SKAGIT COUNTY RESOURCE RECOVERY FACILITY DESIGN OF A 178 TPD WASTE-TO-ENERGY PLANT

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ABSTRACT

The Skagit County Resource Recovery Facility (SCRRF) went into operation in mid-1988, and since then has burned all the county's unrecycled garbage. Operations have exceeded the design capacity of 178 tons (161 Mg) per day of garbage. The plant has met all air pollution regulatory criteria—a common misconception is that the plant is out of service because there is nothing visible coming out of the stack!

The facility is designed around two rotary kilns of Italian manufacture. The kilns have significant advantages in completeness of combustion attained, and the simplicity of having only one basic moving part exposed to the fire.

The flue gas from the kilns goes to waste heat boilers which cool the gas so it can be cleaned. Steam from the boilers is used to generate power in a turbine generator.

Successful operation of the plant has demonstrated:

(a) A smaller practical size for a waste-to-energy plant which meets the latest air pollution control requirements.

(b) The advantages of the rotating kiln technology, combined with a separate post-combustion chamber.

(c) A small, economical acid gas scrubbing system.

(d) Successful concepts in dry bottom ash and fly ash handling.

This paper also discusses the constraints on power generation in a plant whose primary purpose is incineration of garbage.

BACKGROUND — PROJECT REQUIREMENTS

Skagit County, with a population of 70,000, is located approximately halfway between Seattle and the Canadian border to the north. County government, assisted by R. W. Beck & Associates, conducted a study of alternatives, with extensive public involvement, before deciding on the incineration project and selecting and permitting the site. These efforts were reported by Sampley and Bingham [1]. Financing the project was facilitated by a state grant to pay 50% of the cost of the plant.

Proposals were requested on a full-service basis, including a long term contract for operation and maintenance of the plant. At least two processing lines were required, for redundancy. Availability of 90% was to be guaranteed.

Requirements to control emissions were severe:

(a) 0.02 gr/dscf (0.05 g/Nm^3) particulate emissions

(b) 50 ppm HCl

(c) 50 ppm SO_2

(d) Maintaining combustion temperature of 1800°F (980°C) for one second residence time.

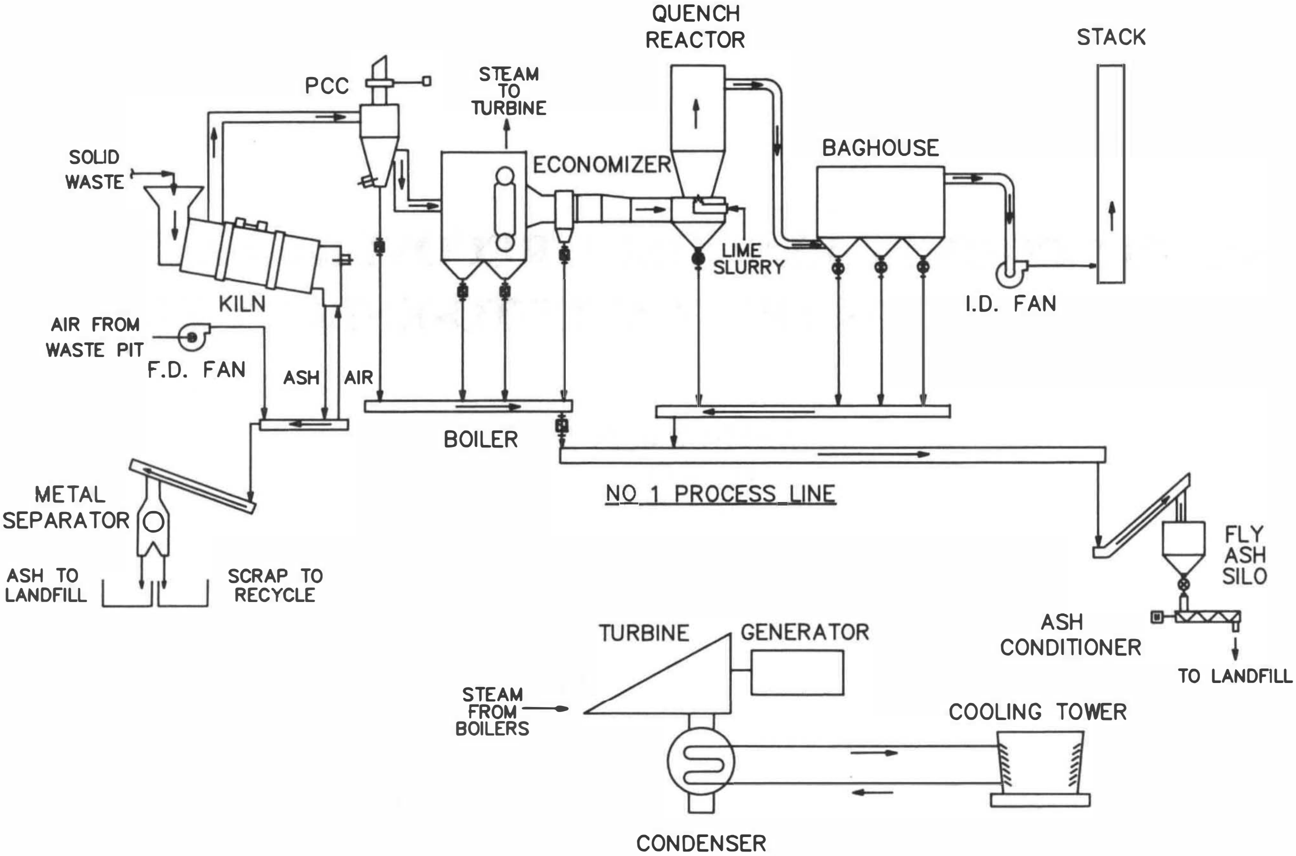

FIG. 1 PROCESS FLOWS

(e) Continuous emission monitoring (CEM) of opacity, CO, O_2, SO_2, and gas temperatures.

(f) Maximum flue gas exit temperature of 290°F (143°C).

(g) The permit specified that tipping areas "be operated at a negative air pressure to prevent the escape of malodors".

The County retained responsibility for disposal of ash, and also required that bottom ash and fly ash be kept separate. This was because of the possibility that fly ash might be treated as a different category of waste for disposal purposes.

Wright Schuchart Harbor Co. was selected from among nine bidders as the full-service contractor, and retained Harris Group Inc. to design the plant.

SCHEDULE

The contract between Skagit County and Wright Schuchart Harbor was signed in January 1987, and called for commercial operation in 18 months. This schedule was particularly difficult for the designers because it required structural designs to be completed in time for excavation and concrete work to be done in the summer and fall of 1987. The structure of this plant is much more complicated than an ordinary power plant.

The plant started up on schedule and has processed all Skagit County's garbage since July 1, 1988.

PROJECT DESCRIPTION

The Skagit County plant is a mass-burn municipal waste incinerator plant rated at 178 TPD of processible garbage. It includes two independent process lines (Fig. 1), each based on a refractory-lined rotating kiln furnace with a post combustion chamber (PCC).

Next in each process line, the flue gas leaving the PCC enters a conventional waste heat boiler generating saturated steam at 450 psig (3200 kPa). Each boiler

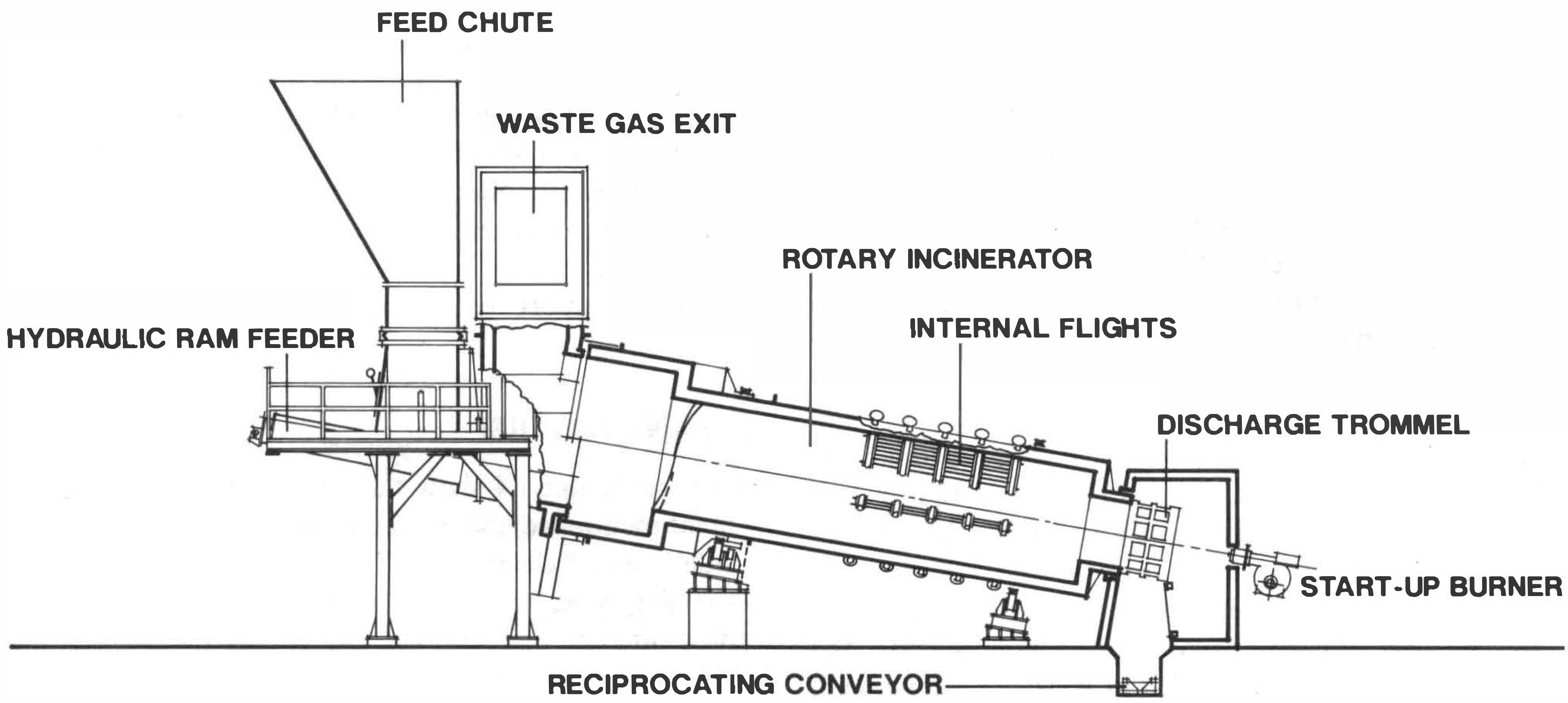

FIG. 2 TECNITALIA ROTATING KILN

has an economizer which reduces the flue gas temperature to about 450°F (230°C).

The air pollution control equipment for each line is a dry scrubber absorber/baghouse combination of the "Teller system" type, with a vertical upflow quench reactor for acid gas removal. The scrubber fluid is a slurry of hydrated lime (calcium hydroxide) injected with an air-swept atomizing nozzle. Atomization is by compressed air.

Power is generated by a single 2500 kW turbine-generator with a surface condenser cooled by a cooling tower. To assure that incineration capability is not lost because of a turbine outage, a dump condenser is provided.

TECNITALIA KILNS

The kilns (Fig. 2), which were supplied by Tecnitalia S.p.A. of Firenze, Italy, have been proven in many years of service incinerating garbage in Italy and elsewhere in the world. They had not, however, previously been used for steam generation, or been subject to air quality controls (except for two installations with electrostatic precipitators).

The rotating kiln has some fundamental advantages over other kinds of waste incinerators which do not provide agitation of the fuel during burning. The 3 Ts of combustion (time, temperature, and turbulence), can all be independently varied. And a kiln, with only one moving part exposed to the fire, has advantages of simplicity and ruggedness over moving grates or other more complex means of agitating the burning fuel.

The Tecnitalia concept includes the PCC to obtain complete burnout of gases. The PCC is a refractory lined chamber which follows the kiln in the gas path. For start-up, natural gas burners are provided to bring the kiln and PCC to the operating temperature of about 1800°F (980°C), which must be attained before any garbage is fed into the kiln. After the kiln and the PCC are warmed up, no supplementary fuel is required.

The control strategy developed by Tecnitalia provides kiln temperature control by a start/stop approach. When the temperature exceeds a set point, the kiln rotation is stopped; when the temperature goes below the set point, the kiln is started up again. There is also a provision for varying the speed of the kiln.

PLANT — INCINERATION SYSTEMS

Trucks deliver waste by dumping it into a pit which is sized to hold approximately 3 days' capacity. One of the two bridge cranes over the pit is used to remove nonprocessible items such as "white goods"—appliances, etc. Oversize items which might not pass through the kiln feed opening are processed through a shredder at one end of the pit. The cranes are also used to mix the waste in the pit to improve its uniformity.

The crane loads the waste from the pit into a charging hopper for each of the two kilns. From the charging hopper, the waste is fed into the upper end of the kiln by a hydraulic ram. Inside the kiln, the waste is lifted and dropped by internal flights projecting into the kiln (see Fig. 2). Combustion air enters the kiln from the lower end and flows counter-current to the burning waste.

The exit gas from the kiln passes into the PCC and thence into the waste heat boiler. Passing through the boiler and economizer, the gas flows into the quench reactor of the air quality control system (AQCS). In the quench reactor, the gas from the economizer contacts a slurry of hydrated lime (calcium hydroxide). By the time the gas leaves the quench reactor, the slurry has been evaporated into a dry powder which has reacted with the sulfur and chlorine compounds in the exit gas. The combination of fly ash, acid gas reaction products, and excess lime is collected in the baghouse.

The gas is removed from the baghouse by the I.D. fan and discharged up an individual flue inside a twin-flue stack.

The stack gases are monitored by a continuous emission monitoring system which analyzes the gas and records the concentrations of pollutants by means of a PC program. Each reading in excess of the emissions limits is recorded, with provisions for the operator to annotate the record with the cause of the reading. In general, emissions are well below the applicable limits; however, rubber tires and gypsum wallboard are two common causes for short term variations in emissions above the limits for SO_2.

Bottom ash from the kilns emerges at the lower end. Oversized pieces are retained in a trommel for manual removal. The rest of the bottom ash passes through the trommel into a reciprocating horizontal drag conveyor. This conveyor runs in a concrete lined trench under the lower end of the kiln; the trench also serves as the duct to deliver combustion air to the kiln. The horizontal conveyor delivers the bottom ash to an inclined pan conveyor which lifts the ash into the loading bays at either end of the waste pit. At the upper end of the inclined conveyor, a magnetic separator is installed to remove the ferrous metal in the bottom ash and route it to a baler for sale as scrap. The bottom ash falls into dumpster bins which are regularly removed to the county landfill.

Fly ash is collected at a number of points in the system:

(a) From the bottom of the PCCs.

(b) From hoppers under the waste heat boilers.

(c) From the bottom of the quench reactor.

(d) From the hoppers under the baghouse.

The fly ash (including acid gas residue from the last two sources) is collected by a system of drag conveyors and delivered to an ash silo. It is moistened in a pug mill type mixer as it is loaded into dumpster bins just before transport to the landfill.

PLANT LAYOUT

Figures 3 and 4 show the arrangement of the equipment mentioned above. The plant building has a "dirty side" and a "clean side". The only connection between the dirty side, where the garbage is unloaded and handled into the hoppers, and the rest of the plant is the air flow into the forced draft fans. The clean side does not contain any garbage exposed to the air. The floor trenches and conveyors which handle the bottom ash are kept at a negative pressure, which prevents dust from escaping. Also, the bottom ash can be sprayed with water as it leaves the vicinity of the kiln to further discourage dusting in this area.

PLANT STEAM AND POWER GENERATION

The steam generated by each waste heat boiler is about 20,000 lb/hr (9,000 kg/h) at 450 psig (3100 kPa) saturated. The combined steam flow supplies a 2500 kW turbine-generator unit. The turbine generator is floor-mounted, with a 36 in. (90 cm) overhead exhaust pipe to an adjacent surface condenser.

In case of unavailability of the turbine, the steam is condensed in a dump condenser. In this mode of operation, the steam systems are simply acting to cool the gas to the proper temperature for the AQCS.

In either mode of operation, power generation or dump condensing, the heat is rejected to a mechanical draft cooling tower.

SITE DEVELOPMENT

The site (Fig. 5) is located a few miles from the existing county landfill, which facilitates disposal of ash and nonprocessible items. The site is centrally located with respect to the cities from which the waste is collected. It is in an industrially zoned area, with few nearby residences.

The layout shown in Fig. 5 provides for a number of types of traffic:

(a) Dumping by the public.

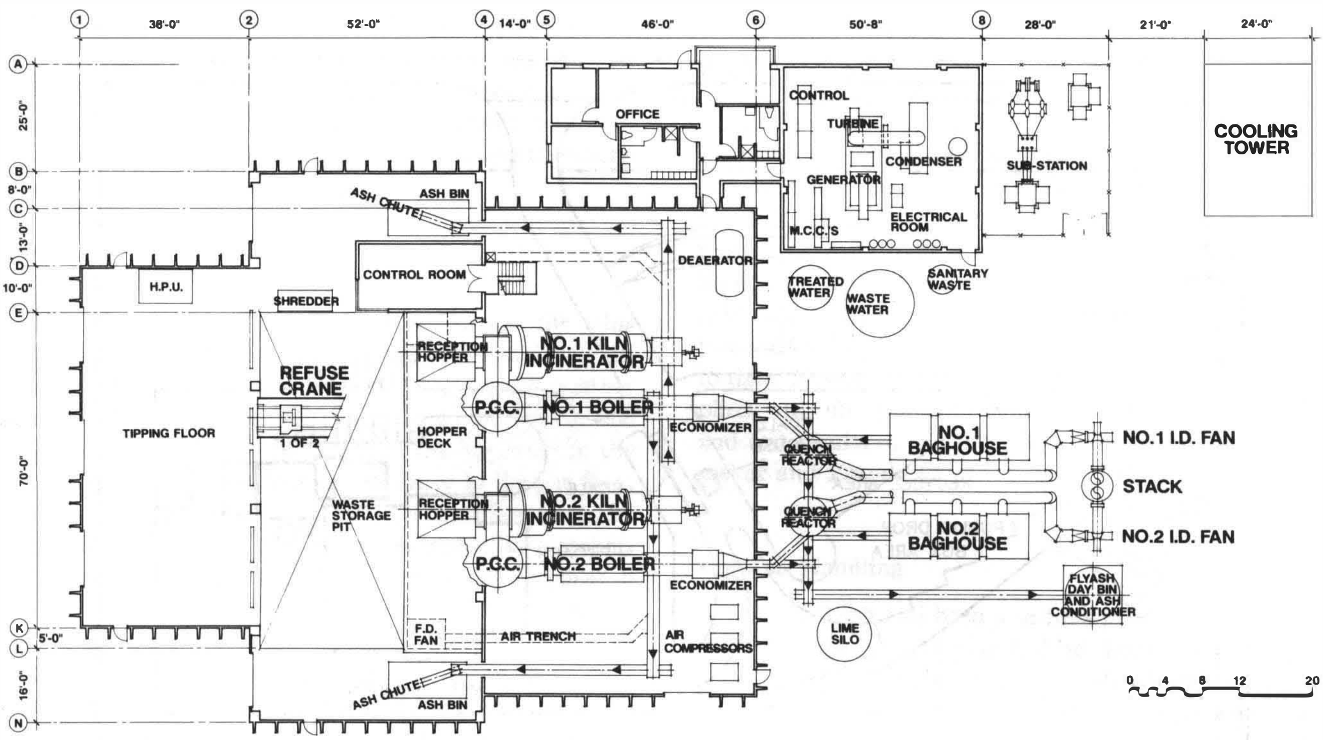

FIG. 3 GENERAL ARRANGEMENT — PLAN

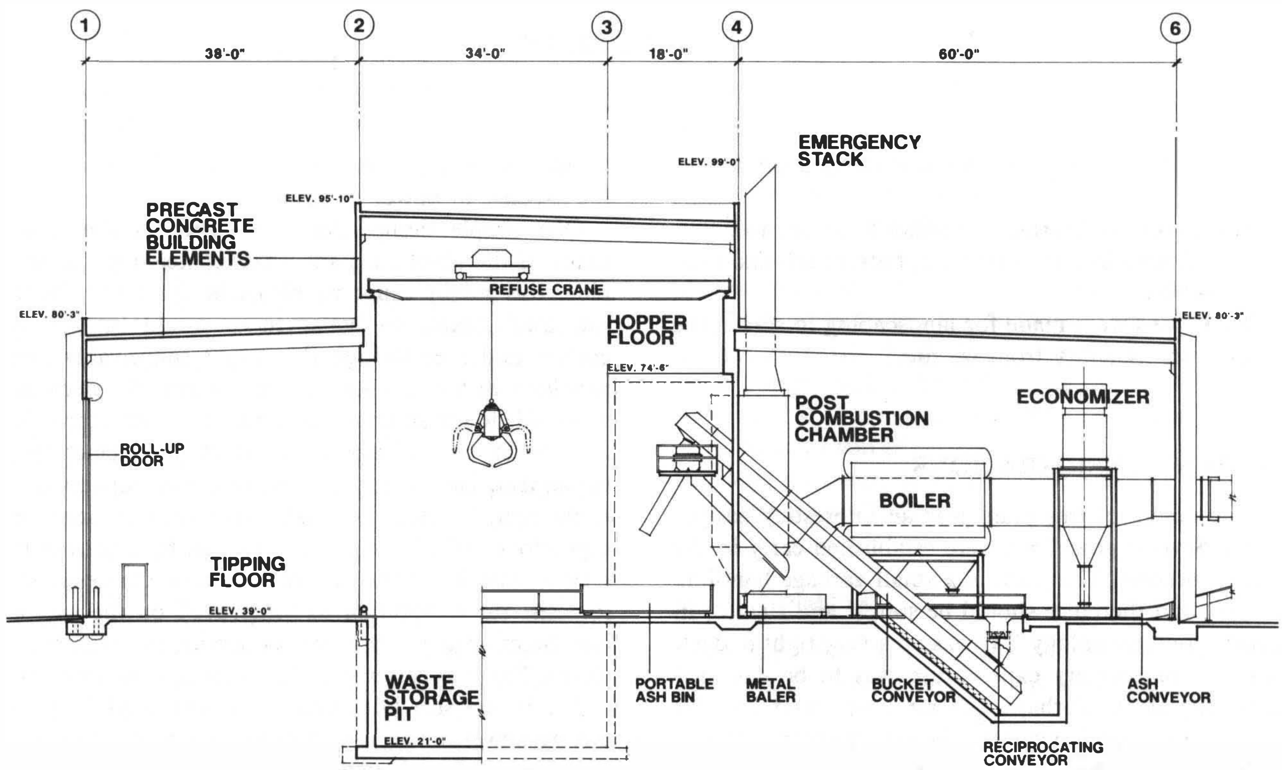

FIG. 4 GENERAL ARRANGEMENT — SECTION

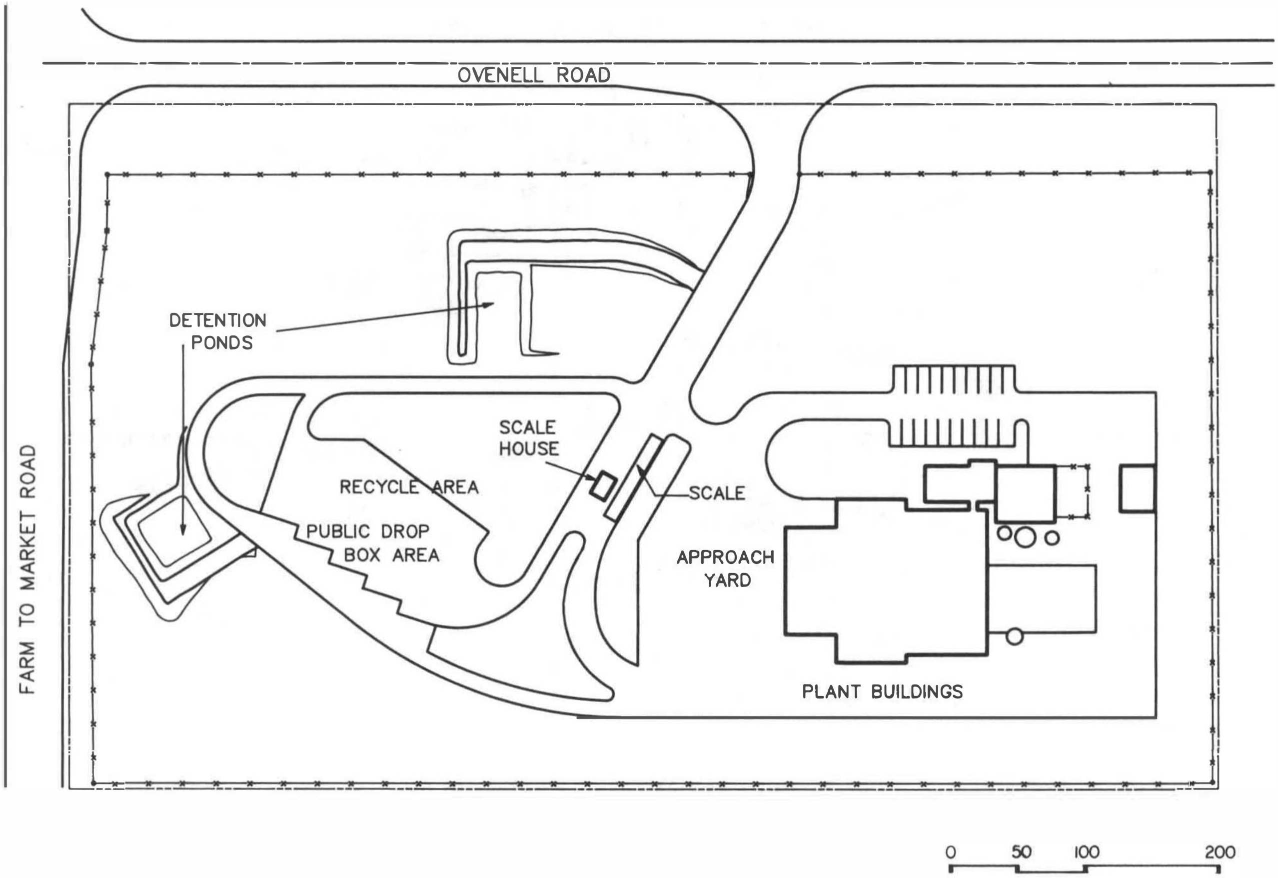

FIG. 5 SITE LAYOUT

(b) A recycling program operated by a private recycler.

(c) Trucks delivering the waste to be burned.

(d) Trucks to remove fly ash, bottom ash and nonprocessibles.

Provisions were made for landscaping to screen the plant from visibility from off site.

DESIGN CONSIDERATIONS

The design of this plant was an interesting assignment. Several guidelines were established early in the design process. The plant is a small garbage handling facility and therefore should be simple and rugged, in short "low technology". It was on a very tight budget, and no unnecessary expenditure was to be designed into the plant. Perhaps the strangest guideline for power plant people was that the power generation was of secondary importance. Contractual conditions made it most important that the continuity of garbage incineration service be maintained, even, if necessary, at the expense of power generation.

One simple design decision illustrates the latter point. If the plant used superheated steam in the turbine, this might cause problems in the boiler. With saturated steam, all boiler tubes would be equally cooled, and even though this might conceivably give problems in the turbine from wet steam, the decision was made to use saturated steam at the turbine throttle.

Another unusual aspect was the Italian incinerating equipment, including the kilns, charging hoppers and equipment, PCCs, bottom ash conveyors and magnetic separators. All of this equipment had been proven in service, and it became incumbent upon the designers to resist the temptation to "improve" on the way it had functioned in its previous service in incinerator plants. This was easier said than done in some respects.

The incinerator kilns had never been used for producing power, or even high pressure steam. The manufacturer had estimates of the heat losses and air required for combustion, but these estimates could not be confirmed. The designers made calculations of the type usually made by boiler manufacturers, to establish the quantities of air required for combustion and flue gas produced, to confirm the energy production, and for final sizing of the waste heat boilers, steam systems and the air quality control system.

Draft System

In their previous applications in Europe, the kilns were most often used with natural draft smokestacks, or in some cases with electrostatic precipitators, neither of which presented much resistance to the flow of flue gases, i.e., draft loss. In this case, the baghouse in the gas path offers considerable resistance to the gas flow, so it was apparent that an induced draft fan would be required. The draft system was designed like a stoker-fired boiler, with a slightly negative draft setpoint in the kiln which controls the I.D. fan inlet damper.

The forced draft system was designed to supply all the combustion air from air intakes in the space over the garbage pit, to keep objectionable odors inside the plant as required by the permit (see above). The air from the F.D. fan discharge is routed to the kilns through the bottom ash conveyor trenches. The air pressure is slightly negative, as mentioned above under plant layout.

The flow of forced draft air is established by a fixed setting of the fan damper. Possibilities of improved control of kiln temperature by automatic control of forced draft air flow may be explored in the future.

Air Quality Control

Not long ago, the removal of acid gas constituents from flue gas was considered practical only on a very large scale, i.e., in central power plants producing several hundred times as much power as the Skagit facility. Such "wet" flue gas desulfurization (FGD) installations using recirculating lime slurries are extremely expensive, and use special metals, fiberglass or rubber linings, and other technology to resist the corrosive and abrasive conditions of the process.

Most garbage burning plants in the past have not attempted to remove the acid gases from flue gas; pollution control was limited to electrostatic precipitators for removal of particulate. Nevertheless, air pollution control authorities have been increasingly insistent that garbage burners have FGD, not only for the acid gas removal, but also because the removal process for acid gas is considered to remove many other undesirable pollutants as well. This situation threatened to make it economically impossible to build small garbage burners which could meet environmental demands.

Recent developments in dry scrubber–baghouse technology, such as the Teller system used here, have made it possible to use acid gas cleaning on plants several times the size of the Skagit facility. On this plant, it was found that by using hydrated lime as the reagent (greatly reducing the capital cost of the spray liquid preparation system), it was possible to build an acid gas removal system at an acceptable cost. At present, this appears to be the smallest such plant built to date. Its operation has been excellent and has complied with all applicable emission limits. The design and test results of the AQCS were reported by Dhargalkar and Zmuda [2].

Fly Ash Handling

Ash handling had been a serious problem with previous garbage burning plants. Also, there was concern about the possible classification of the fly ash as dangerous, made the County want to keep it separate from the bottom ash at the Skagit plant. A unique problem in this plant is the need to remove fly ash from the PCC where temperatures are about 1800°F (980°C). The challenges were to specify a system that would operate well, meet these requirements, and could be purchased at a reasonable cost.

Visits were made to a number of operating garbage-burning plants, and extensive interviews were conducted with ash handling equipment vendors. The experience of others motivated the designers to avoid screw conveyors, star wheel air lock valves, and wet handling of either bottom ash or fly ash.

Drag conveyors were selected for fly ash handling. A water-cooled conveyor trough section under the PCC ash inlets provided a simple solution for the high temperature ash. Flap gate dump valves are used at each hopper outlet. Several single dump valves feed ash into each conveyor, with another dump valve at the discharge end of the conveyor to form an air lock. A timed sequence opens only one valve at a time to keep the air lock intact.

Boiler Reliability

Perhaps the most serious concern, however, was about boiler reliability. In other garbage burning plants, the superheater tubes or screen tubes were found to accumulate molten deposits, which were associated with wastage and failure of the tubes, causing breakdowns and frequent outages for tube replacements. As stated above, it was decided to use saturated steam conditions to improve boiler reliability.

A related concern was that the lanes between tubes might be plugged by deposits anywhere in the boilers or economizers. Measures were taken to increase spacing between tubes, and provisions were made for additional soot blowers if found necessary. Also, the boilers and economizers were laid out for convenient cleaning of any deposits which might occur.

Other Design Considerations

Since the driving force for the reaction in the quench reactor is the heat in the flue gas leaving the economizer, the AQCS supplier specified that the flue gas temperature must be kept up above 425°F (220°C). Since the gas temperature declines with decreasing load, this limited the operating range of each line to approximately 1.5:1 turndown ratio. Provisions were made for possible future changes to keep the temperature of the exit gases up, if greater turndown ratio should become necessary or desirable. So far, the load range capability has been satisfactory, permitting the plant to operate from one-third load (with one process line shut down) on up to full load.

The combustion controls for the plant were a combination of the temperature control strategy that had been proven in the previous use of the kilns, and other features to respond to the additional demands brought about by the AQCS and the air permit restrictions. The draft control is conventional. The turbine governor is controlled to maintain the inlet steam pressure. We believe there may be scope in the future for better control of kiln temperature by controlling the forced draft and the speed of rotation of the kiln, however full exploitation of these possibilities will possibly be achieved only after some period of operating experience.

The steam cycle as shown in Fig. 6, was deliberately made as simple as possible. The pressure reducing valve in the extraction steam line regulates the steam pressure into the deaerator at 3 psig. This maintains constant feedwater temperature to the feed pumps and the economizer, and constant discharge conditions for the condensate pumps.

It will be noted that the design capacity of the turbine generator, at 2500 kW, yields only about 350 kWh/ton gross electrical output. This compares to the capacities announced for larger plants in excess of 600 kWh/ton. Most of the difference can be accounted for by the small size of the unit and the saturated steam conditions; e.g., the gross cycle heat rate in Fig. 4 is about 16,000 Btu/kWh (17,000 kJ/kWh).

OPERATING RESULTS

Boiler Reliability

Since the start of operation in June 1988, there have been no signs of either plugging or wastage in the boilers, and boiler reliability has been excellent. The most probable explanation appears to be that the low steam pressure, without superheat, avoids the high tube crown metal temperatures which have been considered the cause of tube wastage in larger, more efficient units.

Also, the arrangement with the PCC in between the kiln and the boiler, protects the boiler tubes from most of the direct radiant heat. The PCC provides a place for dropout of any partially molten deposits, which might otherwise cause problems in the boiler.

Slagging in PCCs

The most annoying problem in operation was completely unanticipated in the design. The time/temperature requirements in the air pollution control regulations, for 1 sec at 1800°F (980°C), were written for a stationary combustor and there was a certain amount of confusion in applying them to a counterflow rotating kiln. For some time, the regulations were being interpreted that none of the residence time-at-temperature was attributed to the kiln, which required keeping most of the PCC at or above 1800°F (980°C). The only way to maintain this temperature without burning supplementary fuel, was to keep the kiln outlet temperature set point at a considerably higher temperature. This resulted in partially molten material accumulating in the PCC and on the walls of the flue from the kiln to the PCC. Fortunately, the material was not strongly bonded and the problem was alleviated by installing air cannons to break up the deposits.

After calculations by the kiln designers demonstrated that this was too extreme a position, the kiln outlet temperature set point was reduced to 1850°F and slagging in the PCC is much less of a problem. There is still some material build-up on the walls of the flue; these deposits are being dislodged with a water jet from a pressure washer.

Ash Disposal

Another question was whether the fly ash would be classified as some category of waste that could not be put into an ordinary landfill. For several months, the fly ash was mixed with cement and water and cast into "ecology blocks", which were allowed to solidify before being dumped into a segregated area of the landfill. The leachate from the landfill was monitored and no

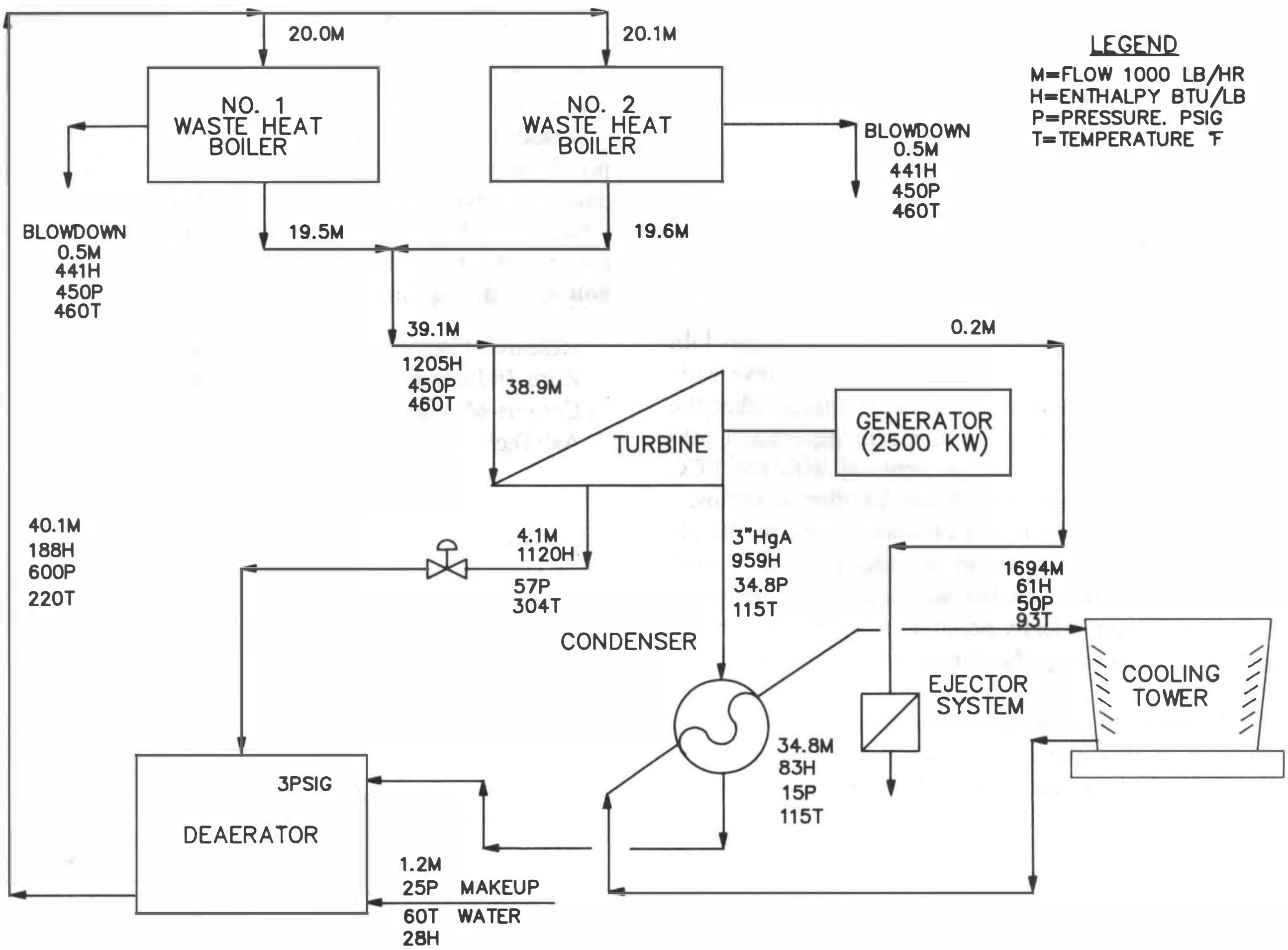

FIG. 6 TURBINE CYCLE HEAT BALANCE

objectionable concentrations from heavy metals or other objectionable substances were found in the leachate, and it passed the prescribed biological (toxicity) tests. After several months of this, the casting of blocks was discontinued and the leachate still passes all requirements. The bottom ash is kept separate and similarly monitored; however there is no problem with it either.

The County attributes their success with the ash to a battery recycling program. They pay people small sums for their used batteries from flashlight batteries to automobile batteries. Since this program started there has been no detectable lead in the ash leachate.

Dump Condenser

There was a problem with removal of condensate from the dump condenser at less than full load. The pressure in the dump condenser was insufficient to lift the condensate to the deaerator; this was similar to the problem of removing drains from high pressure feedwater heaters in central stations at low loads. Several solutions were possible, such as dumping the condensate; however, it was eventually decided to provide a relief valve to protect the condensate pumps and associated piping, so they could be used to pump the condensate to the deaerator.

CONCLUSIONS

It was a challenging experience designing a complete waste-to-energy plant around the Italian kiln technology without a precedent to follow (at least for the power generation and air pollution control aspects of the plant). While there have been a number of improvements found to be desirable in auxiliary systems over the first year's operation of the plant, it is gratifying that it has fulfilled its primary mission during that time, i.e., incinerating all the County's unrecycled garbage while meeting the environmental restrictions.

The successful operation of the Skagit County Resource Facility demonstrates what can be done with the kiln incinerator technology:

(a) A waste-to-energy plant of this small size can be built and operated to meet rigid environmental requirements, at reasonable cost (under $100,000 per TPD), and with excellent reliability.

(b) The principle of a simple refractory-lined kiln with a conventional waste heat boiler may have wide applicability for plants of this size. It appears that the separation of combustion and steam generation into two separate components, particularly with the PCC in between them, has helped avoid boiler problems.

(c) The relatively new technology used in the air pollution control equipment permits the use of acid gas scrubbing for a smaller size unit than previously considered economically possible, not only for burning garbage, but possibly also for coal or other sulfur bearing fuels.

(d) Both the bottom ash and the fly ash handling systems in this plant have been successful and have not limited plant availability. Very few garbage plants can make that statement.

ACKNOWLEDGEMENTS

We wish to express our appreciation to our colleagues in the Skagit County government, R. W. Beck & Associates, Wright Schuchart Harbor, and all of the people at existing garbage burning plants who have patiently answered our questions about their plants which contributed greatly to the design of the Skagit facility. We also recognize the indispensable contribution of the equipment suppliers mentioned below:

Research-Cottrell	Air Quality Control System
Zurn Industries	Waste Heat Boiler
Coppus-Murray	Steam Turbine
AshTech	Ash Handling

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[2] Dhargalkar, P. H. and Zmuda, J. T., 1989. "Dry Scrubbing Systems: Experience in Resource Recovery Applications." AWMA Annual Meeting, June 1989, Anaheim, California (or Research-Cottrell Companies Inc., P.O. Box 1500, Somerville, New Jersey 08876).

Key Words: Air Quality; Incineration; Mass Burn; Power Generation; Rotary Kiln; Scrubber; Turbine