Feasibility of Waste Heat Recovery from Waste Sludge in Paper & Pulp Industry: The Economical Use of Energy Resources

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ABSTRACT

The cardinal change in the world market for energy resources during the last 10 years requires the reoptimization of the entire energy economy and requires that great attention to be paid to increasing the efficiency of using energy resources and thus to reducing their consumption.

Production of sludge as waste in pulp and paper plants can be considered as one of the serious environmental problems that have to be solved. While land filling is not a suitable solution from the environmental & energy recovery point of view, thermal treatment proved to be the most appropriate one. This paper describes an efficient way of processing sludge including waste-to-energy aspects and attention is focused on the performance of the energy recovery. The retrofit has been realized in two stages. The waste sludge is burnt in a multiple hearth incinerator with a fluidized-bed chamber. The different stage of retrofit, can be characterized as a "waste-to-energy" one, where heat from flue gas was utilized for generating the steam, drying the sludge, pre-heating air for combustion and fluidization and preheating water for steam generation . Off-gas cleaning system consists of a filter for particulate removal and a three-stage scrubber system is attached for cleaner stack.

Keywords: *Waste heat recovery; Pulp and paper plant; Thermal disposal of waste; Waste to energy; Multiple hearth incinerator with a fluidized-bed chamber*

INTRODUCTION

Industrial production of pulp and paper is very demanding in terms of energy and raw material consumption. That is why pulp producers make every effort to utilize as much energy and raw material as possible and minimize waste. Sludge originating in pulp mills is a major waste and needs to be treated. Pulp and paper plants produce a large quantity of sludge. Environmental problems connected with this waste were not solved satisfactorily in the past (in the first half of 20^{th} century); from the point of view of energy recovery and environmental protection, an unsatisfactory situation existed in many countries. Wastewater from plants was discharged directly to rivers. Wastewater treatment facilities were introduced step by step into production plants; however, it was still necessary to solve the problem of disposal of concentrated sludge. Moreover, this biological sludge decays gradually. Hence, while land-filling is not a suitable solution from the environmental point of view, thermal treatment of sludge proved to be an appropriate one. These include replacing more expensive fuels by cheaper ones, balance, and increasing the efficiency of fuel and energy use. An especially large potential for savings is to be created.[1]

Characteristic Features of Waste Sludge

The sludge comes from wastewater treatment and sludge house keeping of the process producing bleached pulp and fodder yeast. The treated sludge from one industrial plant, which is a typical representative of such a process, has a composition as shown in Table 1. The heating value ranges within an interval from 0.7 to 1.8 MJ/Kg. The wet sludge is of very soft paste-like consistency. Characteristic properties of the wet sludge only partially change with respect to the content of pulp fiber. [4]

Retrofit of Sludge Incinerator (First Stage of Retrofit)

A unit for the thermal treatment of sludge in a pulp and paper plant can serve as an example of a large industrial incinerator. A multiple hearth combustion chamber with fluidized bed can be considered as a basic device of the unit. One-stage water scrubbing without additives was used for de-dusting the flue gas. De-watered sludge, coming from wastewater treatment process unit, enters the upper section of the multiple hearth combustion chambers. The sludge enters in the form of lumps with their size corresponding to the dimensions of the equipment used for their transport. The rotating rabble arms and supporting air-cooled rotating central shaft gradually move the sludge over the other four hearths. The flue gas passing by the sludge in counter flow dries it gradually. The lumps of sludge, pre-dried this way, fall from the last hearth into the fluidized bed of the combustion chamber where they are incinerated. The high temperature (1000°C) flue gases is used in waste heat boiler where low pressure saturated steam is generated which can be used in process. Low temperature flue gas applications are hot water generation, combustion air preheating etc. The flue gas from the incineration

Table 1: Basic Feature of Sludge

Component	Mass (%)
Dry component	13-35
Dry matter	4-7.5
Water	65-85

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process further passes the multiple hearth combustion chambers and is cooled down by water evaporation from the sludge. After leaving the multiple hearth combustion chambers, the flue gas enters a scrubber where it is first cooled down to its saturation temperature (about 60°C) due to water injection. Then, in the scrubbing stage, a part of the polluting substances is treated. Emission concentration values related to a common operational regime of the incinerator before retrofitting are compared with the valid allowable legislative emission limits as shown in Table 2.

The high value of solid particles was due to rather low efficiency of the off-gas cleaning system. The high Content of carbon monoxide and C_XH_Y was caused by an unsuitable processing arrangement in the incineration unit. The lack of flue gas flow control across multiple hearths of the combustion chamber caused local increase of the hearth temperature, which results in partial concentration of emissions and pollutants.

Before retrofit pollutant measured values (mg/m_N^3) shown in Table 2. Pyrolysis of the sludge may occur during the process of drying. Chlorine emission limits were also trespassed before the change of bleaching technology from the chlorine-based one into a chlorine-free one. After the change of bleaching technology, meeting the limits could be basically preformed without problems. The high content of Sulphur in the sludge was due to the composition of wood used for this pulp production.

A general overhaul of the existing fluidized-bed combustion chamber was carried out during the first stage. The combustion chamber was supplemented by an afterburner chamber with a thermo- reactor (secondary combustion chamber) ensuring combustion of carbon monoxide and hydrocarbons that exceed the limit. The multiple hearth combustion chambers with fluidized bed were supplemented by a by-pass of flue gas. It enabled an efficient control of volumetric flow rate of flue gas through the hearths and the control of the related temperature. [4]

A liquid droplet separator and a particulate solid (flying ash) separator were incorporated. NaOH solution was injected into the water retained in the solid separator in order to maintain the required pH value by neutralizing harmful acid substances (namely SO_2). A part of the un reacted NaOH solution was utilized for neutralization of the environment in the flue gas scrubber. Purified off-gas flew further into stack. The necessary draught for the transport of the off-gas through the whole system was ensured by a flue gas fan placed between the incinerator and the off-gas scrubber.

The guarantee test was carried out at three operational regimes of the incineration unit:
The emission test result is as shown in Table 3.

Table 2: Emission after Retrofit

Pollutant	Before retrofit (mg/m_N^3)	After retrofit (mg/m_N^3)	Allowable limit (mg/m_N^3)
NO_X	50-227	200-250	350
CO	2200-3100	20	100
C_xH_y	<100	0	20
Solid Particles	100-157	20-25	10

Table 3: Emission During Regime I, II, III Test

Pollutant	Concentration measured during test (mg/m_N^3)			Allowable limit (mg/m_N^3)
	Regime I	Regime II	Regime III	
NO_X	261	265	280	350
CO	4	2	4	100
C_xH_y	058	028	010	20
Solid Particles	-	28.9	-	10

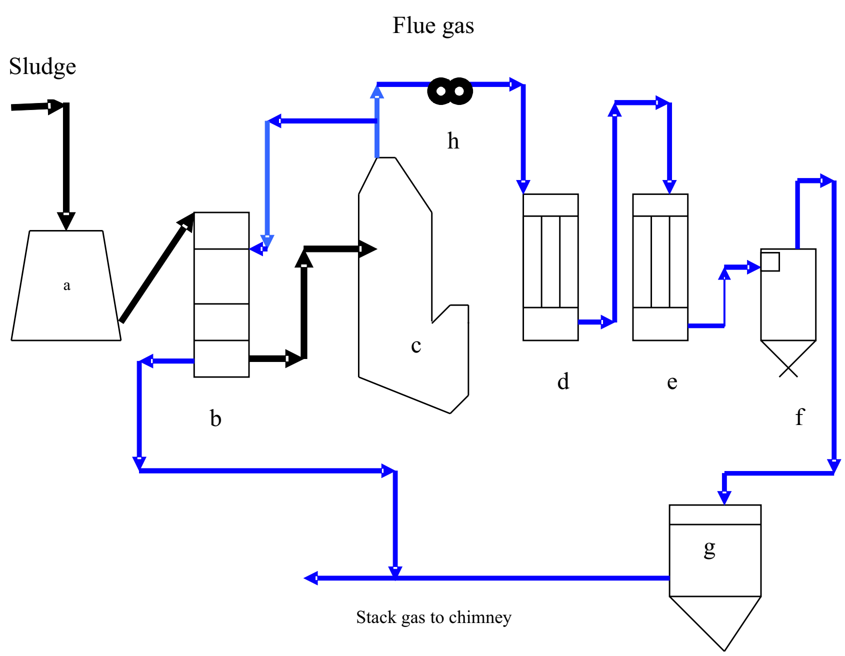

Figure No 1

Regime I: operation at the throughput equal to the immediate production of sludge at the time of the guarantee test.

Regime II: operation at the realistic maximum throughput of the sludge to be processed during the 24- hour's period, i.e. the operation at 65 tons/day.

Regime III: operation at the minimum required throughput during the 24-hour's period (approximately 35 tons/day). [3]

Second Stage of Retrofit

The second stage of retrofit can be characterized as a "waste-to-energy" one. Its purpose was to increase the utilization of heat contained in flue gas leaving the afterburner chamber and the realistic throughput of the sludge to be processed in the incineration unit. The heat carried by flue gas is only partially used presently for pre-heating the fluidization and combustion air. The rest of the heat carried by the flue gas is rejected in the waste heat recovery system. Systematic of first and second stage retrofit in details are shown in figure no 1. [5]

a- Sludge storage

b- Sludge dryer
c- Multiple hearth incinerator with a fluidized-bed chamber
d- Air preheater
e- Water preheater
f- Cyclone
g- Multi stage scrubber
h- Induced draft fan

Flue gas line
Sludge line

Figure-Systematic of Waste Heat Recovery System with First & Second Stage Retrofits

Evaluation of Retrofit

The primary purpose of retrofit consisted first of meeting more sweeping environmental laws on the purity of the emitted off-gas. A comparison of the average levels of emissions before retrofit and after the waste-to-energy stage of retrofit including allowable limits is shown in Table 2. Realization of the second stage of retrofit brought about considerable economical profit. The only acceptable alternative to incineration is sludge land filling. The cost of land filling for 1 ton of sludge is approximately US$ 10.50 per ton but seasonally it can climb up to US$ 30.50 per ton (such a high cost occurs in the season with high ambient temperatures that intensify the biological processes in the sludge). Sludge land filling, even at the low costs mentioned above, but not cheaper than the thermal treatment unit .The typical case study of waste heat recovery for steam generation from waste sludge is given in appendix I. [2]

Possible Retrofit to Increases the Heat Duty

The heat carried out by flue gas is only partially used for steam generation. Rest of the heat is used for generating the hot water, air and drying the sludge. An increase of the realistic throughput of the incineration unit is related to the addition of supplementary heat by means of natural gas. In order to achieve the more throughput natural gas with controlled mechanism burner in the secondary heart combustion chamber can be applicable. Another advantage of this technology modification is to burn the unburnt fly ash carbon. Also complete combustion without Pyrolysis results in cleaner stack gas at the out let. [6].

CONCLUSION

The technology of the incineration unit, as it was designed and realized, is in accordance with the waste to energy philosophy and it also meets the requirements of efficient processing of the sludge resulting from wastewater treatment. The unit utilizes efficiently the energy released in the course of sludge incineration both for its own use and also for the heat-up of a utility subsequently used within the whole plant. A comparison of parameters of sludge incineration on the principles of waste-to-energy approach with those of sludge land filling (the only one acceptable alternative to incineration) leads to the conclusion that the thermal treatment of the sludge by a suitable technology utilizing energy from sludge incineration is favorable both economically and environmentally. In some cases, land filling can be economically advantageous but it remains unacceptable from environmental reasons. After completing the retrofit, this incinerator can also be ranked among the most modern ones from the point of view of process technology. [2]

ACKNOWLEDGEMENTS

I would like to thank all who worked on this study and facilitated the rich understanding and conclusions, which have resulted from it. In particular, I would like to thank the all UDCT, Amravati staff, who generously gave me their time, and provided their view and insight in immense clarity and depth.

Appendix-I

Case Study

Pulp production per day = 500 TPD
Calculated yield of recycled based paper pulp production = 75%
Raw paper required for 500 TPD Pulp production = 666 TPD
In which 5% is non recoverable (nearly 33 TPD is plastic/foreign material)
Another 5 % is not recovered from ETP water due to the ultra fine size of fiber.
Therefore
Recoverable sludge is = 100 (75 + 5 + 5) = 15 % = 99.9 TPD
From nearly 100 TPD; nearly 35 TPD good quality sludge is used for making paperboard and 65 TPD sludge is available for combustion.
Average calorific value of dry sludge = 8360 KJ/Kg
Combustion efficiency of Multiple hearth incinerator with a FBC = 75 %
Therefore
Total heat output from of multiple hearth incinerator with a FBC
= 65 X 1000 X 8360 X 0.75 = 407.55 X 10^6 KJ / Day
In which 30 % heat goes for drying the sludge = 122.26 X 10^6 KJ / Day
50 % heat used for generating the low pressure saturated steam= 203.77 X 10^6 KJ / Day
This is equivalent to 3385 Kg /Hr low pressure (3.5 Kg/cm^2) saturated steam.
10 % heat goes to the air preheater = 40.7 X 10^6 KJ / Day
And 10 % heat goes to the water preheater = 40.7 X 10^6 KJ / Day

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