	---
23	---	231,860	195,320	277,300	---
24	---	198,780	215,280	188,340	---
25	---	199,140	182,580	96,640	---
26	---	244,180	243,420	277,860	---
27	---	262,060	242,640	263,820	---
28	---	237,180	210,880	300,380	---
29	---	---	225,160	281,300	---
30	---	---	185,400	244,260	---
31	---	---	154,280	---	---
	2,219,540	4,910,940	5,664,800	5,446,660	1,967,960

TOTAL STEAM PRODUCED FOR 5 MONTHS = 20,209,900 POUNDS
AVERAGE STEAM PRODUCTION = 214,999 POUNDS/DAY

TABLE VI-3

TYPICAL FLUE GAS TEMPERATURES*

Heat Recovery Incinerator
St. John's Abbey and University
Collegeville, Minnesota

Temperature (of)

TIME	STAGE 1	STAGE 2B	STAGE 2	STAGE 3	STAGE 3-1/2
Noon	1100	1400	1350	1150	1100
1 PM	1300	1525	1500	1225	1150
2 PM	1200	1500	1400	1250	1150
3 PM	1100	1350	1300	1150	1100
4 PM	1200	1425	1400	1200	1125
5 PM	1275	1450	1450	1200	1125
6 PM	1300	1475	1475	1250	1150
7 PM	1200	1400	1400	1225	1125
8 PM	1300	1475	1475	1250	1150
9 PM	1350	1475	1475	1250	1150
10 PM	TEMPERATURES NOT RECORDED - OPERATOR REMOVING CLINKERS				
11 PM	TEMPERATURES NOT RECORDED - OPERATOR REMOVING CLINKERS				
Midnight	1000	1300	1250	975	950
1 AM	1175	1425	1375	1175	1125
2 AM	1225	1375	1375	1200	1150
3 AM	1175	1375	1350	1150	1100
4 AM	1025	1300	1275	1100	1050
5 AM	1075	1350	1325	1125	1075
6 AM	1075	1350	1325	1100	1050
7 AM	1100	1350	1325	1150	1100
8 AM	1100	1350	1300	1125	1100
9 AM	1100	1400	1350	1150	1100
10 AM	1200	1475	1450	1175	1100
11 AM	1250	1475	1425	1200	1125
Noon	1275	1475	1475	1200	1125

*DATA RECORDED MAY 3-4, 1982. UNIT HAD BEEN IN CONTINUOUS OPERATION SINCE APRIL 11, 1982.

Incinerator facility electricity consumption is shown below on Table VI-4 and includes not only process equipment requirements, but also lighting, pumps and compressors, and other ancillary electrical loads. St. John's began recording this data in May, 1982, after the installation of a separate meter dedicated to heat recovery facility operations.

TABLE VI-4

ELECTRICITY CONSUMPTION*

Heat Recovery Incinerator Facility
St. John's Abbey and University
Collegeville, Minnesota

Date	Kilowatt Hours
5-3-82	2080
5-4-82	2080
5-5-82	1920
5-6-82	1920
5-7-82	1760
5-8-82	1600
5-9-82	2080
5-10-82	1120

* Includes electrical power used to operate incinerator, auxiliary equipment such as oil pumps, compressors, etc., and building lighting.

VII. Field Observations/Data

Information obtained during field observations of the St. John's heat recovery incinerator and its operation is organized for presentation by major components of the incineration system. All photographs referenced are found at the end of Section III.

A. Waste Loader

1. The initial gearbox provided with the rack-and-pinion ram drive mechansim was replaced after a crack developed in the housing. The failure was attributed to a defective casting.
2. Sufficient space and access is provided around and under the ram and rack-and-pinion to allow for cleanup of waste spillage. St. John's thorough housekeeping efforts were evident in this area as they were throughout the facility.
3. One of the four (4) steel plates on the inner ram face was missing. The plates were initially installed to protect the refractory under the plates until it had properly cured. St. John's personnel had removed one of the four plates upon refractory dry-out, but had never removed the remaining three.
4. Overall performance of the ram and loader mechanism has been quite satisfactory to St. John's operating personnel.
5. Loader hopper is generally filled each feed cycle. Waste mix is controlled by operator. A pneumatically-activated door seals the top of the hopper prior to ram movement.
6. Smoke which enters the smoke hood when the refractory-lined furnace door is retracted during waste charging is ducted from the hood to the radiant chamber via PVC piping. During the observed refractory dry-out, this piping disconnected from the radiant chamber, filling the facility with smoke until the cause of the smoke was isolated and repaired.

B. <u>Waterwall Radiant Chamber</u>

1. Air inlet ports provided in the hearths extend through the unit walls to the outside of the setting. This was done to permit rodding out the ports if they become plugged. The external openings have been capped in locations where rodding of the ports may represent a safety hazard. Rodding of certain ports to clear ash plugging during pulse hearth operation can cause the poke rod to impact the support steel and injure the operator performing the task.

2. Eight steel rollers, two per side of each hearth, were installed during the maintenance shutdown preceding these observations to minimize lateral motion of the upper and lower hearths. A roller is visible in Photograph 10, to the right of the hearth support cable. Unequal pulsing pressure in the air bags or asymmetrical distribution of waste on the hearths may cause lateral motion and impact with external furnace structure and contribute to refractory cracking and failure.

3. Both hearths were originally constructed of refractory brick. Pulsing of the hearths caused the bricks to shift, opening gaps which became pockets for slag formation. Also, manual removal of slag and clinkers on the hearths' surfaces by raking chipped and cracked the surface of the brick, causing further degeneration. Raking has been discontinued and clinker removal is performed by continued pulsing with no waste feed until the slag cools and loosens.

When recast, the lower hearth's floor closest to the upper hearth was sloped towards the hearth centerline. This modification was incorporated to promote residue discharge from the spaces between the upper and lower hearths at the sides of the radiant chamber. These areas, shown on Photograph 9, were the location of jams due to residues such as cans, bottles, or large pieces of metals.

4. The original steel hearth support arms have been replaced with wire cables. The cable system, shown on Photograph 10, permits a freer motion of the hearths when pulsed, allowing a reduction in pulse air pressure from the original 150 psig to approximately 60 psig.

During the observations, waste did not transit the furnace but accumulated on the upper hearth with very little residue movement to the lower hearth. Various combinations of pulse pressure and cycles were tried in an effort to overcome this.

Further investigation of the upper hearth structure by St. John's operating personnel revealed that the structural member which snubbed or decelerated the upper hearth had to be relocated during the preceding shutdown approximately 2 inches closer to the air bags than originally installed, thus preventing full acceleration of the hearth and travel of the waste/residue across the hearth. The structural member was relocated and residue flow through the incinerator is again acceptable.

5. Air infiltration around the hearths has been an ongoing problem. Spring steel seals were installed around the periphery of the hearths and external plates were installed to minimize air leakage. These seals have been readjusted and St. John's personnel are satisfied with the reduction in air infiltration.

6. No. 2 fuel oil is used as auxiliary fuel in both the ignition burner and the reburn tunnel afterburner. Coking of this fuel in the ignition burner which is located approximately 3 feet above the upper hearth has caused St. John's personnel to abandon its usage and manually ignite the waste. No natural gas is available in the area surrounding the University.

7. The lower 2½ feet of the waterwall surface within the radiant chamber were originally insulated with refractory cement held in place by expanded metal lath in anticipation of a burning waste mound against the waterwall. This refractory has fallen away from the waterwalls, as shown on Photograph 5, 6, and 7, and will not be replaced as operating experience has shown that the burning waste usually does not touch the waterwalls.

A blanket of insulation was attached to the radiant chamber roof area above the upper hearth to increase exhaust gas temperature into the first reburn tunnel and decrease the amount of No. 2 fuel oil fired by the afterburner. No noticeable increase in gas temperature, however, was realized, and the blanket was not replaced after it deteriorated. Photograph 7 shows the mounting studs and remaining insulation.

8. Pneumatic, rather than hydraulic, actuators are used throughout the incinerator.

9. The electrically-driven winch that lifts the furnace charging door into the smoke hood is not equipped with a drum guard. Occasionally, the cable does not wind smoothly on the drum and the operator must adjust the cable, usually using a piece of lumber, to force it into place while the winch is operating. One operator's fingers have become entangled in the cable. Fortunately, serious permanent injury was avoided. The need for a guard around the drum and an improvement in winch design has been demonstrated.

C. Reburn Tunnels

1. No fuel oil meter was originally installed on the afterburner. However, during a subsequent maintenance shutdown of the incinerator to correct the pulsing problem, a meter was installed. Oil usage for the afterburner has been ranging between 250 and 350 gallons per day of normal incinerator operation since installation of the meter.

2. In an effort to increase reburn tunnel temperatures while reducing auxiliary fuel oil usage, Basic Environmental Engineering has installed a "thermal exciter" in the first reburn tunnel. This exciter is a high alumina refractory-coated stainless steel tube, 20 inches in diameter, approximately 12 feet in length, and functions as a heat sink to radiate heat to the exhaust gases while providing turbulent mixing air from the reburn tunnel's

secondary combustion supply. Air is blown through the center of the tube and leaves at the end opposite the afterburner. Higher reburn tunnel temperatures have been noted by operating personnel since this device's installation, but whether they are caused by the exciter, the reduction in excess air due to the seals, or a combination of both, has not been established.

D. Ash Removal System

1. Three electric motors and one friction clutch associated with the ash removal system have been replaced since the facility became operational. Presently, a larger 5 HP motor is being used successfully.

2. Residue tended to float on the surface of the water in the ash pit, impairing operation of the residue removal scoop. To insure a continuous flow of residue to the scoop, the pit was manually agitated every 20 minutes. A Basic-designed circulation system has since been installed subsequent to the plant visit and has greatly reduced the need for operator attention. It functions for several minutes every hour and only occasionally must the operator rake the floating residue.

3. The ash removal scoop discharges to a chute. The original ash removal system included a belt conveyor at the bottom of the chute. This belt conveyor was intended to move the residue into a dump truck parked adjacent to the incinerator, but was undersized for the quantity and size of residues. Spillage during transport of waste to the truck and jamming of the belt by larger, metal

residue such as 5-gallon cans resulted. St. John's removed the belt conveyor and placed a wheeled dumpster hopper under the discharge chute. When full, these hoppers are moved to the tipping floor and removed by private hauler to landfill. Photographs 20, 21, and 22 show the ash removal scoop, conveyor, and chute door.

E. Convection Section/Economizer

1. Sootblowing is performed twice daily by St. John's personnel, although very little soot is evident when sootblowing.
2. Both the convection section and economizer are cleaned of accumulated ash and soot upon incinerator shutdown at the end of an operating period. Little dust has been found in both during cleanout.

F. Main Stack

1. Several smoke and odor complaints have been received at the facility due to downwash of the plume. Stack extension is being considered to alleviate the problem since the present stack extends only 8 feet above the roof. No odors have been noted outside the facility attributable to the solid waste on the tipping floor. Operating practice of charging the older waste before the more recently delivered and good housekeeping procedures have certainly contributed to the absence of complaints.

In general, stack opacity decreased below 20% during the startup observed when the Stage IIB temperature exceeded 1200°F. Stack opacity when Stage IIB temperature was less than 1200°F varied from 20% up to 100% depending on the composition of the waste charged, generally peaking shortly after a charge, during ignition of the waste. A blanket of fiberglass insulation, shown in Photograph 7, covered a portion of the upper hearth, preventing adequate combustion air flow through the burning waste pile. This blanket was temporary, having been installed to aid in curbing the new refractory.

3. A very faint smoke emission was noticed escaping the closed emergency bypass stack caps during the initial stages of startup. This fugitive emission ceased as the startup progressed.

4. ORSAT readings were obtained from a sampling point between the convection section outlet and economizer inlet. Two sets of readings were obtained:

Run No. 1	Run No. 2
2.0% O_2	1.8% O_2
17.6% CO_2	17.8% CO_2
0.6% CO	0.6% CO

G. Miscellaneous

1. Photographs 14 and 15 show the control panels located on the facility's upper level. These panels contain temperature

indicator/controllers, pulse hearth timer control, start/stop pushbuttons, and a variety of status indicators. Photograph 16 shows the loading hopper control panel located adjacent to the hopper at the facility's floor level.

Recording chart with integrator for steam production and steam pressure is also located on upper level. Induced draft fan inlet static pressure is continuously displayed by a digital readout located near the recording chart. No other draft gages are permanently installed, although several ports are installed for the U-tube measurements.

2. One inch of an iron-aggregate mixture is installed on the tipping floor to resist abrasion by the front-end loader when pushing trash between the waste piles and the loader hopper.

VIII. Recommendations

Noted below are recommendations concerning modifications which assist personnel in the operation of the heat recovery incinerator and should be considered for future installations. Most of the items deal with instrumentation.

1. Positioning of remote temperature indicators and steam production chart for operator's convenience is recommended. The suggested location is in the waste loading hopper control panel. This location would eliminate the need for the operator to climb stairs to read the instruments and would allow him to maintain closer contact with the performance of the heat recovery incinerator. Presently, the temperatures are recorded hourly and

excursions from the desired ranges can occur unobserved and unaddressed. The operator is preoccupied with loading and charging of waste and cannot conveniently monitor operating conditions.

2. Indication of exit gas temperatures from the boiler convection section and the economizer would be useful in monitoring performance of these units. Degradation of heat transfer functions and need for sootblowing could be determined from the temperature readings.

3. A remote boiler steam drum level indicator should be provided. It should be easily viewed by the incinerator operator. The present indication on the steam drum can be viewed only from the upper incinerator level by standing between the convection section and economizer.

4. Induced fan draft is the only static pressure currently monitored. Addition draft readouts are suggested for:

   - Radiant chamber
   - Reburn tunnel outlet
   - Convection section outlet

   Remote continuous readouts of all four draft values [illegible]ld provide another measure of monitoring overall incinerator performance.

5. Elimination of floating residues by mechanical rather than manual means would reduce the operator's work load. Basic Environmental Engineering has designed a water circulation system which has been recently installed and is being evaluated for effectiveness by St. John's personnel.

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