THE GREATER BRIDGEPORT, CONNECTICUT WASTE-TO-POWER SYSTEM

FLOYD HASSELRIIS
Combustion Equipment Associates, Inc.
New York, New York

ABSTRACT

The Greater Bridgeport System is established by contracts between the Connecticut Resources Recovery Authority (CRRA), and nine Municipalities to accept Municipal Solid Waste (MSW), and between the CRRA and CEA/OXY Resource Recovery Associates (CEA/OXY) to design, construct and operate the System to receive and process the MSW into marketable products. The main product is ECO-FUEL™II, a dry pulverized fuel which is storable and transportable, and is being cofired with oil at the Bridgeport Harbor Station of the United Illuminating Company, in boilers originally designed for coal and equipped with Electrostatic Precipitators (ESP).

INTRODUCTION

The system, located in the southwestern region of the State of Connecticut, consists of six transfer stations which receive the MSW, transportation equipment, the resource recovery facility, and power station equipment.

The facility is designed to receive 1800 tons (1630 t) of MSW per day, remove metals and other contaminants such as glass, produce a fuel of high quality and economic value, and recover economic value from the removed materials.

The ECO-FUEL™II (Powdered RDF) product has a higher heating value of 7500-8000 Btu/lb (17,400-18,600 kJ/kg) with less than 3 percent moisture and 15 percent ash, as compared with unprocessed or partially processed refuse-derived-fuels (RDF), which contain 4700-5200 Btu/lb (10,900-12,100 kJ/kg) with about 25 percent moisture and about 25 percent noncombustibles.

The conversion of MSW to power by producing a dry powdered fuel and burning it in a utility boiler with a low heat rate results in a high overall process efficiency due to minimization of energy losses resulting from fuel moisture and excess air, and poor combustion. In addition the capacity of the boiler is not reduced significantly, if at all by combustion of low-ash dry powdered refuse-derived fuel cofired with oil or other fossil fuels.

In producing powdered RDF, energy is invested in preparing the pulverized, dry fuel, most of which results in removal of moisture. This investment is substantially returned during the combustion process as the result of maximizing boiler efficiency.

Boiler stack gas losses when firing powdered RDF with oil in efficient boilers such as those at United Illuminating, are only about 14 percent, whereas unprocessed, partially-processed and wet-processed fuels can lose 30 percent of their high heating value in evaporating the moisture and heating the water vapor and necessary excess air to the stack temperature.

The Bridgeport System has the potential to generate over 600 kWh per ton (660 kWh/t), based on Class I MSW at 4700 Btu/lb (10,900 kJ/kg), 81 percent combustibles recovery, and an overall power plant heat rate of 10,000 Btu/kWh (10,600 MJ/kWh). Taking into account 90 kWh/-
ton (99 kWh/t) used to process the fuel, and the 70 kWh/ton (77 kWh/t) power which could have been generated by the oil or other fuel used in the process, the net power potential would be 440 kWh/ton MSW (483 kWh/t).

The Facility began shakedown in May, 1979, and demonstrated 25 tons/hr (22 t/hr) operation in June. The first Powdered RDF was test burned in Unit No. 1 at United Illuminating Company (UI) on November 13, 1979, cofired with low-sulfur oil. Since that time increasing quantities of fuel have been burned under close observation to evaluate the disposition of ash, slagging and fouling characteristics, and the sulfur emissions.

BACKGROUND

The CRRA was established by the Connecticut Solid Waste Management Services Act and charged with the responsibility for implementing solid waste disposal and resource recovery systems, facilities and services where necessary and desirable throughout the state.

The CRRA is empowered to fulfill these responsibilities by: using private industry to construct and operate the solid waste disposal and resource recovery facilities, and to market the products derived therefrom, contracting with municipalities for solid waste disposal services and charging and collecting fees for such services, and providing for the transportation of solid waste and recovered resources anywhere within the State.

Greater Bridgeport System Bonds were sold to finance the acquisition and construction of a solid waste disposal and resource recovery system to serve the City of Bridgeport and the towns of Darien, Easton, Fairfield, Greenwich, Monroe, Stratford, Trumbull and Westport.

The United Illuminating Company (UI) has an agreement with the CRRA to purchase the fuel at a price based on the price of the fossil fuel which would otherwise be burned at the power station, subject to discounts related to the volume of fuel burned, the fossil fuel price, and other considerations.

The system was designed to provide the municipalities with an environmentally acceptable means of solid waste disposal at a reasonable cost, recover a significant amount of resources that would not otherwise be utilized, and achieve these results by using private industry whereby private companies will share with the Authority and the municipalities in the benefits derived from the System.

SYSTEM MAKEUP

The system receives Class I waste delivered by the municipalities at six transfer stations constructed in various towns, from which it is delivered in transfer trailers to the facility which does the processing. Class II waste is also accepted but may be directed to an appropriate disposal site at an agreed cost.

The powdered RDF product is stored in dry-solids silos at the facility and transported by dry-solids container trucks to storage silos at the UI Bridgeport Harbor Station, from which the fuel is metered to the boilers.

TRANSFER STATIONS

Each transfer station is located on a site of about 3 acres (12,000 m²). The stations cover 4000-6000 ft² (370-560 m²). On an upper level incoming trucks dump MSW either directly into a compactor or onto a floor storage area for later transfer to the compactor. On the lower level, trailers which transfer the solid waste to the facility are loaded directly by a compactor. Private vehicles are permitted access to the transfer stations to discharge acceptable solid waste. The transfer stations are designed for a minimum capacity of 554 tons/day (504 t/d).

THE FACILITY

The facility is constructed on 7 acres (38,300m²) on the waterfront in the City of Bridgeport, in an industrial area easily accessible to the Connecticut Turnpike and to rail and barge facilities (see Fig. 1). The main structure of the facility has a trucking module, a tipping module and an equipment building, as shown in Fig. 2, occupying about 85,000ft² (7900 m²). In the equipment building are located two powdered RDF production and ferrous metal recovery lines, each designed to process a peak of 75 tons/hr (68 t/h) of MSW, with one aluminum line serving both production lines. The facility is designed to operate at a nominal capacity of 561,600 tons/year (590,000 t/y), based on a waste input of 1800 tons/day (1,630 t/d) for 312 operating days per year.

TRANSPORTATION EQUIPMENT

It is anticipated that ten tractors and twelve trailers will be required to transfer the compacted waste from the stations to the facility. The dry-
FIG. 1 PHOTOGRAPH OF BRIDGEPORT FACILITY

FIG. 2 SITE PLAN OF BRIDGEPORT FACILITY
solids trailers used to transport the powered RDF to the power station are limited by law to 16-17 tons (14.5 to 15.4 t) as are the transfer trailers. Additional trucks and trailers are required to transport residues and ash to waste and residue disposal sites.

**POWER STATION EQUIPMENT**

The power station equipment has been modified to permit burning powdered RDF along with low-sulfur residual fuel oil in the Babcock and Wilcox Cyclone-furnace-fired boilers. Fuel receiving equipment, storage silos, handling equipment and weigh-feeders to meter the fuel to the boilers, and wet-bottom ash-handling and water pollution control equipment have been installed for three burners in the No. 1 boiler which is rated at 86 MW, with provision for installation of necessary equipment for future burning in the No. 2 boiler, which is similar but larger. The elevation of Unit No. 1 shown in Fig. 3 shows the B&W boiler and the cyclone furnace within which the powdered RDF is burned by pneumatic injection into the primary air. UI engineers operate the power station equipment including the pneumatic handling of the powdered RDF from the trailers to the silos and from the silos to the burners, as well as the ash-handling systems.

The B&W boilers which generate 1500 psi (6.9 MPa) steam at 1000 F (538 C), were originally designed to burn coal, but were converted to heavy oil over 15 years ago. They are equipped with Electrostatic Precipitators (ESP) which collect the particulate resulting from powdered RDF combustion.

**FUNCTION AND DESIGN OF THE SYSTEM**

The system and the facility are designed to process Class I MSW having a composition, established by studies conducted for the State of Connecticut, which estimated that by weight, and on an average annual basis, the MSW to be processed can be characterized as shown in Table 1. This table also shows the potential for recovery of values from the various components, based on 80 percent recovery of combustibles, 90 percent of ferrous metal, 40 percent of aluminum and 60 percent of the glass.

**RECOVERED PRODUCTS**

The main purpose of the facility is to produce marketable products. The output and value of each product will vary due to changes in composition of the incoming solid waste, product yield and quality, and market conditions.

The powdered RDF revenue is based on heat content as well as quantity, and to a certain extent on qualities of the fuel such as ash content. The incoming MSW, having an estimated average Higher Heating Value (HHV) of 4700 Btu/lb (10,900 kJ/kg), is converted into a dried, defiberized and sterilized material with the approximate product characteristics listed in Table 2. The HHV value of powdered RDF is 15-16 Million Btu/ton (15.9-16.9 GJ/kg), the equivalent of 2.46-2.62 barrels (390-420 l) of residual fuel oil.
FIG. 3 ELEVATION SECTION OF UTILITY BOILER AT UNITED ILLUMINATING COMPANY
BRIDGEPORT HARBOR STATION
process. This fraction depends on the methods used, of course, and the quality of the product. For instance, the noncombustible (ash plus extraneous inert materials) in the product might be reduced to 10 percent with a loss of 20 percent of the combustibles, whereas if the noncombustible content were increased to 15-20 percent, the combustible losses might be reduced to 10 percent (a recovery of 90 percent).

The powdered RDF product is expected to generate over 80 percent of the potential revenues, and in view of the rising cost and increased shortage of energy, should become even more valuable. Ferrous metals represent a substantial fraction of MSW input and, being readily recovered by magnetic separation, could make a significant contribution, perhaps 10-15 percent, to recovery revenue. Aluminum, which is a small stream with a proportionately high value was anticipated to contribute about 2 percent to revenue. Glass, although almost 10 percent of the feed, cannot be expected to yield as much since that potential can easily be canceled by operating, capital and transportation costs.

THE POWDERED RDF PROCESS

The Bridgeport Facility is a second-generation design based on about five years of development and demonstration of the powdered RDF process at a pilot plant and at CEA's East Bridgewater (Brockton), Massachusetts facility.

A simplified layout of the Bridgeport Equipment Building is shown in Fig. 4, and the flowsheet of the flail mill line is presented in Fig. 5. The flail mill has two 200 hp (149 kW) motors. The second line has a 2500 hp (1864 kW) hammermill in order to be capable of processing oversized bulky waste (OBW).

The transfer trailers are brought into the trucking module for discharge onto the tipping floor. The trucking module is elevated so that the MSW

FIG. 4 SIMPLIFIED LAYOUT OF EQUIPMENT BUILDING
when unloaded will fall below the discharge end of
the hydraulically-discharged trailer.

Front-end loaders move the MSW either to
storage or to picking areas where the objectionable
objects are removed, thence to the feed conveyor
whereby the MSW enters the processing module.

The MSW first enters the primary trommel
which removes the glass and associated heavies
while passing the light combustibles over the
screen to the size-reduction (shredding) operation.
Both the over and under streams are passed under
a magnet which removes the ferrous materials.
These are densified and air-cleaned before delivery
as the ferrous product.

The air-classifier separates the light materials
from the aerodynamically heavy materials, which
consist of most of the glass and residue. The light
materials are conveyed by hot gases recirculated
through the air-classifier system, and collected by a
cyclone, from which they are dropped into the
secondary trommel where most of the fine inerts
and remaining glass are removed.

This secondary trommel also serves as a device
for applying chemical agents to the MSW which are
part of the proprietary embrittling process. These
agents, in conjunction with the application of heat
in the ball mill, cause cellulosic materials to become
brittle and, under the grinding action of the balls,
become a powder having an as-produced density
of 25-35 lb/ft³ (0.4-0.6 g/ml).

In order to introduce heat into the ball mill for
drying and embrittling, the balls are circulated
through an external ball heater, which uses hot
gases from a process heater as the heat source.
These gases, which contain the water vapor gener­
atated by drying, are also used for drying the MSW,
and are recirculated throughout the system to
maintain the low oxygen levels required to main­
tain safe conditions while drying and processing
the pulverized fuel.

The ground product, together with crushed
aluminum cans and other unground materials, are
separated by a screen, the intermediate product
being recycled, and the oversize including the
aluminum conveyed to the Recyc-AI for aluminum
separation. This device, developed by Occidental
Research Corporation, uses a linear induction
motor powered by an alternator to generate eddy
currents which causes the aluminum to jump out
of the feed stream when it passes under a magnetic
field. The remaining oversize material may be
reprocessed into fuel or landfilled.

The powdered RDF product is air-cooled and
conveyed to the storage silos, which have a
capacity of 300 tons (270 t) each (six are installed
at the facility).

Pneumatic transport systems are used to load
the silos, from which the fuel can be discharged
rapidly into dry-powder transport trailers for haul­
ing to the fuel user. At the UI site pneumatic trans­
port is again used to load the silos and to feed the
fuel to the boilers.

**MATERIAL BALANCE**

The material balance upon which the design of
the Bridgeport plant was based was calculated
from data collected during extensive testing of a
versatile pilot plant constructed in CEA's R&D
facility in Minneapolis, Minn. The MSW used to
generate this data was packer-truck waste which
was typical of the suburban community from
which it was collected, but certainly subject to
the variations in constituents common to MSW.
The variability of this material was found to be
about plus-or-minus 25 percent in the major
properties such as moisture, glass and ferrous
metal, but much more in the case of aluminum. In
view of this, it was recognized that the plant would
have to be designed not only to receive a highly
variable feed stream, but also to cope with
considerable variations in the in-plant process
streams, while yielding a product of uniform
quality. A material balance for a plant processing
MSW must be considered to be a consistent basis
for design, not a set of exact numbers.

The material balance of the plant at any given
time depends upon the MSW composition and the
response of the equipment to the specific materials.
In the final analysis it is not known until the plant
is in full operation and the weights of the internal
streams and the outputs have been determined as
an average over a long period of time.

As soon as the Bridgeport plant was started up
in May, 1979, efforts were initiated to analyze and
weigh the outputs and process streams in order to
confirm the process design, to determine the extent
to which improvements in yield could be achieved
without sacrifice in quality of the products, and
to minimize residues destined to landfill. This will
be an on-going process as the capacity of the plant
is increased and the relationships of the products
to their markets become better known.

The Material Balance shown in Fig. 6 is indic­
tive of the outputs which can be expected from
the plant on average, subject to changes and im­
FIG. 6 MATERIAL BALANCE OF BRIDGEPORT PROCESS

Improvements required for various reasons. The output of powdered RDF is shown to be 50 percent. This yield can be exceeded by process optimization and by further processing of the residue and reject streams. The yield will also be higher when the moisture is less than the 25 percent assumed, and when the MSW input has a higher combustible content.

FUEL UTILIZATION

Burning of the East Bridgewater powdered RDF product was demonstrated at a 60 MW industrial power plant in Waterbury, Connecticut, in Riley boilers having pulverized-coal burners, cofiring with residual oil. These boilers had inefficient mechanical collectors which limited the firing rate to 10 percent of heat input in order to meet stack opacity restrictions. Two of the four installed pulverized-coal burners were converted to fire the powdered RDF, which was metered from the storage silo and pneumatically conveyed to the burners. Slag formations in the furnace were observed to break off due to thermal shock under normal changes in firing rate during the daily load changes.

The B&W boilers at UI are expected to permit cofiring at rates up to 50 percent of thermal input with the units operating at 80 percent or more capacity. The facility was designed to produce up to 880 tons (800 t) per day of powdered RDF. Both economic and technical factors influence the percentage of this fuel which can be cofired with oil. A preliminary economic dispatch study for the years 1978-1986, completed by UI, showed that when operating at 80 percent or greater capacity cofiring rates between 30 and 40 percent are required to burn all of the fuel. Therefore the goal for cofiring with powdered RDF should be 40 percent.

The operational impact of burning powdered RDF in Unit No. 1 has been under observation since November, 1979, to consider slagging characteristics, environmental impact and long-term corrosion effects. The permits for the boilers were based on burning low-sulfur residual oil, allowing emissions of 0.55 lb of sulfur dioxide per million Btu (0.24 kg/GJ) of heat input. A stack monitor was installed to permit evaluation of the contribution of the residual oil and of the powdered RDF to gaseous sulfur emissions.
ENERGY RECOVERY

In order to evaluate the energy recovery from a process which converts MSW into fuel, and ultimately into power, the entire system from feed conveyor to steam turbine must be considered. This is especially necessary when comparing systems which process the MSW to different extents, thus removing objectionable materials, losing some combustibles, removing moisture, and reducing the particle size. The evaluation must start with the amount of energy which is actually available in the MSW, take into account the energy expended in mechanical processing and drying, and yielding the amount of electrical power actually generated per unit of MSW and per unit of energy in the MSW. The following analysis is based on the above MSW specifications relating to a heating value of 4700 Btu/lb (10.9 MJ/kg), and the assumption, supported by considerable data, that the Moisture and Ash-Free Higher Heating Value (MAFHHV) of refuse-derived fuels is 9200 Btu/lb (21.4 MJ/kg). While higher values up to 9600 Btu/lb (22.3 MJ/kg) are commonly encountered, the lower figure is consistent with the assumed 4700 Btu/lb (10.9 MJ/kg). Another assumption is the amount of inherent ash contained in the MSW, as distinguished from the extraneous noncombustible contaminants. It is consistent to assume that the combustibles contain about 6-7 percent inherent ash, consisting of fillers, and chemicals bound with the combustibles. The amount of extraneous ash will vary with the nature of the refuse and the effectiveness of the glass-removal operations, but was assumed in the Bridgeport flowsheet to be 9 percent.

With these assumptions, Table 3 was prepared to show the disposition of moisture, contaminants (noncombustible materials), and inherent ash in the MSW and the powdered RDF product, based on the MSW composition of Table 1, by regrouping the 54.4 percent combustibles, and separating out the inherent ash. This permits use of the MAFHHV, discussed above.

If the total weight of fuel product is 50 percent of the MSW input, the energy recovery is 50 percent of the 82 percent combustible, or 41 percent of the input MSW, versus the 51.1 percent represented by combustibles in the MSW. The energy recovery is thus 80 percent. In round numbers, this was the projected yield of energy of the Bridgeport plant. Preliminary performance data indicates that this yield can be exceeded.

 Provision has been made to use rejected combustibles in lieu of fuel oil in the Process Heater, thus further increasing energy recovery.

The improvement in fuel properties resulting from processing the MSW can then be calculated:

\[
\text{HHV, MSW as fired: } 9200 \times \frac{511}{1000} = 4700 \text{ Btu/lb (10.9 MJ/kg)}
\]

\[
\text{HHV, powdered RDF: } 9200 \times 0.82 = 7544 \text{ Btu/lb (17.5 MJ/kg)}
\]

ENERGY RECOVERY OF THE PROCESS

Since both mechanical and thermal energy are expended in the process of improving the fuel properties, these must be taken into account in any evaluation of net energy recovery.

The Bridgeport process requires 90 kW/ton (99 kW/t) to process the MSW into powdered RDF. The major part of this energy produces a drying effect on the material, while at the same time reducing the particle size. This contributes to the boiler efficiency by eliminating a portion of the water which would otherwise have to be evaporated in the furnace and raised to the boiler stack temperature.

In addition to the electrical input, the Bridgeport process uses 5 gal of fuel oil per ton (20.9 l/t) of MSW, or its equivalent in fuel product (or recovered combustibles) from the plant, to generate hot gases in the Process Heater. Using a heating value of 140,000 Btu/gal (39.0 MJ/l) this represents a heat input of:

\[
\text{Heat input by oil: } 5 \times 140,000 = 700,000 \text{ Btu/ton MSW (0.8 GJ/t)}
\]

\[
\text{Heat input required to produce the power used: } 90 \text{ KW} \times 10,000 = 900,000 \text{ Btu/ton MSW (1.0 GJ/t)}
\]

\[
\text{Total heat input: }
\]
1,600,000 Btu/ton MSW (1.9 GJ/t)

The net energy produced by the facility and delivered to the utility, per ton of MSW, at 81 percent energy recovery, and deducting the total heat input is:

\[
4700 \text{ Btu/lb} \times 2000 \times 0.81 = 7,614,000 \text{ Btu/ton (8.9 GJ/t)}
\]

Deduct heat input:

\[-1,600,000 \text{ Btu/ton (1.9 GJ/t)}\]

Net energy for power:

\[6,014,000 \text{ Btu/ton (7.0 GJ/t)}\]

If the Utility generates 1 kw per 10,000 Btu (95 kW/GJ, the net power produced is 600 kW/ton MSW (660 kW/t). This takes into account the efficiency of the boiler and entire plant, which is relatively high due to the high steam pressure and superheat, and the 86 percent boiler efficiency which is attained with oil-firing and preheated combustion air, and is retained when cofiring with powdered RDF.

If the energy recovery were less than 81 percent correspondingly less power would be produced per ton of MSW, as summarized in Table 4. Reduction in boiler efficiency below 86 percent would also reduce the power accordingly.

### TABLE 4 POWER GENERATED VERSUS ENERGY RECOVERY EFFICIENCY

<table>
<thead>
<tr>
<th>Recovery of MSW</th>
<th>kW/ton MSW</th>
<th>kW/t</th>
<th>MW/1800 tons/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 percent</td>
<td>686</td>
<td>754</td>
<td>51</td>
</tr>
<tr>
<td>80 percent</td>
<td>592</td>
<td>651</td>
<td>44</td>
</tr>
<tr>
<td>70 percent</td>
<td>498</td>
<td>548</td>
<td>37</td>
</tr>
<tr>
<td>60 percent</td>
<td>404</td>
<td>444</td>
<td>30</td>
</tr>
</tbody>
</table>

**CONCLUSION**

The Greater Bridgeport Facility entered shake-down in May, 1979, was checked out at 25 ton/hr (22.7 t/h) for a day shift in June, and since its fuel user (UI) started burning powdered RDF in November, has been increasing production to match increasing fuel use at United Illuminating Company. The fuel produced initially was low in ash, well below the 15 percent specified, indicating that the combustible yield could be increased without exceeding acceptable ash levels. Since the fuel is burned in cyclone furnaces which can tolerate slag, a program is under way to evaluate the optimum ash content. Over 50 samples taken from the first 1,000 tons of fuel delivered showed that the mean HHV was 7850 Btu/lb, with a standard deviation of 350 Btu/lb, and the MAF HHV was 9380 Btu/lb.

The startup and shakedown period was not without event, as is to be expected with a processing plant. Within the first few months, a fuel silo and a bag filter experienced dust deflagrations. The subject equipment was equipped with relief devices, however, which functioned in accordance with design. The reasons for the occurrences were determined and corrected.

The Bridgeport process produces a fuel of high quality and consistency, which can be stored and retrieved effectively, making it possible to burn it in locations remote from the processing plant, thus taking advantage of much higher boiler and power plant efficiencies than are usually possible with smaller, dedicated boilers close-coupled with the processing module. The energy devoted to drying the fuel and producing a pulverized product is returned by the increased combustion and boiler efficiencies.

**Key Words**

Classification Combustion Drying Energy Fuel Refuse Resource