FLUID BED SLUDGE COMBUSTION USING COAL AS AN AUXILIARY FUEL: THE HUNTINGTON, WV EXPERIENCE

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SUMMARY

The Huntington, West Virginia, Waste Water Treatment Plant was one of the first plants in the United States to combust sewage sludge using coal as an auxiliary fuel and remains one of the few doing so. Operational since 1989, the plant has proven to be simple to operate, with minimal maintenance requirements and has an environmental impact that is generally an order of magnitude below its permitted air emissions. The plant meets the operating parameters and emission requirements of the new 503 Regulations (Reference 1), and will require only minor instrumentation additions and an automated data acquisition and reporting system to be in complete compliance.

BACKGROUND

The Huntington Wastewater Treatment Plant serves the City of Huntington, WV, the Spring Valley Public Service District and the Monel Park Public Service District. The original wastewater treatment facilities at the site began operation in 1964 and provided primary treatment. Sewage sludge was burned in an 18′-6″(5.63m) diameter, 6 hearth multiple hearth unit. With the increasing price of natural gas used as auxiliary fuel, incinerator operation was discontinued in 1974 when landfill disposal became cost-effective. In 1983 the Huntington Sanitary Board authorized its Engineer, Chester Environmental, to conduct an extensive sludge management study which evaluated the financial and environmental aspects of various sludge dewatering and disposal alternatives. Fluid bed incineration was shown to be the most cost-effective and environmentally acceptable method for sludge disposal. In 1984 under orders from the Ohio River Valley Sanitation Commission, the US EPA and the West Virginia Department of Natural Resources, the existing treatment processes were upgraded from primary to secondary treatment. In 1986 a contract was awarded to Dorr-Oliver for a fluid bed sludge incineration system. A construction/operation permit was granted by the West Virginia Pollution Control Commission in June 1986 (Reference 2). The system was operational in April 1989 and performance tests were completed in December 1989.

Average influent flow is 13 million gallons (49.2 million liters) per day with peak flows of 30 to 40 MGD (113.5 to 151.4 liters/day). Influent to the treatment plant is about 40% from industrial sources, primarily chemical plants and primary metal facilities. An industrial effluent control program controls the quality of this influent. Wastewater treatment consists of screening, grit collection, pre-aeration, primary sedimentation, conventional activated sludge, secondary clarification and chlorination prior to discharge into the Ohio River.

Sludge input to the three, 2 meter, 2400 dry pound (1087 Kg) per hour continuous belt presses is 40% primary and 60% secondary.

RESULTS OF SLUDGE MANAGEMENT STUDY

As a part of the sludge management study conducted in 1983, capital and operating costs for new fluid bed and multiple hearth incinerators were developed. Incinerators of both types were sized to incinerate 272,000 dry pounds (123,200 Kg) of solids per week at 22% dry solids when operating 146, 105, 70 or 56 hours per week. This would result in fluid bed freeboard units of 15.5′, 18′, 21′ and 25′ (4.72, 5.49, 6.40 and 7.62 meters) diameter respectively.

Capital cost estimates were developed from 3 sources and are considered to be of plus 20%, minus 0% accuracy. Operating costs were based on the following cost factors (1983 rates):

Labor:	$10/Hr
Electricity:	$0.05/KW-Hr
Natural Gas:	$4.50/1000 cf ($158.90/1000m^3)
Coal:	$2.00/Million BTU ($7.94/Million Kg-Cal)
Sand:	$50/Ton Delivered ($45.35/metric ton)

Results of the analysis showed the fluid bed to be the less expensive unit to purchase and to operate. The fluid bed savings were about $250,000 per year, operating and amortization costs for a unit to dispose of 272,000 dry pounds (123,200 Kg) per week in 70 operating hours and becomes $350,000 when operating 146 hours. Table 1 provides a break down of costs for the unit size eventually chosen (105 operating hours). The reason the multiple hearth does not appear competitive is because it does not burn coal, and does not recover afterburner off gases with incoming combustion air, and because it would take a considerable incremental increase in capital cost to accomplish these things.

Other advantages attributed to the fluid bed, non-quantifiable in cost, were in simplicity of operation, improved automation potential and housekeeping advantages due to it being a completely sealed unit.

Although some consideration has been given to reactivating the 20 year old multiple hearth, this was eventually ruled out. Inspection of the unit revealed that three hearths would require replacement and corrosion of the top hearth and exhaust gas breeching would require repair. More significantly, a new off gas system, including afterburner, scrubber and ID fan would be recommended due to changed environmental regulations since the original installation. This would also entail a new permit application. Further, since the unit had not been operated in 9 years, there was no advantage in operator familiarity with the unit or in training requirements.

SYSTEM DESCRIPTION

The basis for the design 105 operating hours per week for the incinerator was selected using the criteria that the Huntington Wastewater Treatment Plant would operate its solids processing facility at the design average loading conditions for two eight hour shifts per day, seven days per week with one hour at the beginning of each day allocated for start-up of the unit (15 hours/day × 7 days/week = 105). Based on this criteria, minimum and maximum loading conditions are accomplished by either reducing or increasing the number of operating hours per week.

TABLE 1 CAPITAL AND OPERATING COST COMPARISON AT 105 OPERATING HOURS PER WEEK (1983 BASIS)

	Fluid Bed	Multiple Hearth
Diameter	21 Ft O.D.	22' 3 x 8H
Estimated Capital Cost	$3,500,000	$4,000,000
Annual Operating Cost		
Sand at $50/ton	$ 12,500	
Labor at $10/Hour	$ 121,320	$ 121,320
Fuel-Running-Coal at $2/mmbtu	$ 66,100	$ 317,000/Gas
Fuel-Start-up-Gas at $4.50 mcft	$ 23,000	$ 45,000
Fuel - Standby		
Power		
For fluidized air blower 750 hrs	$ 7,500	$ 7,500 I.D. Fan
For feeder, panels, pumps,etc.	$ 8,400	$ 11,300 Cooling Air Fan
Maintenance-3% of capital cost	$ 105,000	$ 123,000
Sub-total, direct operating cost	$ 343,820	$ 625,500
Amortization basis 10% of capital cost	$ 350,000	$ 410,000
Total Annual Cost	$ 703,850	$1,035,000

A process flow diagram for the Fluid Bed Incineration System is shown in Figure 1. Design incinerator feed is 205 wet tons/day (186 metric tons/day) at 22% solids (3760 dry pounds/hour) (1703 dry Kg/hr). Since the sludge alone is sub-autogenous (requires auxiliary fuel to sustain combustion), coal is used as an auxiliary fuel at a design feed rate of 1425 pounds (646 Kg)/hour. Design coal characteristics are 1/4″ × 0 (0.635 cm × 0) size, 1% sulfur maximum, 10% water maximum, 15% ash and a Higher Heating Value (HHV) of 11,000 BTU/Pound (6111 Kg Cal/Kg). Coal is ordered to size, delivered by truck, and loaded by gravity into the 9280 cubic foot (263 cubic meter) coal silo through a screen to eliminate oversize, and then conveyed via screw conveyors and bucket elevators to a 130 cubic foot (3.7 cubic meter) day bin. Sludge, fed by screw conveyor from the belt presses, and coal, fed by bin metering screw from the day bin, are mixed in the splitter box and moved by screw conveyors to two tapered barrel feed screws which feed the incinerator. No mixing is incorporated in the splitter box other than the counter-rotation of the screw feeders.

The fluid bed reactor is a 16′ (4.88m) bed, 20′ (6.10m) ID freeboard unit with a design heat input of 32 Million BTU (8.06 Million Kg-Cal)/Hour. The incinerator includes a dual fuel (natural gas & No. 2 oil) windbox preheat burner, oil guns in the bed for start-up and standby operation, and a bed removal system consisting of a slide valve and quench tank. Typical gas residence time in the incinerator is 6 to 7 seconds. A generic detailed discussion of the operation of fluid bed incineration is given in Reference 3.

Because the sludge is sub-autogenous, an air to gas shell and tube heat exchanger follows the incinerator and pre-

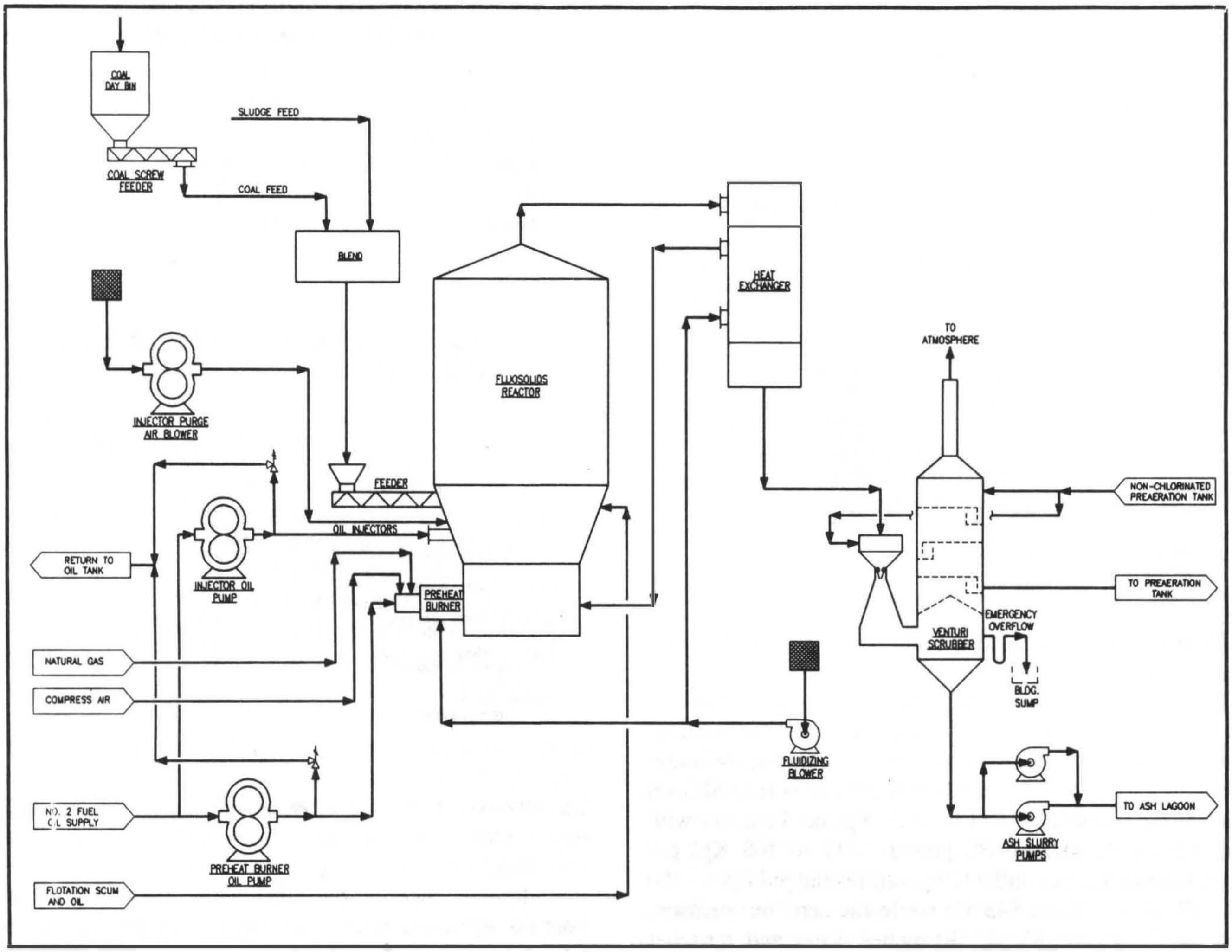

FIG. 1 PROCESS FLOW DIAGRAM

heats the incoming fluidizing/combustion air to 1200°F (649°C) using the energy from the exiting flue gas. This lowers the heat load on the reactor and reduces the requirement for auxiliary fuel, thus conserving energy. The air pollution control device is a wet venturi scrubber with a variable throat and a three tray tower for gas cooling. Acid gas emissions are controlled by water absorption in the tray tower. The ash slurry from the scrubber is pumped to on site lagoons. Toxic Characteristic Leachate Procedure (TCLP) testing on the ash done in 1993 showed priority metal content of leachate to be below detection limits with the exception of barium and cadmium. Barium showed 0.7 mg/l against an allowable of 100; cadmium had a value of 0.006 mg/l against a 1 mg/l allowable. TCLP organics and semi-volatiles were all below detection limits.

OPERATIONS DATA

The system was put into full operation in April 1989. Since typical performance of the belt press achieved 24% dry solids rather than the design value of 22%, and as received coal generally had higher HHV values than design, sludge feed rate could be increased while decreasing auxiliary fuel input. Normal operation is with 4700 dry pounds (2129 Kg) per hour of sludge, 640 pounds (290 Kg) per hour of coal. Typical analysis for coal and sludge are shown on Tables 2 and 3 respectively.

Normal operating schedule is to start feeding sludge to the unit each Monday and Friday and to continue operation until available sludge is consumed. Sludge is stored in the wet process while the incinerator is not operational. Between operations, the unit is shut down and allowed to cool to a minimum of 1200°F (649°C) to remain safely above the auto-ignition temperature of oil. If not restarted prior to this temperature, the reactor is reheated to 1600°F (871°C) using auxiliary fuel oil. The large mass of hot inert material of the bed inside a refractory lined vessel provides a thermal flywheel effect such that the incineration cools slowly, taking approximately 34 hours to go from 1550°F to 1200°F (843°C to 649°C). On the other hand, heatup under fluidized conditions to a temperature

TABLE 2 TYPICAL COAL ANALYSIS

Type:	Bituminous Coal
Size:	1/4" x 0" (0.635 cm x 0)
Sulphur:	1% Maximum
Moisture:	10% Maximum
Ash:	15% Maximum
Heating Value:	11,000 BTU/Lb (6111 Kg-Cal/Kg) Minimum

TABLE 3 TYPICAL SLUDGE ANALYSIS

22% dry solids (by weight) minimum
88% moisture (water) (by weight) maximum
45% volatile solids (by weight) in dry solids
Volatile solids HHV = 10,000 BTU Per Pound (5555 Kg-Cal/Kg)

Metals In Sludge

Metals	Avg Mg/Kg	Feed Rate lb/hr
Arsenic	7.9	0.0339
Cadmium	45.7	0.1955
Chromium	288	1.232
Copper	442	1.397
Nickel	369	1.573
Lead	162	0.697
Selenium	0.43	0.0026
Zinc	1655	5.505
Beryllium	1.9	0.0090
Mercury	1.2	0.0051

TABLE 4 PERFORMANCE TEST RESULTS EMISSIONS

Particulate Matter:	0.0069 Grains/Dscf corrected to 12% CO_2
Sulfur Dioxide:	336 ppm corrected to 7% O_2
Non-Methane Hydrocarbons:	5 ppm corrected to 7% O_2
Nitrogen Oxides:	12 ppm corrected to 7% O_2
Carbon Monoxide:	34 ppm corrected to 7% O_2
Mercury:	0.130 mg/m^3
Beryllium:	<2.5 x 10^{-15} mg/m^3

TABLE 5 PERFORMANCE TEST RESULTS COMPARISON WITH PERMIT LIMITS

	Allowable Per Permit (Reference 2)	Test Results (Reference 4)
Particulate Matter, Lb/Hour	2.43	0.38
Lb/Ton Dry Sludge	1.3	0.18
Sulfur Dioxide, Lb/Hour	57	35.57
Non-Methane Hydrocarbons, Lb/Hour	6.9	0.10
Nitrogen Oxides, Lb/Hour	41.5	0.928
Carbon Monoxide, Lb/Hour	13.8	1.3
Mercury, Lb/Hour	0.294	0.0051
Grams/24 Hours	3200	56
Beryllium, Lb/Hour	0.00092	<9.5 x 10^{-7}
Grams/24 Hours	10	0.01

sufficient to combust sludge and coal is achieved in less than 2 hours.

Performance testing of the system was conducted in December 1989 (Reference 4). Achieved results are summarized on Table 4 and compared with permissible emission limits in Table 5. Sludge feed during the tests ranged from 3600 to 4800 pounds (1631 to 2174 Kg) per hour dry with coal feed from 480 to 680 pounds (217 to 308 Kg) per hour. Incinerator gas outlet temperatures ranged from 1450 to 1550°F (788°C to 843°C) while the scrubber pressure drop was between 35 and 40 inches water and scrubber gas outlet temperature is approximately 120°F.

OPERATIONS AND MAINTENANCE EXPERIENCE

In the five years since start-up, the fluid bed incinerator has provided simple and reliable operation. The entire solids handling facility from the outlet pumps of the gravity thickeners and Dissolved Air Flotation (DAF) units through the belt presses, feed conveyors, incinerator and scrubber to and including the ash pump is controlled by a single operator in the Control Room.

Preventative maintenance is conducted during a two week shutdown each year. In part due to the limited weekly operating schedule, no days of scheduled operation were lost due to unscheduled maintenance in the period from April 1989 through December 1993.

The bed removal system has not been used in normal operation. It was originally included to remove any buildup of bed material from coal ash remaining in the bed. This has not occurred, apparently because of the fineness of the coal feed. Loss of the coal ash plus normal attrition of the bed sand results in a loss of about 2.5% of the bed material every 24 hours. Approximately 2.5 tons (2.27 metric tons) of sand is added every week (126 Tons/Year) (114 metric tons/year).

A design concern which did not occur was high freeboard temperature relative to bed temperature if fine coal particles escaped to the freeboard and burned there. Operation shows, however, that mixing the coal with the sludge is effective in retaining and combusting the coal in bed, as temperature differentials between bed and freeboard range from 0 to 50°F (0 to 28°C).

The use of coal in the incineration process at the Huntington Wastewater Treatment Facility was desirable because of its local availability and its ability to substantially reduce the fuel cost associated with the operation of the sludge disposal unit. After the fluid bed sludge combustion unit became operational and the unit was operated using both coal and Number 2 fuel oil as an auxiliary fuel, additional operational benefits associated with the burning of coal became apparent. Operating units on coal substantially decreased the differential temperature between the bed and the freeboard to a range of 0 to 50°F (0 to 28°C) as noted above. Additionally, with coal, the hot standby period, the time when the unit is idle and not burning sludge, is extended due to the residual coal remaining in the bed when the unit is shut down. This effect is similar to the results obtained when one banks a coal furnace or stove.

Operation of the incinerator itself has been virtually trouble-free. The only significant maintenance item has been temperature induced drooping of the oil feed guns and roof spray nozzles which inhibits their removal. These are treated as expendable items and when replacement is required, they are cut off and allowed to remain in the bottom of the bed until the plant schedules full shutdown. For the oil feed guns, a unique internal support system has been developed. The internal supports were made of 309 stainless steel plate and the oil feed guns were changed to 601 Inconel.

Because of previous experience with downstream corrosion when operating the multiple hearth unit, the heat exchanger tubes and tube sheet and the wetted parts of the scrubber are constructed of Inconel 625. No corrosion has been evident although this may be due in part to the pretreatment control imposed on industrial users and the closure of a car bumper manufacturing facility within the treatment plants service area. The Huntington Sanitary Board also administers an Industrial Pretreatment Program to ensure the industries discharging wastewater into its system maintain compliance with the USEPA pretreatment standards. Some erosion has occurred in the base of the scrubber, for which replacement plates of improved material (Inconel 725) have been added as a temporary fix, although a long term fix would be to add a refractory floor.

The significant maintenance item, as anticipated, is coal handling. Problems fall into two categories; off specification coal and wear. If as received coal is significantly wetter than design or consists primarily of fines, bridging will occur in bins and transport equipment. The only effective solution to the wetness problem is to order the coal during a dry spell when surface moisture will be a minimum. The coal silo has over one month storage capacity.

Conveyor wear was also an anticipated maintenance item and occurs primarily on the tips of the screw feeders and to a lesser extent on the screw conveyors. The screws are rebuilt with a 60C Rockwell impregnated hard face material to the factory specifications, with feed screws removed and replaced every six to twelve months. From a maintenance perspective, separate feeding of coal and sludge would be desirable using pneumatic conveyance of the coal; however, the added cost of the coal feed system is not justified. The Sanitary Board plans on eventually converting to piston feed pumps when funds are available.

IMPACT OF 503 REGULATIONS

On February 19, 1993 a final rule on sludge management, popularly known as the 503 Regulations, was promulgated (Reference 1). In addition to requirements for management practices, monitoring, and record keeping, the Regulations imposed emission requirements for incinerators for certain metals (arsenic, cadmium, chromium, mercury and nickel) and for total hydrocarbons. In the mid-eighties, however, there had already been strong implications of increasing control to be imposed on incinerator emissions (Reference 5). During the 1989 performance tests, therefore, additional testing was performed to provide necessary data to demonstrate conformance with metal and hydrocarbon emissions. Recently the Huntington Sanitary Board contracted with Chester Environmental to determine the necessary changes to the system to conform to all the regulatory requirements.

TABLE 6 METAL EMISSIONS TEST DATA AND COLLECTION EFFICIENCIES

Metal	Emission mg/Nm³	Collection Efficiency %
Arsenic	< 0.9 x 10-4	> 99.0
Cadmium	3.9 x 10-3	99.94
Chromium	4.8 x 10-3	99.98
Nickel	8.9 x 10-3	99.98
Lead	1.6 x 10-2	99.92
Beryllium	6.5 x 10-5	> 99.99
Mercury	0.136	0

TABLE 7 METAL CONCENTRATIONS IN SLUDGE VERSUS CONCENTRATIONS ALLOWED UNDER 503 REGULATIONS

Metal	Average Diffusion Factor	503 Regulations Allowable Metal Input mg/kg	Actual Metal Input mg/kg
Arsenic	3.50371	1,108	7.9
Cadmium	3.53071	2,746	45.7
Chromium	3.53071	31,311	288
Nickel	3.53071	96,343	369
Lead	5.04147*	5,060	162

* Maximum quarterly.

Metal emission data and system collection efficiencies obtained in 1989, are shown on Table 6. As previously noted, beryllium and mercury, which are controlled on an actual stack output per day basis, are well below the requirements of the National Emission Standards in subparagraphs C and E respectively of 40CFR61.

Calculated diffusion factors from the air pollution model are shown in Table 7 with the resultant permissible metal concentrations in the sludge. Also shown on Table 7 are the measured metal concentrations in the sludge. It is evident that the input metal concentrations are well below the allowables. Note that the permit limits shown on Table 6 were unchanged by the 503 Regulatory requirements and the test results are well below the allowable emissions.

As a monitor for good combustion, the 503 Regulations require that total hydrocarbon (THC) emissions be less than 100 ppm. The 1989 testing showed THC levels to be an average of 5 ppm.

The test results, therefore, showed that no changes in either the system hardware or the method of operation were required to conform with the 503 Regulations. However, there are changes to conform with the monitoring and record keeping requirements. A measurement of THC emissions must be added as well as an automated data collection system for THC, stack O_2, stack moisture, combustion temperature and sludge feed rate. The data collection system for Huntington will be computer based and will be report only with no control function (the current control panel is completely analog based).

REFERENCES

[1] "Standards For The Use Or Disposal Of Sewage Sludge, Final Rules, 40CFR Part 257, 403 and 503," Federal Register Vol. 58, No. 32, February 19, 1993, Page 9248ff.

[2] West Virginia Pollution Control Commission Permit RXIII-846, June 27, 1986.

[3] Mullen, John F., "Consider Fluid Bed Incineration For Hazardous Waste Destruction," *Chemical Engineering Progress* American Institute of Chemical Engineers, June 1992.

[4] Kahawata, M. and Briley, G., "Emission Source Test Of The Fluidized Bed Incinerator At Huntington Wastewater Treatment Plant, Huntington, West Virginia," Environment One Corp, Schenectady, NY 12301, 3 February 1990.

[5] "Review of Standards of Performance for New Stationary Sources; Sewage Treatment Plant Proposed Rules, 40CFRPart 60," Federal Register April 18, 1986.