INCINERATION OF HOT SLUDGE

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ABSTRACT

In an effort to reduce the cost of sludge disposal and at the same time to provide full onsite treatment capability, many municipalities have selected thermal conditioning for sludge processing, utilizing incineration as the final reduction process. Multiple hearth furnaces have been used almost exclusively for incineration of thermally conditioned sludge cake. The cake has a higher as-received heat content than sludge cake produced by chemical conditioning, and this "hot sludge" characteristic leads to severe operating problems with conventional multiple hearth furnace operation. Uncontrolled burning, excessively high operating temperatures, excessive emissions, slagging, and unstable operation occur when burning this material, and although there have been many attempts to solve these problems, there are no generally accepted solutions. Through experimentation and a reevaluation of basic principles governing multiple hearth furnace operation, an effective and relatively simple technique has been developed and successfully implemented.

SLUDGE CHARACTERISTICS

The type of sludge conditioning chosen for a particular process is more often than not chosen to provide the most effective dewatering, based on the cost of conditioning plus the cost of dewatering, compared to the cost of incineration (or other treatment method).

Sludge cake from conditioning processes will normally vary in quality, depending on the type of sludge generated (primary, waste activated, trickling filter, etc.), the method of conditioning (polymer, ferric salt, lime, thermal), and the type of dewatering equipment used (centrifuge, plate and frame press, vacuum filter or belt filter press, etc.). Table 1 lists normal ranges of sludge cake parameters for both chemical and thermal conditioned sludge. The values in parenthesis are typical.

The wide variation in the sludge volatile fraction is a function of the conditioning method used. Lime addition would decrease the volatile fraction (lime is inert) while polymer usage would not. In any case, the as-received heating value of a typical sludge cake will be approximately 1000 Btu/lb (556 cal/kg) with chemical conditioning and 1800 Btu/lb (1000 cal/kg) with thermal conditioning. For the same solids load, significantly less moisture will be present with thermal conditioned sludge. For 2500 lb/hr (1134 kg/h) of sludge solids, 7500 lb/hr (3400 kg/h) of moisture will be present with chemical conditioned sludge, whereas only 5833 lb/hr (2646 kg/h) of moisture will be carried with thermal conditioned sludge.

Here, then, is the problem: thermal conditioned

TABLE 1 SLUDGE PROPERTIES (Ref. [1])

Chemical	Conditioning	Thermal
70%-85% (75%)	Moisture	55%-75% (70%)
40%-80% (60%)	Solids Volatile %*	40%-60% (50%)
8,000-11,000 (10,000)	Heating Value (Btu/lb Vol)	10,000-13,000 (12,000)
1,600- 7,260 (4,000)	Heating Value (Btu/lb Solids)	4,000-78,000 [2,222-4,334] (6,000)
480- 1,980 (1,000)	Heating Value (Btu/lb Cake)	1,000-3,510 (1,800)

*Moisture ash of free sludge residual

sludge, as received, has a higher net heating value and a lower moisture content than chemical conditioned sludge. It will lose its moisture content quickly within the furnace, and it will release greater heat; both of these factors tend to result in burning relatively soon, or high, in a multiple-hearth incinerator. This sludge, defined as "hot sludge," requires different furnace operating parameters than sludge from other conditioning processes, which burn in a more conventional manner.

AUTOGENOUS BURNING

"Autogenous burning" refers to that condition where burning will occur without the addition of supplemental fuel. It must be referred to a temperature; e.g., a match will burn (is autogenous at 450°F (232°C), but it is not autogenous at 1000°F (538°C). If a match is to burn at this higher temperature, a supplemental source of heat is required. Likewise, sludge may be autogenous at 600°F (316°C), but supplemental fuel must be added to the furnace if 1000°F (538°C) is the desired outlet temperature. The burning characteristics of sludge cake are a function of its moisture and volatiles content, heating value, and the quantity of combustion air supplied. Of these factors, sludge moisture content is the most significant because it is moisture that is most frequently varied and has the greatest impact on heat dissipation (most of the moisture present must be evaporated before the volatiles will combust). Figure 1 shows the relationship between autogenous burning temperature, moisture content and volatiles content for chemical conditioned sludge, and Fig. 2 illustrates the burning profile of thermal conditioned sludge.

The higher the volatiles content and the lower the moisture content, the higher will be the autogenous burning temperature. At least 800°F (427°C) is required at the multiple hearth furnace outlet for effective destruction of sludge cake. To burn at this temperature, the sludge must have at least a 60% volatiles content and no more than approximately 73% moisture, as illustrated in Fig. 1. Thermal conditioned sludge cake, however, (see Fig. 2) will burn autogenously with significantly less volatiles and at a lower moisture content than chemical conditioned sludge.

EFFECTS OF EXCESS AIR

The ideal amount of air necessary for complete combustion of all the volatiles present, the stoichiometric air demand provides the oxygen required to burn all the carbon to carbon dioxide and all the hydrogen to water vapor. To assure that all of the sludge load within a furnace eventually contacts sufficient air to burn, air in excess of the stoichiometric requirement must be provided. This is true with any burning process, and with any furnace. In a multiple-hearth furnace burning sludge cake, an excess air amount of 75% to 150% of stoichiometric is necessary to ensure complete combustion.

Air added to a furnace in excess of the stoichiometric requirement will tend to lower the temperature of the off-gas. A portion of the heat released within the furnace will be used to raise the temperature of the incoming air stream, resulting in a cooling of the furnace. One method of furnace temperature control is therefore to control the quantity of excess air introduced into the furnace.

CONVENTIONAL MULTIPLE-HEARTH FURNACE OPERATION

A multiple-hearth furnace used as an incinerator is normally designed for three-stage operation. Sludge is dried on the top hearth(s), burned on center hearths, and burns out to ash on the lower hearths. In a 6-hearth furnace, for instance, hearths 1 and 2 would normally be the drying hearths, 3 and 4 the burning hearths, and 5 and 6 the burn-out or cooling hearths. An enlarged top chamber or a separate unit downstream of the furnace is, at times, provided as an afterburner chamber. Combustion air normally enters

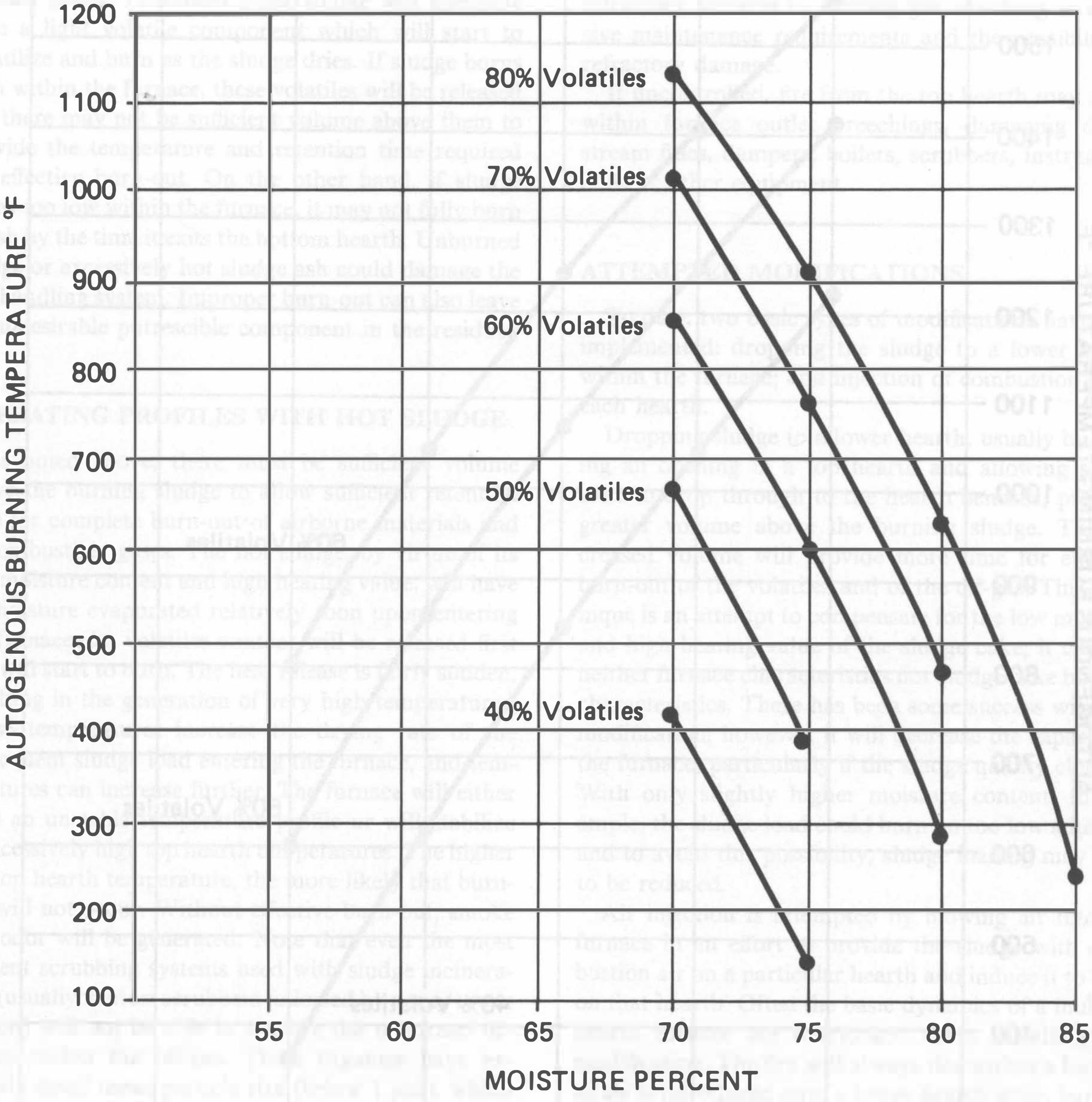

FIG. 1 CHEMICAL CONDITIONED SLUDGE CAKE, 10,000 Btu/lb, 85% EXCESS AIR. AUTOGENOUS BURNING TEMPERATURE VS MOISTURE CONTENT.

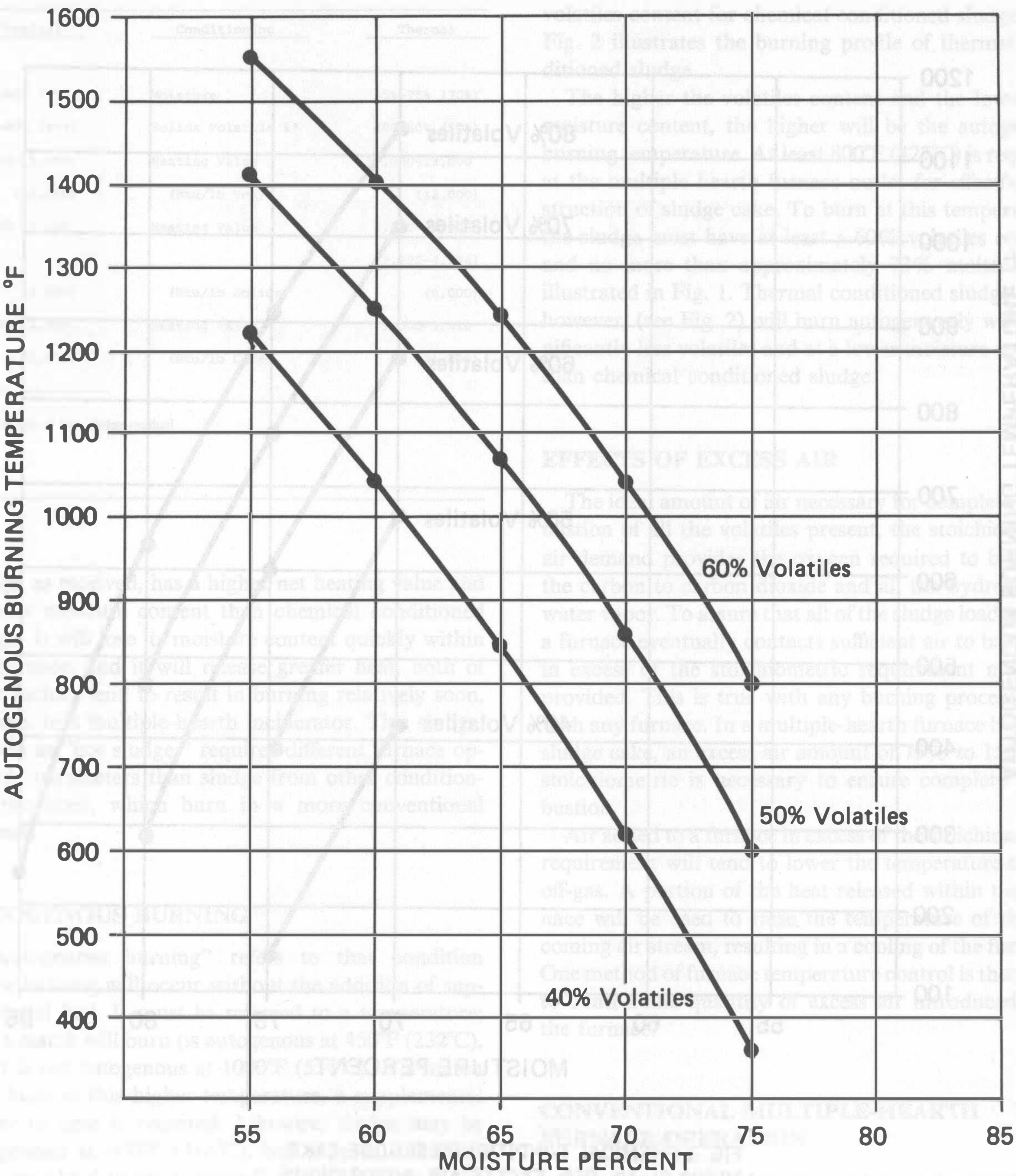

FIG. 2 THERMAL CONDITIONED SLUDGE CAKE, 12,000 Btu/lb, 85% EXCESS AIR. AUTOGENOUS BURNING TEMPERATURE VS MOISTURE CONTENT.

near the bottom of the furnace, picking up heat from hot ash on the lower hearths.

There are serious limitations to the location of these furnace zones. Treatment plant sludge will normally have a light volatile component which will start to volatilize and burn as the sludge dries. If sludge burns high within the furnace, these volatiles will be released but there may not be sufficient volume above them to provide the temperature and retention time required for effective burn-out. On the other hand, if sludge burns too low within the furnace, it may not fully burn to ash by the time it exits the bottom hearth. Unburned sludge or excessively hot sludge ash could damage the ash handling system. Improper burn-out can also leave an undesirable putrescible component in the residue.

OPERATING PROFILES WITH HOT SLUDGE

As noted above, there must be sufficient volume above the burning sludge to allow sufficient retention time for complete burn-out of airborne materials and of combustible gases. The hot sludge, by virtue of its low moisture content and high heating value, will have its moisture evaporated relatively soon upon entering the furnace. Its volatiles content will be released first and will start to burn. The heat release is fairly sudden, resulting in the generation of very high temperatures. These temperatures increase the drying rate of the subsequent sludge load entering the furnace, and temperatures can increase further. The furnace will either have an unstable temperature profile or will stabilize at excessively high top hearth temperatures. The higher the top hearth temperature, the more likely that burn-out will not occur. Without effective burn-out, smoke and odor will be generated. Note that even the most efficient scrubbing systems used with sludge incinerators (usually venturi scrubbers followed by a tray tower section) will not be able to remove the unburned organics within the off-gas. These organics have extremely small mean particle size (below 1 μm), which is beyond the removal capability of these scrubbers. In addition, unburned hydrocarbons are generally hydrophobic, resisting absorption or adsorption into a water stream.

Ash from treatment plant sludge burn-out will start to soften in the range of 1800°F (982°C) to 1900°F (1038°C), which limits the desired level of gas temperature within the furnace. Of the total dry sludge introduced into a multiple hearth furnace, 10% to 30% of the nonvolatile component will be airborne, and if heated to its ash fusion temperature, this ash will soften and form deposits on slightly cooler refractory surfaces. Clinkers may also form within the sludge bed on top of the hearths. These clinkers and other ash accretions are corrosive and prevent normal cooling of refractory surfaces by flowing gas, resulting in excessive maintenance requirements and the possibility of refractory damage.

If uncontrolled, fire from the top hearth may travel within furnace outlet breechings, damaging downstream flues, dampers, boilers, scrubbers, instruments and/or other equipment.

ATTEMPTED MODIFICATIONS

To date, two basic types of modifications have been implemented: dropping the sludge to a lower hearth within the furnace; and injection of combustion air to each hearth.

Dropping sludge to a lower hearth, usually by placing an opening in a top hearth and allowing sludge cake to drop through to the hearth beneath, provides greater volume above the burning sludge. This increased volume will provide more time for effective burn-out of the volatiles and of the off-gas. This technique is an attempt to compensate for the low moisture and high heating value of the sludge cake; it changes neither furnace characteristics nor sludge cake burning characteristics. There has been some success with this modification; however, it will decrease the capacity of the furnace, particularly if the sludge quality changes. With only slightly higher moisture content, for example, the sludge load could burn on too low a hearth, and to avoid this possibility, sludge loading may have to be reduced.

Air injection is attempted by blowing air into the furnace in an effort to provide the sludge with combustion air on a particular hearth and induce it to burn on that hearth. Often the basic dynamics of a multiple hearth furnace are overlooked when installing this modification. The fire will always rise within a furnace as air is introduced onto a lower hearth when burning autogenously. Sludge does not normally burn to an air source within a multiple hearth furnace; it flares in a vertical direction, encouraged upward by air flow beneath it. Automated air injection systems for control of autogenous burning hearth temperatures will not work. One midwest installation utilizes multi-hearth air injection in a system that was originally designed for hearth temperature control. It never worked in the automatic mode. An overtemperature condition would send air rushing onto that hearth, and the hearth temperature would not necessarily decrease; the burning zone would move up to the next highest hearth. Air would be injected on this upper hearth in sufficient quantity to quench the fire and drive burning down to the next lowest hearth where air would be re-injected, repeating this entire process. The result of this activity is uneven burning and an extremely unstable furnace. Rather than control the burning zone, this method of operation forces it to vacillate within the furnace. Even if air injection on one hearth was controlled by temperature on a different hearth, operation would quickly become unstable.

The use of compressed air ports above each hearth to provide turbulence and thereby promote effective burning has also been tried. This has not met with success either. The high velocities and high degree of turbulence produced by these nozzles increase the particulate loading in the flue gas and have no noticeable effect on burning efficiency.

RECOMMENDED SOLUTION

The temperature of the sludge on the top hearth(s) of the furnace must be reduced, in order to reduce the drying rate. By injecting massive amounts of air to quench these temperatures, the burning zone will drop. The quench air must never be injected below a burning zone; it must always be introduced either above a burning hearth or at that hearth, to quench the fire. At Atlantic County (New Jersey), a quench air fan was provided to introduce air at two points on hearth #3. Sludge is side-fed to hearth #2, at up to 45% solids from a Porteous heat treatment system, dewatered by centrifuges. Prior to these modifications the sludge burned too high in the furnace and too hot, producing the problems described above. The quench air was added with local damper control, manually adjusting the damper, with visual indication of the damper position, and hand-locking it with a thumb-screw. This air flow required little attention. It was set to provide reasonable temperatures off hearth #2, and sludge burning did not occur before reaching hearth #4. The off-gas temperatures were maintained at a high enough level to allow the temperatures required for effective destruction of the sludge off-gas. By burning lower in the furnace, sufficient retention time was provided within the hearths above the burning hearth to complete burn-out.

Sufficient air should be injected on the upper hearth(s) to bring the temperature of the off-gas from 1600°F to 800°F (871°C to 427°C) when burning the maximum anticipated sludge load. There should be at least two points of injection on a single hearth. With a single point or improperly chosen multiple injection points, the air velocity could be excessive, encouraging ash to become airborne and thus increasing the emissions load.

The air quench system could be local or remote manual but it should not be automated. It cannot be automated effectively with any set of input parameters from the furnace.

It is virtually impossible to perform a meaningful analysis of the specific area in the furnace where sludge is burning. Sludge appearing to combust on one hearth will flare up on an upper hearth, i.e., volatiles and unburned organics in the off-gas from the burning sludge will combust in the turbulent gas stream above the so-called burning hearth. Much of this combustion will occur as gas exits to an upper hearth, through the drop holes or in the annular area around the center shaft. Attempts to isolate a hearth as a separate and complete system (hearth-by-hearth analysis) in order to determine hearth air injection quantities do not reflect actual furnace operating conditions. It is not possible to calculate the true heat balance for an individual hearth without introducing large enough errors to void the entire evaluation. The only effective determination of furnace equipment parameters is a gross heat balance around the entire furnace. The calculated air flow requirement should be brought to top hearths as discussed above.

SUMMARY

The multiple hearth furnace is designed to burn sludge. In industry it is used for ore processing, lime and carbon regeneration, etc. It has limitations, as does any furnace system. The burning of sludge with low moisture and high heat content can be accommodated to a point, as has been described here, but the furnace cannot burn sludges with moisture contents outside certain limits. At the high end, a moisture content in excess of 85% is normally too wet to be physically rabbled along a hearth or dropped from one hearth to another. The driest sludge cake that can be handled by a multiple hearth furnace is probably from 40% to 50% solids. If sludge cake exceeds these parameters, a different type of furnace may be required for its effective incineration.

REFERENCES

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