Thermal Drying: Turning Bagasse From A Problem To A Profit Center

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INTRODUCTION

Dried bagasse, pith or cane trash has a thermal value of ±8,000 Btus/Ib. (4,400 Kcal/Kg) at 12% moisture (Wet Basis) With an ash content of 7% or less. Indian coal has a thermal value of ±6,000 Btus/Ib. (3,300 Kcal/Kg.) at 8.5 % moisture with an ash content of 30% or more. On a unit for unit basis, the substitution of dried bagasse, pith or cane trash for coal increases the Btus in the boiler by 33% and reduces the ash discharge by over 60%. If the amortized capital costs+ daily operating costs of a Fuel Preparation System are less than the cost of coal, then it makes economic sense to process bagasse, pith or cane trash as a fuel for your boilers. Ash disposal costs are substantially reduced; the environmental impact is reduced; and, boiler operation is eased by burning 1/3 less fuel for the same steam production. Substituting the dried fiber for coal may increase steam production.

Today, We will discuss the elements involved in a Fuel Preparation System and the costs associated with such a system. Every mill is unique so it is impossible to discuss a standard installation, we will offer a typical installation and its costs. I have based this discussion on several assumptions(1):

* India has a large surplus of sugar cane fiber which is available for processing. This may be pith from a papermill's pulping operation, it may be surplus bagasse liberated by the sugar mill's improved operations, or, it may be cane trash processed into fuel cubes.
* India has no significant source of reasonably priced hydrocarbons; therefore, fuel oil, natural gas and bottled gas are not available as energy sources to operate the Fuel Processing System. Dried fiber must be the fuel used to drive the process.
* I have assumed a coal cost of USD $ 65.00/ metric ton in this analysis.
* The crushing season in the sugar industry is about 220 continuous day, the papermills operate about 350 days per year; therefore, it is important to have fuel which can be stored long enough to cover the 130 day period.

There are a number of economic factors unique to India which will influence a mill's "true cost" for a Fuel Preparation System(2), I have not considered them in this overview:

* Accelerated Depreciation Schedules for renewable energy capital equipment,
* Excise and Sales Tax concessions for renewable energy capital equipment,
* Customs Duties concessions and Import License exemptions for renewable energy capital equipment.
* State and local incentives to encourage electrical generation.

PROCESS BASICS

Any biomass fuel must be dried before it will burn. Today mills use the power boiler as the dryer. A number of bad things happen when you do this(3):

* Heat energy from burning fuel is used to vaporize water in the fuel rather than being used to heat water in the boiler tubes;

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* Excess air must be pumped into the bioler to remove the water vapour so it won't smother the boiler fire;

* Volatile gases from the fuel are carried out of the boiler by the excess air; the gases either burn too high in the boiler to be useful or they exit unburned,

* Unburned fuel particulate is carried out of the boiler by the exess air, they either burn too high in the boiler to be useful or they exit unburned (and have to be trapped by environmental equipment.)

Market changes are forcing the paper industry to look at new technologies which are more efficient and more cost-effective; both to expand the fiber supply and to reduce energy costs per tonne of paper sold.

The Indian paper industry has been closely tied to the sugar industry and both have enjoyed an aboundant supply of fiber as a by-product of sugar production. Bagasse has been available in quantities far in excess of what was needed to run the processes and to provide fiber to the paper mills. If the boilers were inefficient, so what? Anything you didn't burn or turn into paper became a problem anyway, even today cane trash is left in the field. Pile burners, travelling grate burners and sloping bed burners have all been designed, modified and refined over the years to burn high moisture fuels, their operating problems and inefficiencies were known and tolerated[4]. A modern natural gas fired boiler will operate at 85%-90% efficiency; a fluidized bed boiler with good quality coal will operate at 65%-70% efficiency, a grate fired boiler with good quality coal will operate in the 50%-55% range; and, a grate or pile fired boiler with medium moisture biomass fuel (50% WB) will be about 40% efficient.[5]

But times are changing. The demand for paper is pulling more fiber from the bagasse stream. Wet depithing (which is needed to increase yield and to improve quality) produces pith which is 65% moisture; it won't burn in the boiler. Both the sugar mills and the paper mills need more steam than they can get from their existing boilers burning bagasse so they burn coal; some mills have upgraded their boilers with fluidized beds. The country needs electricity and there is pressure on industry to operate their power boilers to generate electricity for the national grid. At some point it may make sense for a mill to install a cogeneration plant which has electricity for the grid as its primary product and steam for the process as its secondary product.[6]

Under these new conditions a Fuel Preparation System makes economic sense:

* When a mill has to burn coal to supplement its bagasse burning;

* When the new fluidized bed won't burn pith because when it dries it is too light and rises off the bed;

* When a mill is steam limited and burns coal instead of pith to get more steam from the existing boilers;

* When a mill is looking at a new boiler and could take advantage of suspension-fired technology.

We now turn to a review of the elements in a Fuel Preparation System and then we will review some particulars of boiler efficiencies as related to fuel moisture. Finally, we will look at the economics of some alternatives.

FUEL PREPARATION SYSTEM

If the raw fiber is pith, it is small enough to go through the system without pre-processing. If the raw fiber is bagasse or cane trash it may have to be processed through a hammermill or chopper to get a uniform smaller fiber; fiber length of less than 5 mm is good for cubing. The fiber (at any moisture level) is introduced into the thermal dryer, through a rotary feeder. The heat source for the dryer may be one of several different burners (natural gas; No.2 fuel oil; LPG; LNG; biomass), for India it will be a suspension burner firing dried fiber.

Negative pressure is maintained in the dryer so the heated air from the burner is drawn into the drum along with the moist fiber, Flights in the dryer drum pick up the fiber at the bottom of the rotating drum and carry the fiber to the top where it falls through the air stream back to the bottom. As the fiber loses moisture it loses weight and is carried by the air stream through the dryer. By using a triple-pass dryer the process defficiency is improved, the small fiber size passes easily through the triple-pass unit. Primary and secondary collectors remove the dried fiber from the air stream as it exits the dryer. Air locks and conveyors move the fiber to down-stream equipment for further processing.

Each thermal dryer is engineered for a particular fiber and throughput of dry fiber at a particular moisture level. The air flows, entering air temperature, exiting air temperature and exiting fiber temperature are modelled to determine the dryer's parameters. A dryer and its peripherals would be sized to generate fiber with an exit temperature of around 80°C (185°F); the fiber may have to be cooled. A GreCon fire detection and suppression system is installed with the dryer. IR sensors detect even the slightest spark and activate a zoned water spray system to extinguish the spark.

The dryer will get its thermal energy from a burner fired by loose dry fiber (10% WB.) The burner is a cyclonic suspension burner which has an efficiency equal to that of a pulverized coal fired burner (90%+)[7]. The burner is engineered specifically to the thermal dryer so that burning occurs in the first section of the burner and heated air in the appropriate volume is provided to the dryer from the second section. In some installations, the exhaust gases from the thermal dryer may be cycled through a heat exchanger to pre-heat air into the burner. Typically, 15% of the fiber (Dry Basis) processed through the dryer is used to fire the suspension burner.

If the mill's power boiler can burn the light dry fiber then the discharge from the thermal dryer can be conveyed directly to the boiler; or, the fiber can be cooled and then put into inventory. Because of the existing power boiler base in India (grate or fluidized bed), it is anticipated that most of the net output will have to be cubed. A pneumatic conveyor moves the fiber from the thermal dryer into a spreader box which feeds the cubers.

Conveyors and feeders move the fiber from the spreader box to the cubers. The cuber forces the fiber into a die which uses mechanical force (no binders) to form the cubes. Conveyors transport the cubes either to the boilers or, if the cubes are going to be inventoried, into a cooler. The cubes may be 85°C (190°F) coming out of the cubers and a cooler (spreader floor with fans) will take them to ambient temperature. A small amount of water is used to lubricate the dies during the forming process so a cube will exit the die at 14% moisture (assuming a 10% entry moisture) and will end up at 12% moisture and ambient temperature after the cooler. This dust-free fuel can be stored in a protected area (no rain or moisture) for one year with no degradation in the cube. The cubed fiber can be handled and burned just like coal.

The technology in a Fuel Preparation System centers around the cyclonic suspension burner; the triple-pass thermal dryer; the cubers; and, the engineering experience needed to coordinate the different elements. One of our OEMs licenses a burner manufacturer in India so a suspension burner to our specifications may be built locally. The triple-pass thermal dryer will have to be imported and the cubers will have to be imported. Conveyors, collectors, spreader and cooler boxes can be fabricated to our specifications in India from imported and local components. The Motor Control Center and most of the motors to run the equipment can be purchased locally to our specification.

Site preparation will depend on the System configuration and local costs but we advise budgeting 50% of the equipment purchase price for site work. This will include civil work; a control room; mounting pads for all of the major components, electrical work; and local labor for installation. Supervision, commissioning and operator training is provided on a per diem basis. Project coordination and management will be provided by our local partner, CPE India.

BOILER EFFICIENCIES

If you are building a new boiler and want to use dried pith as the primary fuel source then you should consider a suspension boiler which would have efficiencies equal to pulverized coal boilers.[8] The economic comparison would be a bed-fired boiler burning local coal (at USD$ 65.00/mt and 65%

efficiency) versus a suspension-fired boiler burning dried fiber (at USD$ XX.XX/ mt and 90% efficiency).[9] On the other hand, what improvements in boiler performance can a mill expect from substituting dried pith (12% WB cubes) for the present wet pith (50% WB loose fiber)[10] and coal which is now consumed?

Hog fuel moisture content affects boiler efficiency in two ways: (1) it decreases the effective heating value of the fuel since heat energy is needed to evaporate the water; and, (2) excess air must be pumped into the boiler to remove the water vapor. While no exact data is available, many studies indicate that excess air in a boiler will be equal to the amount of moisture in the fuel; i.e. 50% moisture equals 50% excess air. When you add the normal operating margin for a forced draft fan (20%) you will see hog fuel boilers routinely operating with 70% excess air in the boiler. By reducing moisture in the fuel, you increase the heat energy available to drive the process and you reduce the excess air. One study[11] doubled the steam production of a boiler by reducing the fuel moisture from 62% to 28%; a second study reported a 20% reduction in fuel consumption (at constant steam production) from lowering the hog fuel moisture from ±50% to ±30%[12]. The charts attached to this paper are based on the data reported in the CANMET study. These improvements in boiler performance are substantiated by the computer modelling reported in the Oregon State study by Kirk and Wilson.[13]

EXAMPLES

Case No.1 assumes that a mill is producing 300 mt/d of uncoated free sheet. The mill produces ±300 mt/d of pith (Bone Dry) which is used in the papermaking process. The mill does 100% of the bagasse processing on site and has available to it 180 mt/d (7.5 mt/h) of pith at 50% moisture from the initial dry depithing and 270 mt/d of pith at 65% moisture from the secondary wet depithing. The mill produces 15,000 lbs. of steam for each tonne of paper produced. The mill does not burn the 65% moisture pith in the boilers because the high moisture causes operational problems; it consumes 100% of the 50% moisture pith in the boilers.

Assuming bed-fired boilers with reasonable (50%) efficiency, the mill has to produce 375,000,000 Btus per hour (12.5 mt/h * 15,000 #/mt * 2,000 Btus/#) to meet the process steam demand. The 7.5 mt/h of 50% moisture pith will generate 66 million Btus per hour (7.5 mt * 2,200 #/mt * 4000 Btus/#); it will take 23 mt/h of coal (at 6000 Btus/#) to make up the process deficit. This coal will cost, at USD$65/mt, USD$1,495/h; USD$35,880/d; or USD$12.5 million per year. Energy cost for the mill is ±USD$120/mt of paper produced.

The mill generates 451 mt/d of pith at 59% average moisture; this is equal to 207 mt at 12% moisture. ±15% of this fiber stream will be required to operate the thermal dryer; therefore, 176 mt/d is

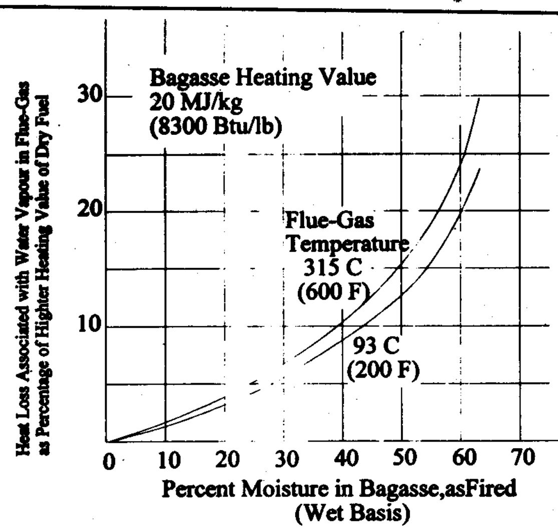


Figure 1: Effect of bagasse moisture content on heat lost with water vapour in stack gas.
(CANMENT : Miller & Hansen)

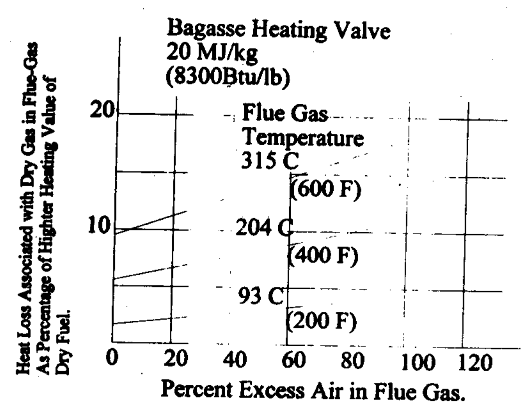


Figure 2 : Effect of Excess Air on Heat Lost with Dry Gas in Flue-Gas.
(CANMET: Miller & Hansen)

available to the boiler. 7.3 mt/h will generate 129,067,000 Btus. The mill's coal purchases can be reduced from 23 mt/h to 18.6 mt/h. The savings (4.4 mt/h) is equal to USD$ 2.4 million/year; or USD$ 23/mt of paper produced for sale. The capital and operating costs of the Fuel Preparation System would reduce this savings.[14]

In Case No.2 the paper mill continues to process the pith from the paper mill operation but turns to the sugar mills for fuel rather than to the coal supplier. Today the sugar mills burn bagasse at 50%+ moisture in their boilers; the boiler efficiency is about 40% (2500Btus/#). A typical sugar mill crushing 2500 TCD will produce 32 tonnes of bagasse an hour (bagasse = 30% of the crush); this bagasse (at 50% moisture WB) has a thermal value of about 282 million Btus (32 * 2200 * 4000). A typical sugar mill will use 550 kg of steam for each tonne of cane[15]. In a boiler which is 40% efficient,

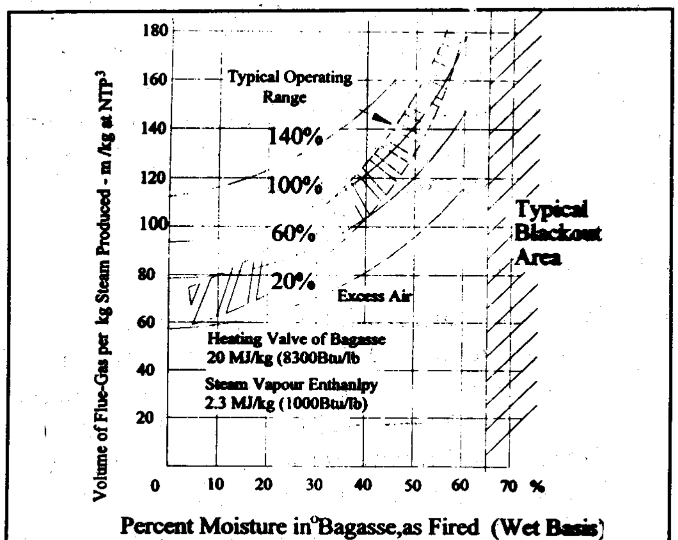
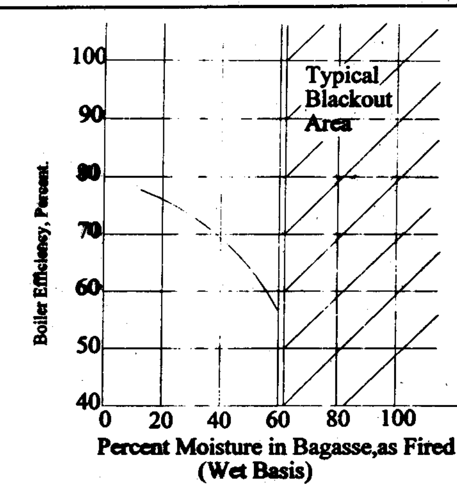


Figure 3 : Effect of Fuel Moisture Content and Excess Air Levels on the Ratio of Flue-Gas Flow Rate to Steam Production. (CANMET: Arola)



Basis: Higher Heating Value of 8300 Btu/lb for Bagasse,Stack Temperature 260 C (500 F), % Excess Air Equal to % Fuel Moisture.

Figure 4: Effect of Bagasse Moisture Content on Boiler Efficiency. (Canmet: R.L. Stewart)

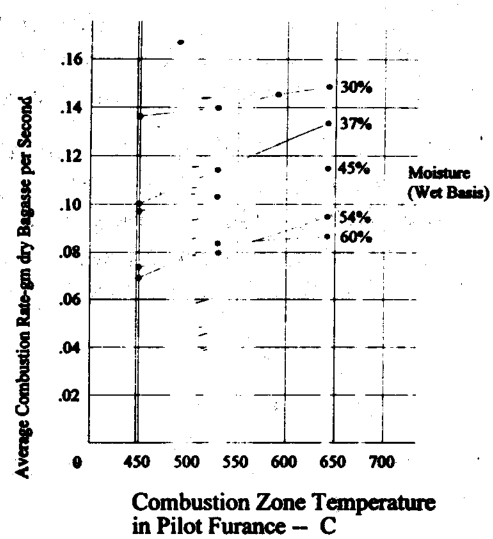


Figure 5 : Effect of Combustion Zone Temperature on Combustion Rate. (CANMET: Prakash and Murray)

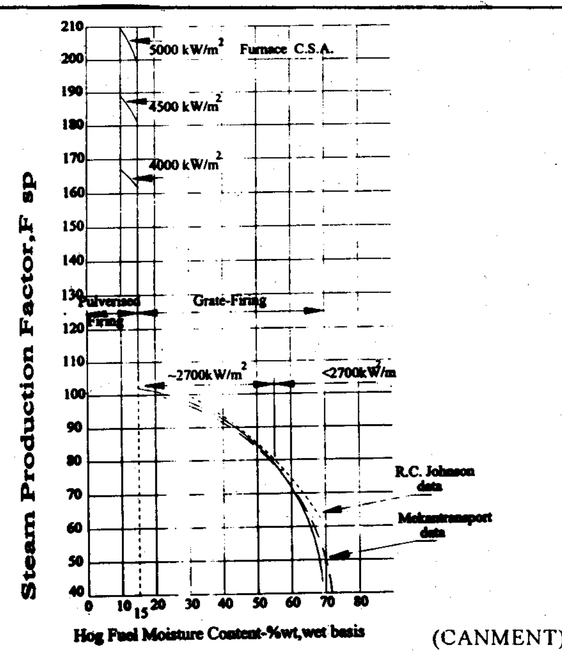


Figure 6: Steam Production Factor, Fsp as a Function of Hog Fuel Moisture Content.

this will require 325 million Btus/hour (550 * 2.2 * 104.17 * 2500); therefore, the mill must purchase 3.9 mt/h of coal to meet 100% of the process steam demand. Any bagasse sold to paper mills must be replaced with coal.

If the sugar mill processes 100% of the bagasse through a Fuel Processing System then the sugar mill will have 18 mt/h of bagasse at 12% moisture. 2.7 mt will be needed to run the dryer and the mill will have 15.3 mt/h for fuel. For reasons discussed above, boiler efficiency will improve; if we assume a 55% efficiency (rather than 40%) then the boiler will need only 227,000,000 Btus/hr for the same production. It will take 12.9 mt/h of fuel cubes to meet this demand; therefore, the mill will not have to purchase any coal and the mill will have 2.4 mt/h of fuel cubes available for sale. At USD$ 50/mt (for example) the fuel cubes have a market value of USD$ 600,000 during the crushing season. The coal not purchased saves the sugar mill USD$ 1.2 million so the net cash position of the mill improves by USD$ 1.8 million.

In a variation on a theme, the sugar mill and the paper mill could be partners in a venture which owns the Fuel Processing System. During the crushing season the joint venture processes bagasse and sells fuel cubes. During the off season the Fuel Processiong venture processes cane trash into fuel cubes. Since the cubes can be stored for a year or longer, the cane trash can be boiler fuel while the bagasse is used to make paper. The economic interests of the parties will adjust the balance. In this alternative the capital equipment is run 350 days a year; the fiber streams are optimized; and, the expensive coal is no longer part of the equation.

A Fuel Processing System to produce (net of the FPS demand) 360 mt/d of fuel will cost about USD$ 3.5 million, complete. The economic life of this equipment is over 10 years, with regular maintenance, and the annual maintenance (spare parts; consumables; labor; utilities) is equal to about 5% of the capital cost If we amortize the equipment and financing cost (12% interest) over 5 years and assume no residual value then the cost for the equipment, financing and maintenance equals USD$ 1.1 million per year. With an annual fuel production of 126,000 mt (15 mt/h * 24 * 350) the cost per tonne is USD$ 8.75. Even when you add other costs (transportation; fiber prep, etc) this is a very cost-effective fuel. If the Fuel Preparation System uses cane trash to produce fuel, this would liberate additional fiber for papermaking and the marginal value is even higher.

CONCLUSION

A Fuel Preparation System produces a fuel which your operators can burn is your boilers today. Fiber cubes are cheaper than coal. Improved boiler efficiency will liberate fiber for higher value uses. The Fuel Preparation System can produce a fuel (cubes) for fluidized bed boilers or a fuel (loose fiber) for suspension boilers; both technologies will support new cogeneration projects.

NOTES

1. Winrock International and International Development and Energy Associates, Inc.: *Advancing Cogeneration in the Indian Sugar Industry*. (May 1993), page 22; National BioEnergy Industries Association. *Bagasse Based Cogeneration in India: A Market Primer for U.S. Companies*. (March 1995), p. 4, page 13.
2. NBIA Study, pp. 15-17.
3. Sandwell & Campany Limited: *Cost Benefit Analysis of Systems Using Flue Gas or Steam for Drying of Wood Waste Feedstocks (ENFOR Project C-96)*, (October 1981), pp. 5 et seq.
4. CANMET, pp. 11-13; Kirk, R.W. and Wilson, J.B.: *Rotary Drying of Wood Waste Fuels with Boiler Exhaust Gases: Simulation, Field Studies, Economics*, Forest Products Journal, Volume 36, Number 7/8 (July 1986), p.57.
5. *Ibid.*
6. AID Study pp.12-14.
7. CANMET, p. 15.
8. CANMET, p. 8.
9. AID, p. 38.
10. CANMET, p. 6 *et seq.*

11. *Ibid.*
12. *Ibid.*
13. Kirk, p. 60.
14. See Section "Boiler Efficiencies" *infra*, page 9, and supporting charts; CANMET, pp. 5-11.
15. AID Study, p. 4.

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