Prospects of incineration of solid waste

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ABSTRACT

Pulp and Paper industry based on agro-residue produces significant amount of solid waste which are source of heat energy upon combustion. Use of biomass residues as a fuel holds the most promising field in a country which does not have enough fossil fuel resources. Direct combustion or mass burning is the first choice to burn these wastes. Many small mills based on agro residues are already burning rice husk and pith in bagasse fired boilers or even coal fired boilers. But as the wastes are bulky materials so they may create problems in conventional coal fired boilers and for that reason burning after densification is another alternative.

In this context, an attempt has been done to burn the Solid Waste e.g. Rice straw and wheat straw dust, effluent sludge and pith efficiently by densification in form of briquettes. Densification makes a compact dust free agro residue product. In our country deforestation will cause a rise in prices of wood. Even coal prices are increasing rapidly. In such circumstances, briquetting of agro-residue waste and sludges can have a legitimate socio-economic role as alternative fuel as it can to some extent reduce use of cow dung as domestic fuel in villages (where 80% of fuel consumption is cow dung) which can be diverted to fields as manure thus decreasing dependence on fertilisers, thus saving in imports. Moreover, it can be used in brick kilns also as an alternative fuel.

1. Introduction :

Pulp and Paper Industry generates a significant quantity of waste at various stages of production during large scale as well as small/mini scale mill operation. The nature and quantity of waste materials produced are determined mainly by the scale of mill operation, grades of paper or board, the cellulosic raw meterial used and the effluent treatment methods. Small mills using agro residue generate more organic solid waste compared to big mills based on wood and bamboo. Central Pulp and Paper Research Inslitute identified and characterised the main sources of combustible solid waste generation in the mills and proposed remedies, for their utilisation. Out of the proposed remedies, one is the use of these combustible waste as a source of heat energy.

The various raw materials commonly available and selected for paper making in this country have specific waste generation implications and can be traced to certain associated characteristic of each fibrous species. The organic waste generated comprises 57% of the total waste generated and Inorganic waste generated 43%.

2. Selection Of Suitable Equipment :

With higher fossil fuel prices and more stringent environmental regulations, the emphasis is on the disposal of bio-mass waste material for efficient recovery of energy from the material. Significant efforts have been made in developing countries, for generating steam to achieve the following goals.

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a : Minimize auxiliary fuel requirements.

b : Minimize particulate emission.

c : Produce steam at conditions suitable to meet process steam demands.

A variety of biomass firing system have been used to meet these three objectives, ranging from 100% grate firing (Pile burning) to 100% suspension firing.

The bio-mass firing system that has been in existence is the conventional spreader stroker fired boiler. The furnace grate can take the form of a stationary pinhole grate, a vibrating grate, or a coutinuous ash discharge travelling grate.

As an alternative to 100% grate firing and in response to the need for more flexible fuel burning system, suspension firing system have seen much development over the last several years.

For efficient burning of the biomass, there are two key variables in addition to time, temperature and turbulence which must be controlled to effectively burn biomass material on a grate or in suspension. These are the moisture content in the fuel and size distribution of the material.

Moisture Content :

The surface and inherent moisture must be evaporated before burning processes can proceed. The amount of heat required varies with the moisture content of the fuel. The higher the moisture content the longer it will take to dry the fuel and for combustion to begin. For this reason high moisture fuels requires the additional time afforded by a stroker firing system while low moisture fuels are suitable for suspension firing

Size Distribution :

The size distribution of the biomass in the form of briquettes or pellets is a very important parameter for grate firing or suspension firing in the boiler.

III. Dewatering of Waste :

The solid waste generated from raw material storage yard and raw material preparation section in the form of dust or whole with a moisture content in the range of 5-15% depending on the climatic condition can be converted to briquettes or pellets without much difficulties.

Paper Industry produces large quantities of effluent sludge each day in the effluent treatment process. Currently, this sludge is mostly used for land fill as for small mills its use in board making is restricted due to high % of fines. The effluent treatment plant, produces a sludge that is approximately 80% primary sludge and 20% secondary sludge on a weight basis. The sludge varies in solid content from 2 to 4% depending upon the specific process. So it has to be dewatered before use as a fuel. Various types of dewatering equipment typically increase the solid content to maximum 50 to 60%. The following are the equipment which can be utilized for sludge dewatering.

1. Belt press.
2. Screw press.
3. Vari-NIP twin roll press.
4. Somat dewatering system.

Further the sludges requires drying, either by the sun drying method or with the waste process steam or flue gases to increase the solid content for burning.

These wastes either be converted to energy by mass burning or by converting to briquetted form. The associated problems in burning pith and dust of raw material are that they have a low bulk density, therefore specially designed combustion chambers are required. Handling and storage problems are more and due to its low calorific value, these can only be burnt with other fuels, since actual calorific value is low.

To get equivalent results in steam production for 1 ton of coal, the following amount of biomass has to be burnt and is being practiced in paper industry.

Tonne of coal	=	2 tons of rice husk
	=	2.5 tons of B.D. bagasse
	=	3 tons of pith.

In case of effluent sludge, mass burning either alone or together with other fuels is possible. The actual calorific value is reduced by ash content (25–30%) and moisture content (40–50%) to 1650 kcal/kg. It is shown in Annexure I. The advantages of mass burning is the energy generation & volume reduction by 75% more. The associated problem with burning sludge is due to its low calorific value & lumpy nature, so it can only be used as a co-fuel.

Annexure-I

Net Heat Value Derived from Organic Waste

CONCEPT

The calorific value, Ash %, moisture % of different wastes samples of a particular mill is found out to be as follows :

Raw material	Moisture %	Ash %	Calorific value
Straw dust	15	22	3600
Pith	50	10	3588
Effluent sludge	40	27	1660

It has also to be dewatered to at least 50% to be handled. Further handling and drying to 80% dry solid is needed for trouble free combustion.

The solid wastes, that are accumulated in the treatment of pulp & paper mills wastes, whether dewatered or undewatered, require either reuse or disposal, disposal being the more commonly practiced option. Incineration has at least initially, become an attractive disposal alternatives on sludges

However, even if incineration becomes common on a wider array of sludges, the disposal of high ash sludges and the residues from incineration will generate an on going need for landfilling operations Table I A shows the elemental composition including heavy metals of different mills effluent sludge.

TABLE 1A

Elemental Composition of Sludge Samples

Parameter	Paper Mill			
	A	B	C	D
	Value in Percentage			
Nitrogen	0.70	0.85	0.61	0.52
Phosphorus	0.13	—	—	—
Potassium	1.74	0.09	0.28	0.17
Calcium	1.74	2.89	5.06	8 17
Magnesium	0.06	1.11	1.2	2.74
Sulphur	—	—	0.27	—
Iron	0.27	0 20	1.30	0.11
Manganese	0.012	0.014	0.011	0.039
Aluminium	—	—	7.08	—
Sodium	0.45	0.66	0.05	0.55
Tin	0.02	—	—	—
Chromium	0.004	—	0.0027	—
Copper	0.0099	0.004	0.0028	0.0006
Lead	0.001	—	0.0019	—
Nickel	0.0013	0.0004	0.0009	0.0002
Mercury	—	—	0.000016	—
Zinc	0.006	0 009	0 0044	0 0031

IV. Evaluation of Sludge Burnability :

The combustion characteristics of dewatered sludge as such or in the form of briquettes do not differ much from that of bark or other biomass fuel. The bulk of the sludge is made of pulp fibers.

Table I-B shows the fiber analysis of dewatered sludge. The major differences between the sludge and bark are the moisture content and heating value shown in Table II.

TABLE IB

Fiber Classification of Effluent Sludges

Mesh Specification	% Fraction (w/w) Paper Mill A	B	C	D
+30	04.10	03.90	10.00	06.30
+ 50	03.00	05.20	17.60	05.70
+100	05.60	11.00	13.60	19.80
+200	03.70	07.50	02.30	17.90
—200	83 60	72.40	56.50	50.30

TABLE –II

Moisture, Ash & Gross Calorific Value (Average Value of Different Solid Waste)

Type of waste	Moisture Content (%)	Ash (%)	Gross calorific value (Kcal/kg OD material)
Straw Dust	15	22	3500
Sarkanda Dust	15	24	3560
Pith	40	10	3590
WWT Sludge	60	27	2500
Bark	25		4500

The heating value of dewatered sludge is also very inconsistent. The average heating value of sludges from mill to mill also varies. Table II shows the heating value of sludges and other solid waste.

The heating value — sludge moisture — thermal efficiency relationship is a balance that must be maintained when burning sludges.

Operating Problems :

It has been reported while burning effluent sludge in boilers, the problems are encountered while increasing the amount of sludge %.

The problems encountered are given below :

1. Stack gas opacity increases with increased amount of sludge.
2. Combustion of high sludge content fuel will lower steam production. Therefore an alternate fuel source has to be installed, or the amount of sludge in the fuel is to be minimised.
3. The ash produced tends to stick to equipment in recirculation system.
4. Burning high sludge content fuel, 50—100% by weight, requires more monitoring and control on the part of the operators.
5. The thermal efficiency is low due to the increasing moisture content of the sludge. An external fuel system to be provided.
6. It has to be shredded for efficient burning in case of mass burning.

Briquetting of Solid Waste :

Briquettes were made in a piston type briquetting machine using straw, straw dust, pith and sludge in different compositions The size of dies used for briquetting are of the size of 60—65 mm dia.

The large size and weight were chosen to ensure that the briquettes would fall to the bottom of the hogged fuel boiler during firing. Some of the briquettes had been stored upto six months. They were still in fairly good shape. Microbial decomposition was not a problem. However it should be protected from rain.

Principle of Briquetting :

Briquetting is a process of compacting of loose combustible material for fuel making purposes. Densification essentially involves two parts :—

a. The compaction under pressure of loose material to reduce its volume.
b. To agglomerate the material so that the product remains in the compressed state.

The briquetting of organic material requires significantly higher pressures as additional force is required to overcome the natural springiness of these material.

A binding agent is necessary to prevent the compressed material from springing back to its loose form. This agent can either be added to the process or when compressing ligneous material, the part of the material itself in the from of lignin, which is a constituent in most agricultural residues act as a binding agent. It can be defined as a thermoplastic polymer which begins to soften at temperature above 100 °C. The softening of lignin and its subsequent cooling while the material is still under pressure is the key factor in high pressure briquetting.

The temperature in many machine is closely related to the pressure, though in some cases external heat is applied.

There are thus two immediate ways of classifying briquetting process.

1. High and Intermediate pressure – 5 and above 100 MPa.
2. Low Pressure – up to 5 Mpa.

A low pressure machine requires a binder while a high pressure machine does not which releases sufficient lignin to agglomerate the briquette.

Briquetting Unit :

The briquetting unit installed, consists of a hammer mill, dosing machine and a briquetting press supplied by maskinfabrikken Cormall A/S Denmark.

The hammer mill consists of a blower unit with 50 mm screen with wings connected to the rotor unit. The average length of chopped material will be approximately half the diameter of the screen perforation. The hammer mill is used to chop sugar cane top, straws and grasses, if they are to be converted into briquettes. In the present case, it was used to convert straw into straw dust which was blown to the Dosing Machine. In the dosing machine, straw dust and sludge were mixed in different proportion and conveyed through a screw conveyer to the briquetting machine. The feeding shutter of the dosing machine was adjusted according to the feeding rate of raw material to the briquetting machine. The briquetting machine consists of piston which moves inside the tapered die and presses the raw material to briquettes, which comes out from the other end of the die. The piston, two in number are connected to a chain wheel which is driven by an electric motor. The operating variables includes the sludge and raw material moisture and feeding rate. Figure III shows the sectional view of the briquetting press of intermediate presssure installed in the Institute.

Heating Value of Different Dusts Mixtures :

Table III gives the heating value of dust mixtures of straw, pith and sarkhanda in different proportions determined in a bomb calorimeter. A comparison between calorific value of dust mixtures as determined in bomb calorimeter and the calculated arithmetical mean heating values show that they are not the same.

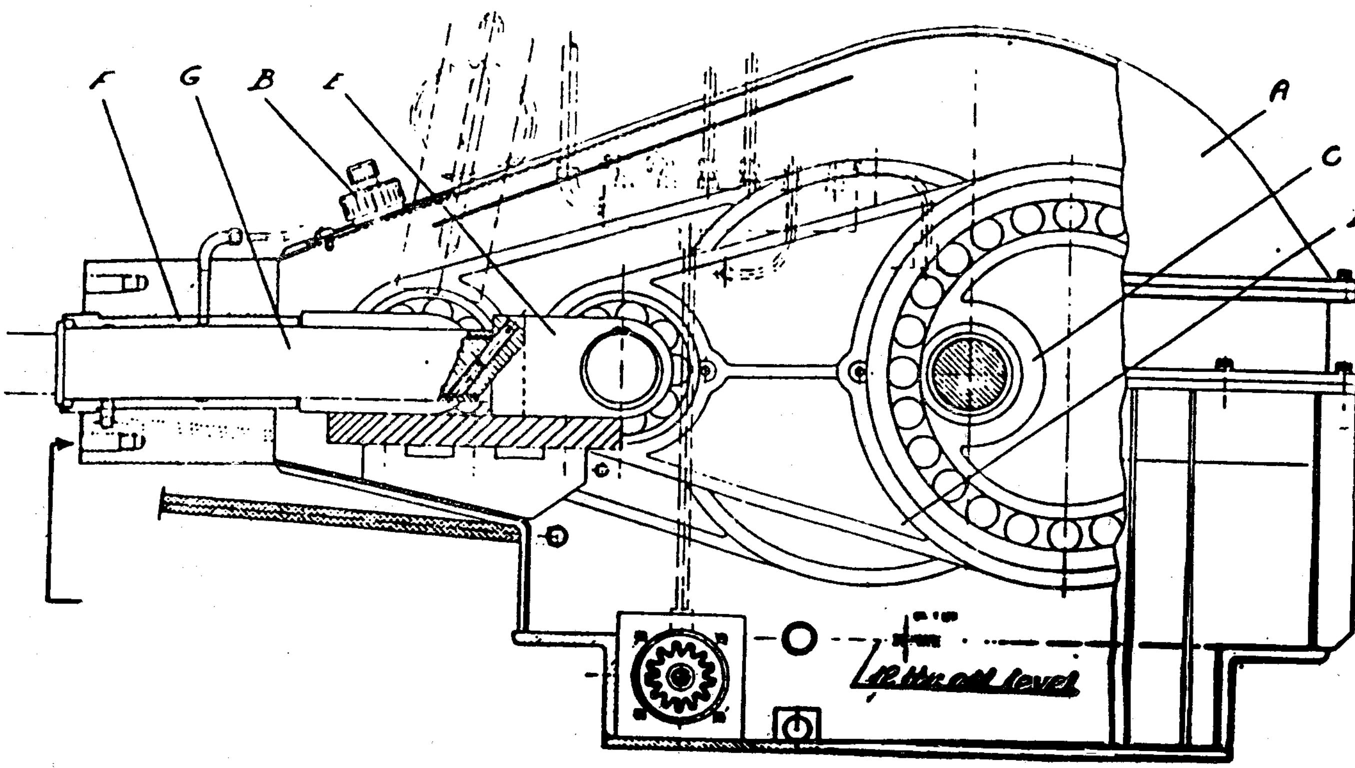


Figure III - Sectional View of Briquetting Press

A — Press housing
B — Inspection hole
C — Crank and Mainshaft
D — Ball bearings of the connecting rod
E — The Piston yokes
F — Cylinder linings
G — Pistons

TABLE—III

Waste Composition and Heat Value

Waste material composition	Composition percentage 25 : 75	50 : 50	75 : 25
	(Calorific value, Kcal/OD kg of material)		
A : B	3500	3400	3260
C : D	3460	3400	3320
A : C	3200	3340	3385
B : D	3410	3475	3530
A : D	3380	3360	3360
B : C	3422	3070	3520

A — Wheat straw dust
B — Pith
C — Rice straw dust
D — Sarkanda dust

Air Dried Weight of Final Briquette :

Table IV shows the weight of the briquettes after air drying at a constant length The weight indicates that they can very easily fall to the bottom of the hogged fuel boiler.

TABLE – IV

Length and Weight of Final Briquettes After Air Drying (Dia of briquette 65 mm) :

S.No.	Briquette Sample	Length cm	Weight of briquette g	OD wt g	Moisture %
1.	Effluent sludge & straw dust	2.75	59.10	56 20	4 91
2.	Effluent sludge	2.75	70.78	66.18	6.50
3.	Sludge & bagasse pith	2.75	54.45	50.98	6.37

Briquetting Trials :

Briquettes were made in a Cormall Briquetting Press using straw dust and effluent sludge, straw and effluent sludge, pith and effluent sludge and also with raw sludge by varying the moisture content of the raw material and also the ratio of sludge and dust, pith or straw At higher moisture content of about 30% of the sludge, the briquettes require further drying to increase the compactness for handling. It was also observed that by addition of effluent sludge with straw dust and pith, the sludge is working as a binder of the dust and also as a lubricant for the die. At too low a moisture between 5 to 10% of the feeding material, the briquettes were not as compact in formation and are breaking on dropping. At a moisture content of around 30% of the feeding material the briquettes were quite compact and on drying upon storage, are quite durable for rough handling. So it is necessary to dry them after formation. This drying will of course increase the as fired heating value in the burning step. Table V shows the moisture content in final briquettes with different composition of waste material and also at different moisture in sludge.

TABLE—V

Conditions of Briquetting Trials in the Briquetting Assembly

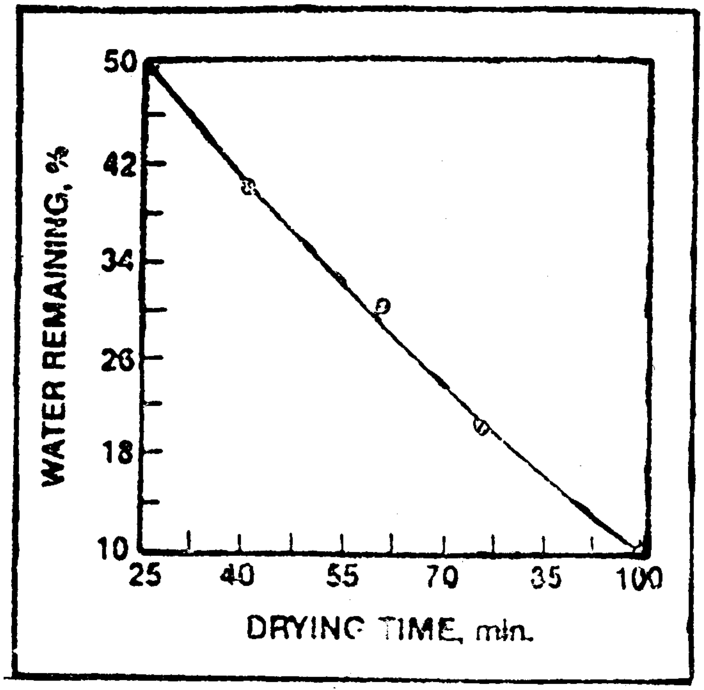
S. No.	Effluent Sludge % moisture	Fibrous Waste % moisture	Wt Ratio sludge other waste	% Moisture in feed mixture	% Moisture in outcoming briquettes
1.	Sludge (40%)	Pith (20%)	3:1	35.80	31.50
2.	— ,, —	— ,, —	1:1	30.25	27.00
3	— ,, —	— ,, —	2:1	34 00	30 00
4	— ,, —	StrawDust(15%)	3:1	34 00	29.80
5.	— ,, —	Straw (17%)	3:1	34 50	29.50
6	Sludge (35%)	Pith (20%)	3:1	31,00	27.20
7.	— ,, —	— ,, —	1·1	27 80	24.50
8.	— ,, —	— ,, —	2:1	29 80	25 40
9.	— ,, —	StrawDust(14%)	3:1	30.20	26.00
10.	— ,, —	Straw (17%)	3:1	30.20	26 50

To determine this optimum point, the briquettes were formed at 60% solid centent, These briquettes were dried in an oven for various lengths of time. Fig 1 illustrates the drying rate. However, they can be sun dried also.

The compactness and resistance to abrasion is also very important to measure its usefulness to withstand the forces normally experienced during material hand-'ing.

Because of the need for increased strength and the need to curtail microbial growth, the briquettes should be dried to 80% solid content, if they are to be stored for any length of time. Once the briquettes are dried,

Fig. I: Drying Rate of Briquette



they do no absorb moisture to a good extent. They retain their shape, though they b.come soft after several weeks of storage under humid condition.

An appropria'e flow sheet has been shown in Fig. II for briquetting the solid waste, drying, storage, inc'neration and possibilities of marketing it as a fuel. The proposed solid waste burning process consist of briquetting the organic waste material to briquettes form for combustion.

The materials which can be used to form briquettes are the fiber dust from raw material section, screen and centricleaner rejects and the sludge from effluent treatment plant and finally coal dust from boiler house waste.

A number of advantages were postulated for the briquetting approach :

1. The additional drying and briquetting would produce a fuel that would burn more efficiently and easily with high effective heat content.
2. The uniform size and shape of the waste would facilitate material handling.
3. The dried briquettes at about 80% solids, would allow storage for extended period.
4. The briquettes of these materials were roughly the size of the charcoal briquettes, which would make them heavy enough to fall to the grates of the boiler, thus enhancing the combustion process and will burn at the bottom of the boiler.
5. The nitrogen content though compared to other sludges is low, the Nox emission is lower if burned in briquetted form in a stocker bed boiler than in suspension phase burning.
6. Due to volume reduction and ease of material handling, it can be marketed as a domestic fuel or as a suitable fuel for brick kiln.

Commercial Evaluation :

A commercial evaluation of the briquette burning plant is summerised below.

Equipment Cost :

There are three major pieces of equipment to be purchased for this process for conditioning the sludge and then briquetting.

1. Equipment to increase the solids content from 30% to 40% prior to briquetting.
2. A briquetting machine.
3. Equipment to dry the green briquettes.

1. Dewatering Devices :

Because of slow heat drying rate, it is much easier and more economical to initially increase the solid contents of the raw sludge by some mechanical means. It exists in the waste treatment after first stage dewatering at 40% —50% solids, but the sludge is too moist for efficient briquetting. Therefore a second stage of water extraction by means of screw press or to 60% to 70% solid content is essential. In Indian context, however, the sun drying will be the more economical solution.

2. Briquetting machine :

Briquetting machine of piston and die type is suitable for this type of raw material provided the mositure content is maintained at around 30%. For higher solid content the briquettes required further drying. An economics is evaluated based on setting up a briquetting machine in the mill premises in Annexure II.

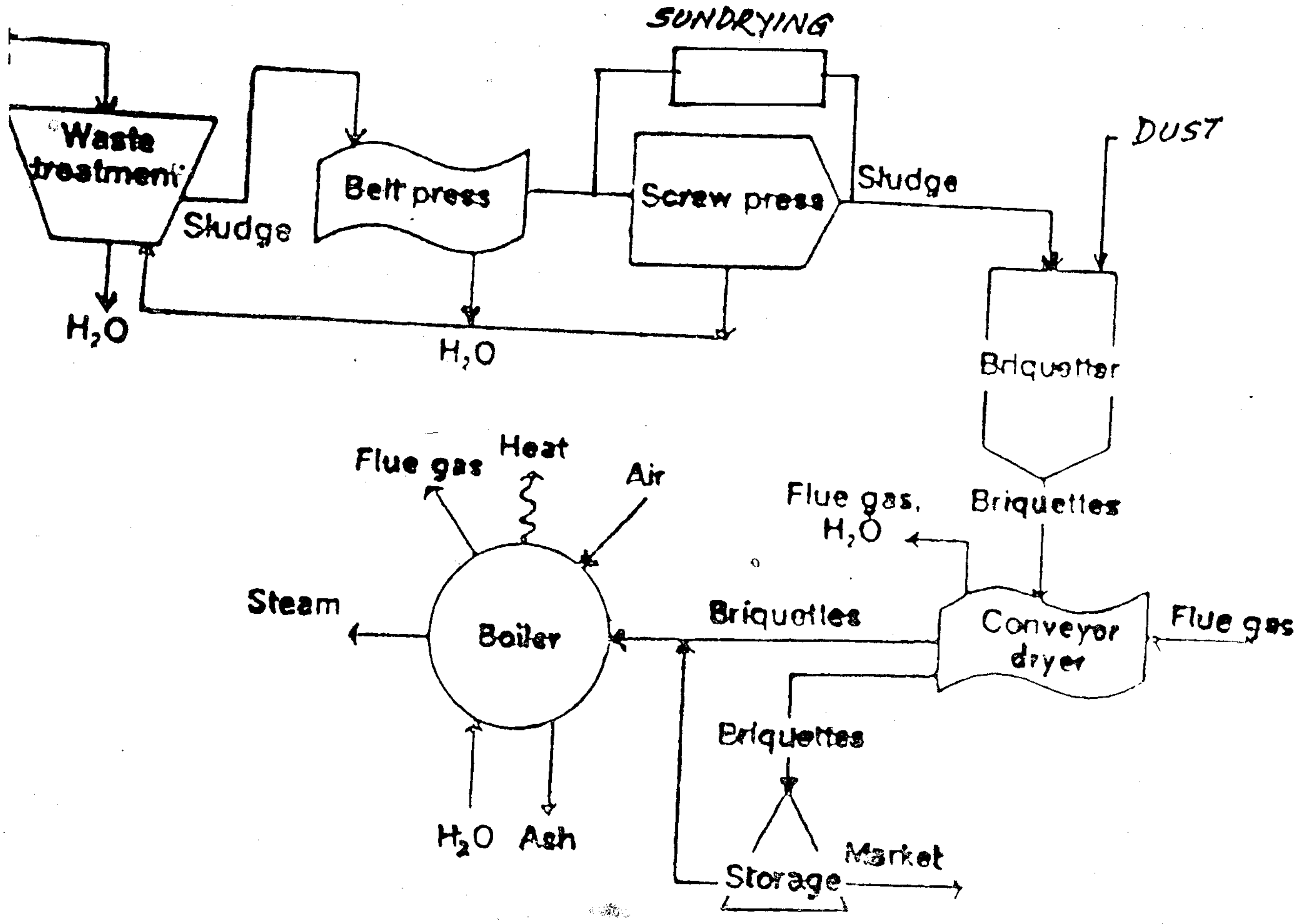


FIG.II, FLOW SHEET FOR BRIQUETTING AND BURNING SYSTEM.

VI Conclusion :

In comparison to other waste disposal methods adopted in paper industry based on agro-residue raw materials though options such as land spreading or composting for silviculture or agricultural purposes are possible, however, their uses get restricted due to economical or environmental reason depending on nature of paper mill process.

ANNEXURE—II

Economics of Briquetting of Wastes

Capacity of plant	:	2 T/HR
Cost of plant 7 machinery	:	20 Lakhs
Land & building	:	3 Lakhs
Total	:	23 Lakhs

Assume plant life	:	8 Years
Interest rate of capital	:	20%
Yearly depreciation	:	2 8 Lakhs
Yearly interest on capital	:	4.6 Lakhs
Interest+Depreciation	:	7.4 Lakhs
Interest+Depreciation per day	:	Rs. 2242 00

Operating Cost : (Per Day)

Waste raw material @ Rs. 150/t * 36 T/D	:	Rs. 5400.00
Electrical power 100 KWH*18 HR/Day*Rs. 2	:	Rs. 3600.00
Maintenance @ 20%	:	Rs. 448.00

Labour :

6 Persons * Rs. 100/-	:	Rs. 600.00
12 Persons * Rs 60/-	:	Rs. 720.00
		Rs. 13,030.0

Energy per day

$36T/DS*2000KCAL/KG*1000$	:	$72*10^{6}$ KCAL/Day
Equivalent coal		
$\frac{72*10^{6}}{4500}$	:	16 T.
Price of coal	:	Rs. 1000/T
Cost of product 16*1000	:	Rs. 16,000/Day
Savings : 16000—13030	:	Rs. 2970/Day
OR 2970 * 330 Day/Yr.	:	9 8 Lakhs/Yr.
Coal equivalent 16*330	:	5280 T/Yr.
* 1 Year = 330 Days, 1 Day	:	18 Hour

Energy Balance

Net loss of heat value during combustion :
Basis : one kg material as such

	Dust	Pith	Sludge
Heat given by fiber (Kcal/Kg)	3060	1794	996
Heat taken by water (Kcal/Kg)	157.5	525	420
Heat taken by solid (Kcal/Kg)	139.74	75	102.24
Net heat value (Kcal/Kg)	2762.76	1194	473.76

Average data for calculation :

Sp. heat of steam	=	0.45 Kcal/Kg C
Straw	=	0 3
Ash	=	0.2
Latent heat of steam	=	538.5 Kcal/Kg
Temperature. of solid, water	=	40°C
Ignition temperature. of solid	=	500°C
Furnace temperature	=	1100°C

Combustion, therefore, offers the only potential large scale use at this time. Briquetting of these solid waste suitable for burning in a hog fuel boiler would minimise other methods of disposal costs and would simultaneously satisfy some of the current and future fuel requirements. No technical difficulties are fore seen with the sludge briquetting process. There should be no difficulty in during briquettes appropriately for burning.

The burning characteristic of each particular sludge must be evaluated before incineration process begins, however, potential technical difficulties might be the slagging of ash and fouling of surfaces.

Finally, the likelihood of tightening of regulation governing land disposal also support the installation of the process.

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