

THE WINNEBAGO COUNTY, WISCONSIN STORY ...

PAPERMILL SLUDGE RECYCLING AND ENERGY PRODUCTION SYSTEM

by
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PROJECT IMPLEMENTATION BACKGROUND

Introduction

Winnebago County, Wisconsin (County), has long been aware of the need to protect the environment and also the need to provide a comprehensive, cost-effective solid waste management program for County residents, businesses, and industries. Winnebago County has a population of 146,000. The County population is forecasted to increase to 151,000 by the Year 2000 and to 157,000 by the Year 2010. Most of the Solid Waste in Winnebago County is disposed of in the County Landfill.

The County has continually sponsored efforts to minimize landfill use by considering the implementation of alternative waste management techniques to handle industrial nonhazardous wastes, papermill sludge, and/or municipal solid waste (MSW) generated in the County. Historically, most of the County's MSW was disposed in the County operated landfill. The actual quantity of Solid Waste generated in Winnebago County and being disposed at the Landfill (including MSW and papermill sludge but excluding foundry sand and auto shredder fluff) was approximately 300,000 tons annually. Residential recyclables and yard waste are managed at the County's Materials Recovery Facility (MRF) and yard waste processing equipment, respectively.

In 1987, the Winnebago County Solid Waste Management Board (Board) retained the services of Gershman, Brickner & Bratton, Inc. (GBB), a solid waste management consultant, to assist with solid waste planning activities. Working for several years in association with Mr. Leonard Leverence, Solid Waste Director for the County, the efforts-to-date have included a series of planning level workshop reports identifying and quantifying waste streams and technology options, as well as the implementation of a 3 Megawatt landfill gas (LFG) turbine project, MRF expansion, and the Minergy Project discussed herein.

Project Implementation Background

In 1992, the landfill received approximately 146,000 wet tons of papermill sludge (approximately 68,000 dry tons) in addition to receiving approximately 147,000 tons of residential, commercial, and nonhazardous industrial waste. Of the total papermill sludge delivered, approximately 25,200 wet tons (26 percent) were co-disposed with Solid Waste at a ratio of four parts Solid Waste to one part papermill sludge. In 1992, the remaining papermill sludge (approximately 100,000 wet tons) was landfilled in dedicated sludge cells. However, there are certain problems with landfilling papermill sludge, which include instability (because of the high

moisture content) and the clay content of the sludge tended to plug the LFG collection system.

The planning activities completed by GBB determined that there was private sector interest in pursuing alternative management techniques for the processing of all or segments of the County's solid waste stream. In order to pursue the development of these opportunities, on October 25, 1993 the Board issued a Business Opportunity Notice/Request for Qualifications (BON/RFQ) for the siting, design, construction, and operation of a waste management Facility in the County. GBB issued a Contractor's Evaluation Report on the eleven firms that responded to the BON/RFQ on January 31, 1994. The Board took formal action on GBB's recommendation and shortlisted the following three firms on March 17, 1994:

Foster Wheeler Power Systems, Inc.;
Wheelabrator-Frye; and
Wisconsin Electric Power Company.

Due to the myriad of interest and technical data compiled by GBB dealing with both MSW and papermill sludge management, the Board decided that the best interests of the County were served by continuing the formal solicitation process. This process served to consolidate the Board's review and provide due consideration of private sector business interest in such a project.

Each prospective proposer was requested to propose a technical approach which, based on their experience, best extended landfill life for the disposal of Winnebago County solid waste and provided flexibility and reliability. The County announced it would consider Proposals that maximized the use of the existing Sunnyview Landfill, if it could be done in an economically viable and environmentally safe way. *Note: For purposes of the RFP, the Board determined that a maximum equivalent tipping fee of \$40/ton would be considered "economically viable" versus the County landfill, and this figure was included in the RFP.*

The Board determined that the purpose and goals of implementing the Facility were as follows:

Reduce the County's long-term dependence on landfill disposal;

Provide local industries with a cost-effective alternative for managing solid waste, particularly papermill sludge;

Provide the County with a more comprehensive and integrated approach to Solid Waste management;

Provide a solid waste management system that will be economical and operate efficiently and reliably for at least a 20-year period; and

Provide a solid waste management facility(ies) that could be expanded to meet the residential, commercial and industrial sectors solid waste generation growth.

The Contractor was to be responsible for the following, among others:

- Designing the facility in accordance with the specified criteria;
- Providing the real property for the facility site;
- Securing all necessary state and local permits and approvals for the construction and operation of the facility;
- Securing all product markets agreements, including all materials products and/or energy products, as applicable;
- Financing the facility, unless other financing arrangements are worked out with the County;
- Constructing any steam and/or electricity transmission line with interconnection to customers, if required;
- Constructing the facility electrical on-site and off-site utility's interconnection, as required;
- Operating of the facility in accordance with applicable law and provisions agreed to between the Contractor and the Board; and
- Delivering of all Bypassed Waste or facility Residue requiring landfilling to the County Landfill.

The County issued the final RFP on Thursday, May 19, 1994 and the selection of the "Preferred Contractor" was made in September 1994.

In the State of Wisconsin, papermills are only required to submit new sludge test data to landfills during development of new landfill areas or if major changes in papermill operations affect sludge content. Therefore, it was strongly suggested to the proposers considering a papermill sludge-based project that then current (company specific) test data be obtained directly by any Contractor interested in proposing a process utilizing papermill sludge.

As noted above, and to eliminate one of the private-sector project risks, the RFP indicated that the Contractor would not be responsible for providing landfill disposal capacity for normal Bypassed Waste or Facility Residues. It was decided that the Board would provide for these disposal needs at the County Landfill and negotiate the terms and conditions as part of the project agreements.

From a field that started with "interest" expressed by several dozen firms, the Board endorsed Minergy's glass aggregate technology and chose Minergy to build the plant as their preferred alternative to landfilling paper sludge.

Corporate/Project Overview

Minergy Corporation is a subsidiary of Wisconsin Energy Corporation, a large holding company with utility and industrial assets of over \$5 billion. Minergy Corporation has developed and implemented several new technologies for the recycling of such high volume wastes as sludge, ash, and foundry sand. These technologies perform mineral recovery from the waste material, converting them into construction material and industrial feedstocks, which are inert, marketable products.

The Glass Aggregate technology is a mineral recovery process, which melts the mineral content of sludge, using a high temperature furnace. Glass aggregate is a glass-like material used for sandblasting grit, roofing shingle granules and asphalt paving. This technology is one of several that Minergy has developed and has implemented on commercial scale projects. The glass aggregate technology contains a significant energy-efficient feature in that heat energy generated in the melting process may be recovered to produce steam for process use or, if desired, to generate electricity.

Minergy Corporation has developed the world's first facility, in Neenah, Wisconsin, to recycle sludge from wastewater treatment systems located at area paper mills, into an environmentally benign glass aggregate product. The Fox Valley Glass Aggregate Plant receives and processes over 1,000 tons per day (350,000 tons per year on an as-received basis) of sludge from eight area paper mills. Energy from the process is recovered and converted into steam, which is sold to the P.H. Glatfelter Co., a local paper mill. (As an alternative to steam, the technology also is capable of producing electricity.) Markets for the glass aggregate that is produced at the \$45 million plant are large and include uses in sandblasting grit, roofing shingles, asphalt and chip seal aggregate, and decorative landscaping.

GLASS AGGREGATE TECHNOLOGY

The glass aggregate technology converts sludge into a glass aggregate product. Sludge plays two beneficial roles when it is processed in Minergy's process. First, the organic component of the sludge provides a significant portion of the energy required. These organics are essentially a biomass fuel that is renewable through the cycle of water use and wastewater treatment. Secondly, the mineral content (ash, clays, and mineral fillers) found in the sludge are put to beneficial use as the minerals required to produce the product. The markets for this industrial material include sandblasting grit, abrasives, roofing shingle granules, and asphalt aggregate. Minergy's Fox Valley Glass Aggregate Plant, located in Neenah, Wisconsin, is the world's first installation to vitrify sludge into glass aggregate.

Fox Valley Glass Aggregate Plant Technical Description

The Fox Valley Glass Aggregate Plant is designed to receive and process up to 1300 tons per day (450,000 tons per year on an as-received basis) of paper mill sludge with a moisture content of up to 60%. The facility design parameters are as follows:

Process up to 1300 tons per day of 60% moisture content paper mill sludge.

Generate up to 235,000 pph of steam, initially at 350 psig/ 575°F.

Export up to 165,000 pph of steam to a steam host 2500 feet away.

Conversion of over 80% of the mineral component of sludge into glass aggregate product.
Extremely low noise and odor affecting neighboring properties.
High operating thermal efficiency to reduce operating cost.

Construction on the Fox Valley Glass Aggregate Facility was begun in July 1996. Boil-out was performed on approximately December 1, 1997. Start-up and initial operation was commenced shortly after January 1, 1998. Beneficial operation defined as firing the unit on sludge producing steam was attained on March 15, 1998. Commercial operation of the facility was attained on May 21, 1998.

The operations of this complex facility can be sub-divided into six (6) major categories, which are as follows:

- Sludge material handling and storage
- Sludge drying and waste water recovery
- Dry sludge firing
- Steam production and distribution
- Glass aggregate processing
- Emissions controls

Each of these areas presented unique challenges of a first-of-a-kind facility. The site itself created several challenges that had to be overcome in both the design and construction phases. The entire facility had to be located on a nominal 4-acre site with an elongated "L" shape geometry. The site is a closed sludge landfill, so the piling and foundation work required careful management of excavated materials to make sure no landfilled material was removed from the site and potential runoff contained during construction. All excavated materials were replaced as backfill under the facility foundations and roadways. A methane gas collection, monitoring, and alarm system was designed and installed beneath the foundations of all occupied buildings.

Sludge Material Handling and Storage

Wet sludge is transported to the facility in large tandem self-dumping trailers. Two truck scales at the plant entrance allow actual sludge deliveries to be measured by weighing trucks entering and exiting the facility. The sludge is dumped in a receiving building either onto a tipping floor or directly into a live bottom pit. From this pit, wet sludge is transported using mechanical conveyors into a 2600 wet ton capacity storage silo.

The sludge is reclaimed at the bottom of the wet storage silo using a live bottom sweep auger that discharges onto a series of screw and belt conveyors to transport the wet sludge to the drying system. The feed rate of the wet sludge storage silo discharge auger is controlled by dryer outlet moisture. The sludge feed to the dryers must be equally divided to provide equal loading to the two (2) rotary steam tube dryers. The sludge handling system was provided with the capability to transport sludge directly from the receiving building unloading pit to the dryers bypassing the wet sludge storage silo. However, operating experience has shown that when feeding the dryers directly from the silo reclaimer, a more consistent and homogeneous moisture content in the sludge feedstock to the dryer can be maintained resulting in smoother dryer operation, more consistent dry sludge moisture content, and ultimately, better cyclone furnace operation.

From the dryers, sludge is again mechanically conveyed through a series of screws and belts to the dry sludge storage silo. This silo has approximately 8 hours storage at full rated capacity. Being a first-of-a-kind design and installation, a pelletizing system was installed between the dryers and the dry sludge storage silo. Any quantity of the dry sludge stream from the dryers to the silo can be pelletized. The pelletizing option was installed in order to allow sizing flexibility in the sludge stream to the cyclone furnaces. The concerns focused primarily on the inability to control excessive small particle sizing and subsequent potential ash and unburned carbon carryover.

Sludge Drying and Waste Water Recovery

In the initial conceptual design stage, a cascade drying system was to be used that would utilize the sensible heat in the exhaust flue gas to dry the sludge. However, due to the nature and location of the facility, Minergy chose to permit the facility with essentially zero VOC emissions. Subsequently, a closed loop drying system was required that would allow recovery of the water vapor from the wet sludge driven off in the dryers. This water vapor is condensed in a packed tower wet scrubber while the remaining non-condensable gases are directed to the secondary air fan inlet making up combustion air to the cyclone furnaces. Therefore, all potential VOC emissions generated in the drying process are introduced into the high temperature cyclone furnace to ensure destruction.

In order to maximize the facility thermal efficiency, steam is used for sludge drying. The facility has two (2) 85' long, rotary steam tube dryers which are designed to dry 1300 tons per day of 60% moisture sludge down to 20% moisture. An initial visit to a previous sludge drying installation revealed that at these high moistures, particularly when high clay content sludge is being dried, the steam dryer tubes have a tendency to foul requiring periodic shutdown and water washing. The dryer system was designed with future dry sludge recycle capability to reduce the propensity for fouling. Operating experience has revealed that the dryers do not foul to the point of requiring periodic shutdown for cleaning. However, downstream firing operations were initially hampered due to the periodic shedding of dry sludge build-up from the tubes. A retrofit installation of a rotary disc screen has essentially corrected this problem.

The dryer system is designed to remove 1.3 million pounds per day of water from the wet sludge stream. The challenge with the closed loop drying system design focused around condensing this water from the saturated vapor stream while simultaneously avoiding fouling of the heat exchanger due to particulate carryover. The final design includes a wet scrubber that condenses all the water vapor from the dryer air closed loop and simultaneously removes the majority of any fine particulate that would potentially foul downstream equipment. The wastewater recovered from the sludge in the dryer system is discharged as a scrubber/condenser bleed stream to the local municipal wastewater treatment plant. Pumps, heat exchangers, and a cooling tower are used to reject the excess heat absorbed by the scrubber water utilizing separate closed loop systems.

Dry Sludge Firing

From the dry sludge storage silo, a system of screws and mechanical conveyors transports the dry sludge to a dry sludge feed bin. This feed bin is a live bottom storage design with approximately one-hour capacity of dry sludge storage. This bin is equipped with eight (8) screws

each controlled by individual variable speed drives. The dry sludge discharge of each screw goes through a rotary valve and is discharged into eight (8) separate pneumatic transport lines which convey dry sludge to the cyclone secant ports. Each transport line has its own mechanical blower which promotes self-cleaning if line pluggage starts to form.

The boiler is equipped with two (2) 7-foot diameter, cyclone furnaces in which the dry sludge is co-fired with natural gas. These cyclone furnaces are a variation of older coal fired cyclone technology as developed and installed for many years by Babcock & Wilcox Co. One major variation is the introduction of fuel into the cyclone using four (4) tangential secant ports on each cyclone.

The absolute key to dry sludge firing in cyclone furnaces is to ensure adequate temperatures to facilitate molten slag formation and tapping. The lower furnace of the steam generator is specially designed to maintain high temperatures to allow the molten slag to run down the lower furnace walls and through the discharge opening in the lower furnace floor.

In order to lower the melting point of the slag, the firing system was designed to add limestone as a fluxing agent. The flux is blended with each individual dry sludge feed line upstream of each rotary air lock. Proper sludge/flux mixing is attained while the material is transported in the blow lines to the cyclones. Initial operation has indicated that limestone supplemental fluxing is not necessary because the sludge feedstock contains sufficient calcium and lime to allow the material to an acceptable melting point. Currently, the system is being fired without a fluxing agent; however, continued testing is being performed using other types of fluxing agents to promote slag tapping.

Steam Production and Distribution

The steam generator is a field erected, top supported, two-drum boiler of single pass design. The complete furnace enclosure is of membrane welded wall construction. The boiler is capable of generating 235,000 pph of steam at 350 psig/ 600°F superheat steam temperature. The actual design of the boiler is for future 800-psig/ 800°F superheated steam operation. This design flexibility afforded Minergy future options regarding higher pressure and temperature operation should a cogeneration retrofit be desired. The thermal efficiency of the facility has been better than predicted.

The steam generator is equipped with an economizer and airheater to utilize high temperature primary and secondary air to the cyclone burners. The facility also includes waterside auxiliaries including a deaerator, boiler feed water pumps, chemical feed systems, continuous and bottom blowdown systems, etc. The original design considerations were for the steam host to provide all feedwater to the facility, however, a small sodium zeolite water softening system has been added to provide back-up and supplemental feedwater capacity.

Up to 165,000 pph of 350 psig/ 575°F steam is exported to the host paper mill through a 2,500-foot long steam distribution piping system. The exported steam is used to drive an existing paper mill backpressure steam turbine-generator producing approximately 4 MW of power.

Glass Aggregate Processing

Once the molten slag discharges through the lower furnace opening, it falls into a quench tank filled with water which is maintained at a temperature of 140°F. The quench tank water is pumped through heat exchangers in a closed loop equipped with hydroclones to prevent fouling of the heat exchangers. The cooling tower common to the scrubber cooling water loop is used to provide closed loop cooling water to the quench tank.

The molten slag generally fractures into tiny glass aggregate pieces approximately 1/2" and below. The bottom of the quench tank is equipped with a wet drag conveyor designed specifically to remove the glass aggregate from the quench tank while simultaneously dewatering the glass aggregate product on the wet drag upslope. The glass aggregate from the drag conveyor is discharged into a loadout area, which is formed by concrete retaining walls. The glass aggregate is loaded onto trucks through the use of a front-end loader.

Emission Controls

During the conceptual and final design of the facility, careful consideration was given to control of all plant emissions. The process and/or systems were designed and installed to control the following emissions:

- Particulate;
- NO_x;
- VOC;
- CO;
- Solids in Waste Water;
- Fugitive Dust;
- Odor; and
- Noise.

Particulate emissions are controlled through the use of a mechanical cyclone collector and fabric filter baghouse. The baghouse is a six (6) module pulse jet unit designed for off-line cleaning. The baghouse design gross and net air to cloth ratios are very conservative. The required maximum stack particulate emission rate of 0.02 lbs./mmbtu heat input has been verified.

As would be expected, the cyclone furnace is an inherently significant generator of NO_x. The uncontrolled NO_x emissions from the cyclone furnaces were predicted and have been verified to be no greater than 0.8 lbs./mmbtu heat input. The facility is equipped with a Selective Non Catalytic Reduction (SNCR) system, which uses urea as the reagent to control NO_x emissions. The stack NO_x emission rate of 0.3 lbs./mmbtu can be maintained by using 50% less urea than originally anticipated.

The potential VOC emissions were addressed in the design phase of the project by installing a closed loop drying system using steam as opposed to contact drying with the sensible heat remaining in the exhaust flue gas. Any potential VOC emissions generated in the drying process are carried to the cyclone furnaces in the combustion make-up air and are destroyed in the cyclone furnaces which have operating temperatures that are typically in excess of 2600°F. The facility is well below its maximum stack VOC emission rate of 17.5 pph.

Like VOC emissions, whatever trace CO emissions generated in the process are destroyed in the high temperature cyclone furnaces. The CO measurements at the stack with approximately 2% oxygen in the flue gas have been less than 5 ppm which are significantly below the allowable level of 200 ppm.

The wastewater generated in the facility, which is dewatered from the incoming wet sludge, was required to have limited suspended solids content. Good engineering practice relating to sizing of gas ducts and transitions, dryer cyclones, and the wet scrubber have resulted in an acceptable solids loading to the local municipal wastewater treatment plant.

Even though considerations to control fugitive dust were part of the original plant design, the control of fugitive dust has been a continuous learning process as the system has been started up and put into operation. Many retrofit systems have been installed on the drying system at numerous points whereby fugitive dust emissions of “dry fluff” were a problem. This “dry fluff” is not only a housekeeping and airborne fugitive dust problem, but small piles of this hot material have a tendency to smolder.

One of the primary concerns of Minergy in the design and construction of this facility was to control odor and noise emissions so that there would be no noticeable impact on surrounding properties. Located in downtown Neenah, Wisconsin, it is easy to understand why this was such an important criteria. The fuel receiving building was designed so that the three (3) truck doors could be closed when the trucks are inside and unloading sludge. The make-up air for the dryer system, which is ultimately the combustion air, is pulled from the sludge receiving building by a large odor control air duct system. This odor control duct system also has other pick-up points in critical areas of the facility. Odor levels have actually decreased in the area because sludge does not accumulate at the local paper mills, but instead is being delivered to the facility 24 hours per day.

The facility was also designed to be a very quiet operating facility. Essentially all equipment is enclosed in buildings or galleries which effectively reduces any fugitive noise emissions. During the initial start-up an abnormally and extremely high noise level emanating from the combination ID fan and stack was experienced. Subsequent testing by sound experts and the design and installation of a silencer in the stack eliminated this problem resulting in a much quieter operation than is typically experienced in similar type installations.

As would be expected in a such a large and complex first-of-a-kind facility, numerous problems have been encountered and overcome. Some of these problems included:

- Sludge handling and storage problems resulting from changing physical properties of wet sludge under high compression loads.

- Corrosive attack of certain systems associated with unexpected constituents in the incoming wet sludge.

- Dry sludge and flux handling problems created by high humidity.

- Dry sludge firing pneumatic transport line pluggage from debris introduced with wet sludge or from dryer system deposit self-cleaning.

- Fouling and hard rock formation in the cyclone furnaces and furnace slag discharge opening due to low operating temperatures and experimentation with sludge/flux ratios.

- Fugitive “dry fluff” emissions control, handling, and containment.

Continued improvements are being made to improve the facility throughput, efficiency, and systems reliability. Currently, the facility is receiving and processing 1000 tons per day of wet sludge from eight different local area paper mills.

CONCLUSION

Using the benefits of the Winnebago County-sponsored procurement process developed as a public-private partnership, Minergy Corporation has tackled the problem of high-volume industrial waste disposal in Winnebago County and developed clean, efficient, cost-effective and proven technologies to manufacture usable, marketable products.

The Glass Aggregate process offers many environmental and economic benefits, including reducing long-term dependence on landfill disposal, providing residents and local industries with a cost-effective alternative for managing sludge, and providing public agencies with a more comprehensive and integrated approach to solid waste management. The Glass Aggregate technology provides the ideal solution to recycle sludge and establish a true low-cost, long term, beneficial re-use. Using mineral recovery technologies, Minergy Corporation has implemented new ways of recycling papermill sludge in Winnebago County, Wisconsin.

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