Paper mill sludge as a valuable fuel

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Sludge can be transformed from a waste product into a valuable fuel for use in steam generation and in fuel-drying operations.

The North American segment of the pulp and paper industry produces more than 8,000 tons of sludge every day. Most of it is landfilled, and a smaller portion is incinerated in some way. Landfilling represents a cost to the mill because of the associated trucking and handling costs and, in some cases, dumping fees. Landfill disposal of paper mill sludges has also become an issue of growing environmental concern.

Incineration as a disposal method is most commonly used in mills that have solid-fuel-fired boilers suitable to handle wet sludge. The mechanically dewatered sludge typically is mixed with bark, wood refuse, or some other solid fuel and then burned in the power boiler.

The problem with this method of disposal is the sludge's moisture content. With conventional mechanical dewatering devices, the solids content of the sludge is typically 15–40%, depending on the type of sludge and the method of dewatering. At these low solids contents, addition of a fairly moderate amount of sludge to the bark stream can substantially increase the amount of water that is being introduced into the boiler. For example, if a mill produces 400 tons/day of bark on a moisture-free basis and the bark has 50% moisture, that corresponds to 400 tons/day of water. If the mill produces 40 tons/day of sludge on a moisture-free basis and the sludge has 25% solids content, that corresponds to 120 tons/day of water. In this case, the sludge adds 10% to the solids, but 30% to the amount of water that has to be evaporated in the boiler. At 25% solids content, the theoretical net heat contribution from that sludge is very low and can, in fact, be negative.

Combustion of moisture-containing fuels

The combustion of solid fuel on a furnace grate is a staged process, starting with evaporation of the fuel's moisture and followed by volatilization—burning of these combustible gases above the grate—and then final burnout of the remaining charcoal on the grate. The higher the initial moisture content of the fuel, the longer it takes for combustion to begin. This affects the capacity of the grate by substantially reducing the grate's heat-release rate, which is a measure of the rate at which fuel can be burned. The effect of fuel moisture on the grate's heat-release rate is illustrated in **Fig. 1**, which shows that the attainable grate heat-release rate drops off rapidly with increasing fuel moisture. Wetter fuel also produces lower combustion temperatures, which reduce the transfer of radiant heat. This, in turn, decreases the evaporation rate of fuel moisture and volatiles. The lower furnace temperatures also result in poorer combustion of these volatiles, further reducing boiler efficiency and increasing emissions.

All water introduced into the furnace has to be evaporated and heated to the final stack temperature. Thus any increase in fuel moisture will decrease boiler efficiency. In addition, higher fuel moisture typically requires higher excess air levels to maintain stable, smoke-free combustion. **Figure 2** illustrates the combined effects of fuel moisture on steam generation.

If a boiler is grate-limited, i.e., burning as much bark as it possibly can based on the size of the grate, then adding 10% sludge to the bark flow will require a decrease in bark flow by 10–20%. In addition, the increased moisture load on the boiler will reduce its efficiency. Taken in combination, these two factors can reduce steam generation by 25%. In such cases, the firing of fossil fuels must be increased to maintain the steam load to the mill. And mills that are not purchasing any hog fuel could wind up trading a 40-ton/day sludge-disposal problem for an 80-ton/day bark-disposal problem.

Sludge dewatering

Dewatering is the obvious solution to problems caused by the presence of excessive moisture. Improved mechanical dewatering is one possible solution. A modern screw press can increase the solids content of primary-clarifier sludge to 45–50% on a continuous basis. However, biological sludge is extremely difficult to dewater, and a solids content over 15% is very difficult to achieve with any type of mechanical dewatering device.

For mills with existing wood-waste-fired boilers, the natural solution to the sludge-disposal problem is to incinerate the sludge within this power boiler. If the mill does not have a solid-fuel-fired boiler, suspension firing in an existing oil- or natural-gas-fired boiler might be an option. However, limited furnace volume and lack of an effective ash-removal system can present problems. If

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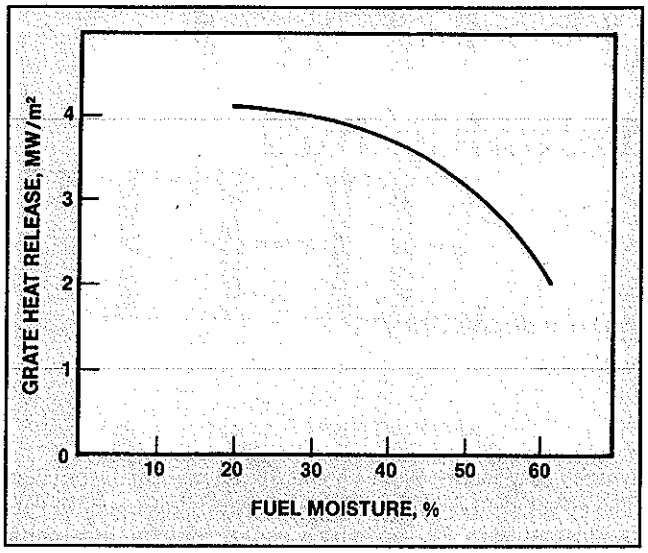
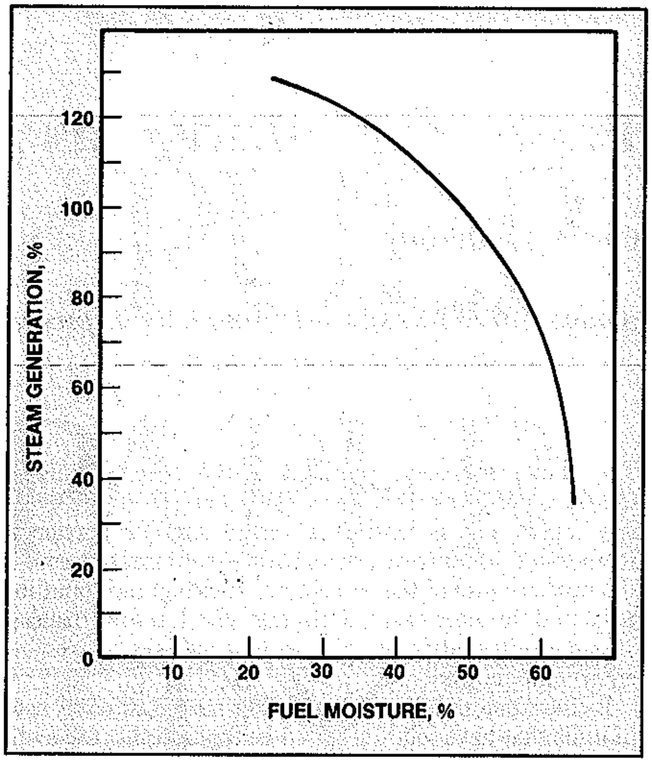
1. Effect of fuel moisture on grate heat release



2. Effect of fuel moisture on steam generation

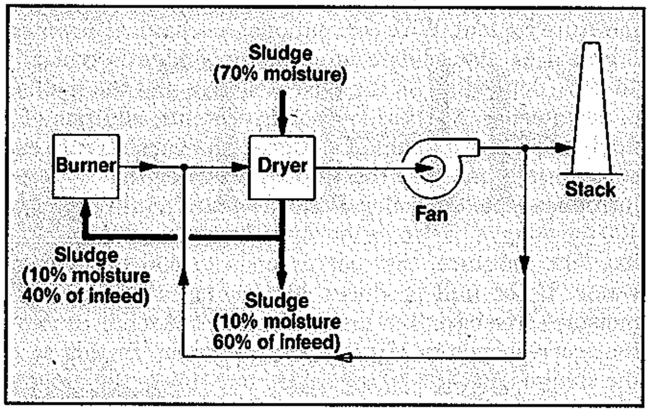


I. Effect of adding wet sludge and dried sludge to an existing bark/oil-fired boiler*

	Base case	*Wet sludge*	*Dried sludge*
Steam load (total), metric tons/h	90.0	90.0	90.0
Steam from bark/sludge, %	85.6	68.1	100.0
Steam from oil, %	14.4	31.9	0
Bark fired (moisture free), metric tons/h	15.1	13.1	15.1
Sludge fired (moisture free), metric tons/h	0	1.5	1.5
Oil fired, m³/h	0.95	2.11	0
Boiler efficiency (bark/sludge), %	66.8	62.6	72.6
Boiler efficiency (oil), %	86.4	86.4	72.6
Grate heat-release rate, MW/m²	3.15	2.68	3.39
Bark moisture (entering boiler), %	50.0	50.0	42.7
Sludge moisture (entering boiler), %	...	75.0	42.7

*Grate area = 27 m²; stack temperature = 204°C; steam generation = 90 metric tons/h.

3. Stand-alone sludge drying system



sludge is to be burned in suspension, its solids content must be about 90%. For these applications, dewatering through thermal drying is the only practical option.

Grate-equipped boilers

The negative effects of adding sludge to the wood fuel can be eliminated by pre-drying the sludge using the waste heat in the boiler flue gases. This strategy also can enhance the overall performance of the power boiler.

Look at the case of an existing power boiler with a grate area of 27 m² (290 ft²) and a stack temperature of 204°C (400°F) generating 90 metric tons/h (200,000 lb/h) of steam from combination firing of wood waste and oil. In this boiler, 86% of the steam (77 metric tons/h) is generated from wood fuel and the balance from oil. This corresponds to an oil consumption of 0.95 m³/h (6.0 bbl/h).

The effects of adding wet sludge vs. dried sludge to this boiler are compared in **Table I.** Addition of 36.3 metric tons/day of sludge at 25% solids (75% moisture) to the wood fuel would increase the heat input from solid fuel by about 10%. The resultant steam generation from the solid fuel, however, would decrease to 61.7 metric tons/h (136,100 lb/h). If the total steam load on the boiler is to be maintained, the oil consumption must be increased to 2.11 m³/h (13.28 bbl/h).

If this boiler is retrofitted with a fuel dryer, lowering the stack temperature to 90°C (200°F), the boiler efficiency from combustion of solid fuel will increase to the point that oil firing can be completely eliminated. This is demonstrated in Table I. Thus, the addition of a fuel dryer can convert sludge from a waste product to a valuable fuel that can be used instead of oil.

In a case like this, the question arises whether to dry just the sludge or the entire solid-fuel stream. The size of the fuel dryer is determined by the flow of flue gas from the boiler. One might as well utilize this capacity to dry the entire fuel stream down to a uniform moisture content.

Suspension firing in other types of boilers

If the mill does not have a grate-equipped boiler, there is still the possibility of burning the sludge in an existing boiler by using suspension-firing technology. However, this means that the moisture content of the sludge must be reduced to below 10%. To achieve this low moisture content, the flue-gas temperature has to be raised above the typically available range of 177–232°C (350–450°F). The required flue-gas temperature is determined by the sludge moisture and the amount of co-firing with supplementary fuel. With a bypass arrangement on the tubular air heater, flue-gas temperatures up to 315°C (600°F) can usually be obtained.

If this is still not efficient, there is always the option of drying the sludge in a stand-alone drying system where the necessary drying heat is generated by burning a portion of the dried sludge in suspension. This approach is illustrated in **Fig. 3**. The exact proportion of sludge consumed in the drying process depends on the initial moisture content of the sludge and the desired final moisture content. For example, Fig. 3 shows that if sludge with an initial moisture of 70% is to be dried down to 10% moisture content, 40% of the sludge flow will be used for the drying process. The remaining 60% of the sludge can be used in a suspension burner in an existing power boiler. The mill also has the option of incinerating all of the sludge in the dryer burner. In the latter case, the extra heat generated must be removed from the system. This can be done simply by adding a spray attemperator to the flue duct downstream of the combustion chamber. This type of arrangement will serve as a stand-alone sludge incineration system, where all the heat required for drying and incineration comes from the sludge itself.

Conclusion

There are many different ways to get rid of paper mill sludge besides landfilling. If the mill has an existing grate-equipped boiler, mechanical dewatering might be sufficient, assuming the boiler has additional firing capacity on its grate and the resultant reduction in boiler efficiency is acceptable. If that is not the case, a fuel dryer makes sense, since it acts to increase the firing capacity of the boiler grate. If the mill does not have a grate-equipped boiler, the sludge can be burned in suspension in other types of boilers by utilizing a dedicated drying system to reduce the sludge moisture down to a level suitable for suspension firing. Yet another option is to install a stand-alone sludge drying/incineration system.□

Received for review May 5, 1989.

Accepted June 26, 1989.

Presented at the TAPPI 1989 Engineering Conference.