DULUTH CO-DISPOSAL FACILITY

WEN C. HUANG and DAN L. NELSON
Consoer, Townsend & Associates
Chicago, Illinois

ABSTRACT

The world's first full-scale fluidized bed reactor co-disposal facility located at the Western Lake Superior Sanitary District's (WLSSD) central wastewater treatment complex in Duluth, Minnesota, began its shakedown operation in the fall of 1979. The authors present herein basic design criteria, a system description, November, 1979 system status, and areas of operational concern.

INTRODUCTION

The Western Lake Superior Sanitary District (WLSSD) encompasses over 500 sq miles (1300 km²) on the Minnesota side of the western tip of Lake Superior. This area has a population of about 150,000 people, about 70 percent of whom live in the City of Duluth.

Consoer, Townsend & Associates (CT&A) was commissioned to study and design facilities to centralize and upgrade wastewater treatment within the District. The preliminary engineering reports had been completed and final design of the facilities had just begun when the oil embargo of 1973 was experienced. Oil-fired multiple hearth sludge incinerators had been chosen for disposal of the solids generated in the wastewater treatment process; however, the oil embargo suddenly put the District in a position of not being able to obtain priority to buy oil. Furthermore, the rapid increase in fuel prices pushed the estimated annual fuel cost for sludge incineration over $1,000,000.

The authority of the WLSSD was expanded in 1974 to include management of the District's solid waste disposal. CT&A was retained to re-evaluate the sludge disposal system to determine and recommend the most technologically and economically feasible system to accomplish the disposal of both solid waste and sewage sludge generated within the District. The study was undertaken, recognizing several rather severe constraints:

1. The system would have to be adaptable to the limited space available at the wastewater treatment plant site.
2. The system would have to be constructed within the previously established sludge disposal system budget.
3. The system should be ready to receive the sludge from the wastewater treatment plant when it was scheduled to start operation.

After a thorough analysis of solid waste and sludge disposal technologies, alternate systems were postulated and evaluated. A fluidized bed reactor and waste heat boiler system using prepared solid waste for fuel in the co-disposal with sewage sludge was recommended. This recommendation was accepted by the Western Lake Superior Sanitary District and design was started in 1975. Bids were received in July, 1976, and the project was scheduled for completion in December, 1978 at a total construction cost of $20,000,000.
WASTE QUANTITIES AND CHARACTERISTICS

SOLID WASTE

Random sampling of residential, commercial, and institutional solid waste was conducted in April and August of 1974. Waste composition as well as residential per capita generation rates were determined from this sampling program. Commercial and institutional generation rates were determined from generator, collector, or landfill records except for schools for which waste quantities were determined from established per student and per meal generation rates. Table 1 shows the resulting 1974 solid waste generation rates and quantities. Table 2 shows the resulting composite waste stream composition and the calculated high heat value (HHV).

TABLE 1. 1974 SOLID WASTE GENERATION RATES AND QUANTITIES

<table>
<thead>
<tr>
<th>Source</th>
<th>lbs/Day (kg/Day)</th>
<th>Tons/Day (t/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>1.84 (0.83)</td>
<td>133 (121)</td>
</tr>
<tr>
<td>Commercial</td>
<td>1.01 (0.46)</td>
<td>73 (66)</td>
</tr>
<tr>
<td>Institutional</td>
<td>0.35 (0.16)</td>
<td>31 (28)</td>
</tr>
<tr>
<td>Total Municipal Waste</td>
<td>3.20 (1.45)</td>
<td>237 (215)</td>
</tr>
</tbody>
</table>

TABLE 2. 1974 "AS RECEIVED" SOLID WASTE COMPOSITION AND HHV

<table>
<thead>
<tr>
<th>Component</th>
<th>% by Weight</th>
<th>Btu/lb Waste (kJ/kg Waste)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>40.42</td>
<td>2413 (5612)</td>
</tr>
<tr>
<td>Plastics</td>
<td>2.52</td>
<td>359 (835)</td>
</tr>
<tr>
<td>Textiles</td>
<td>1.72</td>
<td>115 (267)</td>
</tr>
<tr>
<td>Wood</td>
<td>2.59</td>
<td>183 (426)</td>
</tr>
<tr>
<td>Rubber and Leather</td>
<td>0.65</td>
<td>55 (128)</td>
</tr>
<tr>
<td>Glass and Ceramics</td>
<td>10.95</td>
<td>9 (21)</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.50</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Ferrous Metal</td>
<td>7.23</td>
<td>37 (86)</td>
</tr>
<tr>
<td>Garbage</td>
<td>30.70</td>
<td>1358 (3158)</td>
</tr>
<tr>
<td>Others</td>
<td>2.72</td>
<td>119 (277)</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
<td>4650 (10,815)</td>
</tr>
</tbody>
</table>

Using an annual growth rate of 2.5 percent for the per capita solid waste generation and the population projection for the study area, nearly 320 tons/day (290 t/d) of municipal solid waste were projected for 1984.

Assuming material separating efficiencies of: 90 percent for ferrous metals; 80 percent for glass, ceramics, and aluminum; and 10 percent contamination of the separated materials; a 17.24 percent reduction in weight was calculated after solid waste processing with a corresponding HHV of 5500 Btu/lb (12,700 kJ/kg) of prepared refuse.

Some processible industrial and special wastes were added to the municipal waste to give a 1974 and projected 1984 available solid waste stream of about 320 tons/day (290 t/d) and 400 tons/day (360 t/d) respectively. Only about 200 tons/day (180 t/d) will be required to supply the necessary fuel value to the fluidized bed reactor system at design sludge disposal rates. The District's current plan is to process only sufficient refuse to achieve sludge incineration with a minimal dependence on fuel oil.

SEWAGE SLUDGE

Sewage sludge quantities and characteristics were estimated based on the wastewater plant design. The 44 MGD (167,000 m³/d) plant receives about two-thirds municipal and one-third industrial wastewater. The process includes bar screens, aerated grit chambers, an oxygen activated sludge system, flocculation tanks for phosphorous removal, mixed media filters, chlorination, and dechlorination. Solids wasted from the oxygen activated sludge settling tanks are combined with phosphorous sludges for flotation thickening and vacuum filtration with chemical conditioning. At design flow conditions, about 332 tons/day (301 t/d) of 20 percent solids filter cake plus about 8 tons/day (7 t/d) of grit and screenings will be produced. The design sludge disposal loading is 340 tons/day (308 t/d) at 80 percent moisture. The composite sludge was estimated to be 51 percent moisture. The composite sludge was estimated to be 51 percent volatiles with 5060 Btu/lb (11,780 kJ/kg) of dry solids.

PROCESS DESIGN FEATURES

SOLID WASTE PROCESSING FACILITY

A process flow diagram of the solid waste processing facility is included on Fig. 1. The system has two complete processing lines except for a few common conveyors and the magnetic separators.

Refuse trucks enter the facility over a remotely controlled scale equipped with a credit card type reader, an intercom, and a visual monitor. They then proceed to the enclosed tipping area where they are directed by signs and a spotter to a
desired bay for dumping. The refuse is dumped into one of two surge pits 10 ft (3 m) wide by 22 ft (7 m) deep and 50 ft (15 m) long. These pits are equipped with wire cables to help break up the refuse, reduce direct impact on the pit conveyor, and minimize bridging. Water sprays and multiple dust collection inlets minimize and confine dust.

At the end of the variable speed pit conveyors compression feeders are utilized to facilitate the 90 degree transfer of the refuse to the primary shredder feed conveyors. These compression feeders, which are basically upside-down conveyors, are designed to break up bridging and smooth the flow of refuse from the pit conveyors to the feed conveyors.

As the refuse travels up the steeply inclined variable speed primary shredder infeed conveyors, it passes by a picking station where suspicious or unacceptable items may be removed from the waste. The picker is protected by a blast shield and has local controls to stop the conveyors as well as a hoist to help remove heavy items.

The refuse passes under a blast mat, a belt curtain, and a chain curtain before entering one of the two Williams hammermill-type primary shredders. These 5 ft (1.5 m) wide shredders, powered by 800 hp (600 kW) motors, reduce the refuse to 95 percent less than 4.0 in. (102 mm) in size. These shredders have water sprays and an explosion suppression system to prevent or stop explosions.

Vibrating conveyors under the primary shredders convey the primary shredded refuse to a single transfer conveyor which carries the material to the Dings belt type magnetic separator. Magnetic material is removed and carried by a series of conveyors to one of two ferrous metal bins. Non-magnetic material is directed by a flap gate to one or both of the Williams secondary shredder-classifiers via their various transfer and feed conveyors.

A secondary shredder-classifier consists of a vibrating conveyor, an air knife blower, the shredder, a cyclone separator, and two large air locks. The air knife blower directs a high velocity air stream at the even flow discharged from the vibrating conveyor. The light material is blown into the shredder where the very light material is drawn off in an air stream to the cyclone separator while the rest is reduced to 95 percent less than 1.5 in. (38 mm) in size by the shredder. The shredded material and the material separated by the cyclone pass through their respective rotary valves onto a common prepared fuel conveyor.

The cleaned air from the cyclone is returned to the
blower. The material which falls through the air
knife is the noncombustible stream and is con-
veyed by a series of conveyors under a secondary
magnetic separator and into one of two noncom-
bustible bins. The secondary shredders are also
powered by 800 hp (600 kW) motors. The blowers
are powered by 150 hp (112 kW) motors. The
secondary shredders are also equipped with explo-
sion suppression equipment.

The prepared fuel may be transported either
directly to the fuel feeders for the fluidized bed
reactors or to the Atlas 800 ton (730 t) fuel
storage bin. The bin floor has a Masterplate 300
surface for wear resistance. The bin outfeed con-
veyors transfer the prepared fuel to the fuel
feeders for the fluidized bed reactors.

The solid waste processing facility has a capa-
city of 30 tons/hr (27 t/h) per line. Therefore, one
shift operation of one line can process the 200
tons/day (180 t/d) necessary to burn 340 tons/day
(308 t/d) of sludge. Fuel must be produced and
stored, however, over 5 operating days per week
so that the sludge disposal facility can operate 7
days per week. The nominal plant rating is 400
tons/day (360 t/d) which implies 2 shift operation
of one line. The fluidized bed reactor system is
capable of handling 160 tons/day (145 t/d) of the
prepared fuel per reactor. The design basis is for
80 percent of the refuse to be converted to fuel.

The actual cut may be varied to meet fuel quality
and quantity requirements within the range of 65
to 85 percent by adjusting the air knife air flow.

SLUDGE DISPOSAL FACILITY

The process flow diagram of the sludge disposal
facility is also included on Fig. 1. There are two
fully redundant fluidized bed reactors, waste heat
recovery, and air pollution control systems.

Fluidizing air blowers (not shown) take filtered
air from a plenum room into which much of the
cleaned solid waste processing facility exhaust air
is discharged and blow the air into the reactor
windbox. Each fluidizing air blower is driven by a
600 hp (450 kW) steam turbine to fluidize the
reactor bed and to provide combustion air for the
reactor.

Each fluidized bed reactor is 45 ft (14 m) high
and has an inside diameter of 34 ft (10 m) at the
freeboard. The top of the windbox is an orifice
plate which supports the sand bed and allows the
fluidizing air to enter the bed. The orifice plate,
the reactor shell, and the reactor top are lined with
ingulating castables. The shell is also lined with a
super-duty spill-resistant refractory. The outside
of the reactor is covered with mineral-insulating
material. The “hot shell” design minimizes cor-
rrosive effects. Each reactor is capable of incinera-
ting 340 tons/day (308 t/d) sludge cake on a
continuous basis.

Two oil fired overbed burners on each reactor
provide the heat for startup. Once a bed tempera-
ture of about 1200 F (650 C) is attained, the over-
bed burners are no longer used, and prepared
solid waste fuel is pneumatically fed into the
reactor bed area. If the fuel feed is insufficient to
maintain the desired temperature, oil is auto-
matically supplemented. When temperatures ex-
ceed 1600 F (870 C), the freeboard water sprays
are automatically actuated.

Refuse Derived Fuel (RDF) can be conveyed
either from the storage silo or directly from the
solid waste processing train to the surge conveyors
equipped with-levelizers to smooth the flow of
RDF to the pneumatic feeders. The RDF feed rate
is manually controlled by varying the bin outfeed
conveyor speed or the rate of refuse processing as
appropriate. The total heat input to the reactor
may be varied from 65 to 100 percent of its design
rating without using auxiliary fuel.

Sludge is admitted into the top of the reactors
through a cake breaker, dump gates, and a knife
gate. The sludge feed rate is metered and manually
controlled.

Flue gases leaving the reactors enter refractory
lined twin cyclone separators which remove the
larger particulates. Then the gases enter the
45,000 lb/hr (20,400 kg/h) waste heat boilers
where steam is produced at 250 psig (1.7 MPa gage)
saturated. From each boiler the gases then pass
through an air to air heat exchanger, a high energy
venturi scrubber system, the induced draft fan,
back through the cold side of the air to air heat
exchanger, and out the stack. The induced draft
fan maintains the reactor freeboard slightly below
atmospheric pressure.

Both induced draft fans are driven by 600 hp
(450 kW) steam turbines. Smaller turbines are
used for two of the three boiler feedwater pumps
and for one of the three scrubber water pumps.

Ash is removed from the reactors, cyclone dust
collectors and waste heat boilers and is quenched
in ash tanks, thickened, and classified before being
conveyed to ash containers for final disposal in a
landfill.

The various turbines exhaust steam at 5 psig
(30 kPa gage) for use principally in heating hot water heat exchangers which provide space and ventilation air heating for the entire wastewater treatment complex. Excess steam is condensed in excess steam heat exchangers using final effluent as cooling media. Negotiations are underway to sell waste heat energy to the Duluth Transit Authority bus terminal.

One unusual system incorporated into this project is equipment for refuse sterilization. Federal law governs the quarantine and storage of foreign shipboard garbage as well as its final disposal by incineration, sterilization, or grinding into a sewage system. In addition, the State of Minnesota requires refuse to be incinerated within 24 hr of the time it is brought to the incinerator. The small quantity of these wastes make it practical to use excess steam and three 20 cu yd (15 m³) containers to sterilize this material.

CURRENT PROJECT STATUS

As of November, 1979, the wastewater treatment portion of the facility has been in operation for several months. The effluent quality has exceeded both federal and state standards. The solid waste processing facility is essentially completed and has made several short test runs. This is particularly significant in that the plant was able to produce credible RDF, ferrous metals, and non-combustibles from its first load of refuse. Although capacity and other performance tests have yet to be carried out, the equipment seems to be performing well.

The fluidized bed reactor systems have been tested with RDF and sewage sludge. The major difficulties encountered during the startup were the incapability of the RDF feeder to feed design quantities of RDF into the reactor, which limited the quantities of sludge which could be burned without auxiliary fuel; excess carryover of sand into the waste heat boiler; and faulty control wiring and instrumentation.

Preliminary indication is that the fluidized bed reactor system can co-dispose of sludge and RDF without requiring auxiliary fuel. The combustion of sludge and RDF in the reactor appears good and there is no visual trace of air pollution. The startup problems were centered on the ancillary equipment rather than the major components of the system.

Due to increasing concern with shredder explosions, steps have been taken to modify shredders and the roof structure to allow the safe relief of gases without causing major equipment or building damage should an explosion occur in the shredders. Blast mats will be installed around the shredders to protect the operating personnel. Additional explosion suppression systems will be installed to reinforce the safety of the shredding system.

Negotiations are underway to sell the recovered ferrous metals and excess heat produced from the reactor system.

The startup date for the sludge disposal facility represents a significant slippage from the originally scheduled startup date of December, 1978. The primary reason for the slippage is the bankruptcy of the reactor system subcontractor.

CONCLUSION

A fuel price and availability crisis provided the impetus to search out the most technologically and economically feasible system to co-dispose of solid waste and sewage sludge. A fluidized bed reactor co-disposal system was designed and constructed within the available space and budget to fulfill this need.

ACKNOWLEDGMENTS

This project was funded by the United States Environmental Protection Agency, the State of Minnesota, and the Western Lake Superior Sanitary District. The authors wish to thank the WLSSD staff for their aggressive leadership and support of innovation on this project. Thanks are also due to Consoer, Townsend & Associates Ltd. for their support of this paper.

REFERENCES

Key Words
Fluidized Bed
Refuse Derived Fuel
Sludge
Waste Heat