DULUTH CODISPOSAL FACILITY UPDATE

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ABSTRACT

The codisposal plant at the Western Lake Superior Sanitary District wastewater treatment complex in Duluth was completed late in 1979. While the principle of utilizing refuse derived fuel for sewage sludge disposal in fluidized bed reactors was proven sound at that time, it could not be done consistently until the recent completion of several plant modifications. This paper delineates the problems that developed and the plant modifications required to solve the problems.

BACKGROUND

The Western Lake Superior Sanitary District (the District) serves a 500 square mile (1300 km^2) area in northeastern Minnesota that includes the cities of Duluth and Cloquet, Carlton County and southern St. Louis County. The District was created by the Minnesota State Legislature in 1971 to serve the Duluth area and combat water pollution in the St. Louis River and the St. Louis Bay (in Lake Superior). The population in the District is approximately 150,000 with about 70% of the people residing in the Duluth area. While the District's principal mandate was to control water pollution in the area, since enabling legislation was passed in 1974, WLSSD has been given the additional responsibility of solid waste disposal.

The District commissioned a consulting engineering firm to study and design facilities to centralize and upgrade wastewater treatment in 1971. Design of a 44 million gal/day (167,000 m^3/d) central wastewater treatment plant was well under way when the oil embargo of 1973 occurred. The District and their consulting engineers were planning to dry and burn the sewage sludge from the wastewater process in multiple hearth incinerators fired with No. 2 fuel oil. When the embargo caused oil prices to quadruple and the District was faced with a $1,000,000/year fuel bill, the engineers were instructed to find a cheaper, more plentiful fuel. Solid waste in the form of refused-derived fuel was recommended, and the District sought and obtained legislative authority to control the solid waste stream in the area. All of this delayed design and construction of the sludge disposal portion of the project, but the rest of the treatment plant remained on schedule and was completed in 1978. The codisposal portion was designed in 1975 and construction essentially completed by November 1979.

The codisposal system as originally designed and constructed at the plant consisted of two stage refuse shredding with air classification prior to secondary

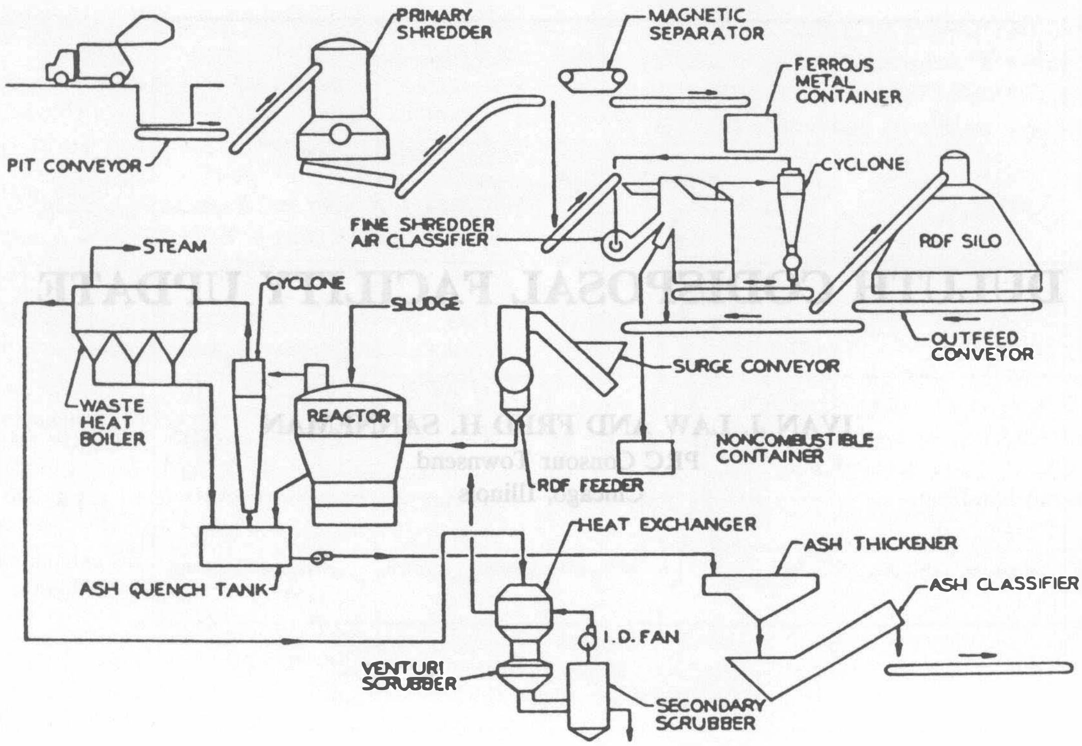


FIG. 1 ORIGINAL PLANT FLOW DIAGRAM

shredding. Two fluidized bed reactors (FBR) were installed for combustion of the shredded refuse and sewage sludge. The sewage sludge is dewatered to a sludge cake with 16–20% solids. Figure 1 is a flow diagram of one of the processing lines as it existed in 1979. There were two processing lines, each with one 30 ton/hr (27t/h) primary shredder. Both lines discharged into the same refuse-derived fuel (RDF) storage silo. The secondary shredders were specified to reduce 95% of the material from the primary shredders to 1½ in. (38 mm) size. Details of this system were presented in papers at the 1980 and 1982 National Waste Processing Conferences [1, 2]. The refuse derived fuel portion of the system is housed in a receiving and shredding building and the fluidized bed reactors and auxiliary equipment in a contiguous reactor building. Space constraints were a serious concern in the original design. During the planning stages for the wastewater treatment plant, space was allocated for the multiple hearth sludge incinerators. The treatment plant construction proceeded without waiting for the change to the RDF and sewage sludge codisposal system. Consequently the incineration and RDF plant had to be constructed in the same area originally allocated for the sludge incinerators alone. This lack of space later proved to be a problem.

Due to bankruptcy of the original fluidized bed reactor vendor during the latter stages of construction, completion, start-up and testing of the codisposal plant was delayed for over a year. Performance tests of the reactors were conducted in June, 1980. While the reactors and air pollution control equipment passed a variety of tests from firing all RDF to firing combinations of RDF, sludge and auxiliary fuel (fuel oil), some problems emerged which made daily operation difficult.

The performance tests required that the following criteria be met for each FBR:

(a) Burn 14.25 tons/hr (12.83 t/h) of sewage sludge with 6.67 tons/hr (6 t/h) of RDF and no auxiliary fuel.

(b) Burn 14.25 tons/hr (12.83 t/h) of sewage sludge with from 1.67 to 3.33 tons/hr (1.5–3.0 t/h) of RDF and fuel oil quantities as needed.

(c) Burn 6.67 tons/hr (6.0 t/h) of RDF alone without auxiliary fuel.

(d) Burn 6.67 tons/hr (6.0 t/h) of RDF with from 7.16 to 10.68 tons/hr (6.44 –9.6 t/h) of sewage sludge.

(e) Limit particulate emissions to 0.03 gr/dscf (0.07g/dscm) of flue gas.

OPERATING PROBLEMS

As with any innovative, first-of-a-kind plant, everyone expected problems to surface when the plant was put into operation. The District Board and staff were aware of this and expected a lengthy shake-down period. The project had qualified for extra funding from the U.S. EPA due to its innovative nature. The main problem areas that did develop were:

(a) material handling
(b) fuel (RDF) feed
(c) sludge feeding
(d) ash removal
(e) slagging

Material Handling

The material handling problems were mainly due to cramming the RDF system into a less than adequate space and a lack of general knowledge of the characteristics of RDF "fluff". The former resulted in many right angle turns at conveyor transfer points which created potential for bridging and spillage. The latter was the result of the material handling engineers and manufacturers being confident that their equipment could handle RDF just as well as they have handled a wide variety of other materials. Those who have helped pioneer the RDF field have now learned that refuse and RDF are like no other material with which they have worked before.

The material handling problems started right at the front end where the live bottom receiving pits discharged at right angles onto the steel pan, inclined shredder infeed conveyors. Even with a "compression feeder" at the transfer point (that obscured the operator's vision), jamming and bridging were common. This carried on to the discharge of the inclined conveyors at the primary shredder inlets where blow-back of the lighter fractions of the refuse creating a mess around the shredder fronts. Shredder windage acted like a fan blowing the material out of the inlet shroud. The air classifier proved very sensitive to the rate of RDF feed and characteristics of the material processed to the point where either considerable combustible material was lost to the heavy fraction or considerable noncombustible material ended up in the RDF.

Problems of this nature followed all the way through to the RDF pneumatic feeders serving the fluidized bed reactors. The rotary air locks would jam with noncombustibles or stringy material such as long rags and bind the rotating elements. Another problem occurred at conveyor transfer points where adequate distance between the tail pulley of the receiving conveyor and the point of transfer had not been provided. This caused material to fall off the end of the receiving conveyors and created a housekeeping problem.

Fuel (RDF) Feed

The FBR's were originally designed with a single 8 in. (0.2 m) port for RDF feed. The equipment was constructed with a port 24 in. (0.61 m) above the top of the active bed and an alternate port just below the surface of the fluidized bed.

Use of the top port resulted in considerable amount of carry over of burning material into the twin cyclones at the reactor outlet and very little, if any, in-bed burning. In a short time the pneumatic feed was reconnected to the lower nozzle. This improved the performance somewhat in that more in-bed burning resulted, but considerable burning was still occurring in the freeboard area and in the twin cyclones.

Sludge Feeding

The original sludge feed method was that used on multiple hearth sludge incinerators. The sludge belt conveyor discharged into a motor driven cake breaker on each reactor roof. The breaker discharged into a counter weighted flop gate. Once a certain weight of sludge was built up in the gate, it would dump into the reactor and return to the closed position to receive another load. This proved inadequate for a couple of reasons. Every time the gate dumped, it upset the negative pressure in the FBR. Also, the batch feed of a clump of sludge into the bed upset combustion conditions, since there was no distribution of the material across the surface of the bed. The drying and burning of the sludge was greatly impeded.

Ash Removal

The FBR's were originally fitted with a wet ash system. This system was designed to handle the excess bed material (sand, noncombustibles and ash) from the FBR's, the cyclone ash and the waste heat boiler ash which were all discharged into a quench tank (one for each combustion train). An agitator was installed in the quench tank to keep the ash in suspension so it could be pumped to an ash thickener. Once thickened, it was to be drained into a screw type ash classifier consisting of a settling tank with an inclined screw for dewatering. The dewatered ash was to be discharged on a belt conveyor for delivery to drop-off containers. It was expected that most of the ash would be removed in the FBR outlet cyclones, but not that it would be so fine that it wouldn't dewater. It merely built up in the ash system as a slurry. It wouldn't settle out or thicken. The coarse bottom ash from the fluidized beds often carried metals and other noncombustibles. When these entered the quench tank, they found their way into the pump suction and clogged it. The ash that did make it to the belt conveyors was still so wet that it would flow onto the floors at each conveyor transfer point.

The wet scrubbers are supplied with final effluent water from the wastewater treatment plant. The scrubber discharge water containing the fine fly ash removed in the scrubbers was, and still is, pumped back to the front end of the sewage plant for treatment.

Slagging

A slagging problem developed in the cyclones on the outlet of the FBR's very early during start-up and testing in 1980. It did not always cause a shutdown, but when it did, it proved a real chore to remove the slag. The downcomer at the ash outlet in the bottom of each cyclone was connected by a 12 in. (0.3 m) diameter, vertical pipe about 20 ft (6.1 m) long directly into the quench tank in the reactor building basement. In these pipes and in the base of each cyclone is where the slag apparently would cool enough to solidify and, if large enough pieces developed, clog up the downcomers. Once these formations developed, they proved very difficult to dislodge, often requiring jack hammers for removal. The operating staff named these formations "moonrock" to describe their texture and density. With bed temperatures of 1400–1600°F (760–870°C) the temperature readings in the cyclones were often over 1900°F (1038°C). This indicated that combustible material was being carried over into the cyclones while it was still burning. Reducing the fluidizing air quantity and lowering the point of fuel feed improved conditions somewhat, but did not eliminate this problem.

INITIAL MODIFICATIONS

During 1980 and 1981, modifications were made to plant equipment and operational procedures to address the main problems. In summary, the plant alterations were as follows:

Material Handling

The collector truck drivers were instructed to dump on the receiving building floor and a front end loader was used to feed the material into the receiving pits. In this manner a more even overburden could be provided on the pit conveyors, thus minimizing pluggage at the transfer point to the inclined shredder feed conveyors. The compactor at the transfer point was removed for improved operator visibility and control. Hoods and shrouds were revised at other conveyor transfer points to minimize bridging and plugging. Numerous access doors were installed to allow inspection and to facilitate the removal of a stoppage when it did occur. The primary shredder direction of rotation was reversed to change the air flow direction at the shredder inlet, which greatly reduced the blowout of refuse.

Fuel (RDF) Feed

The pneumatic fuel feed pipe to each FBR was lowered twice more, finally ending up about 12 in. (0.3 m) above the orifice plate at the bottom of the bed.

Sludge Feeding

The original sludge feed system at the top of each FBR was removed. The sludge belt conveyor from the sludge filter presses to the Reactor Building was replaced with a flexible wall, troughed type conveyor for better control of the sludge cake and the water draining off of it. Two progressive cavity type sludge pumps were installed with rotary feeders on the inlet side where the sludge discharges from the conveyor. The pump discharge piping was run to and through the top of each reactor. The ends of the pipes, inside the reactors, were each fitted with a flared cone at the end. Small diameter, high pressure steam piping was installed concentrically inside the cones and fitted at the sludge discharge point with high pressure steam atomizing nozzles. This sprays the sludge in a wide pattern as it enters the reactor and gives good distribution over the fluidized bed. The pumps and piping are interconnected so each pump can feed sludge to either reactor.

Ash Removal

The system was, except for the scrubber water and ash, converted into a dry system. The scrubber water is still piped to the front end of the wastewater treatment plant for processing as a liquid waste. The ash from the twin cyclones and the waste heat boilers is now discharged into screw type coolers (one cooler for each cyclone—a total of four). The coolers are screw conveyors with water jacketed housings and hollow flights through which cooling water is circulated on a once through basis. Protected water from the treatment plant is used for cooling. The ash is cooled to 200–250°F (93–121°C) or lower, depending on the ash production rate, and then transferred by enclosed screw conveyors (for dust control) to drop boxes. The drop boxes had to be fitted with covers and shrouds to control dust as it is discharged into the boxes. The boiler ash is handled via a pneumatic system utilizing a steam ejector for the vacuum source. The original wet ash system had a wet cyclone and air washer for separating the transport air and the ash. The ash and wash water were discharged to the ash quench tank. With the change to a dry ash system, the boiler ash is now discharged to a dry cyclone and then to one of the screw coolers while the air is discharged through a bag filter for particulate control.

The bed sand and bottom ash from the FBR's is now handled by a manually operated system. Since the quantities are low and the period of removal infrequent, it was decided to install a monorail and motorized foundry bucket system to transport the sand and ash from the FBR's to a concrete storage slab outside the building. When the bed depth grows to the maximum recommended height and becomes difficult to fluidize, sand, ash and accumulated noncombustibles are withdrawn to bring it back to the proper level.

Slagging

Despite efforts to improve combustion conditions, the slagging problem persisted. Attempts were made to improve the quality of the RDF by fine tuning the air classifier without any great success. The lowering of the RDF feed port in the FBR's was intended to reduce carryover of burning fuel into the cyclones by providing longer fuel retention time in the bed. This was not the solution. Finally water sprays were installed at the inlet of the cyclones to lower the temperature of the flue gas and suspended material so burning would not continue inside the cyclones. This stop-gap measure did work, but it had the disadvantage of reducing the steam capacity of the boilers. Heat lost in evaporating the water is lost for steam generation. With a heavy load on either of the processing lines, the steam capacity would be reduced to the point where the auxiliary oil fired boiler would have to be operated, along with the waste heat boiler to produce sufficient steam to drive the plant auxiliary equipment and, in the winter, heat the buildings.

THE EXPLOSION HAZARD

At the time the codisposal plant was designed, it was becoming evident that explosions taking place in the shredding process could be a serious problem. The state of the art approach was to install explosion suppression systems in the shredders, relying on them to snuff out any explosive action before it caused significant damage. The shredders were fitted with this equipment under the original construction contract. However, during plant completion and start-up, it became known that explosions could still occur even though the suppression system was in place and armed. This created a growing concern among all involved with operation of the plant. Consequently, it was decided to "harden" the plant as part of the previously discussed modifications to the system.

The plant was hardened by installing:

(a) two 42 in. (1.07 m) diameter vent pipes from each shredder through the roof

(b) armor plate on the walls of the control room (which was between and in front of the primary shredders); windows were removed and replaced with plate

(c) combustible gas detection and alarm systems

(d) slotted conveyor belt partitions (blast walls) around the primary conveyors

(e) blowout skylights in the shredder room roof

Rules were formulated for the operating personnel to protect them in the event of an explosion. They were not allowed in the shredder enclosures during operation. Fortunately the safety program was finished while the other plant modifications were being completed. It wasn't too long after restarting the plant that the safety measures proved their worth. On July 15, 1982, an explosion, with an estimated force of 5 lb of TNT, occurred in a primary shredder!

BLAST EFFECTS

The damage to the shredding building structure, equipment, and personnel was extensive, but not devastating. No one was hurt. The shredder venting and roof skylights released the pressure to the outside effectively, but not without damage to the more frangible items such as sheet metal ducts, small piping, nearby conveyors, conveyor shrouds, light fixtures, etc. There was a fireball, but no residual fires started. The armored wall of the control room moved about one inch, but held up. Numerous concrete blocks in the building walls were cracked, but not destroyed. All in all, the plant hardening was successful, but the blast made everyone aware that it would be very difficult to completely eliminate the explosion hazard.

POST BLAST ACTIVITIES

The shredding plant was insured, and as a result the District was compensated for repairing the blast damage. While repairing the plant, it was decided to take further steps to make the plant more blast resistant. A third 42 in. (1.07 m) vent was added to each shredder, connecting to the inlet shroud and extending through the roof. More blowout skylights were added and the control room walls further reinforced. The District also embarked on some long range planning as well as planning for immediate, short range plant modifications. For the short range, they decided to relocate the pit conveyors, install them on the tipping floor, and turn them 90 deg. to line up directly with the inclined shredder feed conveyors. The plan was to feed the end of the relocated, horizontal conveyors from the tipping floor with front end loaders and station "human pickers" along the side of the conveyor to look for potentially explosive materials. A system for detecting combustible gases was also installed in the picking area.

The long range plan was to accept the fact that the possibility of explosions would always be present and arrange to isolate the shredding process from the rest of the plant and the operating personnel.

INTERIM OPERATIONS

The rehabilitation of the plant after the 1982 explosion put the plant out of operation until late 1983. Throughout the various plant outages, the District would send the solid waste directly to their landfill and, in the summer, supply the sewage sludge to farmers for land application. The latter was difficult to do during the harsh Minnesota winters, so the District looked for another "cheap" fuel to use for sludge incineration when the RDF plant was not in production. They found they could obtain wood chips from the local lumber industry for about \$2.00/million Btu's (1055 MJ). This compares very favorably with fuel oil prices of about \$7.00/million Btu's in the area. With some front end modification to accommodate the transfer of the chips to the RDF storage bin, it was discovered that wood chips could be used as a fuel to incinerate the sludge in the FBR's without any slagging! Also, and more important, there was no danger of shredder explosions. The chips are delivered to the plant site in a size small enough to permit transport through the pneumatic fuel feed system. Even though the RDF plant was hardened further after the 1982 blast, none of the operating personnel wanted to work in the same building with the shredders. Consequently, for the 1983 and 1984 winters the District operated very comfortably on wood chips and probably would have stayed with this mode of operation permanently if not for one thing; the frustrating, and now commonplace problem, of siting a new landfill.

The existing WLSSD landfill has been frequently used to bypass the RDF plant during the past 5 years. Therefore, the available life has been used up much faster than predicted. This forced the District to start seeking a new landfill site. The well known "NIMBY" (Not In My Backyard) syndrome quickly developed. This motivated the District to move forward with their long range planning for the RDF plant.

1984 MODIFICATION PROGRAM

Early in 1984, the District took bids on contracts to make further modifications to the RDF and FBR systems. The revisions to the FBR system were to be relatively minor, but major changes were planned for the RDF system. This work was awarded to Rader Companies, Inc. a division of Beloit Corporation on a total system responsibility basis. It was essentially completed by June 1, 1985. Figure 2 shows the modified shredding system and Fig. 3 the modified FBR system. The key elements of work were:

(a) Remove all four existing shredders from the receiving and shredding building (Building No. 11).

(b) Remove the existing air classifiers.

(c) Install one new shredder in a separate building.

(d) Provide the new shredder building with blow-off wall and roof panels. Install shredder vents.

(e) Install a primary and a sizing disc screen.

(f) Install new conveyors as needed to accomplish the major equipment changes, while reusing the existing conveyors as much as possible.

(g) Revise the RDF pneumatic fuel feed system to the FBR's to allow quick change over from RDF to wood chip feed and vice versa.

(h) Provide four fuel feed ports in each FBR instead of one.

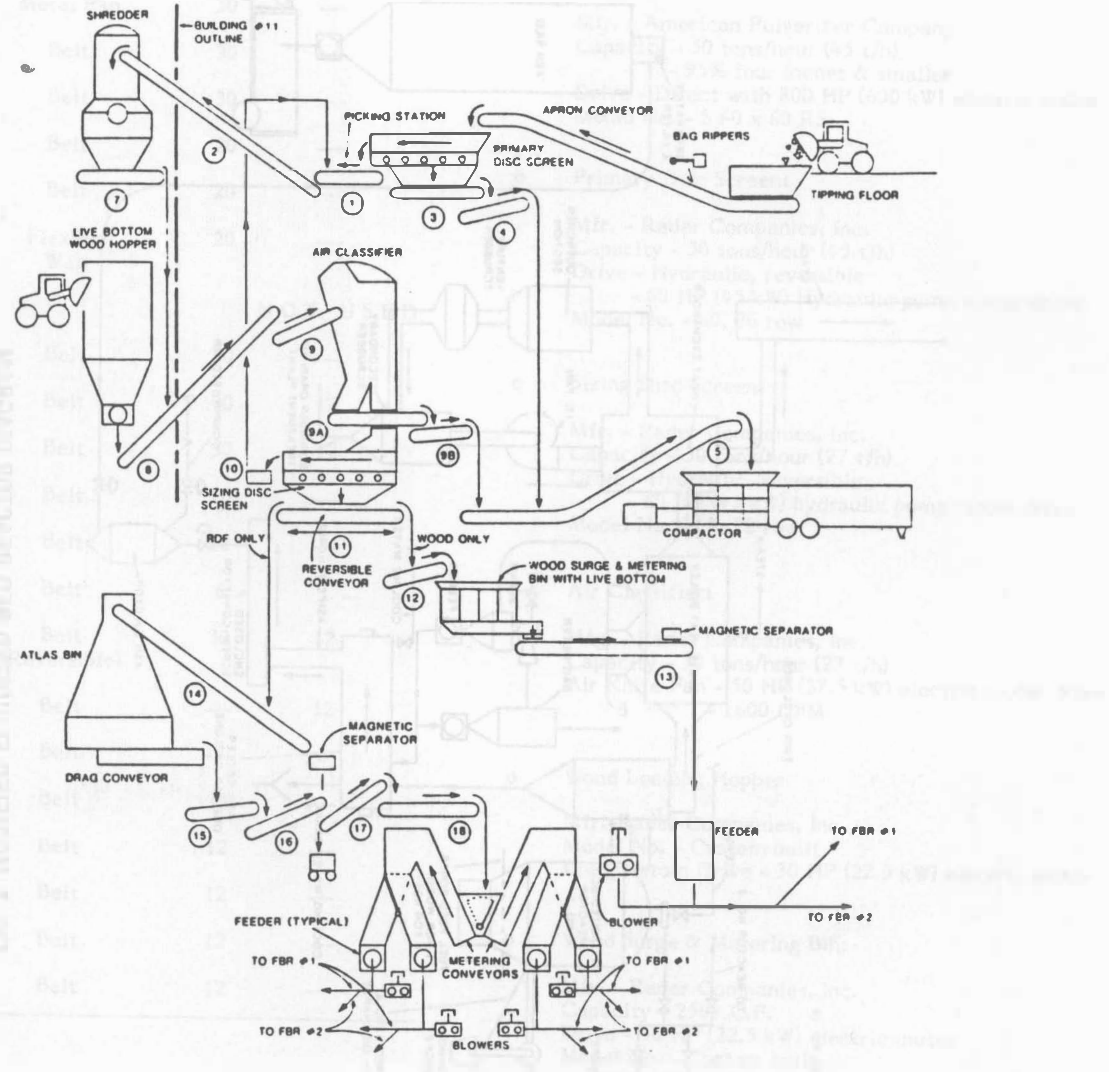


FIG. 2 MODIFIED RDF SYSTEM DIAGRAM

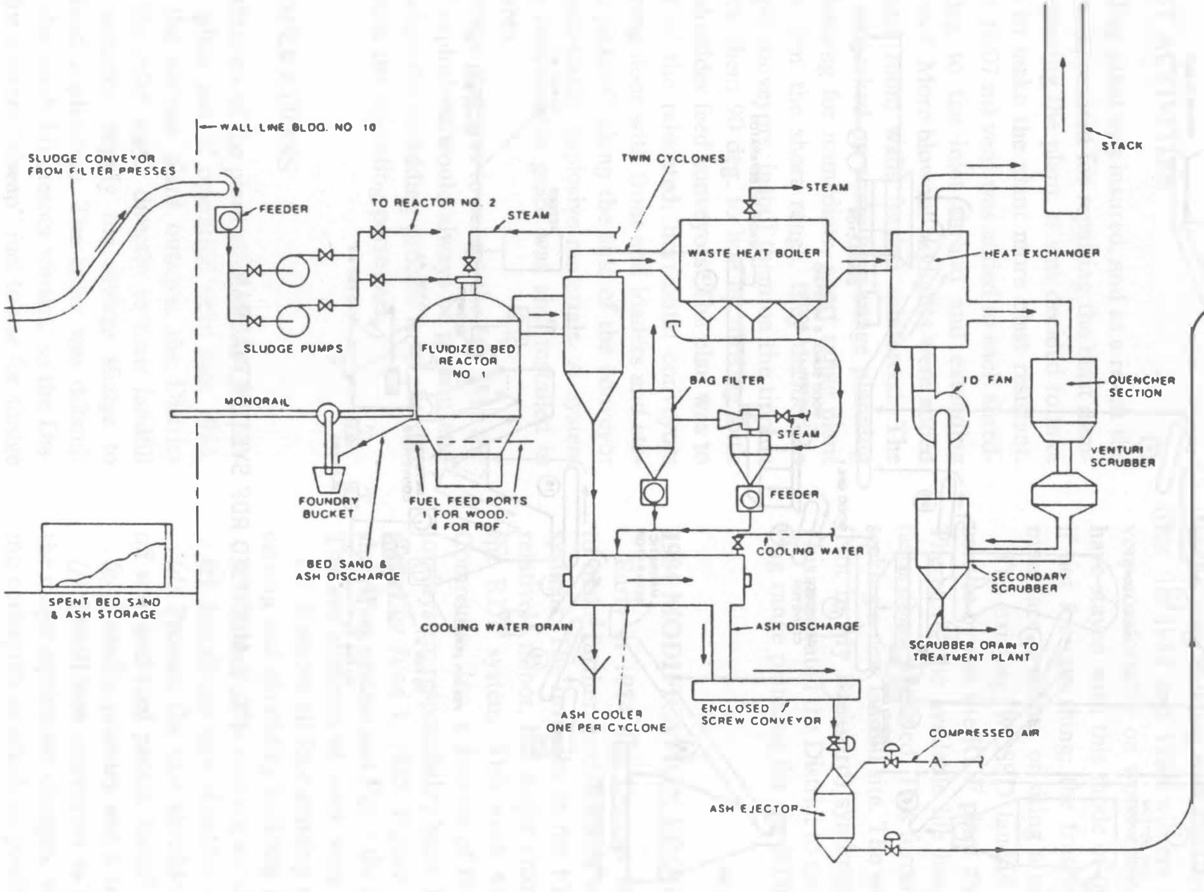


FIG. 3 MODIFIED FLUIDIZED BED REACTOR DIAGRAM

TABLE 1 CONVEYOR SCHEDULE

DESIGNATION	CONVEYOR TYPE	CAPACITY	TPH
		REFUSE	WOOD
APRON	Metal Pan	50	---
(1)	Belt	30	---
(2)	Belt	30	---
(3)	Belt	20	---
(4)	Belt	20	---
(5)	Flexible Wall	20	---
(6)		NOT USED	
(7)	Belt	30	---
(8)	Belt	30	12
(9)	Belt	30	12
(9A)	Belt	10	---
(9B)	Belt	10	---
(10)	Belt	6	1
(11)	Belt (Reversible)	30	12
(12)	Belt	---	12
(13)	Belt	---	6
(14)	Belt	30	---
(15)	Belt	12	---
(16)	Belt	12	---
(17)	Belt	12	---
(18)	Belt	12	---

TABLE 2 MAJOR EQUIPMENT

1984 MODIFICATIONS

- Shredder:

  Mfr. - American Pulverizer Company
  Capacity - 50 tons/hour (45 t/h)
  - 95% four inches & smaller
  Drive - Direct with 800 HP (600 kW) electric motor
  Model No. - S 60 x 60 RS

- Primary Disc Screen:

  Mfr. - Rader Companies, Inc.
  Capacity - 50 tons/hour (45 t/h)
  Drive - Hydraulic, reversible
  - 60 HP (45 kW) Hydraulic pump motor drive
  Model No. - 60, 26 row

- Sizing Disc Screen:

  Mfr. - Rader Companies, inc.
  Capacity - 30 tons/hour (27 t/h)
  Drive - Hydraulic, reversible
  - 60 HP (45 kW) hydraulic pump motor drive
  Model No. - 60, 22 row

- Air Classifier:

  Mfg. - Rader Companies, Inc.
  Capacity - 30 tons/hour (27 t/h)
  Air Knife Fan - 50 HP (37.5 kW) electric motor drive
  - 1600 CFM

- Wood Loading Hopper

  Mfr.-Rader Companies, Inc.
  Model No. - Custom built
  Live Bottom Drive - 30 HP (22.5 kW) electric motor

- Wood Surge & Metering Bin:

  Mfr. - Rader Companies, Inc.
  Capacity - 2500 C.F.
  Drive - 30 HP (22.5 kW) electric motor
  Model No. - Custom built

- Wood Chip Pneumatic Transport System:

  Mfr. - Rader Companies, Inc.
  Capacity - 6 tons/hour (5.4 t/h)
  Drive - 75 HP (56.3 kW) electric motor
  Blower - MAC No. 12015, TUMP
  Air Lock - Rader 20X30ESW

- RDF Pneumatic Transport System:

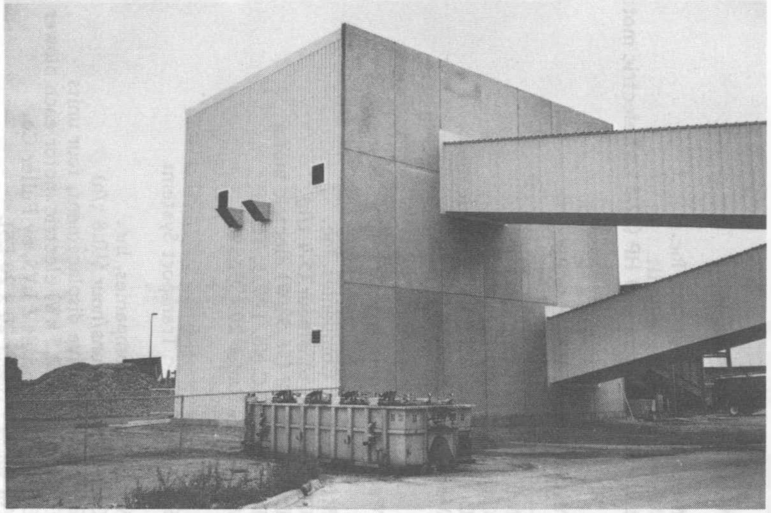
  Mfr. - Rader Companies, Inc.
  Capacity - 12 tons/hour (10.8 t/h)
  Blowers - Positive displacement, four units
  Drive 30 HP (22.5 kW) electric motor each blower
  Blowers - Sutorbilt 7 LVS, by Fuller Co.
  Air locks - Rader 20 x 20 ESL

(i) Provide wood chip storage separate from the RDF storage bin.

(j) Revise the dust control system to serve the new equipment and conveying system.

(k) Revise the system controls as necessary to provide electrical interlocks between the various items of equipment in the revised RDF system.

There were other changes, some of which the District performed with their own personnel. For example, they installed an overfire air system on each FBR to enhance combustion efficiencies and reduce the carry over of burning material into the cyclone ash separators. This was done by diverting some air from the existing fluidizing air supply system. They have also

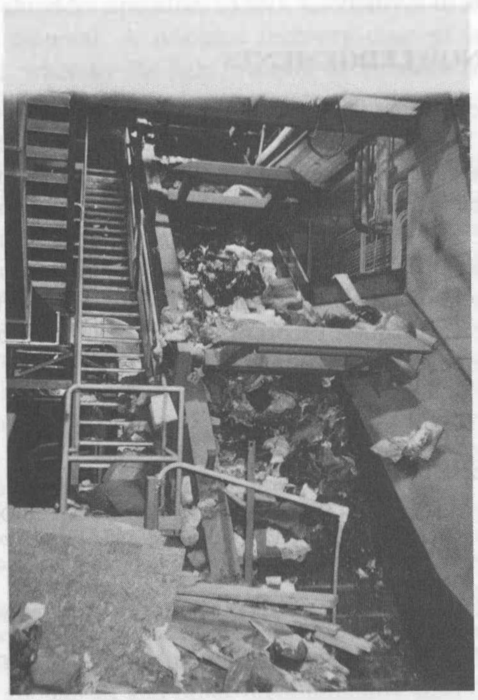


NEW SHREDDER BUILDING AND CONVEYORS #2 AND #8

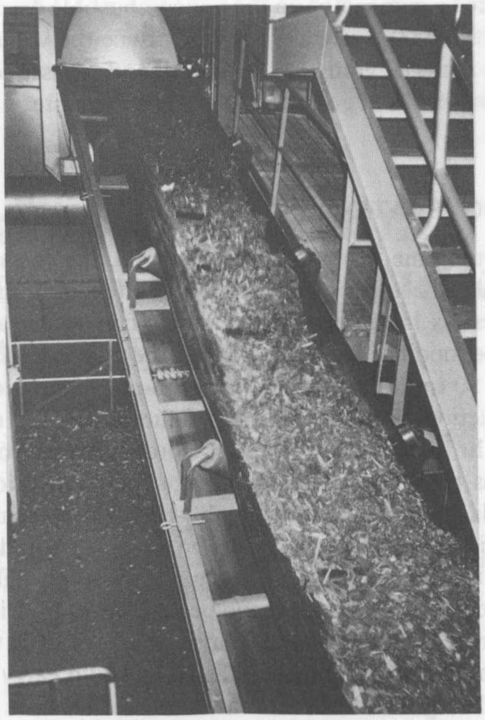
LIVE BOTTOM WOOD CHIP HOPPER

PRIMARY DISC SCREEN AND PICKING STATION

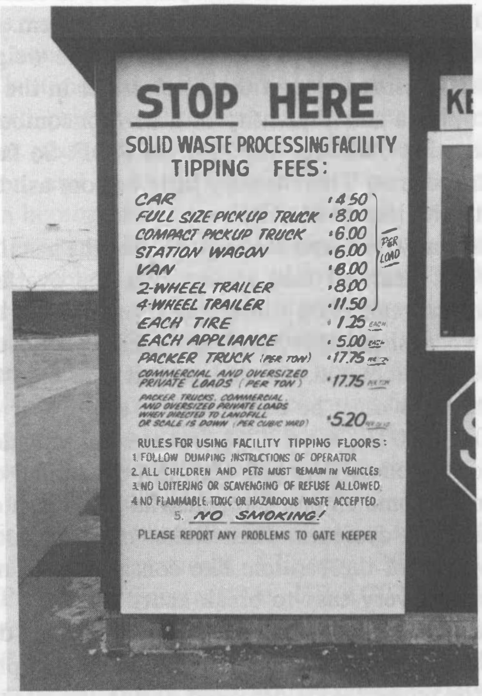
PRIMARY SCREEN REJECTS ON CONV. #5



APRON CONVEYOR WITH BAG RIPPERS



WOOD CHIPS ON CONVEYOR #12



STOP HERE

SOLID WASTE PROCESSING FACILITY
TIPPING FEES:

CAR	$4.50	PER LOAD
FULL SIZE PICKUP TRUCK	$8.00	
COMPACT PICKUP TRUCK	$6.00	
STATION WAGON	$6.00	
VAN	$8.00	
2-WHEEL TRAILER	$8.00	
4-WHEEL TRAILER	$11.50	
EACH TIRE	$1.25	EACH
EACH APPLIANCE	$5.00	EACH
PACKER TRUCK (PER TON)	$17.75	PER TON
COMMERCIAL AND OVERSIZED PRIVATE LOADS (PER TON)	$17.75	PER TON
PACKER TRUCKS, COMMERCIAL, AND OVERSIZED PRIVATE LOADS WHEN DIRECTED TO LANDFILL OR SCALE IS DOWN (PER CUBIC YARD)	$5.20	PER CU YD

RULES FOR USING FACILITY TIPPING FLOORS:
1. FOLLOW DUMPING INSTRUCTIONS OF OPERATOR
2. ALL CHILDREN AND PETS MUST REMAIN IN VEHICLES
3. NO LOITERING OR SCAVENGING OF REFUSE ALLOWED
4. NO FLAMMABLE, TOXIC OR HAZARDOUS WASTE ACCEPTED
5. NO SMOKING!

PLEASE REPORT ANY PROBLEMS TO GATE KEEPER

CURRENT DISPOSAL RATES

installed a compactor on the noncombustible discharge from the RDF system. This will reduce the volume of reject material going to the landfill and, consequently, the number of truck trips to the disposal site.

1985 OPERATING RESULTS

At the time this paper was prepared, the codisposal plant has been back in service only a few months, but the results have been encouraging. The specifications for the modifications require that the contractor guarantee 50 tons/hr (45 t/h) through-put of raw refuse. Production has exceeded this figure and runs of 70 tons/hr (63.0 t/h) have been recorded. The important item is the effect on the quality of the RDF. Most of the glass (and other noncombustibles) are separated out via the primary disc screen prior to shredding. With the original system, the glass went through the shredder, was pulverized, and became embedded in the shredded material. The air classifier was of little value in removing the glass since the glass would carry over with the light fraction into the combustibles. The presence of glass in the shredder and in the pneumatic RDF feed system caused considerable wear. It is anticipated that this wear problem will be greatly reduced.

Another effect of more efficient glass removal is the reduction of FBR bottom ash. This used to run about 0.45 tons/hr (0.4 t/h) with the original system. It was estimated that this was about equal to the weight of the glass passing through the air classifier in the RDF stream plus a small quantity of other noncombustible material that made its way into the RDF. So far this has proved true. There is very little bottom ash buildup with the improved RDF.

The removal of most of the glass, plus the installation of a four quadrant feed system and the overfire air system, has enhanced the combustion process to the point where slagging (when firing RDF) in the cyclones has been eliminated. Of course bed and free board temperatures must be controlled in the proper range of 1400–1600°F (760–870°C), but the only incident of slag formation to date has been the occasional development of some clinker-like material at the ash outlet of one of the cyclones. This clinker material does not display any of the ceramic like consistency of moonrock and is very easy to break apart.

The plant personnel have has been shredding during one shift per week day and have been able to process all of the refuse that is delivered during the week. The refuse deliveries run as high as 350 tons/day (315 t/d) on Mondays and fall off to 150 tons/day (136 t/d) or so during midweek. The revised system has been run interchangeably on RDF and wood chips without interrupting the sludge burning process. The District is currently negotiating to take in additional refuse from the surrounding area.

CAPITAL COSTS

The capital expenditures for the Co-Disposal Plant have been as follows:

Original Construction Costs	$20,000,000	(1977 dollars)
1980–81 Modifications	$ 1,500,000	(1980 dollars)
1984–85 Modifications	$ 4,500,000	(1984 dollars)
Total Capital Expenditure	$26,000,000	

CONCLUSION

The principal of utilizing RDF as a fuel to dispose of wet sewage sludge in a fluidized bed reactor without auxiliary fuel (except for warming up the bed) was established when the Duluth Co-Disposal Plant was completed and tested in 1980. However, persistent operating and safety problems and a serious shredder explosion have prevented reliable plant performance. Now that a number of plant modifications have been completed, it appears that the plant is capable of day to day operation at the required production rate.

ACKNOWLEDGEMENTS

The authors wish to thank the staff of the Western Lake Superior Sanitary District for their tenacity and perseverance in working to overcome the numerous obstacles that developed on the way to putting the plant into successful operation. Since the District is the owner and operator of the plant, it could not succeed without their dedication. We also want to thank Rader Companies, Incorporated for their contribution to the development of this paper.

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Key Words: Classification; Codisposal; Combustion; Disposal; Fluidized Bed; Incineration; Refuse Derived Fuel; Shredding; Sludge