DESIGN, EVALUATION AND OPERATING EXPERIENCE OF THE CITY OF MADISON – MADISON GAS & ELECTRIC COMPANY ENERGY RECOVERY PROJECT

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ABSTRACT

The City of Madison and the Madison Gas & Electric Company jointly developed and implemented an energy recovery project to utilize a prepared municipal solid waste (refuse-derived-fuel) for use as a supplemental fuel for cofiring with coal in two Babcock & Wilcox 50 MW pulverized coal fired boilers for electrical power generation.

The RDF produced has an ash content of 10 to 12 percent (wet weight) and moisture content ranging from 18 to 25 percent. The ¾ in. (19 mm) particle size RDF has been fired into the utility boiler at a replacement range of 15 percent.

INTRODUCTION

Although several discussions were held between the City of Madison and the local electric utility beginning in 1969, it wasn’t until 1974 that the City of Madison and the Madison Gas & Electric Company started to formalize their respective participation in a joint program that began with an engineering feasibility study for the modification of the City’s Olin Avenue Refuse Processing Plant to produce a refuse-derived-fuel (RDF) that could be burned at the Madison Gas & Electric Company’s Blount Street Power Plant.

The City of Madison, Wisconsin, has been processing solid waste by shredding prior to landfilling since 1967. During the 10-year life of that project the City processed close to one-half million tons (450,000 t) of municipal solid waste. The facility was originally designed and developed under a demonstration grant received from the Department of Health, Education and Welfare in 1966. It was subsequently modified and enlarged by the City into a full-scale operating facility owned and operated by the City of Madison. At the time of shutdown the facility was shredding from 150 to 300 tons/day (136 to 272 t/d), five days per week. For the last full year of operations, 1977, the annual cost for shredding and landfiling refuse was $9.44/ton ($10.48/t). Costs included depreciation, labor, utilities, transportation and disposal.

In light of the experiences of other projects in the U.S. and the City’s experience, the City of Madison and the Madison Gas & Electric Company (MGE) agreed to proceed with the project with the following prime objectives:

1. Capital investment should be as low as possible for both parties and still provide a satisfactory project. Due to the size and scope of the project, 200 tons (181 t) of raw refuse per day, this objective appeared attainable.

2. A high quality refuse-derived-fuel (i.e., low ash and appropriate particle size) is necessary to successfully burn the material in MGE’s pulverized coal boilers. Evaluations of similar projects at St. Louis, Ames, and Milwaukee gave evidence that low ash RDF with low glass content is a major factor in getting acceptance of RDF from operators of suspension fired boilers.

BOILER EVALUATION AND FUEL REQUIREMENTS

MGE, after consulting with the manufacturers of the five coal fired boilers at its Blount Street
Generating Station, determined that Boilers No. 8 and 9 would be suitable for burning RDF. These Babcock & Wilcox boilers, installed in 1957 and 1961, have a capacity of 425,000 lb (191,250 kg) of steam/hr at 1250 psig (8600 kPa) and 950 F (510 C).

Both boilers are equipped with electrostatic precipitators with sufficient capacity to adequately control any anticipated increased particulate emissions that may result from firing RDF.

The boilers are front fired with pulverized coal. There are six coal burners located at three elevations. The bottom ash is collected in a dry ash pit prior to removal. The ash is removed via a dry vacuum system for silo storage prior to ultimate disposal.

In an effort to determine the RDF particle size requirements and the rate of RDF burnout within the boiler, two short term test burns were conducted. One of the existing coal feed ports was modified to permit the entry of RDF. A leaf blower owned by the City was utilized to air transport the RDF into the boiler. The solid waste fuel was prepared by first handsorting, then shredding at the City's processing plant and loaded onto an over-the-road transfer trailer for delivery to the utility. Four people, stationed in the transfer trailer, hand shoveled the prepared solid waste, which was then fed into the leaf blower for firing into the boiler.

Two tests of approximately 5,000 lb (2250 kg) each were conducted. The first test used material with a nominal particle size of 2 in. (50.8 mm). The second test used material with a normal ¼ in. (19 mm) particle size. The tests indicated by visual observation that:

1. The ¼ in. (19 mm) particle size provided a better burnout. There was a noticeable reduction of coal input to the boiler. There was no such indication with the 2 in. (50.8 mm) particle size.

2. There was a considerable fire in the ash pit from material that did not burn in suspension both with the ¼ in. (19 mm) particle size as well as with the 2 in. (50.8 mm). Under normal operation with the boilers burning coal there is no fire in the ash pit.

3. There was a slag build-up in the ash pit apparently caused by glass that was not removed.

As a result of the firing test and based on the recommendations of the boiler manufacturers, it was determined that:

1. The RDF would be fired via two independent feed ports between the two lower coal feed port levels.

2. To increase the potential of burning, the RDF in suspension a nominal RDF particle size of ¼ in. (19 mm) would be prepared.

3. To maximize the burnout of the RDF and to prevent clinkering in the ash pit, a drop grate would be installed at the bottom of the boiler and above the dry ash pit. This would allow time for complete burnout of RDF not burned in suspension.

4. To minimize the creation of slag, the process plant must be designed to remove as much glass as practical.

**PROCESSING PLANT DESIGN**

The so called "first generation" RDF processing plants utilized air classification as the prime method of separation. Based on data made available on the operating experience at the City of Ames, Iowa, and other locations, it appears that air classification alone does not significantly reduce the ash content of the incoming waste. (Reported ash content 25 to 30 percent wet weight.)[1] An alternative process method as the primary step to remove the non-desirables from the desirables to maximize the potential of producing a good quality fuel was required.

In the early 1970's the Continental Can Company[2] undertook an extensive study of the strengths and weaknesses of the emerging technical approaches to resource recovery. One of the conclusions was that intensive primary shredding caused glass and other inerts to become imbedded in the paper, fabrics, and other combustible materials, to the point that further efforts to remove the glass and inerts to achieve a low ash combustible product was essentially futile. The best processing system appeared to be one where the glass, sand, dirt, and other inorganic materials were separated from the solid waste prior to excessive shredding. The research efforts included a full evaluation of refuse screening systems throughout the world. Studies were made of refuse screening in North America and Europe, and subsequently, a test laboratory screen was developed to evaluate refuse in several regions of the country.

The general conclusions developed were that refuse screening is an effective means of removing sand, dirt and glass, and other noncombustible fines, and the results are predictable. Further, the process is proven and highly reliable and is a low energy approach to primary classification.

The test work also confirmed that a low energy type of shredder was effective in opening bags to
expose the ferrous and other noncombustibles for subsequent removal. The intent of the flail type shredder is to loosen and expose ferrous metals for magnetic separation and glass and other inorganics for screening. Following ferrous separation, fines composed of sand, broken glass, rocks, ceramics, etc., could be removed by rotary screens.

After determining the fuel requirements, low ash, particle size, etc., of the utility, the processing plant design was developed to meet those needs. After evaluating available data on several existing process flow patterns at other locations and further based on the City's ten year experience in shredding, it was determined that the process would consist of primary shredding, ferrous metal removal, separation of combustibles, secondary shredding, and an air sweep to convey the combustible material (Figs. 1 and 2).

STORAGE

Raw waste is discharged from the collection vehicles onto a concrete floor. The original building (with some modifications) was utilized for this purpose. A front end rubber tired loader is utilized to stockpile the raw solid waste prior to processing. Foam filled tires have solved the puncturing of tires. The end loader is equipped with a four-in-one bucket to permit the end loader operator to pick up and remove any unprocessable material from the waste stream before loading waste onto the conveyor feeding the primary shredder.

FAIL SAFE SYSTEM

The City of Madison, Division of Streets, is charged with the responsibility to collect and dispose of approximately 200 to 250 tons (181 to 227 t) of solid waste daily. As stated previously, the City has owned and operated a shed for landfill facility since 1967. From 1973 through 1977, the original processing facility maintained an availability factor of over 95 percent. However, the 5 percent of the time that the system was down necessitated a bypass system to insure disposal of the waste. During those years, the City operated a landfill within the City corporate limits. Raw waste was simply direct hauled to the land-
fill if there was a plant shutdown. That option was no longer available.

The present plant is designed to bypass the main process line and function as a transfer station in the event the processing system is inoperable. In this mode, collection vehicles discharge the refuse on a concrete floor and the loader operator pushes the raw refuse into a stationary packer, which injects the refuse into a semitrailer.

The process system is also designed to permit operation of the primary shredder only, or the primary shredder and ferrous recovery system as a unit and transfer the shredded refuse to a landfill. Including the basic RDF preparation system, in all, there are four separate options.

RAW WASTE FEED AND PRIMARY SHREDDER SYSTEM

The primary shredder is a flail type shredder (Fig. 3). The shredder is powered with a 300 hp (224 kW) belt drive motor. The rotor has an effective width of 5 ft (1.524 m) and rotates at 1200 rpm. The rotor, designed to permit installation of up to 48 hammers, is currently operated with 24 hammers.

The horizontal feed shredder is designed to simply grab the material off the 5 ft (1.524 m) wide slat feed conveyor (Conveyor No. 2) as it is pushed into the path of the hammers. Material passes through the shredder across a heavy steel breaker plate and is thrown against an end plate. The breaker plate located 4 in. (101.6 mm) below the hammer tip protects the rubber belt discharge conveyor from damage by projectiles or other objects. Material is discharged directly into the takeaway conveyor (Conveyor No. 3) for conveyance to the ferrous metal removal system. The overall process system was designed for a 50 ton/hr (45 t/h) capacity. During short bursts, the primary shredder has processed at over 100 tons/hr (90 t/h).
The most critical step in the process system is to maintain a consistent feed into and through the primary shredder system to ensure consistency in processing through the other process steps to produce the desired product quality. It has been the experience at the previous plant that the prime responsibility to achieve feed consistency is dependent upon the end loader operator. Conveyor No. 1, a 5 ft (1.524 m) wide pan conveyor with a variable speed drive, has a speed range of 6 - 15 ft/min (0.03 - 0.08 m/s). In order to provide a uniformly consistent feed to the primary shredder, the end loader operator must consistently feed Conveyor No. 1 at a uniform depth of 3 - 4 ft (0.91 - 1.22 m).

It has been the City’s experience that explosions will occur. The primary procedures, which have been taken to avoid explosions or dampen their effects and protect plant personnel, include:

1. Educating collection personnel to provide visual inspection of the solid waste while loading the collection packer truck.
2. Operator inspection of the metered feed to the primary shredder ahead of the isolated primary shredder room.
3. Use of a dust and fume vent system.
4. Housing the shredder in an isolated concrete and cement block room.
5. Permitting explosion relief in a direction that will cause the least amount of damage.
6. Selection of a shredder that will permit an explosion to expand and be discharged into the room for venting. Conveyor No. 3, below the shredder, is equipped with shock rollers to permit the explosion to escape.

The primary shredder room is constructed with breakaway explosion vents. Should an explosion occur, it is anticipated that the room vents will blow off to dissipate the energy. To date, one explosion has been experienced, the origin of which is unknown. The process equipment was not damaged. The only damage was the cracking of some plastic window plates in the roof vent sections. Energy from the explosion appeared to be dissipated as desired.

FERROUS REMOVAL SYSTEM

The ferrous metal removal process was originally installed by the Continental Can Company in 1972. This was one of the first examples of a City and private enterprise working together in developing successful resource recovery technology. The ferrous system was developed and installed with private capital. The City has operated the system continuously since installation in 1972.
receives 10 percent of the profits from the effort, with all operating and capital costs charged to the company. Continental Can subsequently assigned all their rights to the agreement with the City to the original private investors. The agreement included an option to extend the term of the contract for an additional 10 years. That option was exercised and the original investors financed the new ferrous system installed in the RDF facility.

The ferrous removal system includes a single stage drum magnetic separator. The recovered ferrous metal is densified and conveyed (Conveyor No. 5) for air cleanup before discharging into a semi-trailer for transporting to a metal processor. The ferrous removal system has been tested and is found to be between 90 and 93 percent effective in the removal of the ferrous metal from the waste stream that is discharged from the primary shredder.

SEPARATION UNIT

The prime area of risk and uncertainty in the energy recovery industry has been the effective removal of the nondesirables from the desirables in the production of a high quality (low ash) RDF. After reviewing available technologies, the City design team staff members were reluctant to recommend that the City purchase a separation system. A lease arrangement was developed, whereby, the City did not purchase any of the separation equipment, but rather a service was acquired by the City to separate the desirables from the nondesirables. The separation unit selected by the City incorporates the use of rotary screening to perform the desired separation. The internal working of the separation unit are considered proprietary. The contract between the supplier and the City requires that the supplier’s system be capable of handling 50 tons/hr (45 t/h) of solid waste input to produce an output with an ash content at a maximum of 15 percent (wet weight). In addition, the contract provides that the supplier is to recover a minimum of 60 percent of the raw waste input as the combustible fraction, provided it is available. If the system performs as specified, the City will pay the owner an annual fee of $112,800/year, plus a unit fee per ton of RDF produced. All cost to operate the system is the responsibility of the system owner.

SECONDARY SHREDDER SYSTEM

The desirable combustibles discharged from the separation unit are conveyed into the secondary shredder system. The secondary shredder system includes a vertical shaft shredder discharging directly into an air column for final separation by air to remove any heavy undesirables from the final RDF.

FIG. 4 SECONDARY SHREDDER & AIR SWEEP SYSTEM
product (Fig. 4). The secondary shredder is powered by a 1250 hp (933 kW) motor.

The material being processed by the secondary shredder is unique in the industry to date. The feed stock to the secondary shredder consists of essentially paper and light plastics. Since the glass, dirt and fines have been removed, the feed stock is very light in density, less than 3 lb/ft³ (48 kg/m³). A minimal amount of work was applied to the waste product at the primary shredder. Therefore, the secondary shredder must take large pieces of paper, including newspaper and corrugated paper, or other fibrous material and shred that material down to a nominal ¾ in. (19 mm) particle size in a single stage. The particle size objectives are 90 percent under ¾ in. (19 mm) with 2 percent over 2 in. (50.8 mm).

Because the material being shredded is lightweight, a problem of throughput through the secondary shredder was anticipated. It was our opinion that air should be introduced into the shredder to transport material through the shredder, otherwise the material would remain in the shredder with a high residence time and therefore become mulched and seriously hamper production rates. Therefore, in order to provide a final classifying step, ensure good production through the secondary shredder and smooth takeaway of the light material and control dust, a full air sweep pneumatic takeaway system is provided after the secondary shredder. The secondary shredder discharges directly into a vertical column for air classification. Objects removed include: shoe heels, ferrous metal not previously recovered, some aluminum and other nonferrous materials, rubber hose, wood chips, etc. The remaining RDF product is pneumatically transported through a cyclone and discharged onto a two-way conveyor to feed either of two stationary packers for loading into semi-trailers (Stationary Packers Nos. 2 and 3). The air is recirculated and is self-regulating with an automatic damper ahead of the fan with bleed off through the dust cleanup system. Adjustable dampers ahead of the shredder infeed and the air column intake allow air to be pulled through the shredder if desired. In order to avoid excessive wear, the material handling fan is located after the cyclone.

**RDF RECEIVING STATION**

RDF from the processing plant is delivered by the City in 75 yard³ (57.3 m³) transfer trailers and unloaded into one of two bins at the RDF receiving station adjacent to the power plant. The receiving station consists of a 100 x 60 ft (30.5 x 18.3 m) preengineered metal building (Fig. 7).

The building is divided into two rooms. The receiving room, maintained by the City, is large enough to store two transfer trailers. The second room houses the RDF storage bins and feed system and is operated and maintained by MGE. The bins, each of which serves a boiler, have two twin H-type auger unloaders. Each auger, which can operate at a variable feed rate, supplies the RDF to an individual conveyor belt which in turn discharges the RDF into a feed chute containing two fluffers and an airlock feeder. A positive displacement blower conveys the RDF from the feeder to the boiler (Figs. 5 and 6). The controls for the augers, conveyor belts, feeders, and blowers are located on a separate panel installed in the boiler control room. Thus, boiler operating personnel can feed RDF to each RDF injection nozzle at individually variable feed rates as desired.

**BOILER MODIFICATIONS**

Modifications to the boilers to burn RDF included the installation of drop grates above the ash pits at the boiler neck and two fans per boiler to supply overfire and underfire air to the grates. Two air cooled RDF injection nozzles were installed on each boiler between the bottom and second tier coal burners. The RDF nozzles are located relatively low in the furnace to maximize burnout of the RDF before the unburned RDF that remains suspended in the flue gases reaches the convection passes of the boiler (Fig. 7).

It was not necessary to modify the boiler controls to burn the RDF. Since the RDF is fed through an independent system, the existing fuel control system responds to load changes by changing the coal feed rate and treating the RDF system as a constant fuel input. Operating personnel are skilled at burning natural gas and coal simultaneously in the boilers. The RDF and coal are fired simultaneously in the same manner that coal and natural gas are fired utilizing similar procedures.

Permissive interlocks have been inserted into the controls, however, to prevent burning RDF unless the following conditions are met:

1. Boiler must be at a 60 percent load or above.
2. Both coal pulverizers must be in service.
3. Coal pulverizer feeders must be in automatic.
4. Underfire/overfire air fans must be on.
FIG. 5 M. G. & E. RECEIVING STATION

FIG. 6 EQUIPMENT CROSS SECTION
START-UP EXPERIENCE - PROCESSING PLANT

The initial ton of solid waste was processed through the primary shredder on January 27, 1979. The primary shredder and ferrous recovery system were operated independently of the rest of the plant during shakedown. After gaining operating experience and after the remainder of the process system was debugged for operation, the first ton of RDF was produced in March 1979.

There were no major modifications required to achieve the desired end products. Minor modifications include relocating one tail pulley of the feed conveyor into the separation unit (Conveyor No. 4) shortening that conveyor by approximately 15 in. (381 mm) to increase the effective length of the rotary screen. That was the only major equipment change required as part of the shakedown process. There were minor readjustments of the ferrous system to properly align the magnetic system with the waste stream, modifying some air hoods for dust control and other minor adjustments to achieve the desired plant cleanliness.

The basic changes in the primary and secondary shredders included changing hammer patterns to achieve the desired outputs, and in the case of the secondary shredder, closing in the inner shell of the shredder (i.e., wear plates) to fill gaps that appeared to cause bridging inside the shredder.

All process equipment, with the exception of the secondary shredder system, has been accepted by the City. As of the fall of 1979, the secondary shredder system has not functioned at the desired production rate of 30 tons/hr (27 t/h), while maintaining the desired \( \frac{3}{4} \) in. (19 mm) particle size on a continuous basis. The secondary shredder has an infinite variety of hammer patterns that can be installed. There are 72 stations in which a hammer can be placed. The City is working with a number of different hammer sizes and patterns to achieve the desired particle size and production rates. The hammers used are bell shaped hammers, 3 in. (76.2 mm) thick and \( \frac{3}{4} \) in. (19 mm) thick knives of varying lengths and widths.

The air handling system was designed and built to transport up to 40,000 CFM (18.9 m\(^3\)/s) through the air classifier. The 300 hp (224 kW) fan is
located after the cyclone. The fan discharge is split to direct the air flow to either the baghouse for cleanup and discharging to the atmosphere or recycled to the air classifier. The recycled air can be either routed directly to the air classifier or to the shredder feed hood to pass through the shredder, or it can be divided between them. To date all recycled air has been bypassed around the shredder. It is anticipated that passing some of the air through the shredder, the system, along with other steps of identifying optimum hammer patterns and maintaining smooth feed by the operator, will meet the desired production levels and achieve the desired particle size.

REFUSE-DERIVED-FUEL QUALITY

The overall process system is producing an RDF with ash contents being maintained consistently between 9 and 14 percent on a wet weight basis (Figs. 8 and 9). To our knowledge the RDF produced has one of the lowest ash contents of any refuse fuel currently used.

The separation unit is effectively removing glass, dirt and sand. During the months of June and July 1979, the quantity of solid waste recovered as a fuel is below the 60 percent requirement. During those months the recovery rate averaged 54 percent of the incoming waste. Based on an analysis of the residues from the process system, a 60 percent recovery rate may not be achieved on a seasonal basis. An analysis of the process residues revealed that over 95 percent of the combustibles desired for suspension burning were being recovered as an RDF. This includes predominately the paper and plastic fraction. The undesirable combustibles removed include food wastes, heavy wet grass, and other yard wastes which have a Btu value, but also contain a very high moisture and ash content. The initial recovery rate, lower than desired, appears to be strongly influenced by the seasonal variations in the waste generated. The percent of municipal solid waste attributed to high moisture bearing yard waste can vary substantially from season to season. All tests conducted, to date, have been during periods when there is a high grass content in the waste materials. It is anticipated that during the late fall and winter months and early spring the combustibles recovery rate as a percent of incoming will be much higher than experienced thus far and that an average annual recovery of 60 percent or better will still be achieved.

The material delivered to the air classifier consists, as stated earlier, of essentially paper and
plastics which have been shredded to 90 percent less than ¼ in. (19 mm) and a small percent of dense undesirable material that is substantially heavier than the desired RDF. Except for rags, which appear to be dropping with the heavies, the feed to the air classifier is a relatively simple material to classify. Less than 1 percent of the raw waste input is removed as a heavy residue from the air classifier. Objects removed from the RDF at the air classification step include ferrous metal not recovered by the magnet, heavy glass and ceramic chips not removed by the separation unit, aluminum, other nonferrous metals, wood chips, rags, and some heavy and light rubber. The air classifier removal of heavies decreases the RDF ash content by 2 to 3 percent, while removing specific problem materials from the RDF.

MOISTURE CONTENT

One of the unexpected benefits to the process system is the removal of moisture from the RDF and concentration of this moisture in the separation unit residues. Some moisture is also evaporated during processing. The total quantity of moisture loss has not been determined. However, material content such as grass, food wastes, and heavy papers being removed by the separation unit has very high moisture content while the RDF moisture content has been maintained comparatively low and steady through the spring and early summer (Figs. 8 and 9).

START-UP EXPERIENCE

RDF RECEIVING STATION AND BOILER PERFORMANCE

During initial operation at the RDF receiving station a few minor problems in the feed system developed. The problems occurred at the transition from the auger discharge onto the rubber belt conveyors. The manufacturer modified the discharge system and it is now operational. The conveyor belts, feeders and air conveying system have been basically problem-free. The auger discharge area between the bins had to be enclosed because of excessive dust in the receiving station, resulting from the RDF falling onto the conveyor belts as it was discharged from the auger.

The variable auger speed feeding system provides only minimal control of the RDF feed rate. It appears that fine adjustment of the feed rate will not be possible with the augers in their present configuration.

As of the fall of 1979, RDF burning is still in
a start-up stage. Approximately 800 tons (725 t) of RDF have been fired into Boilers 8 and 9. Due to boiler maintenance schedules Boiler 9 was retrofitted first with the RDF feed nozzles installed, but the drop grates were not installed. The Boiler No. 9 grate will be installed in the fall of 1979. Boiler No. 8 is completely retrofitted.

The initial test firing was done in Boiler No. 9 without the grate. Experience from this test indicated that the decision to install drop grates was justified. The fire in the ash pit was excessive. Since the initial firing all firing has been in Boiler No. 8 where results to date have been positive.

The RDF appears to be burning well in suspension, although large pieces of RDF burn on the grate at the bottom of the boiler. If the grate is not dumped regularly it appears that the RDF will form clinkers which must be broken up to be removed through the dry ash handling system. There is no evidence that burning RDF has been carried into the convection passes. There have been no observed ash hopper problems or air heater problems.

The underfire air displaces preheated air from the boiler forced draft fan. By displacing and not using the forced draft fan air, which receives its heat regeneratively from the boiler flue gases, the boiler stack temperature increases about 30 F.

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| TOTAL CAPITAL COST                 | $2,722,765|
| ANNUAL COST (10 Yrs, Interest = 5.5%) | $326,560  |

Madison Magnetic Operation (Ferrous Metal System)

Madison Solid Waste Fuel Company (Separation Unit)

Private Capital - City received 15% of profit from the sale of ferrous

Service Agreement - Annual fee - $112,800, plus unit cost per ton of RDF produced

FIG. 10 M. A. R. R. C. COSTS
Building & Grounds

General (includes site improvements) $199,713
Mechanical 16,162
Plumbing 24,130
Electrical 42,060

$ 282,065

RDF Feed System

Twin-Auger Unloader & Bins $220,390
Feed Conveyors 60,700
Pneumatic Feed System 177,410
Equipment Installation 71,859
Electrical Equipment 14,112

$ 544,471

Other

Consultants $ 88,135
City Engineering 40,000
Start-up Costs 100,000

$ 228,135

TOTAL CAPITAL COST $1,054,671

ANNUAL COST (10 Yrs., Interest = 5.5%) $ 136,000

Boiler Modifications * (MGE Financed) $ 500,000

Annual Cost (10 Yrs., Interest = 8.0%) $ 74,500

*Costs not finalized.

FIG. 11 RDF RECEIVING STATION COSTS

(16.7 C). This loss of heat up the stack equates to about a 1½ percent loss in boiler efficiency. It also reduces boiler induced draft fan capacity, although there has been no noticeable boiler derating to date.

The boilers which do not naturally slag when burning coal have shown no tendency to slag when burning RDF. The maximum fuel replacement rate has been 25.8 percent. The average fuel replacement rate has been approximately 15 percent.

There have been no visible emissions from the stacks of Boilers Nos. 8 and 9 while burning RDF. The cold side electrostatic precipitators, which are in series with centrifugal mechanical collectors on each boiler, were designed to maintain clear stacks while burning low sulfur Eastern coal. The precipitators are also handling the low sulfur RDF ash adequately.

CAPITAL COSTS

The City and MGE have met the desired goal of developing a refuse energy recovery system with a low capital investment. This was accomplished in part due to:

1. Utilizing an existing location and structure for the processing plant. Although the existing structure required considerable modifications, site improvements, office and employee areas, and
Madison Area Resource Recovery Center

Processing & Product Transportation

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<td>Miscellaneous</td>
<td>$5,000</td>
<td></td>
</tr>
<tr>
<td>Disposal of Residues</td>
<td>$65,000</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$1,186,200</td>
<td>$23.72/T</td>
</tr>
</tbody>
</table>

RDF Receiving Station

<table>
<thead>
<tr>
<th>Capital Investment</th>
<th>Annual Cost</th>
<th>UNIT COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Madison</td>
<td>$136,000</td>
<td>$6.01/T</td>
</tr>
<tr>
<td>Madison Gas &amp; Electric</td>
<td>$74,500</td>
<td>$6.68/t</td>
</tr>
<tr>
<td>Labor</td>
<td>$40,000</td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td>$15,000</td>
<td></td>
</tr>
<tr>
<td>Materials &amp; Supplies</td>
<td>$15,000</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$10,000</td>
<td></td>
</tr>
<tr>
<td>Increased Ash Disposal</td>
<td>$10,000</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$300,500</td>
<td>$29.73/T</td>
</tr>
</tbody>
</table>

Utilities were available with minimum added cost.

2. The City’s existing processing plant personnel were utilized to remove, refurbish, and install some of the original equipment for reuse (Conveyor No. 1 and Stationary Packer No. 1).

3. Plant personnel also were involved with the new equipment installation and worked with the suppliers during construction to make minor modifications to assure proper operation and access for maintenance.

4. The ferrous recovery system and the separation unit are not owned by the City. Therefore, the City has no capital investment in that equipment.

5. The City acted in the capacity of prime contractor and retained control of all aspects of the project. This was done to insure the maximum benefit of the City’s past experience in waste processing.

The final capital investment by the City for the
processing plant modifications, City owned process equipment, site improvements and engineering totaled $2.72 million (Fig. 10). The final capital investment for the Blount Street RDF Receiving Station, including the building, RDF feed equipment, site improvements, engineering and start-up costs, is estimated at $1.05 million (Fig. 11). The City's capital investment for the project totaled $3.77 million.

The modifications to the two Babcock & Wilcox pulverized coal boilers, including installation of drop grates, boiler breaching RDF piping and start-up is estimated at $0.5 million. This amount was financed by MGE.

ANTICIPATED ANNUAL COSTS

The 1980 total annual operating cost to handle 50,000 tons (45,000 t) of solid waste, including processing, transporting the end products to their respective markets (RDF to utility, residues to landfill), cost of firing the RDF and disposal of residues and increased ash is estimated at $29.58/ton ($32.61/t). Anticipated revenues are estimated at $7.90/ton (8.71/t) as received to the processing plant with a net system cost of $21.68/ton (23.90/t) (Fig. 12). This cost compares to a 1977 cost to shred and landfill of $9.44/ton ($10.48/t).

CONCLUSIONS

Based on the operating experience at the Madison Area Resource Recovery Center and the MGE Power Plant the following conclusions and observations can be made:

1. The solid waste processing plant can produce a high quality RDF consistently with an ash content range of 10 - 14 percent (wet weight).
2. The processing plant can be operated on a consistent basis at production levels of 35 - 40 tons/hr (32 - 36 t/h).
3. The RDF receiving station feed system can provide a relatively consistent RDF flow to the boilers. However, the desired variability in feed rate does not appear possible.
4. Based on short term RDF firing runs (4 - 6 hr), it appears that the RDF can be fired in the boilers without significant impact to boiler performance or bottom ash clinkering. Additional operating experience is necessary to confirm boiler performance results.

Detailed performance data on all systems is being developed to define any seasonal changes in process equipment performance and boiler performance. In 1980, stack emission tests will be conducted to determine what impact, if any, burning RDF has on electrostatic precipitator performance and air emissions.

REFERENCES