HEAT RECOVERY INCINERATION FOR THE CITY AND BOROUGH OF SITKA, ALASKA

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ABSTRACT

The City and Borough of Sitka, Alaska, constructed a heat recovery incineration (HRI) facility to burn solid waste (MSW) and primary dewatered sewage sludge. The energy from the HRI is used to heat Shelton Jackson College. The plant construction began in 1984, with start-up in May 1985. The plant has unique features not commonly found in a small modular system; i.e., a knuckleboom crane for waste handling; a stepped refractory hearth; excess-air incinerator; an electrostatic precipitator (ESP); and codisposal of sewage sludge. The plant has processed an average of 93 tons (84.5 t) of MSW and 3.52 tons (3.2 t) of sewage sludge per week. Steam production has averaged 2.25 lb/lb (kg/kg) of MSW and sludge. Some start-up problems occurred with the incinerator (slagging) and ESP (energizing), but these were solved in the first 6 months of operation by Sigoure Freres, the contractor.

NOMENCLATURE

ACFM = actual cubic feet per minute
Btu = British thermal units
°C = degrees Celsius
cm = centimeter
cu yd = cubic yard
DSCF = dry standard cubic feet
ESP = electrostatic precipitator
°F = degrees Fahrenheit
ft^3 = cubic feet
gal = gallons
gr = grains
hp = horsepower
hr = hour
HRI = heat recovery incinerator
ID = induced draft
kg = kilograms
kPa = kilopascals
kW = kilowatt
kW·h = kilowatt hour
kV = kilovolt
L = liter
lb = pound
m = meter
m^3 = cubic meter
mA = milliamps
mg = milligram
min = minute
MJ = megajoules
ml = milliliter
mm = millimeter
MSW = municipal solid waste
Nm^3 = standard cubic meter
psi = pound per square inch
t = metric ton
wk = week

INTRODUCTION

This paper presents the unique design and equipment and operational start-up experiences of a 50 tons/day (45.5 t/day) municipal solid waste/sewage sludge incinerator with energy recovery constructed in Sitka, Alaska. The facility was designed by SYSTECH Corporation, Xenia, Ohio, and built by a joint venture between McGraw's Custom Contracting, Inc., of Sitka and Sigoure Freres SA of France. Funding for the $4,171,000 project was as follows: $1,022,000 from the U.S. Environmental Protection Agency (EPA), sewage treatment plant funding, and Innovative/Alternative Technology funding programs; $1,602,000 State of Alaska Department of Environmental Conservation grant and a direct legislative grant; and $1,547,000 from the City of Sitka general fund and grant funding.

Major equipment components and suppliers are:

Knuckleboom crane—HIAB, Model 2070AW
Weigh scales—Mastron model MU5050
Incinerator—Sigoure Freres Model SG-5
Boiler—York Shipley, Inc., Model HRH-1500 Two Pass
ESP—PPC Industries Series 1800
Sludge bin—Nott Company
Sludge pump—Robbins & Meyers Model 2FOFS3

FACILITY DESIGN

The facility process flow diagram, building layout plan views, and cross section are illustrated in Figs. 1–4, respectively. There are several unique features of the Sitka HRI that are not found on other small incinerator systems in the U.S. These are:

(a) Knuckleboom cranes for waste handling on the floor and for feeding the incinerator

(b) Sigoure Freres Model SG-5, 1.2 tons/hr (1.09 t/h) refractory stepped hearth, poker system, and residue dredge

(c) ESP for particulate air emissions control

(d) Sewage sludge co-disposal system

KNUCKLEBOOM CRANES

The HIAB cranes are used to stack the waste from the tipping area into the storage area and to feed the incinerator (Fig. 5). An orange peel grapple with four fingers is used to handle the waste. A bucket grapple was also tried, but did not work as well. The increased surface area of the bucket edge made it more difficult to penetrate the solid waste pile. The operators control the crane from an enclosed cab located above the storage area. The proportional electric/hydraulic crane control levers permit the operators to almost feel the grapple. A small item, such as a 5 gal bucket, can be separated and lifted from the waste pile. While transferring the waste from the tipping floor to the storage area, the operators lift the grapple of waste well over the pile before releasing the waste. This permits the operators to view the waste and remove undesirable items, e.g., wire, car parts, pipe, etc. The cranes are powered by a 40 hp (30 kW) hydraulic power system, which is located in the maintenance area at the rear of the building.

The unique features of the incinerator are the refractory stepped hearth (Fig. 6), pokers (Fig. 7), and residue dredge (Fig. 8). The refuse is pushed onto the upper step by the charging ram. Successive loads of refuse push the material down onto the steps. At each step, a series of pneumatically-driven pokers enter the incinerator and operate in sequence from bottom to top, thus moving the burning material down the steps. At the Sitka facility, a riding contact strip (Fig. 8) was used in place of the feston or accordion electric cord.

The residue dredge consists of a water quench tank beneath the incinerator drop chute, an inclined chute, and a hoe-like dredge. The dredge is driven up and down the inclined chute on a rack and pinion system. The dredge rides on the bottom of the chute during the up cycle and on an elevated rail on the down cycle. After the last row of incinerator pokers has completed its motion, the dredge is activated to pull the residue slowly up the chute. The dredge stops near the top of the chute to permit water to drain from the residue before it is pulled out the top of the chute. The dredge carriage then changes to a high track to carry the dredge back down without contacting the bottom of the chute.

ESP

The ESP has special construction considerations for noncontinuous use (5 days/week) with small incinerators. The box, hoppers, and collection plates are constructed of 12 gauge (2.54 mm) Corten steel to reduce corrosion effects. The rigid wires and frames, items more easily replaced, are constructed of mild steel for economic reasons. In addition to the standard top and hopper access doors, the ESP also has a side access door and internal walkway at the flue gas discharge end. Although most maintenance is done through the standard doors, this added door system permits more detailed examination of the collector

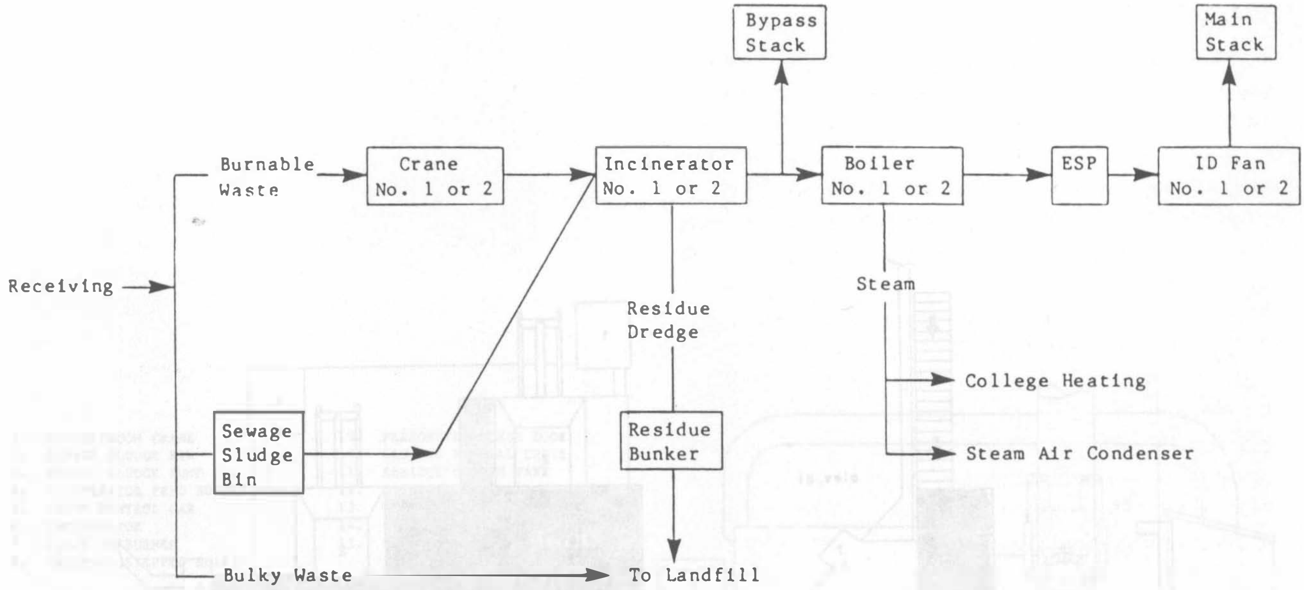

FIG. 1 PROCESS FLOW DIAGRAM SITKA HRI FACILITY

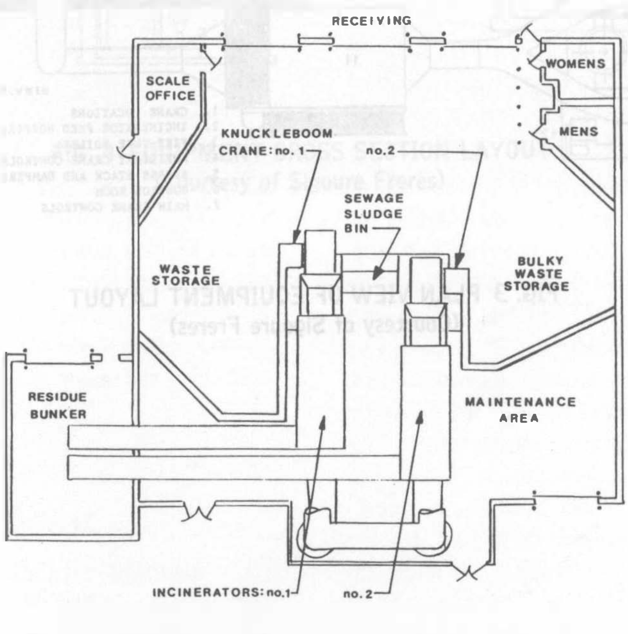

FIG. 2 SITKA HRI FACILITY BUILDING LAYOUT

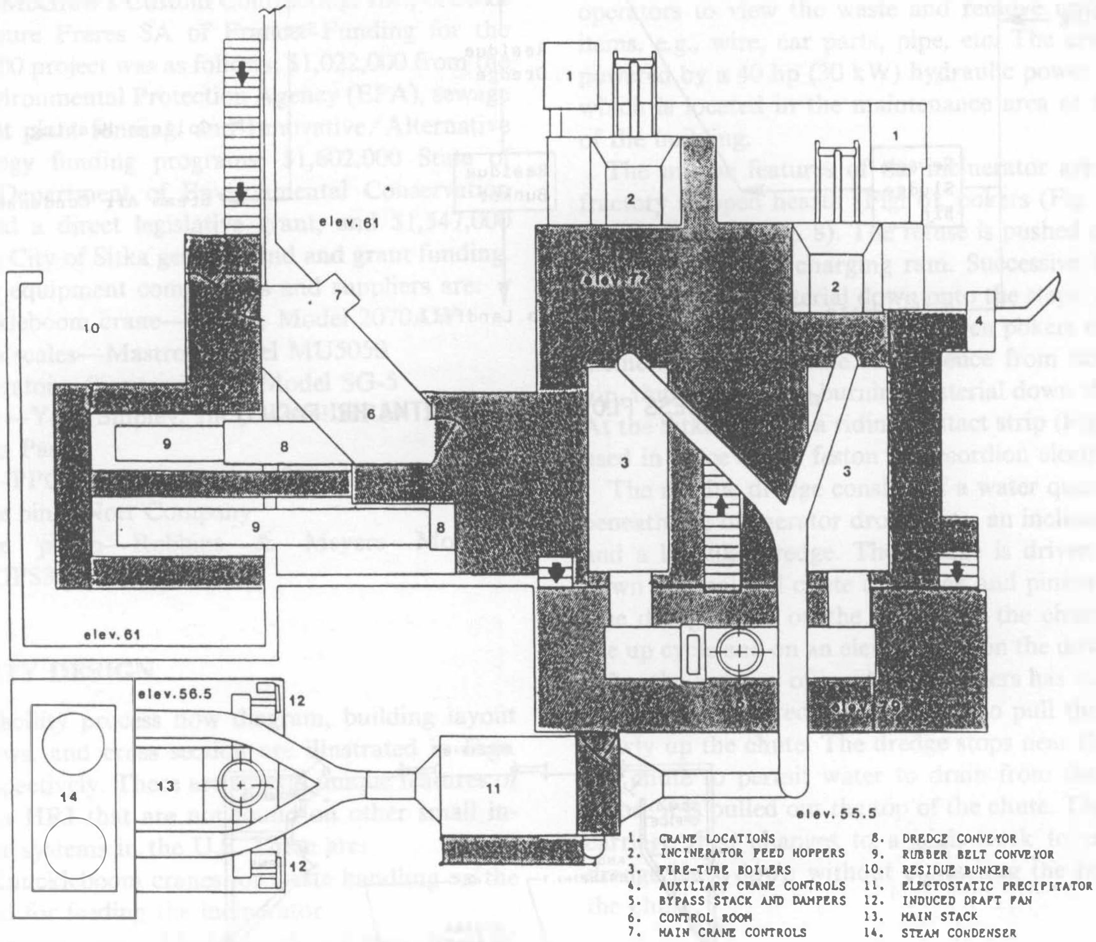

FIG. 3 PLAN VIEW OF EQUIPMENT LAYOUT
(Courtesy of Sigoure Freres)

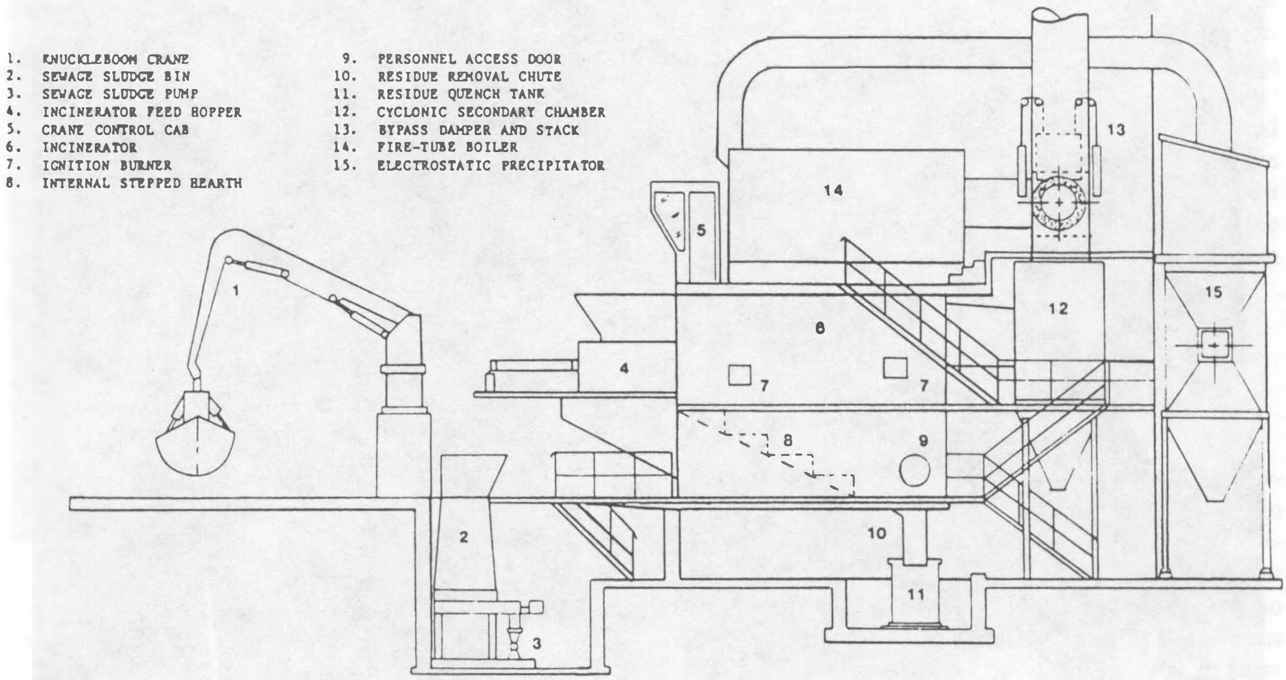

FIG. 4 EQUIPMENT CROSS SECTION LAYOUT
(Courtesy of Sigoure Freres)

FIG. 5 VIEW OF KNUCKLEBOOM CRANE WHILE FEEDING INCINERATOR HOPPER

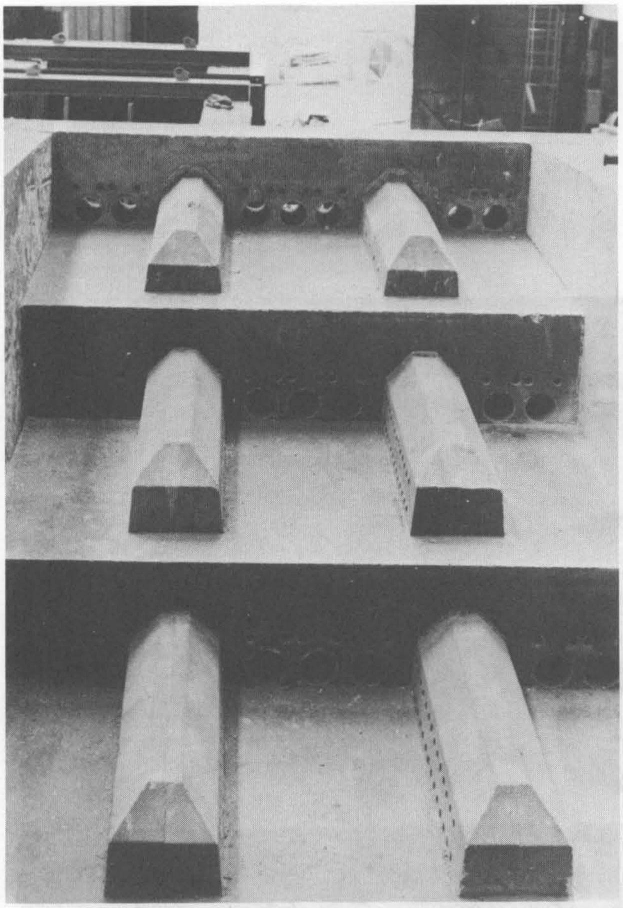

FIG. 6 VIEW OF STEPPED REFRACTORY HEARTH

plates. Other corrosion reduction items are hopper heaters, ESP isolation dampers, and 6 in. (152.4 mm) of insulation. During start-up and shutdown, the auxiliary incinerator burners are operated for a period of 1 hr. During shutdown, this purges the ESP of refuse generated gases and heats the ESP during start-up. The isolation dampers are then closed to prevent air infiltration. Although the ESP has gone through start-up/down cycles at least twice a week since its first use, no corrosion is evident.

SEWAGE SLUDGE CODISPOSAL

Primary dewatered sewage sludge is delivered to the HRI in a rolloff container (Fig. 9) and transferred into a live bottom bin as shown in Fig. 10. (Notice in Fig. 10 that the sludge is still in mats or sheets just as it comes off the belt press at the sewage treatment plant.) Three screws in the bottom of the bin transfer the sludge to a single transversing screw. This screw moves the sludge to the pump hopper as shown in Fig. 11. The transversing screw breaks the sludge mats into small lumps. The pump then moves the sludge up 30 ft (9144 mm) through a 6 in. (152.4 mm) diameter pipe to the incinerator hopper. The pipe extends across the hopper (Fig. 12) and has three 1 in. (25.4 mm) square openings on the bottom to discharge the sludge. At each incinerator loading cycle, the pump moves sludge into the feed hopper (Fig. 11). The sludge is not compressed by the pumping action and stays in small clumps of less than 1 in. (25.4 mm) in diameter. The pump action does squeeze water from the sludge and the water drips into the hopper.

Controls for the sludge system (Fig. 13) are located between the incinerators on the main floor above the sludge bin. The bin screws and sludge pump speed can be set at this location. Operation time is set at the main control panel located in the control room above the incinerator.

SYSTEM START-UP

The incinerators were started in April 1985. However, the ESP was not operational until May 1985. To address the anticipated emissions, a temporary variance was obtained from the State Department of Environmental Control. Also, a public statement on radio and in the newspaper was made to inform the citizens of the temporary nature of the emissions. For the first 2 weeks, the incinerator was operated in the nonenergy recovery mode, i.e., the flue gases were released through the by-pass stack.

During that time period, there were problems with the grate stokers sticking in the incinerators. The problems were caused by improper air flows which caused slagging on the hearth and excessive length of the poker stroke. This resulted in warped pokers which had to be replaced. The replacement did not create excessive downtime as sufficient numbers of spare pokers were provided by Sigoure Freres and were available on site. The primary and secondary airflows were adjusted, and the control sequence was reviewed. After the start-up period, no further major problems occurred with the pokers. However, the operators reported a few occurrences of the pokers being stuck in the incinerator due to entanglement in trolling wire, fencing, and other stringy wire items. More careful removal of these items during stacking of the solid waste has all but eliminated this problem.

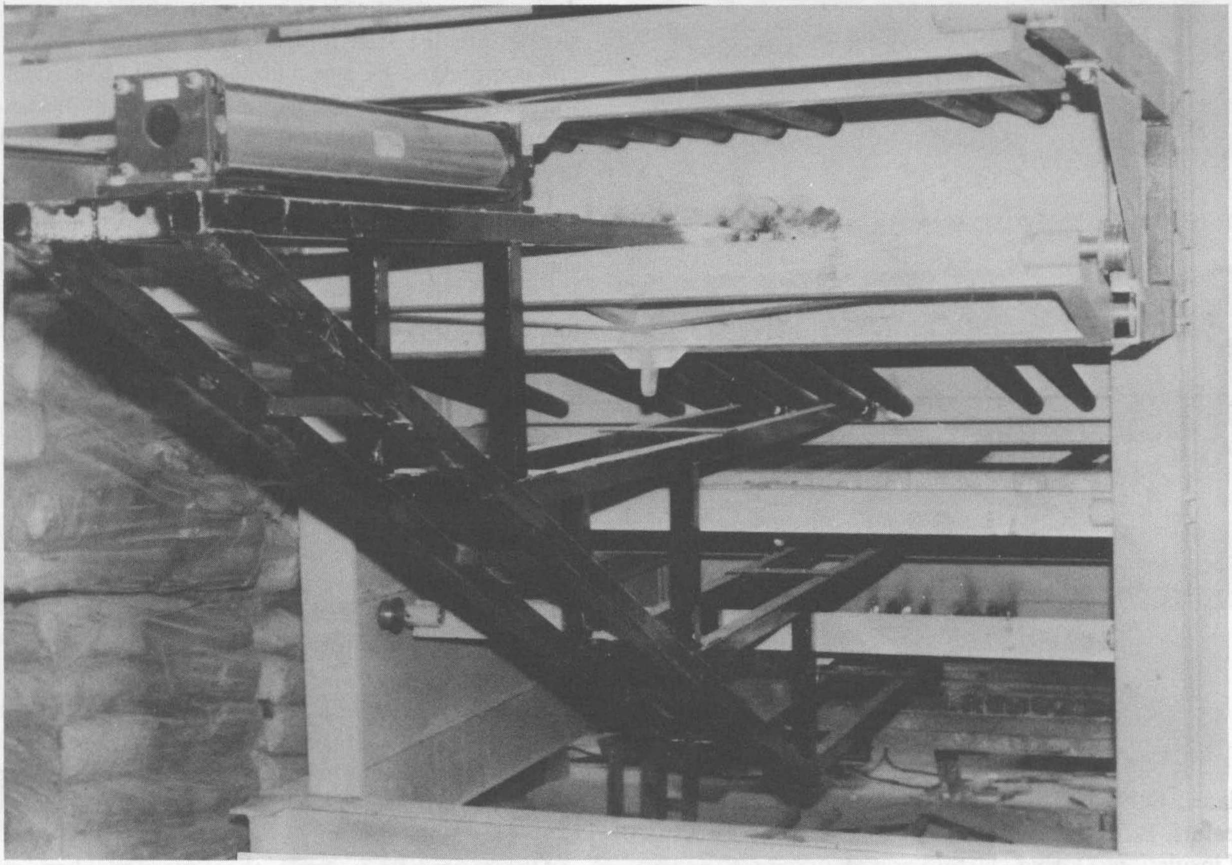

FIG. 7 VIEW OF POKERS AND SUPPORT STRUCTURE

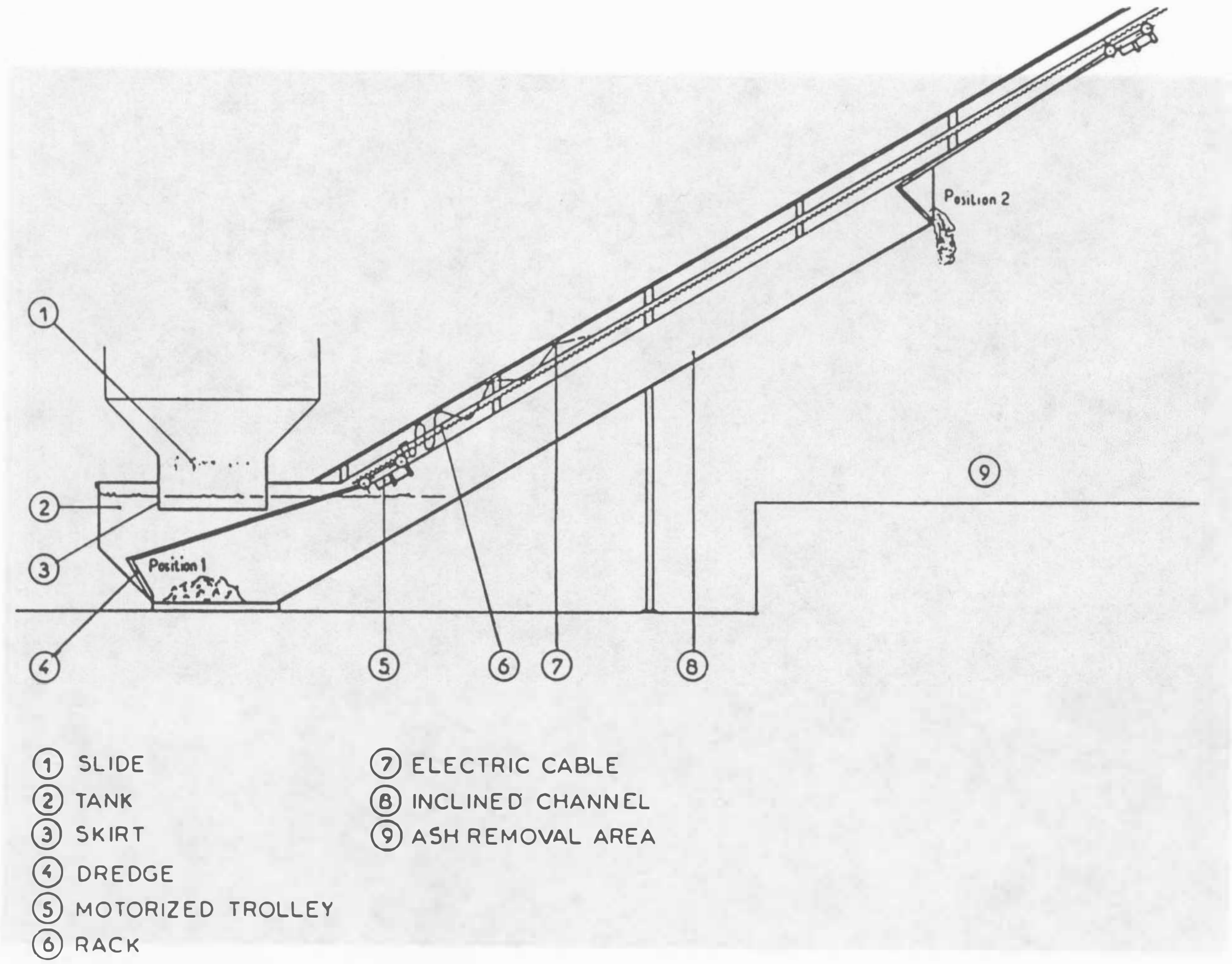

FIG. 8 SCHEMATIC CROSS SECTION OF RESIDUE REMOVAL DREDGE
(Courtesy of Sigoure Freres)

FIG. 9 VIEW OF SLUDGE DELIVERY TRUCK PREPARING TO DUMP SLUDGE INTO THE SLUDGE BIN IN THE HRI BUILDING

FIG. 10 VIEW OF SLUDGE EXITING ROLL-OFF CONTAINER INTO THE SLUDGE BIN

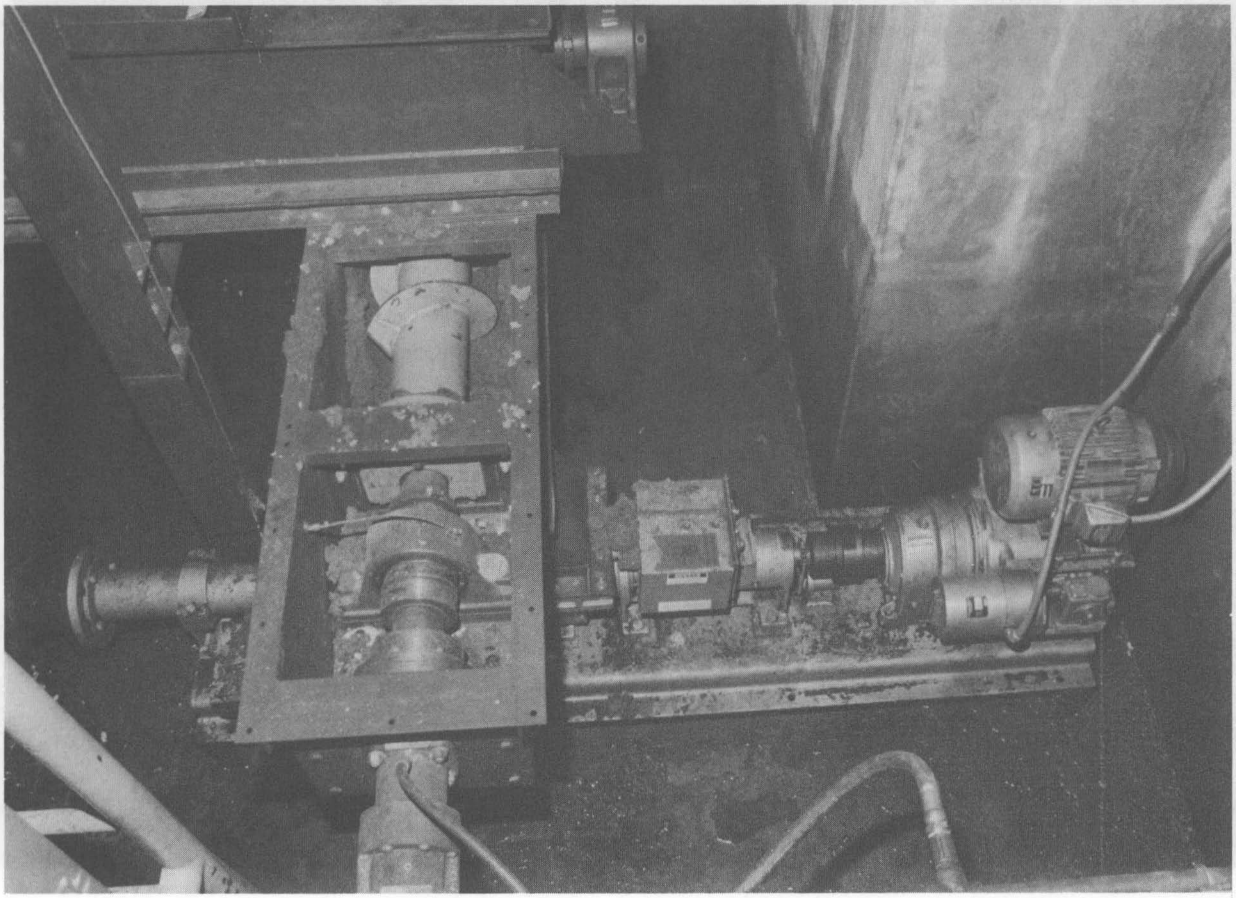

FIG. 11 VIEW OF SLUDGE BIN TRANSFER SCREW AND SLUDGE PUMP

FIG. 12 VIEW OF DELIVERY PIPE AND SLUDGE IN THE FEED HOPPER OF THE INCINERATOR

Full operation began in May 1985. Few problems occurred with the incinerator or boiler, but problems in the ESP did cause interruptions in the operation. The ESP kept turning off due to excessive voltage arcing. Visual inspection of the ESP, while it was still hot, revealed that the plate tops had buckled. Additional supports were added to correct this. Two weeks later the same problem occurred with the plate bottoms. Additional supports were added and have eliminated the problem. When the ESP is operational, the stack is very clear. Emissions were evaluated using the EPA Method 5. The results averaged 0.029 gr/DSCF, (0.070 gr/NM^3), 9550 ACFM at 310°F (154°C). The ESP power settings were 30 KV and 50 MA.

The ESP is slowly cooled over the weekend and opened up on Monday morning for visual inspection. Any fly ash deposits are removed from the plates and hopper area.

A second problem with the ESP system occurred in the fly ash hopper rotary valves. The valves bound up after "squeaking" for a short time period. The valves were stored on site for several months prior to installation, and it was thought that rust could have built up in the rotors. The rotors were removed and ground slightly to re-establish a clean edge. The sides of the valve were also cleaned. The result valves operated smoothly for a few weeks, however, the squeaking noise then returned. The valves did not bind up the second time.

The sewage sludge system was started 2 months after the burning of solid waste began. This allowed time to adjust the incinerators and to train the plant operators. When the sewage pump was first started, the gear box drive broke. The start-up instructions provided by the supplier were not detailed enough to indicate that hand turning was required prior to power driving. This procedure is intended to prevent frozen gears from cracking. The system has functioned smoothly after restarting. The bin screw speed was adjusted to prevent overfilling the sludge pump, and the pumping action per cycle was increased until the desired rate of 200 lb/hr (91 kg/h) was obtained. The pump hopper is equipped with a bridge breaker. The discharge slot in the pipe over the incinerator feed hopper was first sized at 1 in. (2.54 cm) wide by 2 ft (0.6 m) long. However, all the sludge came out at the very start of the slot. Therefore, the length of the slot was reduced to force the sludge out in the center of the hopper.

OPERATION RESULTS

Solid Waste Amounts

The amounts of solid waste delivered to the site during the start-up period varied from 89 to 98 tons (80 to 84 t), but averaged 93 tons (84.5 t). This is very close to 90 tons/week (81.8 t) estimated in the feasibility study.

Incinerator Operation

The incinerator demonstrated stable generation and good performance at high and low weekly burning rate averages of 1.25 tons/hr (1.1 t/h), and 0.68 ton/hr (624 kg/h), respectively, for a turndown ratio of 1.8 to 1, or 55%.

During the emissions testing, the CO_2 level measured in the stack was 5.5%. This corresponds to an excess air level of 113%. The incinerator operates at a temperature range of 1700°F (926°C) ±100°F (38°C) in the hearth chamber and 1900°F (1038°C) ±100°F (38°C) in the post-combustion chamber.

There is no modulation of the air based on temperature. The automatic control cycle regulates the hearth chamber pressure by controlling the induced-draft fan. There is no combustion air injected into the post-combustion chamber.

RESIDUE

The residue removal dredge system functioned near flawlessly from start-up. The water level in the quench tank had to be lowered to reduce spilling and splashing. The only other problem occurred when the dredge failed to change tracks during the return cycle. No reason was found for this single occurrence. The residue exhibits characteristics of very good burn out. Its color is light grey, and its texture is very granular. Few, if any, clinkers, unburned papers, or organics can be found.

The weekly amount of residue weight averaged 30% of the incoming refuse weight for a 70% weight reduction. No measurement of volume reduction was made. However, only two 8 cu yd (6 m^3) dump trucks of residue are taken to the landfill site each day, where it is covered weekly.

STEAM PRODUCTION

Steam is produced at 25 psig (172 kPa). Pressure losses in the 1200 ft (366 m) long steam line to the college boiler house amount to approximately 5 psig (34.5 kPa). Steam use at the college is at 5 psig (34.4 kPa). Steam production has varied from 1.8 to 2.6 lb/lb (kg/kg) with an average of 2.17 lb/lb (kg/kg). The lower steam per solid waste rates occurred on days when two or more up/down cycles occurred. During those times, energy was released in the bypass stack. During part of these down cycles, the boiler continued to deliver steam (at less than full capacity) due to the high boiler pressure. The boiler time clock continues to run during these time periods. Neglecting the two low data points results in a steam rate of 2.25 lb/ (kg/kg).

SEWAGE SLUDGE

The dewatered primary sludge has a solids content in the range of 25 to 28% as delivered to the HRI facility. Heating value tests averaged 6287 Btu/lb (14.6 MJ/kg) on a dry basis. The ash content averaged 27% on a dry basis.

The sludge pump runs during each incinerator charging cycle (every 10 min). Approximately 35 lb (16 kg) of sludge are added to the hopper each cycle for an hourly rate of about 211 lb (96 kg). The 16 kg charge of sludge has a volume of about 0.067 ft^3 or a 5 gal bucket (0.018 m^3). Introduction of the sludge did not produce any combustion problem. The ratio of as-fired refuse to wet sludge is approximately 7 to 1.

UTILITIES

The plant has had an average monthly electric consumption of 42,000 kW·h and a demand use of 120

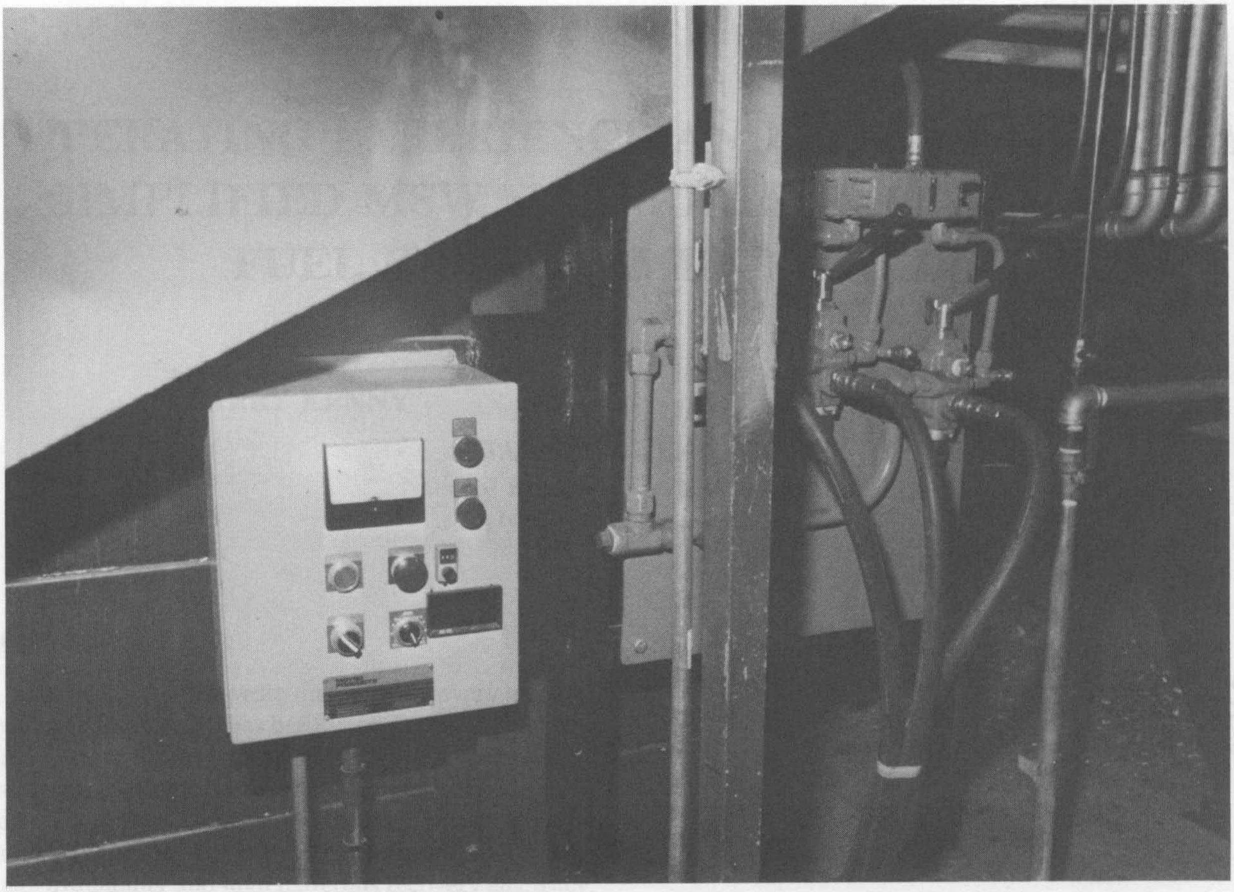

FIG. 13 VIEW OF CONTROLS FOR SLUDGE BIN SCREWS AND SPEED OF SLUDGE PUMP

kW·h. For the average monthly solid waste processing rate of 400 tons (363 t), the electrical use is 105 kW·h/ton (0.66 kW·h/kg). The use of No. 2 oil for auxiliary burners has averaged 2 hr per week at a rate of 28 gal/hr (1.76 L/min). The total fuel usage per week is approximately 56 gal (211 L) or 0.60 gal/ton (2.5 mL/kg).

LABOR

The plant is operated by one man per shift. During the day, two additional staff are present on site: the plant supervisor and the plant mechanic. These two personnel are on call to assist the operator on the other two shifts.