EPI
Energy Products of Idaho

Paper Sludge - Waste Disposal Problem or Energy Opportunity

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By

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ABSTRACT

A new significant waste stream has emerged with the focus on recycled products in the paper industry. Paper sludge has been a disposal liability for a number of years, but deinking sludge is a relative newcomer to the waste streams of paper mills. Plants with on-site landfills are running out of storage space, or are faced with the environmental concerns and liabilities involving potential ground water contamination from earlier disposal practices. Off-site commercial landfill for paper sludge disposal is becoming prohibitively expensive in many parts of the world. As an option to landfilling, modern fluidized bed boiler technology provides a means for successful thermal oxidation of these high ash, high moisture waste streams, producing process steam and/or electricity while reducing the mill's reliance on costly fossil fuels for steam production. These systems not only utilize the current production of deinking and paper sludges, but also material mined from existing on-site landfills to mitigate ground water contamination concerns. Fluidized bed combustion is rapidly becoming the ultimate solution for final disposal of paper mill wastes. This paper describes two new fluidized bed energy systems constructed to generate process steam and power while simultaneously solving paper mill sludge disposal problems.

A MAJOR MIDWEST PAPER MILL - BACKGROUND

The first fluidized bed sludge boiler to be discussed is located in Green Bay, Wisconsin and is owned and operated by Fort James Co. (Formerly Fort Howard Co.). This particular facility is the largest recycle mill in the world, receiving highly filled papers including ledger and glossy stock in the recycle stream. Fitting the classification of "office waste" the material is deinked and repulped. Deinking sludge, the unusable residue, has an ash content of 47% and an average solids content of 55% after dewatering with filter presses and rotary drum dryers. The total generation of deinking sludge is approximately 454 dry metric tons/day (DTPD), of which the fluidized bed boiler receives 227 DTPD. Prior to the construction of the fluidized bed, this quantity was landfilled at a company owned and operated landfill. Fluidized bed was the technology of choice due to the low net energy value of the fuel and the requirement for complete combustion with minimum hazardous air pollution (HAPs) generation. Steam, generated from the combustion of the sludge, would be piped into the existing header to increase the mill's generating capacity and reduce fossil fuel usage. Deinking sludge is a biomass material which is classified as a renewable energy resource with no net increase in carbon dioxide to the atmosphere. Fossil fuels, on the other hand, are non-renewable, and when combusted to raise steam, contribute to global warming. The paper mill also wanted a white ash product with no residual carbon after combustion of the sludge. Rather than continue to landfill this portion of the waste stream, the paper mill chose to explore the potential of a beneficial use for the ash generated during the combustion process. A variety of possibilities, including cement additive, reuse of the high calcium ash as a filler for the paper product, and other alternatives, have been and are currently being evaluated since the completion of the fluidized bed boiler.

DESCRIPTION

The boiler equipment beginning with the fuel storage transfer conveyor through the I.D. fan was supplied and erected by EPI. EPI's project team worked closely with Fort James Co's. project team to integrate the boiler equipment into the overall process. Dried fuel is received from the mill's storage silo which has an 8 hour capacity at maximum continuous rating (MCR). A transfer conveyor moves the fuel to a single metering bin based on fill level signals. The metering bin discharges onto a weigh belt which serves the dual role of providing feedback on system operation to the boiler operators and also controls the boiler fuel input to comply with the regulatory permit requirements of a maximum of 227 dry tonnes/day of sludge combustion. Fuel is then discharged into a pneumatic blow line for conveyance to the boiler. A stoker arrangement is used to spread the fuel utilizing the conveyance air and a refractory dispersal plate positioned at the top of the active bed. Fluidizing velocities at the superficial interface of the active bed are maintained below 2 meters per second across the 5.5 meter (18 feet) diameter of the fluidized bed vessel. The fuel spreading equipment is designed to insure that a majority of the sludge is injected into and burned within the fluidized media, minimizing vapor space combustion and the resultant temperature excursions that would affect the efficiency of the selective noncatalytic reduction (SNCR) reaction. Stringent oxides of nitrogen (NOx) emission standards require SNCR. This boiler utilizes aqueous ammonia at a 19 weight percent concentration injected through dual flow compressed air atomized nozzles. The nozzles are located around the periphery of the fluidizing vessel above the second overfire air manifold. An extended residence time design allows a reaction time of greater than 1 second from the point of aqueous ammonia injection to the first set of boiler tubes. A NOx reduction of at least 50% is required by the owner and the environmental permit.

Sulfur dioxide (SO_2) and oxides of nitrogen (NOx) emissions are stringent for this facility. To gain confidence that the full scale fluidized bed boiler would be able to achieve the projected emission limits, a pilot test program was developed to burn the deinking sludge and gather emission data. A week long trial burn in the Energy Products of Idaho (EPI) 1 x 1 meter pilot fluid bed boiler proved the NOx emissions could be controlled with SNCR and that SO_2 emissions could be abated without additives due to the available quantities of calcium in the fuel ash. Pilot testing showed that the lowest SO_2 emissions were achieved when the system was operated at the lowest bed temperatures. The matrix of the calcium rich ash and the particle size of the reacting ash were attributed to this phenomenon. A low bed temperature design was utilized in the full sized boiler to realize the lowest SO_2 emissions potential.

The additional residence time designed into this fluidized bed assures successful SNCR when firing fine, light deinking sludge and also promotes the complete oxidation of carbon monoxide and other organic toxics including PCB's, dioxins and furans. The "as received" fuel value of the sludge out of the dryer, considering the moisture burden and ash content, is only 892 kcal/kg (1606 Btu/lb). This is below the energy levels required for autogenous combustion. A flue gas-to-air heater positioned after the boiler preheats the fluidization and overfire air to provide the additional energy to allow combustion of the fuel. Combustion temperatures are intentionally maintained below 732˚C (1350˚F) in the bed to achieve the optimum SO_2 capture while vapor temperatures are allowed to escalate to 950˚C (1750˚F), which when coupled with the extended residence time design of the fluidized bed vessel, provides complete oxidation. Additional air preheat is available from the steam coil heater positioned between the forced draft fan outlet and the air inlet of the flue gas-to-air heat exchanger. The steam coil design is staged with three coils in one stage, one coil in the other stage, and two steam supplies to produce air preheat at either 66˚C (150˚F) or 120˚C (250˚F), depending upon the ambient temperature and fuel characteristics. Cold end corrosion potential is eliminated by the addition of the steam coil heater; plus, the heater provides additional combustion latitude if fuel drying problems are encountered in the process area outside of the boiler island.

The flue gas-to-air heat exchanger is followed by an economizer, baghouse, induced draft (ID) fan and stack. Cold end corrosion is also a concern in the economizer. High ash loadings coupled with flue gas moisture burdens of 21.5 % (by weight), compound the difficulty of maintaining economizer tube metal temperatures above the acid dew point. The methods used to counteract this potential problem include a retractable sootblower, which is cycled approximately every eight hours, and a feedwater supply of at least 121˚C (250˚F). Ash loading also has an impact on the design of the particulate abatement device. The baghouse used for this facility is a four module, pulse jet unit with the capability to isolate one or more modules for off line cleaning or maintenance. A conservative air-to-cloth ratio was specified by the customer to assure long bag life with an inlet loading in excess of 2800 kg/hr, or 85.8 gm/dscm (37.5 gr/dscf). The baghouse is under negative pressure with the ID fan pulling flue gas through it and discharging out the exhaust stack. Continuous emission monitoring equipment (CEMs) are positioned on the stack with feedback from the NOx analyzer controlling the aqueous ammonia feed rate for the SNCR system.

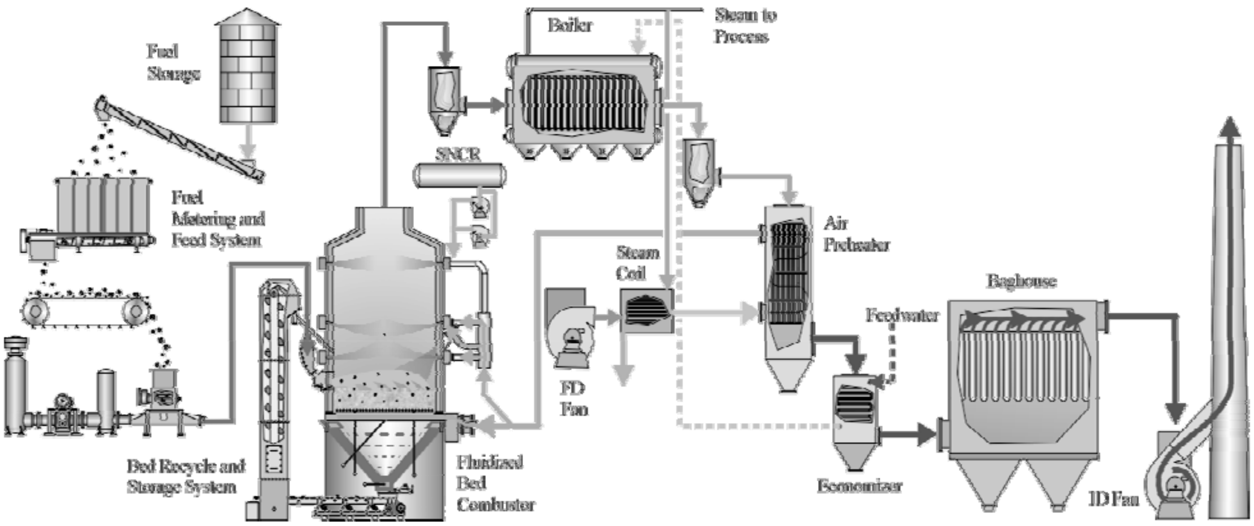

Figure 1. 226.8 Tonnes/Day Fluid Bed boiler (Paper and Deinking Sludge)

62,186 mJ/hr (59 Million Btu/hr)
22.9 tonnes/hr @ 11 Bar (saturated)
(50,500 lbs/hr saturated)

DESIGN SPECIFICS

Cold startup of the boiler is accomplished by firing two 26,350 MJ/hr (25 million Btu/hr) natural gas burners located in the upper vapor space of the combustor. The flame from these burners impinges on the fluidizing media, heating it at a rate of approximately 100˚C (200˚F) per hour to avoid thermal shock to the refractory. The heat input from these startup burners warms the entire boiler train to reduce condensation when wet solid fuel firing commences. As the baghouse has no bypass dampers for startup (the environmental permit doesn't allow bypass), the preheating sequence prevents condensation on the bags which have a high calcium content dust filter cake. When the upper vapor temperature achieves the environmental requirement of 927˚C (1700˚F), solid fuel feed begins. The startup burners continue to fire at progressively reduced heat input rates as the combustor is stabilized on solid fuel to assure all products of incomplete combustion are oxidized. A residence time of two seconds from the highest overfire air injection to the first boiler tubes and a temperature minimum of 927˚C (1700˚F) is required by the regulatory agency. Furnace temperatures are continuously transmitted to the distributed control system (DCS), which archives the data for future retrieval to prove compliance with the environmental permit temperature requirements.

Pilot testing of the fuel indicated a substantial generation of fluidizing media was formed from granular layered growth of fuel ash. The bed depth increase amounted to 2.5 cm/hr and this material had to be continually discharged to maintain a consistent pressure drop through the bed. The full scale boiler accommodated this requirement with a modified media discharge system that allows a portion of the cooled and sized media to be injected back into the fluidized bed. Excess media is directed to the ash system and to the media storage silo as needed. Continual growth of the particle size of the fluidizing media has resulted in experimentation with screen sizing in the media recycle equipment and ultimately a crusher may be installed ahead of the sizing equipment to provide a smaller range of media size.

A refractory tee with an ash drop was installed ahead of the boiler to reduce the inlet ash loading. This ash drop design has been used in other high ash applications and has proven to be effective on this project. However, stickiness of the ash that occurs during vapor space temperature excursions results in pluggage if ash is allowed to reside in the hopper.

Increasing the frequency of operation of the double tipping valves has alleviated much of the bridging and an air lance retrofit is being implemented to solve the remaining bridging problem.

High ash loading with regard to boiler design required significant innovation to assure on-line availability. The water tube waste heat boiler is an A-type with progressively tighter tube spacing to maintain a conservative 12.2 m/second down the length of the single pass. Whereas typical A-type boilers have the majority of the mud drums within the gas stream, this boiler has only one third of each drum in the gas passage. Ledges for ash buildup are minimized with this configuration. To further reduce the potential for ash buildup, only 90 degrees of the mud drum is used for boiler tube penetrations. Five retractable sootblowers provide complete cleaning coverage for the boiler and the heat exchange surface is conservatively designed with a substantial fouling factor. Erosion protection for the leading tubes at the inlet of the boiler is accomplished with studding and silicon carbide fill. Due to the conservative boiler design, sootblowing is only necessary several times per week as indicated by the boiler flue gas outlet temperature. Sufficient excess steam generating capacity exists to allow the operators to regulate the boiler flue gas outlet temperatures with the sootblowers to handle variations in fuel quality. Increased fouling increases the flue gas temperature which increases the temperature to the air heater for a wetter fuel feed scenario. Operating experience has proven the plant dewatering equipment to be well designed for the task and excessively wet fuels have not been encountered. Non-condensible gases from the rotary drum dryer are routed into the boiler forced draft fan inlet for combustion in the fluidized bed, thereby eliminating a potential source of organic gaseous emissions.

Both particulate emissions abatement and bag longevity were considered in the design of the baghouse. A flue gas-to-cloth ratio of 3 to 1 was specified for the baghouse with two of the four modules off-line. With this large cloth area, compressed air pulsing pressures have been reduced to 4 Bar (60 psi). When a differential pressure of 1.5 kPa (6 inches of water) across the baghouse is achieved, pulse cleaning is initiated. The low pulse pressure, short pulse duration, on-line cleaning, and the overall conservative air-to-cloth ratio promotes long bag life and excellent particulate abatement.

EMISSIONS

Emissions testing of a new energy system to prove compliance with the environmental permit is the goal after start-up and stable operation has been achieved. Extensive pilot testing of the expected fuels prior to the design of the full scale facility exposes the potential emission problem areas. The ultimate design resulting from this testing formalizes the equipment and operational design of the full scale plant to assure predictable and dependable emissions estimates. Attainable emission factors used in securing the environmental permit for the full scale plant increase the probability of meeting environmental compliance when the new system is ultimately tested.

TABLE 1.0 SUMMARY OF EMISSIONS

Constituent	Units of Measurement	Contract/Permit Limits	Average Tested Emissions
Particulate Matter (PM10)*	lb/MBtu	0.15	0.022
* Includes Condensable Particulate	lb/hour, (kg/hr)	3.9, (1.8)	1.75, (0.79)
	gr/dscf, (mg/cm)		0.0086, (19.7)
Sulfur Dioxide	lb./hour, (kg/hr)	9.0, (4.08)	3.22, (1.46)
Nitrogen Oxides	(ppmdv)	100	74
Hydrogen Chloride	lb./hour, (kg/hr)	44.63, (20.24)	8.52, (3.86)
Ammonia	(ppmdv @ 7% O2)	35	11.9
Carbon Monoxide	(ppmdv @ 7% O2)	50	<1.2
VOC's (as propane)	(ppmdv @ 7% O2)	N/A	<1.5
VOC's (as carbon)	(ppmdv @ 7% O2)	N/A	<4.5
PCB's	(lb./hour)	1.14 E-5	<4.70 E-7
	(ng/dscm @ 7% O2)		<2.81
EPA TEF PCDD/PCDF's	(lb./hour)	1.14 E-8	1.04 E-9
	(ng/dscm @ 7% O2)		0.542
Opacity	(%)	20	0

"<" designates that the compound was not detected, or was below the method detection limit

CARTIERE BURGO - BACKGROUND

The second sludge fired boiler to be discussed is Cartiere Burgo, a paper mill located in Mantova, Italy. The mill has been landfilling its paper sludge waste stream in lined cells on mill property since production began. Continued landfilling was expected to meet environmental opposition and the landfill was nearing capacity. Italy is a country with an area of 13,500 square miles and a population of 58 million people. In comparison, California has 27 million people and 156,300 square miles of area. In terms of population density, Italy has 510 people per square mile whereas California, which many consider to be overpopulated, has only 170 people per square mile. Land in Italy that is not inhabited is either mountainous or dedicated to family farms which are passed down from generation to generation. Developing a landfill site in Italy is very expensive and nearly impossible to permit from an environmental standpoint. The average landfill in northern Italy commands a tipping fee of US$65/tonne with newer landfills charging as much as US$80/tonne. Disposal fees range between US$30 to US$50 per tonne in the lesser populated areas of southern Italy. In an effort to extend the life of their landfills, municipalities are willing to pay an added fee of US$ 25/tonne above the landfill charge to take their garbage to waste-to-energy electrical generation plants.

The demand for electrical power and the preferential pricing given to producers generating power from waste materials strongly influences the decision to combust waste streams. Italy’s state-owned utility, Ente Nazionale per l’Energia Elettrica (ENEL), was established in 1962 to oversee the production and distribution of electric power in Italy. It continues to be the largest producer and supplier of electricity in Italy and one of the largest utilities in the world, ranking above the Tennessee Valley Authority and American Electric Power Company. With the privatization of ENEL in August of 1991, independent power producers are now permitted to increase the production of energy for their own use and to sell excess electric power to ENEL at attractive rates. These rates were established based on ENEL’s avoided cost plus incentives paid for eight years. The incentives vary according to the type of fuel burned and the process efficiency. Hydrocarbon fuels qualify for incentives of 22-33% above the base rate, coal up to 43% and process or waste fuels earn a 62% premium. Fluidized bed technology qualifies for the highest incentives due to the complete combustion characteristics and history of low emissions. As independent power producers compete for the environmentally driven incentives, electrical production by independent (non-utility generators) is projected to increase from the present 22% to a predicted 32% by 2003. Land availability for waste disposal is not the only stimulation for waste combustion. Italy currently imports 30,000 Gwh/yr (the equivalent of 3,435 MW) of electricity. This demand is expected to increase an additional 18,000 MW over current domestic production by the year 2010. Economic incentives for power production and environmental sanctions against continued landfill favor non-utility generation of electricity from waste materials.

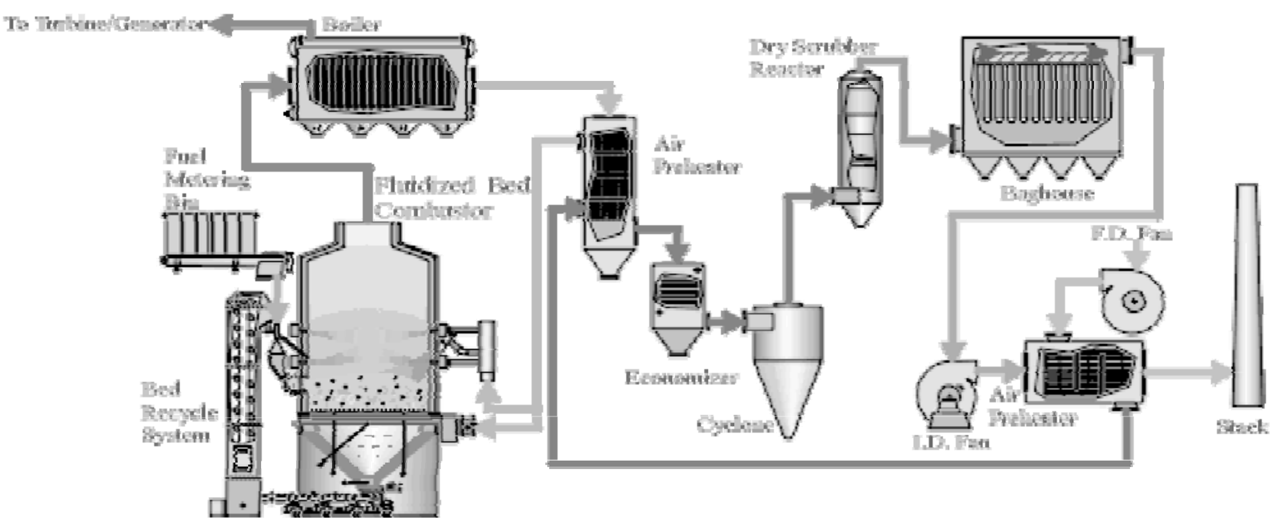

Figure 2.94.

3 Tonnes/Day Fluid Bed boiler 47,641 mJ/hr (45.2 Million Btu/hr)
(Paper Sludge) 14 tonnes/hr @ 52 Bar, 430˚C
3.2 MWe (30,700 lbs/hr 750 psi, 806˚F)

DESCRIPTION

The arrangement of equipment for this project is very similar to the Wisconsin project discussed above; however, the fluidized bed combustor vessel is slightly smaller at 4.9 meters (16 feet) in diameter and the steam is superheated to supply a condensing turbine/generator set. Electrical power in the amount of 3.2 MWe will be cogenerated for sale to the electrical grid. The fluidized bed equipment scope of supply is from the inlet of the fuel metering bin through the outlet of the combustor vessel. A single 26,350 mJ/hr (25 Million Btu/hr) natural gas fired burner is provided for startup and can be used simultaneously with solid fuel firing to complete thermal oxidation of organic emissions during initial temperature stabilization and as needed during fuel upsets. Fuel to be burned includes the daily production of paper sludge plus mined sludge from the existing landfill. The "as-fired" moisture content of this fuel mix is expected to be 55%, with included ash of 43+% resulting in an available calorific heat value of 925 kcal/kg (1665 Btu/lb).
Fluidized bed technology was chosen for its successful record of:

1. Meeting the most stringent emissions requirements

2. Receiving and continuously discharging large rocks and other noncombustible “tramp” material without affecting on-stream availability

The mined sludge is expected to contain some percentage of rock and dirt, and will fluctuate in energy content depending upon its state of decay. In a similar fashion to the Wisconsin facility, the ash calcium content is expected to abate a portion of the SO_2, with final abatement occurring in a dry scrubber to meet very stringent Italian emissions requirements. NOx emissions abatement will be achieved with SNCR utilizing a urea solution. Following the fluidized bed, the train includes a waste heat boiler, secondary air preheater, economizer, cyclone, dry scrubber reactor, baghouse, ID fan, primary air preheater and stack. EPI has teamed with two Italian companies who have split the scope of equipment supply and construction of the balance of plant. One Italian entity will provide the boiler, air heaters, FD fan, and economizer equipment and will install the fluidized bed combustor. The other entity will be responsible for the fuel storage and dewatering equipment, cyclone, dry scrubber, baghouse, ID fan, and the turbine generator island plus the overall emissions guarantees. This second Italian company will also be the EPC contractor for the project.

EMISSIONS

Emission requirements for this plant are regulated by Italian law. Local emissions standards are additive to the federal law, making the emissions requirements even more stringent. The system design provides for the addition of lime or limestone with the fuel to remove a portion of the SO_2 emissions. The remainder of the abatement occurs in a dry scrubber reaction vessel utilizing sodium bicarbonate injection. Hydrogen chloride (HCl) will also be removed in the dry scrubber and activated carbon may be added, if needed, to adsorb dioxins, furans and heavy metals. As previously mentioned, a urea based SNCR system coupled with low temperature combustion will handle NOx emission abatement. The local government has added an additional stipulation of 100˚C and one second residence time to the federal law, which raises the required combustion temperature and residence time to 950˚C (1742˚F) at three seconds. The refractory wall design of this fluidizing vessel reduces the potential for cold areas within the furnace, inspiring confidence that the organic emissions will be below detectable levels. The emission limits are shown in Table 2.0.

TABLE 2.0 EMISSIONS LIMITS

Constituent	Units of Measurement	One Hour Limits	24 Hour Limits
Particulate Matter	mg/Ncubic meter @ 10% O2	30	10
SO2	mg/Ncubic meter @ 11% O2	50	
NOx	mg/Ncubic meter @ 11% O2	200.0	
CO	mg/Ncubic meter @ 10% O2	100.0	50
HCl	mg/Ncubic meter @ 10% O2	30.0	10
HF + HBr	mg/Ncubic meter @ 10% O2	2.0	
HCN	mg/Ncubic meter @ 10% O2	0.5	
P2O5	mg/Ncubic meter @ 10% O2	5	
VOC	mg/Ncubic meter @ 10% O2	20	10
PCB + PCN + PCT	mg/Ncubic meter @ 10% O2	0.1	
PAH	mg/Ncubic meter @ 10% O2	0.05	
Total Metals	mg/Ncubic meter @ 11% O2	0.5	
Cd + Hg + Tl	mg/Ncubic meter @ 10% O2	0.1	
PCDD + PCDF (TEF equivalent)	ng/Ncubic meter @ 10% O2	0.1	0.1

SUMMARY

High ash, low energy value waste materials can be used as fuels if the proper combustion system design is chosen. The two boiler systems described in this paper utilize fluidized bed combustion (FBC) boilers to generate process steam and, at the Cartiere Burgo paper mill, cogenerated electrical power. Compliance emissions testing of the Fort James facility (see Table 1) shows organic emission levels ten times lower than the permit limits. Particulates, SO_2, NOx, HCl and ammonia slip emissions are also substantially below the permitted requirements. This provides some comfort that the energy system will not require additional expenditures for emissions abatement in the near future. Design of the Cartiere Burgo sludge boiler is not substantially different from the Fort James boiler, so it is expected to meet or exceed the emissions limits imposed by the Italian government. Low emissions levels are critical to assure public acceptance of the projects. Another criteria for these projects will be a beneficial use of the ash generated from combustion of the sludge. Ash collected from the Wisconsin boiler is white in color, and carbon-free. Both of these features, including the level of calcination are important in establishing the best use for the ash. Testing is currently underway to utilize this product which is generated at a rate of 4.5 tonnes/hour. The Italian sludge boiler will fire the paper mill's current production of sludge, plus sludge mined from an existing landfill site. The boiler will provide a solution for the potential groundwater contamination and environmental liability of the existing landfill. Beneficial use of the ash, which is generated at a rate of 2.5 tonnes/hour is equally important for this project. Coupling the environmental and process goals of these sludge boilers with an equipment design that assures high on-stream availability, firing high ash, high moisture fuels, is the measure of success.