TECHNIQUES OF SOLID WASTE FUEL COMBUSTION

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WORCESTER, MASSACHUSETTS

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ABSTRACT

The burning of industrial or municipal waste as a supplement to conventional fossil fuel is receiving much attention. It has been judged to be an environmentally acceptable concept for simultaneously relieving the concerns associated with waste disposal in landfills and the cost of fossil fuel.

This paper presents Riley Stoker Corporation's experience burning both prepared and unprepared municipal refuse, wood waste, production or process waste, fumes, and related items.

It presents the fuel handling and burning equipment design concept used and the operating experiences associated with them. The effect of waste fuel combustion on steam generator operation and performance is reviewed, with attention to actual vs. predicted performance and recent trends.

INTRODUCTION

The burning of industrial or municipal waste as a supplement to conventional fossil fuel is receiving considerable attention in the United States in the present era. It has been judged to be an environmentally acceptable concept for simultaneously relieving the concerns associated with waste disposal in landfills and the rising cost of fossil fuel. The trend in the 1970's has been towards increased usage of heat, from the incineration process to generate steam for process or power applications, as well as recovery of by-products from the raw refuse or from the residue.

This paper presents Riley Stoker Corporation's experience burning both prepared and unprepared municipal refuse, as well as industrial refuse, with emphasis on operational experiences and technical design details. Three separate plant sites have been used for analysis, since as a group, they represent a considerable cross-section of the overall refuse burning field as it is applied in the United States. The installations include Riley Units 1 and 2 at the town of Braintree, Mass., Thermal Waste Conversion Station, Riley Unit 5 at the City of Ames, Iowa Municipal Power Plant and Riley Unit 8 at General Motors Truck and Coach Division Plant #2, in Pontiac, Michigan.

The scope of refuse burning is discussed with respect to several common items:

1. Raw refuse receipt, preparation and processing.
2. Fuel burning equipment design.
3. Fuel burning operating experiences.
4. Steam generator operating features.
5. Steam generator operating experiences.

Particular attention is given to the area where operation on refuse or combined refuse and coal differs from operation on conventional fossil fuels alone. Significant achievements, as well as major problem areas, are discussed such that the trends over several years of operation can be determined.

A summary of Riley Stoker Corporation's experience burning wood wastes is also presented. A brief discussion of fuel burning equipment design and a summary table of operating experiences at three installations are given. The three installations are the ITT Rayonier, Inc. Plant at Port Angeles, Washington, the U.S. Plywood Co. Plant at Bonner, Montana, and the Plum Creek Lumber Company Plant at Columbia Falls, Montana.

BRAINTREE THERMAL WASTE CONVERSION STATION

This municipal refuse incinerator was originally designed for mass burning of refuse or natural gas firing. It was started up in 1971, and commercial operation began in October, 1972. Riley Stoker supplied the fuel burning and steam generating equipment for both units 1 and 2 at the site.

Raw Refuse Handling, Preparation and Processing

The characteristics of the raw refuse are given in Table 1. As refuse is unloaded at the dumping area of the incinerator plant, minor refuse classification is performed. The largest debris, i.e., longer than 3 ft (0.9 m) or thicker than 4 in. (10.2 cm) is manually separated. No further preparation or processing is required. A grapple bucket loads refuse from the dumping area directly into the incinerator's charging chutes for delivery to the stokers.

Fuel Burning Equipment Design

As shown in Figure 1, each unit is equipped with a tandem pair of traveling grate stokers. A 7 ft wide (2.13 m) by 12 ft long (3.66 m) inclined drying grate receives refuse from the charging chute. This grate, in turn, discharges the dried refuse to a 7 ft wide (2.13 m) by 21 ft long (6.40 m) horizontal burning grate, which is located directly beneath the furnace. Unburnable residue from the end of the burning grate falls into a quench tank, then is conveyed outdoors to waiting trucks. The trucks transport the unburnable residue to a landfill site. The residue's weight is approximately twenty-five percent of the weight of the original raw refuse.

TABLE 1

BRAINTREE FUEL CHARACTERISTICS

General Characteristics: of Raw Refuse (Design)	Trash — paper, bags, wrappings, cardboard cartons, rags, wood Garbage — grass clippings, leaves, greens, tree trimmings, waste food stuffs, and other family refuse Industrial — plastics, vinyls, cork, rubber products, etc.
Analyses of Refuse Fed to Stoker (Design):	Design Point (Ultimate—as Received): C—30%, O—25.5%, S—0.1%, H—4.25%, N—0.15%, water—20%, ash—20%, 5000 BTU/lb (11630 kJ/kg) as fired. Range — 10-20% moisture, 5-20% non-combustibles
Analyses of Supplemental Fuel (Nat. Gas — Design):	Ultimate—as Received (by Volume): CH_4—95.32% C_2H_6—2.66%, C_3H_8—0.57%, CO_2—0.69%, N—0.43%, 23560 BTU/lb (54800 kJ/kg) as fired, 1050 BTU/ft^3 (39.16 mJ/m^3)

The drying grate has three air zone compartments, each with an underfeed air regulating damper. The burning grate has four air zone compartments, each with an underfire air regulating damper.

Each stoker is equipped with a hydraulic drive and a stalled grate alarm switch. Recently manufactured Riley Traveling Grate Stokers also feature an overload relief valve to prevent grate damage, if a refuse jam occurs.

Overfire air jets are provided on both sidewalls of the unit and also in the front arch above the stoker. These are provided to effectively burn materials in suspension and to create the necessary turbulence for good combustion efficiency.

Design conditions at maximum continuous steam flow rating per unit are a 5 TPH (4540 kg/hr) burning capacity of 5000 BTU/lb (11.63 mJ/kg) refuse at 50% excess air and a 285,000 BTU/ft²/hr (773,200 kcal/m²/hr) grate heat release rate.

A natural gas burner is provided, per unit, for supplemental combustion.

Fuel Burning Operating Experiences

The fuel burning equipment originally installed proved capable of burning the design refuse quantity. Refuse burning capacity was achieved in the first year of plant operation. The grates have successfully burned the wide variety of refuse, in an unprepared form, as specified in the design (Table 1).

Initially, refuse alone was burned on a 2 shift, 16 hour per day basis. Natural gas alone was burned on the third shift, 8 hours per day, and also was burned throughout the weekend. Maintainability, reliability and

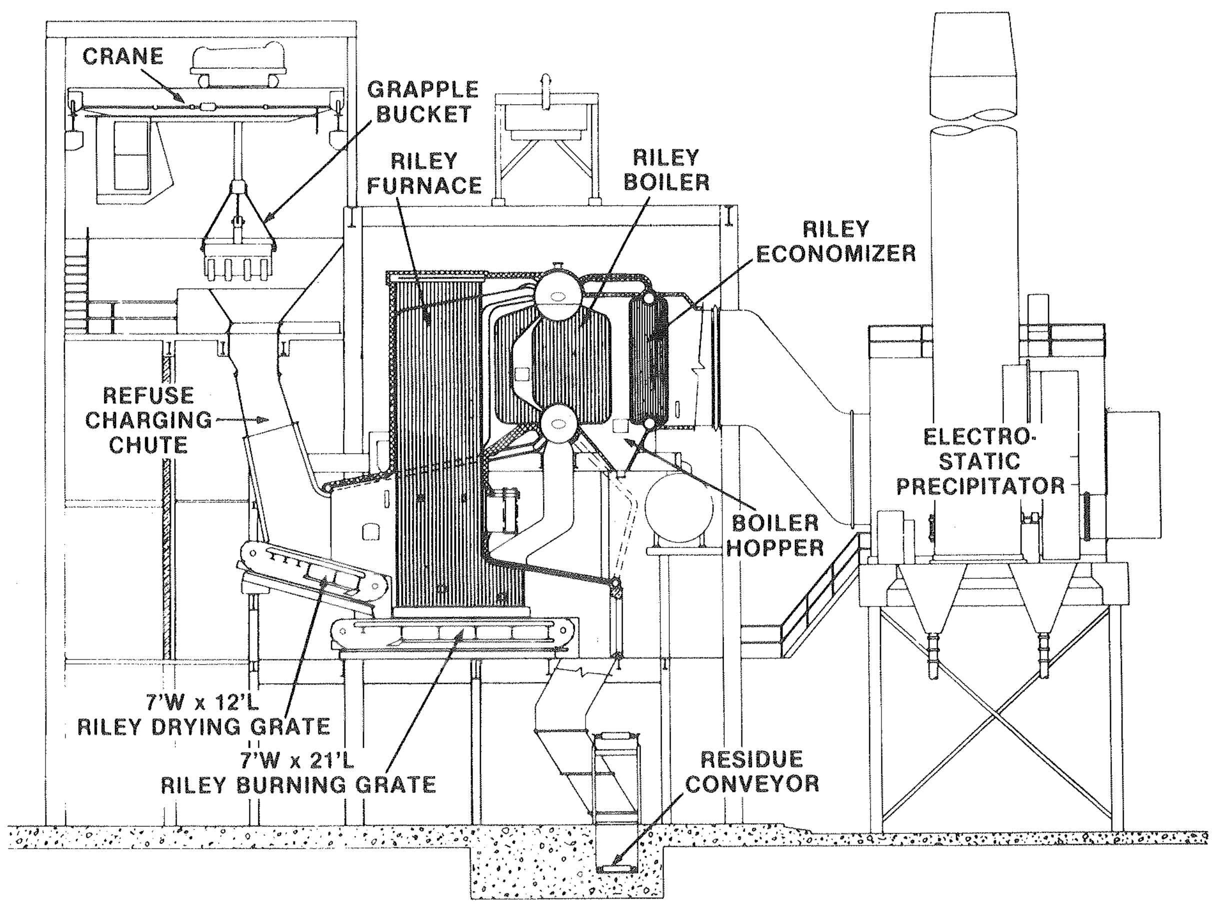

Figure 1 Braintree Municipal Thermal Waste Conversion Station (Original Unit)

availability of the refuse burning system has steadily improved, such that present day normal operating procedure is to burn refuse alone, 7 days per week, 24 hours per day. During labor shortages, refuse alone is burned 7 days per week, 2 shifts per day. Natural gas alone is burned during the third shift (8 hours) in order to keep the boiler hot to avoid precipitator and boiler corrosion and to maintain a steady steam supply to the nearby industrial plant customer. During any infrequent outages, due to the refuse-related problems, natural gas is burned continuously to maintain the steam supply [1].

Samples of refuse ash have indicated a carbon loss and putrescible content well within design limits of five and two percent, respectively.

The by-product ash, including glass and other non-combustibles of limited recovery value, is used as a sanitary landfill on a previous dump site adjacent to the incinerator.

Overall, the engineers and operators at Braintree have expressed satisfaction with the fuel burning operating experiences during the life of the plant.

Fuel Burning Problems and Solutions, Occurring in the First Five Years of Plant Operation

The following paragraphs discuss minor system changes (Figure 2) which have improved operating performance.

The plastic content of the refuse melted through the grates, causing ash pit fires. The aluminum content of the refuse melted into the grate bars, causing stretching and breakage of grate chains, as well as fouling steel sections. Installation of hoppers beneath the grate sections had *not* been initially provided since it was

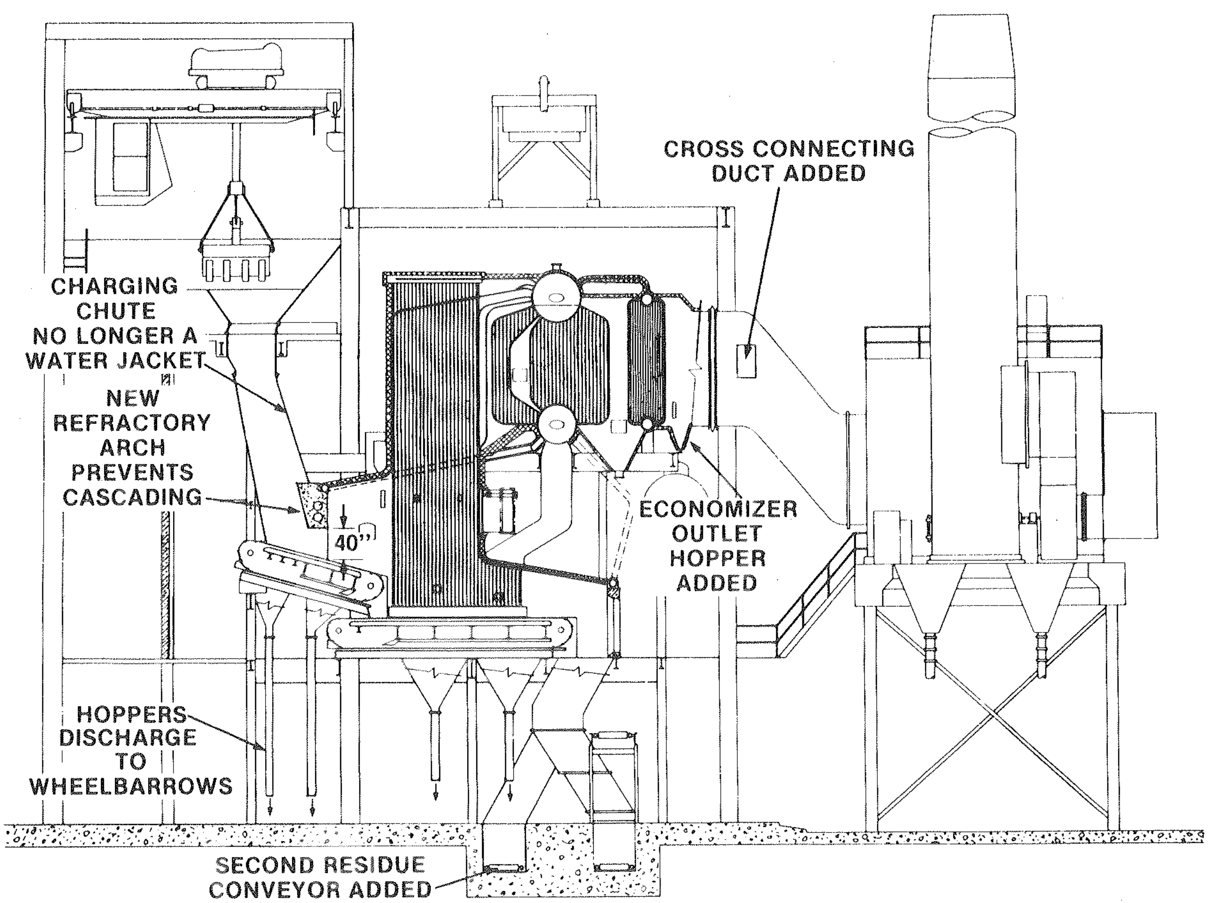

Figure 2 Braintree Municipal Thermal Waste Conversion Station (Recent Modifications)

assumed that an ash buildup would provide an effective seal beneath the grate. However, ash buildup caused excessive wear on stoker clips.

To overcome the problems discussed in the preceding paragraph, several actions were taken. Temperature quenching equipment was installed and prevented fires in the ash pit. Recently, hoppers were installed under the grate sections, which empty through vertical downspouts and discharge through gates into wheelbarrows. Close attention to the dumping of the wheelbarrows on a per shift basis, has resulted in the prevention of accumulating undergrate ash, thereby reducing, significantly, ash pit fires and clip maintenance. Without the build-up of undergrate ash, the maintenance personnel have greater accessibility to the grates in order to remove aluminum deposits on the grate bars and keys on a regular basis. Overall, the alterations have significantly reduced maintenance.

Initially, there were problems with stoker side clips on the drying stoker. As the side clips traversed to the front of the unit, due to distortion and protrusion these clips struck the waterbox, broke off and lodged in the chain drive sprockets. This, in turn, caused the chain drive to jam and distort grate racks. The larger side clips have since then been replaced with standard Riley stoker clips and maintenance problems have been greatly reduced.

There were initial problems associated with the grate zones where burning occurred and with partial burnout of the refuse. Burning was observed on the lower third zone of the drying grate, while burning was not occuring on the first zone of the burning grate (one-third of its total surface area). As refuse advanced on the drying stoker, the forward face of the material took shape as a large burning vertical wall. As it advanced into the furnace, it eventually tumbled (cascaded) onto the burning stoker causing sudden peaks in steam generation, smoking, or in some cases slowed the combustion rate.

An oversized throat opening at the drying stoker inlet was considered to be the cause of the above problems. It resulted in an oversized combustibles surface area and an underspeed stoker (to satisfy furnace BTU requirements). Suggestions to overcome these problems included decreasing the size of the throat opening or adding an adjustable baffle to the drying stoker inlet, to allow a variable height of refuse on the drying stoker based on the BTU content of the fuel and conditions of burning. The final solution, as discussed below, is effectively a smaller throat opening area.

There was also a problem with warpage of the water-jacketed charging chute. That chute has been replaced and in its place is a refractory baffle of a similar configuration. At the baffle core are open-ended pipes which allow cooling ambient air passage, thus affording cooling for the refractory. These pipes run from side to side of the unit and are arranged one on top of the other. In addition, at the bottom of this new chute is a refractory arch, which is 40 in. (101.6 cm) vertically above the drying stoker. It effectively breaks the build-up of refuse and prevents the cascading effect as the refuse passes from the drying stoker to the burning stoker. Percent burnout of the combustible portion of the refuse has increased from an estimated 75% in 1971, to 90-95% in 1978.

A recent problem, attributed to the installation of undergrate hoppers was air shortcircuiting due to a lack of sealing. Air was being drawn from in back of the refuse pile and was carried along the underside of the stoker and then up through the ash being discharged to the quench tank. This could result in increased ash loads in the gas stream going to the unit and a loss of combustion air. To counteract this occurrence, a seal has been added to the ledge beneath the return surface of the stoker.

A final, recent improvement is the installation of a second residue conveyor at the discharge of the ash quench tank. This allows for increased flexibility of operation and maintenance.

Steam Generator Operational Features

A summary of design process conditions at Maximum Continuous Rating steam load are given in Table 4. Normally, one unit is in service and the other unit is in hot standby (to prevent tube failure due to thermal cycling). When there is an extraordinary steam demand or when a refuse back-log builds in the storage area, both units are in service. A small portion of steam generated is used for plant auxiliaries. Most of the steam is sold to an adjacent industrial plant (up to 20,000 PPH, (9080 kg/hr)). Since steam demand from the adjacent customer is not steady, during periods of excess steam generation, the excess is condensed through roof condensers on the unit. This allows the continuous burning of refuse. Revenues from the sale of steam are approximately $150,000 per year, based on $1.38 per thousand lb steam.

Steam Generator Operating Experiences

Predicted performance, i.e., overall steam generator capacity, unit efficiency and total draft loss, on refuse firing, was achieved in the first year of operation.

The extent of slagging, fouling, and corrosion has been similar to the levels normally obtained in coal-fired units and therefore, maintenance is considered to be normal.

With respect to air emissions, the visual appearance of the smoke plume is comparable to that of an oil-fired unit. From 1971–1975, the plant's emissions complied with federal and state requirements. In 1976, increasingly stringent federal and state particular emission requirements brought the plant into non-compliance and forced shutdown (as well as other incinerator plants). Three modifications were made which effectively allowed the plant to burn refuse and satisfy federal and state particulate emission levels. They were modification of the flue gas circulation path, addition of an economizer outlet dust hopper and addition of a water sluice gate for the electrostatic precipitator.

With regard to the dust hopper, prior to its installation, ash that left the boiler would lay out in the duct downstream of the economizer. It would build to a level where high flue gas velocities would overload the precipitator. Load changes caused periods of high ash concentration and subsequent objectionable stack discharge. The duct immediately downstream of the economizer was modified to allow for addition of the dust hopper. Excessive ash from this hopper is drawn off continuously and this, plus the continuous dumping of the hopper section before the economizer, has resulted in satisfactory continuous performance of the precipitators.

With respect to flue gas circulation path modifications in 1977, a cross-connecting duct was installed between the two units' ducting to the precipitators to allow one unit to be served by either or both precipitators.

The eventual goal was to use only a single precipitator in series with a single boilers, yet achieve acceptable emission levels even when the boilers were run well above their design capacity of 120 TPD (109,000 kg/day).

As of fall, 1978, the positive results of these modifications include:

1. Ability to serve each unit with only one precipitator and satisfy present federal and state particulate emission requirements.
2. Refuse burning capacity, per unit, has been increased from 120 to 192 TPD (109,000 kg/day to 174,000 kg/day), while satisfying emission standards. Thus, original design capacity has been exceeded by sixty percent.
3. Overall cost of these major modifications was only $550,000, approximately eight percent of the cost of an entire new plant.
4. The Riley boilers and stokers, originally specified in 1971, were the best available technology and were conservatively rated. The success of the modifications demonstrates the versatility of the unit to meet considerable changes in emission requirements during its operating life.
5. Since two precipitators in parallel are not required to serve a single unit, both units can operate simultaneously and the overall plant capacity can be virtually doubled to approximately 400 TPD (362,000 kg/day) and still meet mandated emission limits.

Potential Future Expansion under Customer Consideration

Three options are presently being considered [2]:

1. Expand the steam producing capacity of the present boilers to allow for feed to a second, nearby industrial plant.

2. Build a larger facility to serve as a regional waste disposal plant and generate 20 MW power for municipal lighting (add a turbo-generator).

3. Install a new boiler with increased capacity, in the present plant, but limit its output to industrial steam (no power production). There is room at the present site for the addition of at least one more unit.

CITY OF AMES, IOWA MUNICIPAL POWER PLANT

Unit #5 was originally designed for firing on high (5–7%) sulfur Iowa coal. Riley Stoker supplied the fuel burning and steam generating equipment for this unit, which was started up in 1951.

By 1972, the City of Ames was advised that the existing city sanitary landfill would soon be full and that it would be difficult to locate a new site [3]. A feasibility study lead to a recommendation to design and install a municipal solid waste recovery system based on the following features:

1. An economic alternative and more environmentally acceptable method of disposal.
2. Ability to convert existing furnaces to burn solid waste (refused-derived fuel) as a supplement to coal firing, at a reasonable cost and with no increased air pollution.

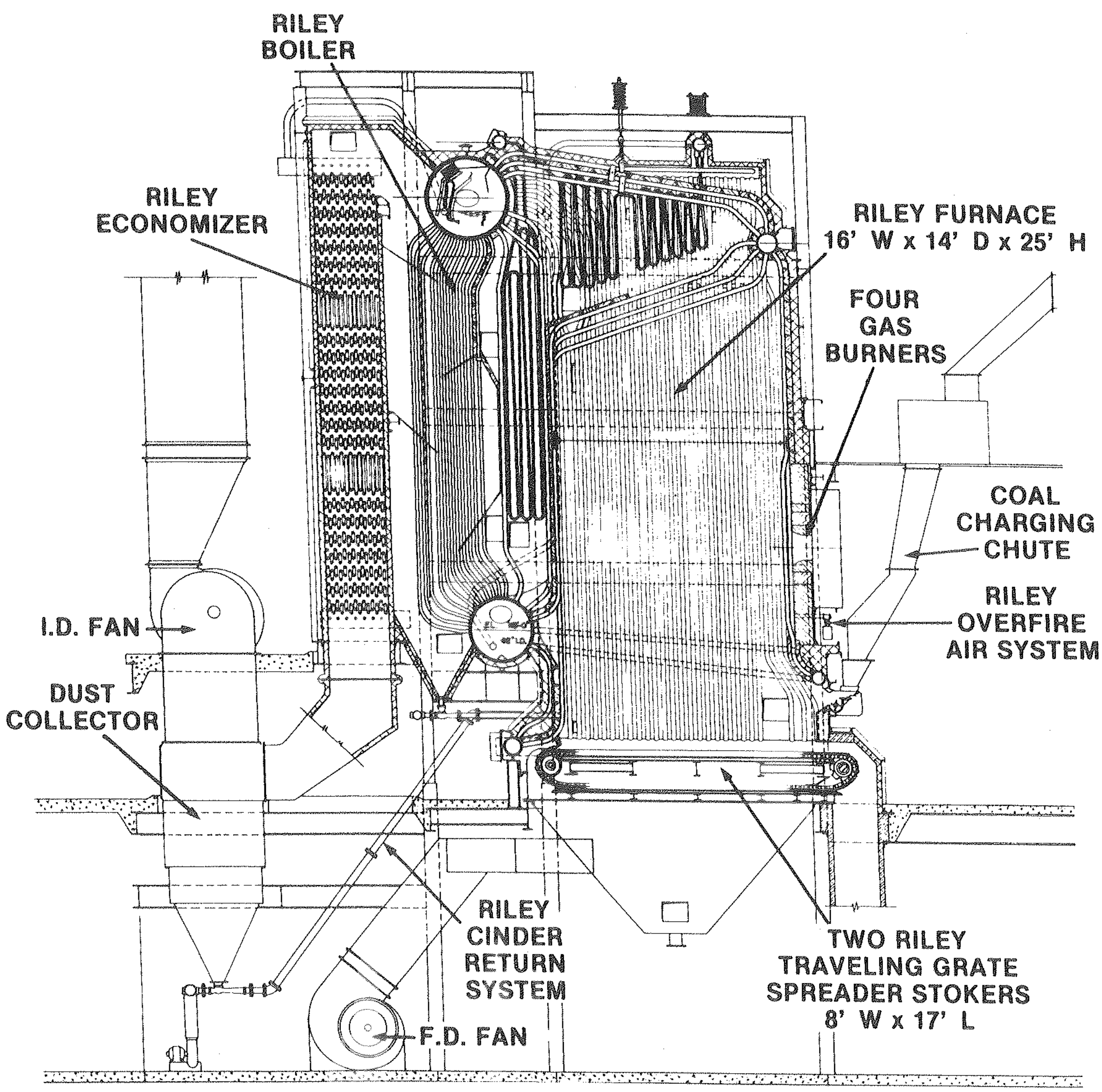

Figure 3 Riley Unit #5 (Original Unit)
City of Ames, Iowa Municipal Power Plant

3. A readily available source of low sulfur power plant fuel, which when mixed with the current blend of Iowa/Western coal would result in a composite fuel having a lower sulfur content.

4. A way to recover valuable metals and other by-products.

Construction of the waste processing plant and retrofitting of the Riley Unit #5, as well as the other units at the Municipal Power Plant began in 1974 and commercial operation began in November 1975.

TABLE 2

CITY OF AMES FUEL CHARACTERISTICS

General Characteristics of Refuse: (Actual)	Corrugated cardboard, rubber and plastic products, aluminum foil and alumina sandpaper, carbon paper, wood chips, glass, sand, stones, other ferrous and non-ferrous metals, food waste, yard waste.
Analyses of Prep. RDF: (Actual)	*Proximate* (As Received) 1/27/78 — moisture—21.3%, volatile—59.9%, ash—14.5%, fixed carbon—4.3%; 6,355 BTU/lb (14782 kJ/kg) 9/75 — moisture—18.7%, volatile—59.4%, ash—14.8%, fixed carbon—7.2%, 7046 BTU/lb (16389 kJ/kg) *Ultimate* 1/27/78 (dry) — C—45.9%, O + N—29.3%, S—0.4%, H—5.6%, ash—18.4%, chlorine—0.42% 10/75 (wet) — C—35.9%, O + Misc.—23.5%, S—0.3%, H—5.6%, water—24.9%, ash—9.8% Ranges of heating values: 4910-8422 BTU/lb (11421-19590 kJ/kg) (8/75-6/76) As Received. Ranges of moisture content: 15-30% (8/75-6/76)
Analyses of Coal Blend: (Actual)	*Proximate* (As Received) 1/27/78 — moisture—13.8%, volatile—33.7%, ash—12.4%, fixed carbon—40.1%, 10,697 BTU/lb (24881 kJ/kg) 10/75 — moisture—18.76%, volatile—34.99%, ash—8.37%, fixed carbon—37.88%, 9,670 BTU/lb (22492 kJ/kg) *Ultimate* 1/27/78 (dry) — C—68.5%, O—7.7%, N—1.5%, S—3.6%, H—4.3%, ash—14.4%, chlorine—0.026% 10/75 (wet) — moisture—18.76%, C—54.96%, O + Misc.—10.27%, S—2.17%, H—5.47%, ash—8.37%

Raw Refuse Handling, Preparation and Processing

The characteristics of the prepared refuse-derived fuel (RDF) are given in Table 2, as well as the characteristics of the blended Iowa/Colorado coal. The processing plant has a capacity of 50 TPH (45,400 kg/hr) or 200 TPD (181,600 kg/day), based on a 2-5 hour operating phase, with the remaining shift hours used for maintenance and cleaning of the processing equipment. It services 3 units, including Riley Unit #5.

By-products of the processing phase include baled paper, recovery of magnetic metals as well as recovery of aluminum and other non-ferrous metals. Ferrous metals are sold to help defray operating costs [4, 5].

Fuel Burning Equipment Design

Original equipment, supplied in 1951, includes twin Riley traveling grate spreader stokers and two rows of overfire air nozzles (Figure 3). The stokers are each 8 ft wide (2.43 m) by 17 ft long (5.18 m), each having two, model 26 in. (66 cm) B feeders and a maximum rated speed of 14 ft/hr (4.27 m/hr). Control of refuse firing rate is performed by automatic or manual variation of storage bin drag conveyor speed. This provides the desired fixed volume flow rate into Pneumatic feeders and for a constant density refuse media, a fixed mass flow rate occurs. Generally, the manual operating mode is used.

Retrofitting for refuse burning, in 1975, included four steps (Figures 4 and 5). The four natural gas burners in the front wall were removed. Two Riley pneumatic Distributors with air swept spouts were added, at the elevation of the old gas burners. One row of overfire air nozzles was added in the rear wall, below the elevation of the pneumatic distributors, to complement the existing nozzles and a larger overfire air fan was installed to allow for increased OFA flow rates. A larger OFA air duct was also installed.

The firing system was designed for a 50/50 refuse to coal ratio by heat input.

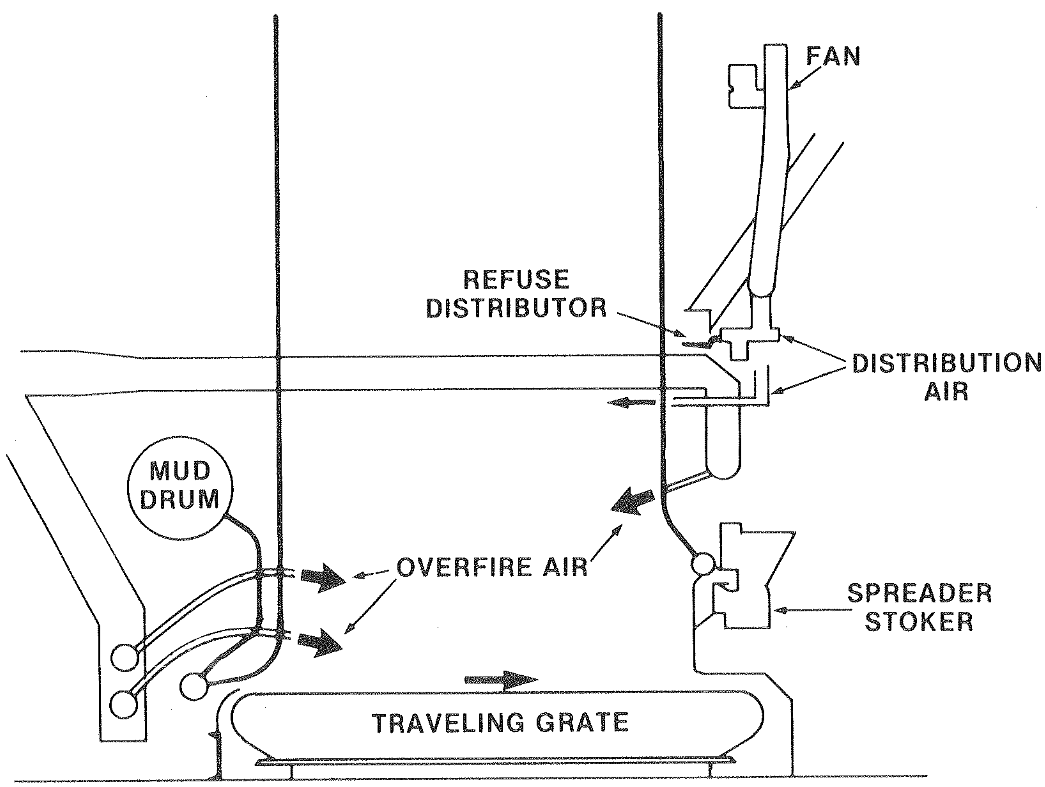

Figure 4 Modified Fuel Burning System
Riley Unit #5, City of Ames, Iowa

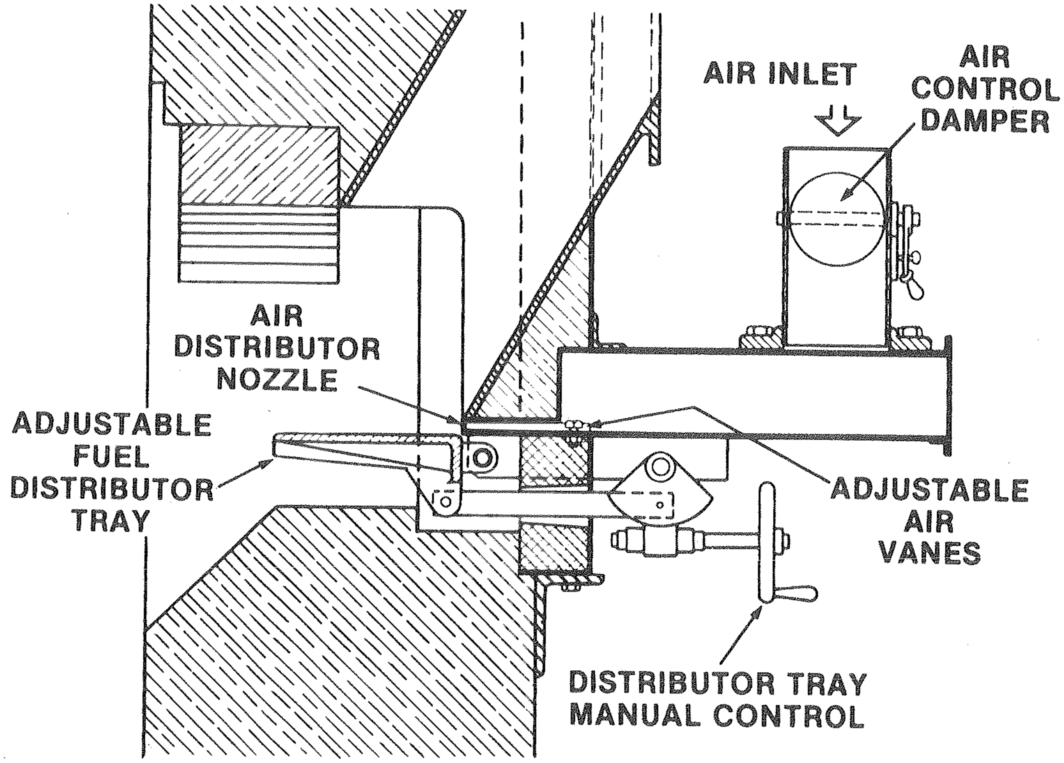

Figure 5 Riley Pneumatic Refuse Fuel Distributor

GENERAL MOTORS CORP. TRUCK AND COACH DIVISION, PLANT #2

Unit 8 at this Pontiac, Michigan Plant was initially designed for combined coal and refuse firing. It is supplied with a Riley Stoker steam generating unit. Start-up date was in May, 1973 and only coal was fired during the first three years of service. In 1976, combined coal and prepared refuse firing commenced. The predominant refuse fuel is industrial solid waste, unlike the Ames or Braintree unit, which fire a higher proportion of residential refuse.

Raw Refuse Handling, Preparation and Processing

The characteristics of the prepared refuse-derived fuel (RDF) are given in Table 3, as well as the characteristics of the coal.

The processing plant has a capacity of 200 TPD (181,600 kg/day) and provides RDF to Riley Unit #8, as well as to another unit at the plant site. Full capacity is exercised during the winter months, during 2-shift operation, when both units are in service. This results in a savings of 120 tons per day (109,000 kg/day) of coal on an equivalent heat basis [6].

Fuel Burning Equipment Design

As shown in Figure 6, the Unit #8 was originally designed to handle either coal firing or combined refuse/coal firing. It includes a traveling grate spreader stoker with front ash discharge, with the design provision to burn a 70/30 refuse to coal ratio, on a heat input basis. Retrofitting of additional equipment to allow for combined refuse and coal burning was not required.

Fuel Burning Operating Experience

At no time is firing on 100% refuse allowed, since a sudden loss of refuse feed would result in a drastic loss of steam and incapability to meet continuous steam demand. Experience has shown that the optimum ratio of

TABLE 3

G.M. TRUCK AND COACH FUEL CHARACTERISTICS	
General Characteristics of Raw Refuse: (Design)	From various GM manufacturing plants: wood (42%), paper (33%), cardboard (23%), rubber and plastics (2%)
Analyses of Prepared Refuse (Design):	C—41.5%, O—34.2%, S—0.5%, H—5.9%, ash—6.7%, water—11.2%, 7500 BTU/lb (17445 kJ/kg) as fired.
Analyses of Coal (Design):	C—71.44%, O—12.6%, S—0.98%, H—5.21%, N—1.69%, ash—8.08%, 12,250 BTU/lb as fired. Ash fusion temp = 2700°F. 45 Hardgrove grindability
Prepared Refuse: (Actual)	7000 BTU/lb (16282 kJ/kg) as fired.
Coal: (Actual)	0.8% Sulfur (Present Allowable Limit)

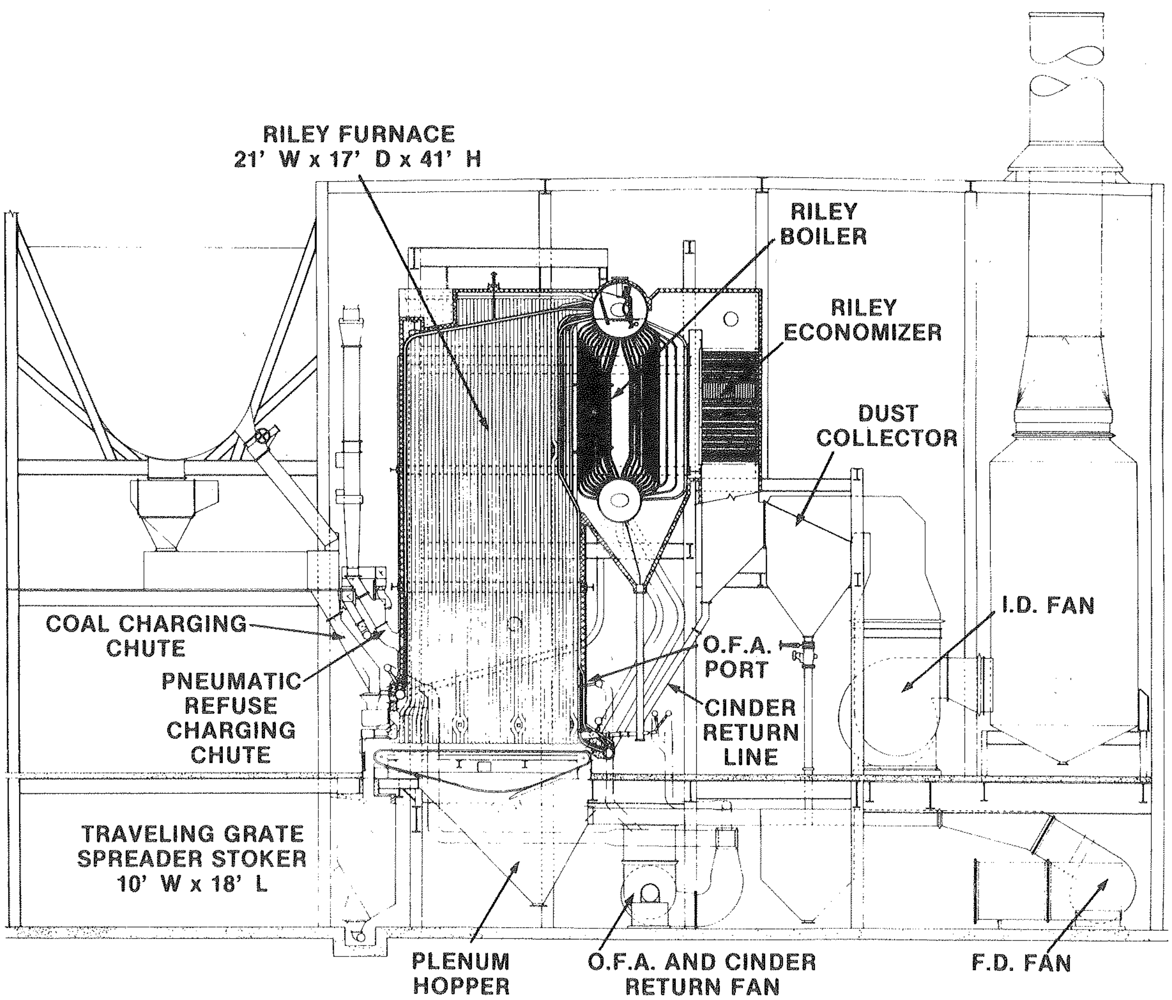

Figure 6 Riley Unit #8, Plant #2
GMC Truck and Coach Division

refuse to coal is 60/40 by weight (46/54 by heat input). This allows for a safe operating margin, i.e., if refuse feed is lost, coal fuel rate can be moderately increased, without a drastic loss of steam output. The 60/40 refuse to coal weight ratio occurs during weekend operation and a 50/50 refuse to coal ratio is maintained during weekday operation, as an additional conservative measure when there is a higher steam demand.

Steam Generator Operating Features

The summary of design process conditions at MCR steam load are given in Table 4. Riley Unit #8 is operated continuously (18-20 hours per day) in generating steam.

Steam Generator Operating Experiences

There have been no appreciable slagging problems (especially in the upper firing chamber) since continuous firing on refuse was initiated in 1976. Cleaning (water-blasting of tubes) has been required only twice since

TABLE 4

DESIGN CONDITIONS AT MAXIMUM CONTINUOUS RATING

	Braintree Refuse (100%)	Braintree Nat. Gas (100%)	Ames Refuse Coal	Ames Coal	GM Truck & Coach Refuse Coal	GM Truck & Coach Coal
Steam Flow (lb/hr)	30,000	30,000	95,000	95,000	200,000	200,000
Sat. Steam Press. (psi)	250	250	710	710	161	161
Outlet Superheater Press. (psi)			630	630		
Sat. Steam Temp. (°F)	406 (Leaving	406 Superheater)	830	830	371	371
Fuel Flow (Tons/Day)	120		175 (R)[1] 91 (C)	182.4	300 (R) 75 (C)	120
(Tons/Hour)	5		7.3 (R) 3.8 (C)	7.6	12.5 (R) 3.2 (C)	10
(lb/hr)	10,000	1,530	14,600 (R) 7,600 (C)	15,200	25,000 (R) 6,250 (C)	20,000
Air Flow (lb/hr)	61,800	31,700	131,600		281,000	252,000
Excess Air (%)	50	20	50		50	38
Heat Input (BTU/hr)	50×10^6	36×10^6	73×10^6 (R) 73×10^6 (C)	146×10^6	187.5×10^6 (R) 76.6×10^6 (C)	245×10^6
Fuel Heat Content (BTU/lb) (As Fired)	5,000	23,560	5,000 (R) 9,541 (C)	9,541	7,500 (R) 12,250 (C)	12,250
Furnace Heat Release (BTU/ft³/hr)	18,000	15,000	27,540	27,540	17,500	17,100
Furnace Heat Release (BTU/ft²/hr)	43,200	36,000	14,520	14,520	76,000	74,600
Grate Heat Release (BTU/ft²/hr)	285,000	—	589,000	589,000	730,000	695,000
Overall Unit Efficiency		81.66	60	80	75.64	80.88

1: R - Refuse
C - Coal

TABLE 4 CONVERSION FACTORS

1 PPH = 0.454 kg/hr	1 BTU/hr = 0.2522 kcal/hr.
1 psi = 0.0703 kg/cm²	1 BTU/lb = 2326 J/kg
°F = 1.8°C + 32	1 BTU/ft³/hr = 8.899 kcal/m³/hr
1 TPD = 908 kg/day	1 BTU/ft²/hr = 2.713 kcal/m²/hr
1 TPH = 908 kg/hr	

TABLE 5

WOOD WASTE BURNING EXPERIENCES[2]

	ITT Rayonier	US Plywood	Plum Creek Lumber
Design MCR (PPH Steam)	200,000	160,000	120,000
Max. Achieved (PPH Steam)	230,000	160,000	150,000
Oper. Press. (psig)	425	600	300
Fuel(s) (normal)	hogged wood, hogged bark, sander dust	hogged wood, sander dust, plywood shavings	hogged wood, hogged bark, sander dust, plywood shavings
Fuel(s) (emergency)	#6 oil	natural gas	natural gas
% sand in fuel	5-6%	2%	2%
moisture in fuel	range: 35-75% avg. 60%	avg. 35%	avg. 55%
Dist. Air Tray Adj.	const. setting of 5° below horizontal	const. setting of 5° below horizontal	const. setting of 5° below horizontal
Dist. Air Pressure	18-20" static	approx. 12" static	10-15" static
Overfire Air Pressure Front Pressure Rear	12-15" static 7-10" static	2-5" static 7-10" static	no front OFA 5" static
Type of Refuse feeding	belt & screw conveyors	belt & screw conveyors	belt & screw conveyors
Fuel Distribution	complete coverage to ⅔ the grate length	complete coverage to ⅔ the grate length	complete coverage to ⅔ the grate length
Fuel Bed	2-3" during normal operation 0-½" bed with sander dust	½-1" during normal operation	1-3"
% Hogged Fuel Fired in Suspension	30%	30-40%	30%
Ash Bed	½-1"	0-½"	½-1"
Ash Handling	manual hoe	screw conveyor (no problems)	screw conveyor (minor problems due to rocks & tramp metal)
Flyash Reinjection	one nozzle in each sidewall	one nozzle in each sidewall	one nozzle in each sidewall
Reinjection Problems	minor plugging on sander dust firing	minor plugging on sander dust firing	minor plugging on sander dust firing
Carryover Problems	tube first pass blockage (minor) when firing large amounts of sander dust		
Sootblowers used	yes	yes	yes
Grate Cleaning	hand-operated steam lance	steam cleaned grates with minor hand lancing to clear large clinkers	steam cleaned grates with minor hand lancing to clear large clinkers
Grate Steam Pressure (psig)	400	150-200	250
Steam Cleaning Sequence	once every 8-12 hrs fuel & air left on	once every 8-12 hrs fuel & air left off	once every 8-12 hrs fuel off & air on

2: June, 1976 data.

refuse has been continuously fired. Flue gas flow paths are appropriately sized for refuse firing and the furnace chamber is sized properly such that the products of combustion and any refuse carryover do not have time to cool below their fusion temperatures and subsequently fusing, before reaching the upper tubes.

For emission control, a mechanical collector and a wet scrubber are employed. In comparison to coal burning, flyash from refuse/coal is lighter and finer (similar to talcum powder). Some of the flyash escapes capture in the mechanical collector, and has resulted in I.D. fan wear. A wet scrubber captures the bulk of the fine ash that eludes the mechanical collector.

The predicted collection efficiency of the mechanical collector is 94% when firing coal, and 92% when firing a 60/40 refuse to coal ratio by weight, at MCR steam load. Actual tests recently performed indicate an actual efficiency of 93% on coal firing and 87% on 60/40 refuse/coal (by weight) firing, at three-quarters MCR steam load [(7)]. In summary, the mechanical collector provides nearly maximum efficiency in removing coal burning particulate and does quite well when firing a refuse/coal mix. However, as the refuse/coal ratio increases, efficiency of the collector may decrease.

In conclusion, the Riley Unit #8 has performed very successfully on refuse/coal firing in the 1976–1978 period. The only major problem that occurred was erosion of the I.D. fan, partially attributed to the fine refuse ash escaping the mechanical collector, but directly caused by installation of a number of fan cones of the wrong size. Erosion has been greatly curtailed since the improper cones were replaced.

WOOD WASTE BURNING APPLICATIONS

A summary of wood waste burning experiences is given in Table 5. Each of these applications includes a Riley Stoker water-cooled grate (Figure 7). It is a stationary grate, supported by floor tubes in the furnace, and with no moving parts. During operation, accumulated ash is periodically removed by steam jets from nozzles located within certain of the grate segments. The motive energy provided by the jets propels the ash down the sloping grate surface and into the ash pit. Control of steam flow into the jets is accomplished by a piping network equipped with remotely actuated valves which can be hand operated or can be programmed to automatically clean the grate surface at predetermined intervals.

Analysis of Table 5 reveals that design steam flow rates have been achieved or exceeded, burning a variety

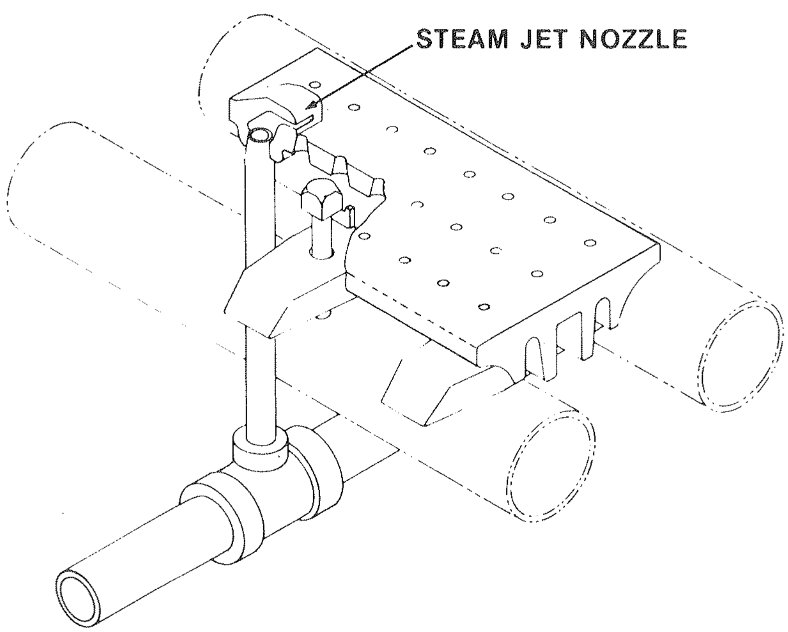

Figure 7 Riley Water Cooled Grate Clip With Steam Jet Nozzle

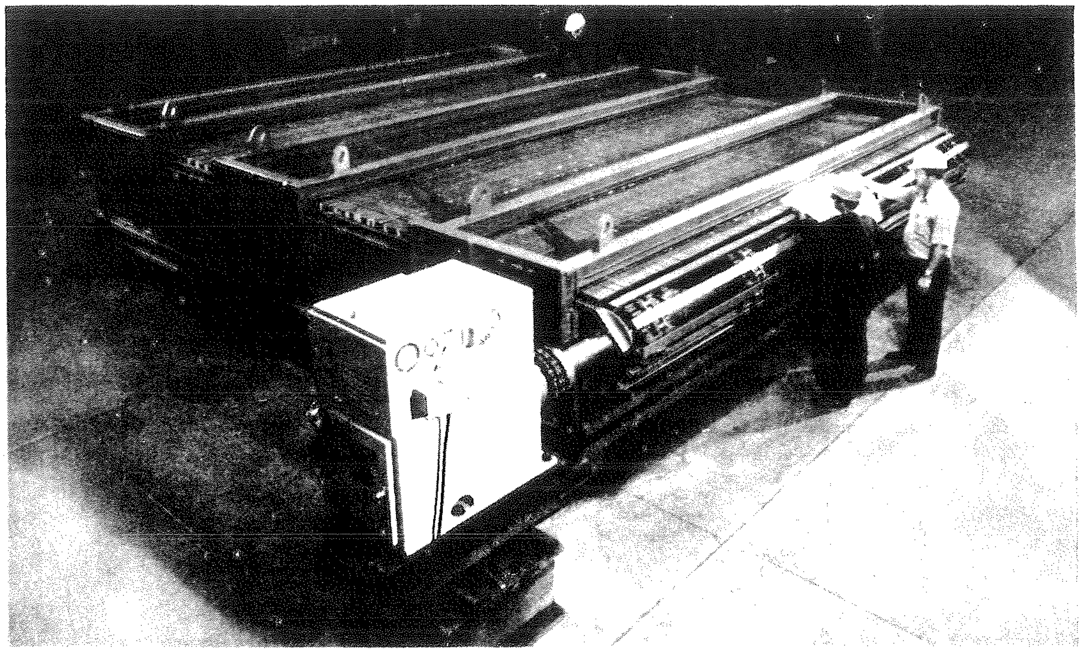

Figure 8 Shop Assembled, Modular Riley Traveling Grate

of waste wood fuels having a considerable moisture range. An adequate fuel distribution over the grate and a sufficient depth of fuel bed have been achieved.

FINAL SUMMARY

This paper has presented the design and operational aspects of fuel burning and steam generating equipment at three solid waste refuse burning installations; two burning primarily residential refuse and one burning primarily industrial process refuse. Also, the experiences in burning wood wastes at three forest product plants was briefly summarized.

Riley Stoker has also designed and installed equipment for the burning of other types of solid wastes, as well as liquid and gaseous wastes. These include bagasse and furfural residue at sugar mills, coffee grounds at coffee plants, wastes from food processing plants, liquid residues and tars from process plants and waste gases at refineries. These are fired solely or in combination with other fossil fuels.

Refuse burning is a diverse and promising growth area which will take on additional significance in the future, with respect to the environment and with respect to our nation's needs to achieve a higher degree of energy independence.

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