FUEL SPECIFICATIONS - SLUDGE

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ABSTRACT

Since its beginning the pulp and paper industry has generated waste streams from their operations. As times changed so did the handling of these streams. More and more the environmental implications of these streams have created new handling methods. Economic impacts of sludge disposal have driven the industry to search for alternative uses for mill sludge, one of which is as a partial fuel replacement for the power and steam generation complex. Properties of the available sludge can vary widely and require numerous areas to be examined when designing a combustion system for sludge. Items of concern could be the sludge components, dewatering, handling, combustion, ash generation/disposal, air emissions, and boiler equipment.

SLUDGE COMPONENTS/ANALYSIS

Sludge solids produced by pulp and paper mills typically include a majority fraction of fiber. Depending on the mill, ink, sand, rock, biological solids, clay/fillers, boiler ash, grits from recausticizing, etc. may make up the other fractions. Because of the constituents that may exist, along with the water fraction, typical sludge analysis can vary widely. Therefore, it is critical to characterize the sludge feedstock carefully when designing systems to allow for the incineration of sludge.

Table 1 outlines a portion of the analysis of various sludges published in the last several years. Review will show the wide variability between sludges produced by different sources. Two areas that a chemical analysis will address include the combustion characteristics and the "other" materials which will pass through the boiler with the ash or possibly react within the boiler with refractory or metal surfaces.

Combustion properties of a sludge are generally related to the amount of fiber present. Energy available is usually inversely related to the ash content. As noted in Table 1, high ash values (up to 50 % on a dry basis) correlate with relatively low heating values. Sulfur values are important as related to emissions and will be discussed later.

Other constituents that can react within the boiler or pass through will be discussed later.

Combustion of sludge could occur either in a new boiler or through the use of an existing unit either with modifications or as is. Due to these possible approaches the sludge stream will be examined from both sides.

DEWATERING/DRYING

Dewatering of the sludge stream will be required to increase solids up to some minimum level before combustion will be beneficial or even breakeven. Self-sustained combustion is available with some sludges generated depending on the moisture and organic levels(1). Cost and benefit evaluations can be made that will indicate the moisture level for optimum performance.

Initial dewatering of the sludge stream to increase the solids from the 1 to 3 % consistency range up to the 25 to 50 % range for proper handling (landfill placement, conveying, etc.) will be necessary. Methods available for this includes rotary screen thickeners or gravity tables feeding screw presses or belt presses. Other thickeners such as a coil filter may also be an alternative.

Removal of additional water to increase solids above 50 % requires a different method similar to paper passing from the press section to the dryer section on a paper machine. Thermal drying with hot gases or air can be done in a conveyor dryer(2), cascade system(3), or a stand alone drying unit(4). Reduced water content obviously helps improve efficiency and also can improve long term storage options through reduced microbial growth(2).

Several of the characteristics of the sludge stream can affect the dewatering ability and cost. These include the amount of the fiber fraction, the amount of biological sludge, the amount of "inerts" (fillers), the solution pH, and the solution charge characteristics.

In general, a sludge with a lot of fiber or filler and little biological sludge dewaters easier and at a lower cost. Some screw press installations are able to dewater sludge without the need of a coagulant or flocculent. Biological solids (cell bodies) hold water and some installations use steam to indirectly heat the sludge to "burst" the cell bodies so the water can be removed.

The solution chemistry (pH and charge characteristics) greatly affect the chemical treatment needed. Most chemical additive programs work over a broad pH range (i.e. - 5.5 to 7.5), however, some are very pH specific. Formation of a sludge floc suitable for dewatering requires neutralization of the particle charges that repel each other and agglomeration of these particles with a flocculent. The materials going into the sewer from the mill (dispersants, coagulants, etc.) along with chemicals added in the waste treatment process (alum, coagulant, flocculent, etc.) affect the charge density of the sludge. The charge density dictates the level of coagulant or similar material needed to neutralize or satisfy the charge demand before flocculation can occur.

HANDLING/CONVEYING

Handling of the sludge from the dewatering process to the combustion process is somewhat dependent on its moisture content and particle size. Behavior anywhere from that of bark or wood chips to a heavy paste (high biological solids) may be encountered. Conventional means of handling materials (conveyors, pneumatic, screws, drag chains, etc.) can handle dewatered sludge.

The sludge product may be in several forms depending on the method of combustion and the boiler used. Dewatered sludge straight off a screw press will be lumpy and after moving through several conveying operations begin to break up into a fuel that is fine, uniform, and fibrous in nature. Sludge may also be processed further into briquettes or pellets(2) to improve handling, storage or combustion characteristics. Blending dewatered sludge with other fuel (chip fines or sawdust) can help improve conveying characteristics(5).

Addition of the material to the boiler and the ability to evenly distribute the sludge over a grate or within the boiler is essential to gain the full benefits available through combustion. Isolation of the sludge feed equipment from the boiler gases should be considered. Air bustles and pressurized equipment have been used to help keep feed equipment cool as well as assist feeding and help prevent sub-stoichiometric conditions from occurring if combustion begins before the sludge reaches the combustion zone. The Southeast Paper feed point is in the loop seal return leg which contains flowing bed material at operating temperatures. These temperatures will cause combustion to begin immediately as the sludge comes in contact with it.

Interruptions in boiler or dewatering operation need to be planned for. Surge capacity between the two systems reduces variability in each operation. Provision should also be made to reclaim stockpiled material if needed.

COMBUSTION

With Sludge

Combustion of sludge can be self-supporting but most installations currently burning sludge do so with another primary fuel (bark, coal, or oil.) Impacts of the moisture added to the boiler, ash generated, oxygen requirements, and time requirements for complete combustion should be considered.

Moisture added with the fuel will be vaporized and carried out the stack. More efficient operations can occur depending on the sludge dryness but a cost/benefit analysis will pinpoint the optimum point. The combustion temperature in the bottom of the boiler is greatly affected by this moisture. This abundance of moisture helps create a large heat sink that helps moderate the combustion zone temperature. This is more noticeable in a boiler fired on coal (low moisture primary fuel) than on one fired on bark (40 to 50 % moisture.)

Oxygen and residence time requirements for sludge combustion are dependent on the specific sludge and the form it is to be fired in. The form of the sludge fired (fibrous, pelletized, briquettes, etc.) dictates its behavior in the furnace and sets the residence time requirements for complete combustion. The composition of the sludge may require additional oxygen for complete combustion. In addition, the mixing and combustion temperature control needs for a boiler can cause higher than required oxygen levels.

The sludge generated by Southeast Paper is burned in a circulating fluidized bed boiler. At Southeast Paper, benefits are gained by using a high amount of "grid air" to improve mixing (higher efficiencies) and control the combustion temperature (low NOx, ideal sulfonation temperature of limestone.) These benefits cause excess air to be added over the required amount. On the other hand, for modifications of an existing boiler, considerations of the time requirements for combustion based on boiler design help dictate the form (fibrous fluff, pellets, or briquettes) the sludge will be fired in.

Numerous types of combustion methods are available and include(3 - 9):

- Travelling Grate Boilers
- Vibrating Grate Boilers
- Other Hog Fuel Boilers
- Bubbling Bed Combustors
- Circulating Fluidized Boilers
- Stage Combustors
- Rotary Kilns
- Pyrolysis/Pulse Combustors

The practicality of those listed above would be based on the sludge characteristics (contaminant contents, fuel size, volatility, ash characteristics, heat content, etc.) and to a great degree the volume to be fired.

Without Sludge

Operations of the boiler must also be considered when the sludge is not available as a fuel. Several points of consideration include the combustion temperature, fuel feed systems and boiler rating. Older boilers burning sludge as an alternative fuel would simply return to earlier operating states. Boilers built or retrofitted to burn the sludge may have special requirements they need to maintain operation without a sludge feed. For instance, the circulating fluidized boiler at Southeast Paper operates at a low combustion temperature (780 - 870 degrees Celsius(1450 to 1600 degrees Fahrenheit.)) Maintaining this temperature is important to minimize NOx emissions and to efficiently remove sulfur dioxide through limestone sulfonation. A flue gas recirculation fan is used to add flue gas to the boiler for cooling during coal only operation.

AUXILIARY EQUIPMENT

Auxiliary equipment for the boiler that can be affected by the fuel mix include the fans, particulate matter control, and ash removal systems.

Fan capacity can be greatly affected by the fuel moisture content and must be considered for all possible fuel feeds. Higher than anticipated moisture levels or sludge production can create extra water vapor to be removed by the ID Fan. In addition, more air may be needed depending on the fuel mix. Changes in the fan ducting was necessary at Southeast Paper to meet air needs during the summer months. Pulling hot air from the top of the boiler (lower density) helped efficiency, however, it did not allow the desired amount of air to be put in the combustion chamber through grid nozzles in the floor due to limited fan capacity.

Sizing of the ducting in the back pass (economizer, air heaters, multi-clones, etc.) will influence velocities. High velocity gases with ash can cause erosion of components in this section (air heater tubes, air heater walls, multi-clones.) Any corrosion products on air heater tubes can be removed by the gas stream laden with ash. Removal of this protective layer accelerates metal wastage.

Flue gas particulate matter characteristics can be affected by the fuels and thus its removal. A portion of the ash generated from a given fuel will end up leaving with the flue gas. Removal of this material can be accomplished with a precipitator or baghouse. Resistivity and particle size would be a function of the specific fuel.

The sludge analyses shown in Table 1 indicate a wide variety of ash contents. Ash formed during the combustion must be removed from the boiler taking heat along with it. These higher ash removal rates must be considered when designing new equipment or preparing for a trial burn on an older unit. Final disposition of the ash must also be considered in relation to the various metals.

AIR EMISSIONS

Several constituents should be considered as they relate to air emissions. Nitrogen and sulfur fractions will increase emissions of these "acid rain" compounds depending on the combustion process and these compounds will be regulated by a new air permit.

Nitrogen Oxides generation is primarily influenced by combustion temperature, therefore, proper control is needed to minimize production. Temperature control is aided by the moisture usually present in the sludge. The NOx issue will be a concern of any boiler operation in the future regardless of fuel mix.

Sulfur Dioxide generation is generally reduced in a coal fired unit with sludge substitution as most sludge is lower than coal in sulfur per energy unit. In addition, sulfur dioxide generated by sludge (alternate fuel or non-fossil fuel) can be used as a credit against that generated by a fossil fuel as outlined in the Code of Federal Regulations (40CFR60.45b(c3i.)) Current air emission limitations on new boilers require determination of percent sulfur dioxide removal (greater than 90% in Georgia.) Sulfur dioxide is either measured before and after a wet scrubber or, for a circulating fluidized bed boiler, the sulfur dioxide generated is calculated from fuel addition rates and daily fuel sample composites and the stack sulfur dioxide is measured.

Emissions generated by metals or toxic materials in the sludge could eliminate or limit incineration as a viable alternative. Detailed analysis of the sludge stream should be made to determine potential areas of concern.

BOILER FIRESIDE INTERNALS

Several fractions (moisture, chlorides, sodium, potassium) of the sludge can cause problems to the internals of the combustion process vessel.

Corrosion of materials throughout the gas passages (metal surfaces) can occur. Additional particulate loading in the flue gas can create an erosive environment that can remove corrosion products and accelerate metal wastage. The acid dew point of the flue gas will be reduced as the moisture of the flue gas increases and corrosion in the back end could be experienced as the dew point approaches the tube metal temperatures.

Ash deposits throughout the boiler can be influenced by the compounds in the ash and their influence on the "tackiness" of the ash. Softening or deformation temperatures of ash at Southeast Paper are around 1310 to 1370 degrees Celsius(2400 to 2500 degrees Fahrenheit.) A small build-up on the tube shields on the screen tubes (first tubes the gas sees after the cyclones) is noticed but can be easily removed. Ash build-up is very slight and only requires soot blowing once per week with only small changes seen in the location of heat transfer. Changes in mill processes or waste treatment plant operation can have an effect on deposits. Alum use creates an aluminum laden floc that stays with the sludge and contributes nothing to combustion. Aluminum in the ash can affect the ash softening temperature.

Deposits or a build-up of material has been noticed in the circulating fluidized boiler at Southeast Paper. These predominantly occur in the areas where an abundance of bed material circulates and normally only occur on the refractory. This build-up, which may be up to 5 centimeters (2 inches) thick that provides a protective layer over the refractory. Accumulations of several inches per year is normal and routine cleaning on the annual outage keeps them in control.

SUMMARY

Disposal of sludge by combustion is becoming an alternative for many pulp or paper manufacturers due to constraints imposed on other disposal methods and the continuous push to reduce costs. Effective dewatering techniques have been and are being developed to produce a fuel with real potential. Many variables in this fuel stream can effect the design of the combustion processes and these are summarized in Table 2. Experiences with sludge combustion throughout the industry during the last 10 years have shown it to be a task that can be mastered given the correct design or retrofit. Each sludge stream is different; therefore, a detailed analysis is needed to understand the requirements to make that stream into a valuable fuel source for your mill.

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TABLE 1. SLUDGE CHARACTERISTICS/COMPOSITION

% Dry Basis	Virgin Mill Sludge							Deink/Recycle Mill Sludge				Municipal Sludge	
Component	#1	#2	#3	#4	#5	#6	#7 (54 avg)	#8	#9	#10	#11	#12	#13
Carbon		59.36	54.3	48.7	48.0				50.00		42.05		
Hydrogen		6.90	6.2	6.6	5.7				6.55		5.12		
Nitrogen		4.68	1.8	0.2	1.2	1.06	0.85		0.38		0.32		3.3
Sulfur	0.09	0.39	0.6	0.2	0.8	0.55	0.468	0.08	0.31	0.07	0.14	0.0022	1.10
Oxygen		28.67	28.9	42.4	36.3				42.76		30.22		
Ash	8	50.0	8.2	1.9	8.0	22		21	5.5	48.9	22.15	11.5	
BTU/lb.	*4100	5182	9102	8643	8500	6318		*4000	8371	3553	7009	*5500	
Potassium						0.21	0.22				0.08		0.3
Calcium						3.15	1.40				0.19		3.9
Magnesium						0.69	0.155				0.62		0.45
Aluminum						2.49	1.34				7.91		0.40
Arsonic						0.00862	0.00012						0.0010
Cadmium						0.00053	0.00012						0.0015
Mercury						<0.00032	.000035						0.0006
Sodium						0.083	0.22				0.14		0.24
Lead						0.00144	0.0028						0.050
Iron						0.9089	0.154				0.27		0.17
Chlorides	0.02							0.07			0.03	0.02	

* Estimated from Reference by Author to put on dry basis.

REFERENCE TABLE:

MILL	REFERENCE
1,8,12	6
2,9	7
4	8
5	5
6	9
7,13	2
10	1
11	Southeast Paper, Dublin, GA.

TABLE 2. SLUDGE EFFECTS ON COMBUSTION PROCESS EQUIPMENT

	EFFECTED PROCESS AREA								
	Dewatering			Combustion					
SLUDGE PROPERTIES/ CHARACTERISTICS	Ability	Cost	Handling/ Conveying	Charac- teristics	Cost	Boiler Aux. Equipment	Emissions	Fireside Internals	Comments on Effect/Impact
Inlet Solids to Dewatering	✓	✓							Water to be Removed
Biological Solids Content	✓	✓							Harder to Dewater
Charge Density of Sludge	✓	✓							Must be Neutralized
Sludge pH to Dewatering	✓	✓							Polymer Effectiveness
Availability of Waste Heat (Drying)		✓	✓			✓			Higher Solids, Conveying Options, Heat Supply
Minimum Acceptable Solids		✓	✓		✓				Breakeven Point
Actual Dewatered Sludge Solids		✓	✓	✓	✓	✓		✓	Evaporation, Gas Volume, Acid Dew Point
As Fired Sludge Form/Shape			✓	✓		✓			Feed Systems, Residence Time Requirements, Storage
Sludge Feed System			✓			✓			Safe Isolation from Fireside, Even Distribution
Boiler Reliab./Dewatering Reliab.			✓			✓			Surge Capacity
Ultimate Analysis				✓	✓		✓	✓	Heat Content/Ash Characteristics, Deposit Potential
Metal Analysis							✓	✓	Hazardous Emissions/Ash, Corrosion
Ash Content	✓	✓		✓	✓	✓		✓	Removal, Disposal, Erosion
Ash Characteristics						✓		✓	Erosion, Build-up on Tubes
Boiler Type				✓	✓	✓	✓		Residence Time, Combustion Temperature, Modifications