A 200 TPD MODULAR WATERWALL COGENERATION FACILITY IN NEW HANOVER COUNTY, NORTH CAROLINA

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ABSTRACT

This paper describes a 200 tons/day refuse fired cogeneration plant under construction in New Hanover County, North Carolina (Wilmington). This resource recovery facility, which is scheduled for startup in September 1984, comprises American-made equipment featuring two 100 TPD (91 tpd) modular waterwall combustion systems.

This paper describes or illustrates: (a) project cost and procurement; (b) the modular waterwall combustion system; and (c) general facility and process design.

BACKGROUND/PROCUREMENT

Planning for a resource recovery facility for New Hanover County, North Carolina, began in 1979 when the County contracted with outside consultants to provide services on a three-phased solid waste management project. The first phase of the project was to identify potential sites to replace the County's existing landfill since its lease expired in late 1980. The second phase of the project was to open a new interim sanitary landfill until a plan for long-term needs could be developed. Finally, phase three of the project was to develop a long range plan for solid
waste volume reduction and/or resource recovery. The results of the three-phase study and a subsequent New Hanover County Citizens Task Force report was a recommendation to implement a mass-fired solid-waste-to-energy cogeneration facility.

The objective of this facility was to accommodate the needs of solid waste volume reduction while simultaneously producing energy to be sold to local energy markets which would offset the costs of solid waste disposal.

There were several potential steam customers within New Hanover County, but none could take all of the steam which could be generated by the resource recovery facility. Therefore, it was determined early that any viable project would also have to incorporate power generation for sale to the local utility (Carolina Power and Light) in addition to its cogenerated steam.

Once the potential energy customers and the scope of the project were identified, New Hanover County retained outside consultants to provide procurement documents for the selection of a qualified design/build contractor as well as comply with North Carolina's Public Works procurement policies and statutes. The procurement effort began with the issuance of a Request for Qualifications in January 1982. After the evaluation of the qualifications packages, the County and its consultants selected four firms to respond to a Request for Proposal. In April 1982, the Request for Proposal documents were prepared and submitted to qualified bidders and, in accordance with North Carolina procurement statutes, any other firms which were interested in receiving the Request for Proposal document.

Finally, two proposals were received on July 12, 1982. Following proposal review and evaluation, final selection of the facility site and the energy customer, Clark-Kenith, Incorporated, was awarded a contract on November 1, 1982, in conjunction with Velzy Associates, Keeler-Dorr Oliver and Detroit Stoker, to design and construct the 200 TPD (182 tpd) refuse fired cogeneration facility for New Hanover County which would sell process steam to W.R. Grace Company and electricity to Carolina Power and Light.

The $13,084,000 facility construction cost was financed with general obligation bonds and an equipment lease-purchase arrangement between New Hanover County and First Union National Bank. The G.O. bond issue was for $12 million, a portion of which was allocated for the County's new permanent landfill site. The bonds were sold on August 24, 1982, at a rate of 8.5% to 9% over a 15 year period. The balance of the facility cost was financed by a $4 million lease purchase agreement, wherein First Union National Bank bought the boilers and overhead bridge cranes from Clark-Kenith and leased them to New Hanover County for 60 months at an interest rate of 8.9%. At the end of the 60 months period, New Hanover County will own the equipment.

The turnkey construction was based on the "fast track" method, which allows construction to commence as soon as the drawings of that phase are completed. And, in order for the contractor to successfully "fast track" the project, it was necessary to identify major component suppliers at the proposal phase.

By selecting these suppliers in advance, the contractor was able to complete its preliminary subcontract negotiations, providing the opportunity to immediately execute these subcontracts upon receiving a notice to proceed. Additionally, this early selection of major system components enhanced early project management and design efforts by allowing the particular expertise of each major vendor to be applied to construction scheduling and engineering. All of this "fast tracking" allowed the contractor to propose construction completion and system startup within 21 months from the notice to proceed. Including the 30 day acceptance test period, construction scheduling and on-site activity at this writing (January 1984) indicates that construction will be completed ahead of schedule.

The only major delay associated with the project construction was a result of legal action against New Hanover County by the local Association of General Contractors contesting that North Carolina law prohibited "turnkey" projects under public works control. The local court ruled in favor of the project after a temporary injunction was issued which halted work on the facility, and the resulting 18 day delay has not significantly affected the project schedule.

### DESIGN OBJECTIVES

A major objective in the design of the New Hanover County Facility was to combine a shop assembled water tube boiler design which has been successfully utilized in the combustion of solid fuels for five decades in the United States with the process design and control strategy of the Hampton, Virginia plant [1]. In many ways the New Hanover County design is a second generation of Hampton; however the idea of mounting a standard (modular)

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**TABLE 1 MAJOR SUPPLIERS**

<table>
<thead>
<tr>
<th>Category</th>
<th>Supplier</th>
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<tbody>
<tr>
<td>Contractor</td>
<td>Clark-Kenith, Incorporated</td>
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<td>Facility Design</td>
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<td>Grates</td>
<td>Detroit Stoker Company</td>
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<td>Turbine-Generators</td>
<td>Turbodyne</td>
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<tr>
<td>Cranes</td>
<td>Harnischfeger Corporation</td>
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<tr>
<td>Residue/Fly Ash</td>
<td>Beaumont Birch Company</td>
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<td>Precipitators</td>
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TABLE 2 ECONOMIC PROFILE

<table>
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<th>Construction Cost</th>
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<tr>
<td>Est. Annual O&amp;M</td>
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<tr>
<td>Est. Steam Sell Price</td>
<td>5.10/Kibs</td>
</tr>
<tr>
<td>Electricity Sell Price</td>
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</tbody>
</table>

shop assembled solid fuel boiler above a standard shop assembled reciprocating grate system to provide a modular waterwall plant emerged through the combined efforts of the boiler manufacturer, the stoker manufacturer, the consulting engineer and the contractor.

As a result, the building volume of the 200 TPD (182 tpd) modular waterwall facility in New Hanover County (including turbine generators) is about 30% smaller than the 200 TPD (182 tpd) field erected plant in Hampton, Virginia.

Beyond that the design objectives stem from: (a) improvements based on operating experience; and, (b) differences in the New Hanover County project objectives such as:

- (1) superheated steam @ 450 psig (3101 KPa), 650°F (343°C);
- (2) turbine-generators for cogeneration;
- (3) grate surface area increased to improve fuel burn-out;
- (4) Chrome/Nickel (25/12) grate composition to improve grate life.

Because there is duplication of some Hampton design features, descriptions of some systems and arrangements are taken from the Hampton Paper [1]. These descriptions are repeated in italics for continuity and the convenience of the reader.

THE PLANT
REFUSE RECEIVING AND HANDLING

After weighing, collection trucks enter the tipping area and tip into the refuse storage pit as shown in Figs. 1 and 2 (Facility Plan and Section). With stacking, the effective storage volume of this pit is about 3000 yard³ (2250 m³) which translates to about 660 tons (545 t) of refuse, or a three day fuel supply.

The refuse charging system is similar to that found in most waterwall mass-fired plants. An overhead crane with 5.5 ton (5 t) capacity and 3 yard³ (2.3 m³) grapple retrieves refuse from the storage pit and feeds the charging hoppers of both stokers.

The duty cycle of the crane was selected to allow both stokers to be fed at capacity rates in less than half of the available time, allowing over 50% for operator fatigue, refuse mixing, and removal of bulky items. A second crane identical to the first is available for standby service. The arrangement of these cranes is shown in Fig. 1 (Facility Plan). The redundancy offered by two cranes, each with a 46% duty cycle, serves to maximize process availability and thereby enhance long term project economics.

BOILER/STOKER

Unlike most other MSW-fired waterwall boilers, the New Hanover County boiler/stoker units are not field-erected but rather of modular construction. The major advantages of modular construction are:

- (a) Permits standardization, quick delivery and lower cost. To date, standard 50 ton (45.5 t), 75 ton (68.25 t), 100 ton (91 t) and 115 (104.7 t) ton units have been developed.
- (b) Less field erection time for the boiler/stoker. This permits more time for other work in the boiler/stoker area and reduces conflicts with other construction activities.
- (c) Factory assembly which allows better quality control.

In designing the modular boiler/stoker units, care was taken to assure that design parameters and/or features of proven refuse burning boiler/stoker units were not compromised. The combustion chamber is completely water-cooled. Unit efficiency, furnace exit gas temperature and furnace volumetric heat release rates are all comparable to those associated with field erected waterwall units. The stoker is about 40% wider and the effective grade burning area is about 30% greater than those used at Hampton, Virginia. The wider stoker and lower burning rates per unit area result in a shorter luminous flame and less required furnace height.

The modular units are packaged into three major assemblies: (a) boiler with convection bank, superheater, and upper furnace waterwalls; (b) stoker with lower sidewall headers and waterwalls; (c) feed chute and hydraulic feed ram. Miscellaneous items such as hoppers, header supply pipes and access doors are shipped loose for field installation.

The boilers are natural circulation, top-supported units with structural members under each end of the steam drum (Fig. 3). All sidewall, furnace frontwall and bridge-wall tubes originate from two lower sidewall headers and terminate in the steam drum without intermediate headers. The boilers are an adaptation of a successful design used for solid fuel firing for over fifty years.

The boiler manufacturer supplied a complete package from the charging hopper through the economizer, including the stoker, combustion air fans, and overfire air system. This assures a coordinated, single responsibility for the combustion-steam generation system.

The boiler is of the long-drum (longitudinal gas flow)
FIG. 1 FACILITY PLAN

FIG. 2 FACILITY SECTION
type which permits variation in furnace depth and/or convection bank depth, but retains the possibility of standardization with a particular boiler height and boiler/stoker width.

The superheater is part of the boiler module. The total steam temperature is 650°F (343°C) a pressure of 455 psig (3105 KPa) at the superheater outlet. The superheater is located in the convection section, behind the upper rearwall (screen) tubes to protect it from direct furnace radiation and flame impingement.

The refuse feeding system consists of a charging hopper, hydraulically operated cut-off gate, and a refuse chute. The lower part of the chute is fabricated of stainless steel with a refractory covering in those areas where it may become exposed to flames during upset conditions. A full width, hydraulically operated ram controls the feeding of refuse to the furnace. Both the stroke length and frequency can be varied. The automatic combustion controls vary the refuse feed rate by varying frequency to maintain a selected steam flow.

The stoker is an 8 ft - 6 in. wide unit, two section, reciprocating grate with a vertical dropoff between sections to provide mixing and breakup of the refuse. The stoker is assembled on a heavy structural steel frame with
heavy side plates and bulkhead at the rear where the hydraulic drive cylinders for both grate sections are mounted. The duplex hydraulic pump-set is shop mounted on the stoker frame. All hydraulic lines are shop installed. The entire hydraulic system is flushed in the shop to expedite startup.

The assembled stoker frame is delivered to the boiler manufacturer to finish assembly of the lower module by mounting the waterwall headers, lower waterwall tubes, refractory tile, insulation, overfire air system and casing. Both the sidewall cast iron transition blocks at the stoker grate line and the “fired” shape silicon carbide blocks up to the top of the normal fuel bed profile are shop installed. Above the “fired” silicon carbide shapes the lower waterwall tubes are shop studded to support and retain a silicon carbide castable coating which is applied in the field to avoid damage in shipment.

On completely field erected units the site work can take six to nine months. With the modular construction the field assembly of the three modules and miscellaneous parts is relatively simple and can be completed within four to six weeks. The major steps are:

(a) set lower module in place (stoker and lower waterwalls);
(b) erect support steel for the top module (boiler);
(c) set top module;
(d) lift lower module — align and weld waterwall tube ends;
(e) remove shipping support pins to free lower waterwalls from the stoker frame. At this point, the waterwalls become top supported and hand from upper module. The stoker is bottom supported;
(f) set hydraulic feed ram and lower chute module;
(g) install sidewall header supply pipes. Install refractory tile, insulation, and casing at the split line between modules;
(h) install grate bars;
(i) apply silicon carbide to the studded tubes.

Each of the two sections of burning grate have a separate air plenum/sifting hopper. The ash from each hopper discharges to a common drag conveyor. The siftings drag conveyor is skewed from the centerline of the boiler-stoker so it can discharge to either bottom ash conveyor. The top flight of the sifting conveyor moves the sifting. A seal between the two hoppers is accomplished by hinged seal plates on each side of the individual hopper discharge.

Every other row of grate bars reciprocate to move the burning refuse through the unit. Grate wear can be reduced by reducing the number of strokes required for a particular firing rate. To make the stoker grate action more effective and reduce the number of strokes, the following improved features were incorporated:

(a) the slope of the grates was increased to 12° to let gravity be more effective;
(b) the height of each grate bar nose was increased to give it better grabbing or pushing power;
(c) the length of grate bar stroke was increased so that more effective movement of the fuel bed is obtained with each stroke.

The stoker frame and the support assembly for the moving grate is fabricated of heavy structural members and it is supported on rollers rather than on friction blocks. In addition, the moving grates are cantilevered from the support assembly so that wear to the stationary grates is not caused by friction from supporting the fuel bed via the moving grate.

All grate bars, tuyeres, and other stoker parts that are exposed to direct radiation from the fire are made of high chrome-nickel alloy.

The hydraulic drive cylinders for both grate sections are located on a heavy, structurally reinforced bulkhead where they are readily accessible for operating inspection and preventative maintenance. Similarly, all hydraulic controls and valves are located on a shop installed panel for ease of operation and inspection.

Since municipal refuse is characterized by a high percentage of volatile matter, an extensive overfire air system is necessary for good combustion. The furnace frontwall and the rearwall each have two levels of overfire air nozzles and there is a row of nozzles on each sidewall immediately above the normal bed profile. Overfire air, which can be as much as 50 percent of the total combustion air, bypasses the grate and therefore does not unnecessarily disturb or cool the fixed carbon burning on the grate. Overfire air is introduced under relatively high pressure to cause turbulence to mix combustion air and volatiles leaving the fuel bed to help prevent streamlining and complete the combustion process. Combustion is completed and the products of combustion are homogenous and oxidizing as they leave the area of the overfire air introduction.

Fireside waterwall tube metal wastage in the lower furnace has been experienced in mass fired units both in Europe and in this country. There is still uncertainty as to the mechanics and chemistry by which this metal wastage occurs. It is generally accepted that the lower waterwall surface should be protected from the products of combustion. Protection is necessary up to a level above where one can be assured that the furnace atmosphere is consistently oxidizing.

Silicon carbide has been used as the tube protection material because of its high coefficient of heat transfer compared to other refractories. This results in higher heat adsorption in the lower furnace and assists steam/water
circulation in the furnace waterwall circuits and helps keep the hot face temperature of the refractory as low as possible to minimize slagging.

Two type of silicon carbide material are: (a) "Fired" shapes used to protect the waterwalls where the fuel bed rubs these areas; and (b) castable silicon carbide gunned over the waterwall tube studs up to a level above the overfire air ports. The "fired" shapes in the bed area are held in place by keying around the tubes. The cast iron transition blocks (at the grate line) are wedged shape and keyed to the tubes without bridges or bolts. The cast iron blocks along with the "fired" shapes can both be replaced from inside the furnace without casing removal.

The waterwall construction is typical of industrial practice for solid fuel fired boilers; the 2 1/2 in. (63.5 mm) tubes on 4 in. (101.6 mm) centers are backed by 2 in. (50.8 mm) of high duty refractory tile, 3 in. (76.2 mm) of block insulation, 10 GA. seal welded (hot) casing and 2 in. (50.8 mm) of blanket insulation with a 10 GA. outer casing. The 10 GA. seal welded (hot) casing is maintained at a sufficiently high temperature to prevent acid dew point corrosion. The hot casing will normally be at 300°F (149°C) plus during normal operation.

The convection bank consists of 2 1/2 in. (63.5 mm) diameter tubes arranged in-line on 6 in. (152.4 mm) side spacing (perpendicular to gas flow) and 5 in. (127 mm) back spacing (parallel to gas flow). Gas velocities through the superheater and convection bank are below 30 ft/sec (9.1 m/s). One retractable and one rotary steam soot blower provide on-line cleaning for the superheater and convection bank areas.

The superheater is directly behind the rearwall and is comprised of 2 1/4 in. (57.15 mm) diameter tubes on a 5 1/4 in. (133.35 mm) side spacing and a 5 in. (127 mm) back spacing. There are two steam passes to increase steam mass flows and reduce metal temperatures.

Due to the steam flow fluctuations normally associated with mass refuse fired units, a 42 in. (1.07 m) diameter by 31 ft - 11 in. (9.7 m) long steam drum has been used to help produce a stable water level and dry steam for the superheater.

The economizer is shop assembled and consists of 2 in. (50.8 mm) bare tubes on 4 in. (101.6 mm) side spacing and 3 in. (76.2 mm) back spacing. The surface is arranged for upflow water and downflow gas with an exit gas temperature of 450°F (232°C) at rated capacity. The economizer gas velocity does not exceed 30 ft/sec (9.1 m/s).

Fly ash from the two boiler hoppers is returned continuously by rotary valves to the rear of the furnace where it drops into the bottom ash removal system.

**CONTROLS**

The process control scheme is an analog system comprising six basic control loops:

(a) three element feedwater;
(b) constant furnace pressure;
(c) stoker feed and underfire air;
(d) furnace temperature trim;
(e) constant steam header pressure;
(f) steam distribution between steam customer and condensing turbine-generator.

The first and second loops are common in steam plants. Signals sensing steam flow and drum level are summed to provide a total feedwater control signal which is finally verified against the flow of feedwater supply. And constant furnace pressure is maintained by dual inlet box dampers on the induced draft fans.

The combustion control system comprising loops 3, 4, and 5 was developed for the NASA/Hampton facility and has been repeated in New Hanover County due to satisfactory performance at Hampton. These combustion controls are designed to simultaneously maintain: (a) constant steam header pressure; (b) selected steam flow; (c) constant upper furnace gas temperature; and (d) metering control of the refuse entering the furnace.

With the steam header pressure held constant as shown in Fig. 5, the boiler master maintains a selected steam flow of up to 33,000 lb/hr (15,000 kg/h) each unit by modulating the ram frequency and inlet dampers on the undergrate air fan (Fig. 4). Additionally, this primary loop is trimmed by modulation of the reciprocating rate of the two grate sections to maintain a constant upper furnace gas temperature for the selected flow. Without this feature, the exit gas temperature, which is indicative of steam generated, will vary considerably due to the nonhomogeneous nature of the refuse.

Although the inventory of fuel in the furnace cannot be changed quickly, this control scheme achieves rapid variation in the heat release by simply varying the undergrate air and modulating rate (stirring) of the burning grates. At NASA/Hampton, this system has been able to automatically maintain the selected steam flow to within ±10 to 12% of set point with infrequent upsets outside of this range. And, in doing this, the excess air varies from 50 to 90%, which is sufficient range to keep CO production minimal.

Operation to date indicates that the variation of undergrate air is much more effective than the furnace temperature “tie-back” in maintaining a selected steam flow. Also,
the boiler steam pressure control system (back pressure system) has added significantly to drum water level stability.

Referring to Fig. 5, loops 5 and 6 combine to simultaneously control three key process variables: (a) pressure in the steam header is maintained at throttle pressure of 450 psig by modulation of CVZ; (b) steam customer’s flow demand automatically is satisfied at constant pressure by maintaining constant pressure downstream of the back pressure turbine-generator; and (c) all steam generated in excess of the customer’s demand is automatically directed to the condensing turbine.

The latter two are achieved by modulating the throttle flow (CV1) to the condensing turbine to satisfy constant pressure at the back pressure turbine-generator outlet. The intention with this criss-cross strategy is to take advantage of the accumulation afforded by 2000 ft (6096 m) of 8 in. (203.2 mm) steam transmission line to reduce the sensitivity of the modulation rate of throttle steam to the condensing turbine.

RESIDUE AND FLY ASH HANDLING

The residue and fly ash handling system is the common scheme comprising water filled residue conveyors and dry mechanical chain fly ash conveyors. The residue is discharged from the second grate section directly into the residue conveyors troughs as shown in Figs. 2 and 3. Similarly, all of the fly ash either falls by gravity or is conveyed mechanically from various collection points to the residue conveyors (Fig. 2). All of the residue and fly ash is mechanically conveyed to the residue truck. As with all ash handling systems, the main objective is to keep the system working, which is considerably more difficult in a mass-fired plant. The residue in this plant will literally contain any noncombustible material or items which can be found in municipal refuse and which will pass through the system. As a result, residue conveyors must be very rugged and liberally designed, and they must include a standby system to minimize plant outages due to conveyor breakdowns. The bifurcated chute shown in Fig. 2 allows residue to be discharged into either residue conveyor and the lower level fly ash conveyor provides the same choice for the fly ash discharge.

ENVIRONMENTAL

The two primary environmental considerations which must be formally addressed by the design effort of any new boiler plant are air quality at the stack outlet and water quality of all plant discharges.

The air quality criterion for these stacks is limited to particulate emissions. The maximum amount of particulates which may be emitted at any time is 0.08 grains/dscf (0.18 g/m³) corrected to 12% CO₂. Electrostatic precipitators were selected to emit no more than 0.05 grains/dscf (0.11 g/m³) for the gas flow rate and temperature produced with the boiler operating at a refuse input of 100 TPD (91 tpd) with refuse having a higher heating value of 5000 Btu/lb (11.6 MJ/kg) and 100% excess air. Model studies were conducted by the precipitator manufacturer for this particular application to insure adequate flow distribution and to verify the draft loss from economizer outlet to induced draft fan inlet.

A major water quality compliance problem associated with all solid fuel fired boiler plants today stems from ash-contaminated discharges. As just described, all of the ash collected in the plant is dumped into water filled residue conveyor troughs. The overflow from these troughs is sufficiently contaminated with ash to preclude legal discharge into the environment or sanitary sewer. Therefore, in order to achieve zero discharge from the residue quench troughs, an elevated surge tank has been located above the discharge end of the conveyors. This tank is sized to retain the volume of quench water in a single residue trough to allow a trough to be “pumped down” periodically for removal of floating ash and residue. The quench water will then be gravity discharged back into the trough.

In order to contain the odor and light debris within the enclosed refuse pit area, the primary combustion air fans draw through grilles located high on the refuse pit wall. Thus, normal boiler operation will simultaneously ventilate the refuse receiving and storage area of the plant, provide a slight negative pressure to contain odor and light debris.

CLOSURE

The authors look forward to updating this paper with performance data at the 1986 National Waste Processing Conference.

REFERENCE