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EXPERIENCE IN BIOMASS FIRED CO-GENERATION POWER PLANT IN THAILAND

by

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Introduction

Thermal power generation is considered a predominant option to meet global increase in demand for electricity. Steam power plants account for a major portion of thermal power generation. Oil, coal and natural gas are in the forefront as fuel for steam generators. But biomass can be effectively used to fuel commercial steam generators. My experience in biomass, mainly risk husk, fired steam co-generation plant is described here. The interesting aspect of the plant is that because it uses biomass, mainly rice husk, as fuel much attention is paid to characteristics of biomass as fuel and boiler characteristics. The company, which I am working presently, is engaged in Small Power Producer (SPP) business in Thailand. In my view the technology can be used in Sri Lanka even though not in this large scale.

This $37MW_e$ power plant is located in Chachengsavo province about 140 Km east to the Bangkok, Thailand. Economy of Chachengsavo province is mainly based on agriculture and paddy cultivation is predominant. As a result many small, medium and large-scale rice mills are common in the province.

The plant is situated in an industrial park, which consists of two large rice mills, a paper mill, a starch mill and a modified density fiberboard (MDF) factory as key factories among other small-scale mills. All of above-mentioned mills use direct steam as one energy source. The plant was built to cater to the growing demand for steam and electricity in the industrial park with the intention of exporting the excess power to Thai grid.

2. Biomass As a Fuel

The heat content (dry basis) of commonly used bio fuels is shown in table 1.

The data in Table 1 show that the heat quantity of paddy husk, our predominant fuel, is second only to fuel wood among standard bio fuels.

The detail characteristics of the main bio fuels used in the plant are as below.

Rice Husk

Ash from Dry Solid	: 17%
Moisture Content average	: 13%
Moisture Content Range	: 10-30%
Average Density	: 150 kg/m³
Characteristics of Ash	:
- Softening Temperature	> 1200 °C
-Melting Temperature	> 1240 °C
- Flow Temperature	> 1290 °C
Viscosity	: CSt 350

Table 1 : Heat content of key bio fuels (dry basis) based on National Energy Policy Office, Thailand, records.

Fuel	Paddy Husk	Fuel Wood	Baggases	Garbage	Saw Dust	Wood Bark	Agriculture Waste
Heat Content Kcal/Kg	3440	3820	1800	1160	2600	1900	3030

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Wood (mainly Eucalyptus) Bark

Ash from Dry Solid	: 17%
Moisture Content	: 5%
Moisture Content design wet basis	: 50%
Moisture Content wet basis	: 35-55%
Average Density	: 300 kg/m^3
Characteristics of Ash	:
- Softening Temperature	> 1150 oC
- Melting Temperature	> 1240 oC
- Flow Temperature	> 1290 oC
Particle size	50 mm

Usually biomass fuels are highly reactive and have high volatile contents and low particle densities. Thus a significant portion of combustion occurs in boiler freeboard space above the bed. Even for the same type of fuel the moisture content of biomass fuel is highly variable, mainly due to differences in sources and weather patterns. Moisture content is one of the key considerations in design and operation of biomass fired boilers and also biomass fuel handling systems.

Most interestingly in environment aspects due to low sulphur content of most biomass fuels, including our main fuel risk husk, and the high alkalinity[1] of fuel ash it is not necessary to add calcium based sorbent such as limestone to the bed for SO_2 control. Realative to coal the nitrogen content of most biomass fuels is low. So most of the time, including our case, NOx emissions meet environment concerns without additional control.

2. Plant Characteristics

The plant consists of 50kg/sec, 81 bar(a) 480 ° C boiler coupled with two stage 37 MWe steam turbine with facility of extracting auxiliary steam out of expanding steam through turbine. Steam can be extracted at two levels i.e. low-pressure (LP) 4.5 bar(a), 170 °C with maximum capacity of 22kg /sec and medium pressure (MP) at 12.5 bar(a), 250 °C with maximum capacity of 6 kg/sec. The plant major thermodynamic parameters are shown in figure 1.

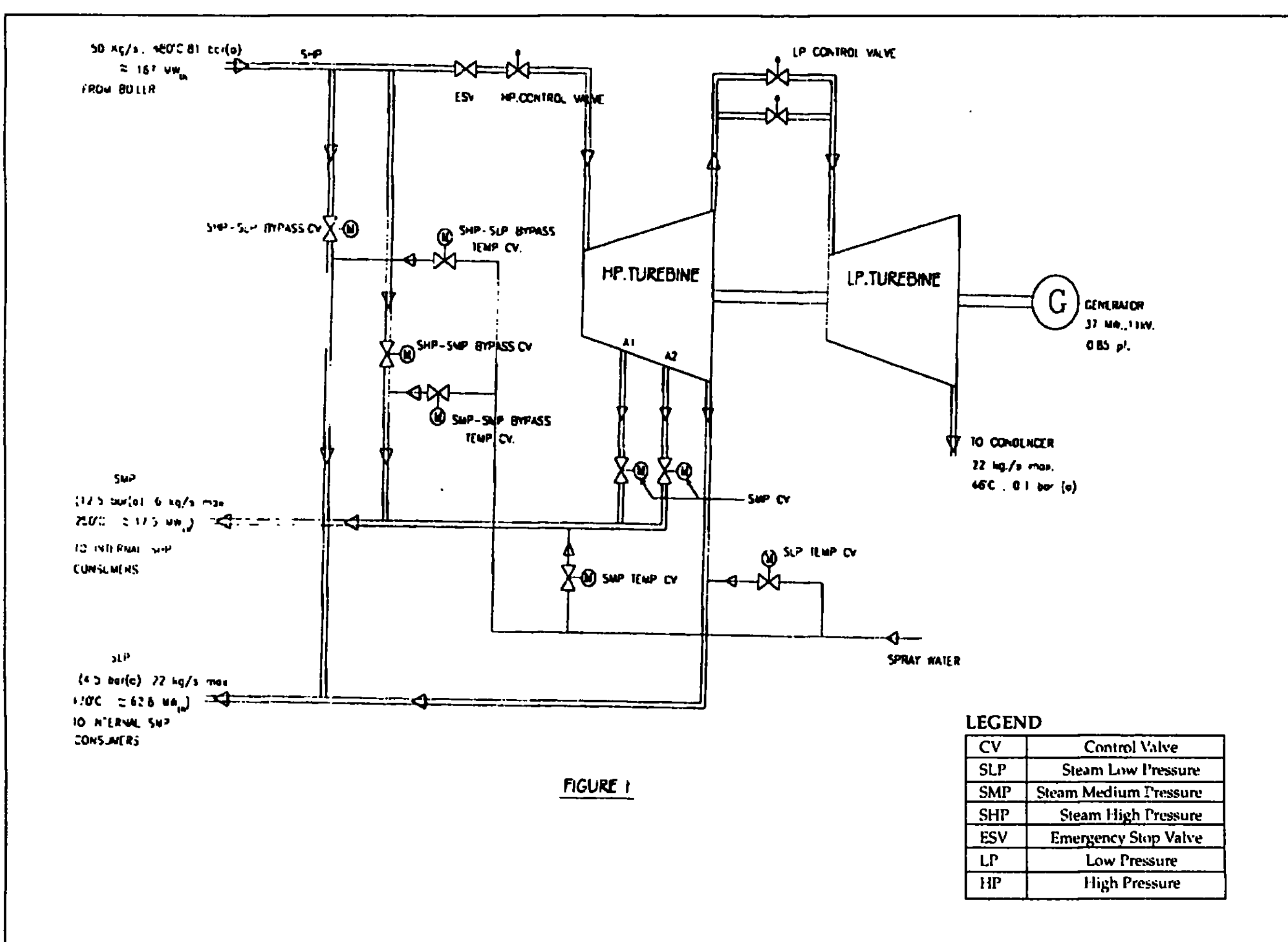


Fig. 1 - Turbine Parameters

It is interesting to note that though the electrical output of the generator is 37 MW_e the thermodynamic out puts of LP and HP steam amounts to 61.8 and 17.5 MWth respectively. The input steam condition and rate amounts to 167 MW_{th} Thus the turbine efficiency at full load with co-generation is 70% [(37+62.8+17.5)/167)].

The boiler is supplied by former Tampella Power Oy of Finland with guaranteed 90% efficiency and 97% availability even with these difficult fuels. The boiler use latest Bubbling Fluidized Bed (BFB) Combustion Technology.

If nicehsk is borad exclosively, at full load continues operation, alone, the boiler consume 12.8 Kg/Sec (46 Tons/hr) which amounts to 306 m^3/hr. If nice husk is to be transported from out side the average lorry can bring 7 tons of husk per trip and thus one lorry load for every 10 minutes.

Although in the Sri Lankan context this seems to be considerably high, a major part of this consumption accounts for auxiliary steam production. If not auxiliary steam, with 90% boiler efficiency, which is an achievable target, assuming 40% overall thermal efficiency (with no co-generation) to produce 37 MW_e it would require only 6.42 Kg/Sec rice husk flow which means a lorry load for every 18 minutes.

For more practical data our group has a smaller size plant with 10MW_e output which consumes, when running only with rice husk, average 200 tons of rice husk per day (8.3 Tons /Hr) which is equivalent to a lorry load for every 50 minuets which is fairly a feasible limit for Sri Lanka.

4. Bubbling Fluidized Bed Boliler

4.1 Bubbling Fluidized Bed Technology

Although literature is available on Fluidized Bed Combustion (FBC) technology it is worthwhile to mention the following key characteristics of FBC technology in particular the problems encountered with bio fuel fired Bubbling Fluidized Bed (BFB) technology and possible remedies in design as well as operational stages.

In BFB the fuels are burnt in a fluidized bed i.e. bed of particles, generally of smaller size and density suspended in a vertical airflow. In this condition the bed behaves like a fluid. Usually the bed temperature remains of 750-950 °C, a relatively low temperature than grate boilers. Grate boilers, which run at higher temperatures, operate above the softening temperature of many components in the ashes.

Figure 2 illustrates the stages of FBC.

Incase of air passes through the gaps between the static sand particles and when the velocity between the particles increases the particles in the bed becomes suspended in the airflow, and the bed becomes fluidized.

The bottom of the furnace contains a large number of nozzles through which primary air is forced. A layer of sand particles of specified dimensions approximately 50 mm deep covers the entire base of the furnace. When primary air is forced through the nozzles it agitates the sand and keeps the sand in suspension in a fluidized bed thereby creating the bubbling effect.

The freeboard zone above the bed is generally low velocity and provides insufficient turbulence for the mixing required for combustion if all the combustion air is fed through the bed. With no mixing the flame becomes very long and sooty, carrying large quantities of unburned material out of furnace. To overcome this problem especially design secondary air system injects air into the freeboard to allow complete combustion.

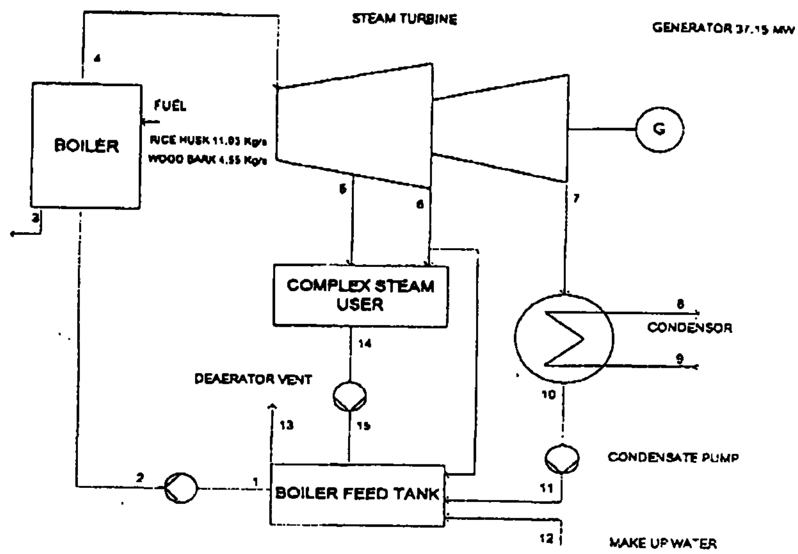
The freeboard combustion is controlled primarily by the secondary air jets, which add sufficient air to complete combustion with required turbulence to the fuel and air. The furnace resident time is set to ensure that the combustion is complete within the confines of the furnace, so that the combustion gases leave the furnace and enter the heat exchange zones.

Initially the bed is heated by external means using start up burners using oil until it reaches ignition temperature, the bio fuel can then be burnt in the same air used for fluidization.

Fluidized Beds have a two-stage combustion process whereby combustion takes place both in the bed and in the immediate freeboard. The combustion temperature in each zone is important to achieve good combustion efficiency. The proportions that burn below and above bed are functions of fuel size, density, volatility, bed velocity and temperature.

In case of volatile fuels such as wood, rice husk and baggases, more combustion will take place above the bed so the bed becomes a source of ignition and preheating for air for combustion above bed.

The low combustion temperature leads to more flyash than comparable technologies. Thus effective fly ash collecting system such as efficient Electro Static Precipitator (ESP) is essential to meet allowable dust emission levels.



DESCRIPTION	MASS FLOW (kg/s)	PRESSURE (bar)	TEMP. (oC)	ENTHALPY (kJ/kg)	PHASE
1. FEED WATER	60	1.7	115	452.5	COMPRESS LIQUID
2 FEED WATER	60	104	115	483.0	COMPRESS LIQUID
3 BLOW DOWN WATER	5	95	307	1,385.0	COMPRESS LIQUID
4 MAIN STEAM	50	84	480	3,381.4	SUPER HEAT STEAM
5. MEDIUM PRESSURE STEAM	5	12.5	245	2,921.8	SUPER HEAT STEAM
6 LOW PRESSURE STEAM	22	4.5	170	2854.1	SUPER HEAT STEAM
7. STEAM TURBINE PASS OUT STEAM	22	0.1	46	2,132.6	SATURATE STEAM
8. CONDENSOR COOLING WATER OUTLET	820	2.5	42.5	-	WATER
9. CONDENSOR COOLING WATER INLET	820	3	30	-	WATER
10. CONDENSOR PASS OUT WATER	22	0.1	45	191.8	WATER
11. CONDENSATE FEED WATER	22	6	45	152.0	COMPRESS
12. MAKE UP WATER	11.4	6	30	126.0	COMPRESS.
13. DEAERATOR VENT	1.6	1.7	115	475.0	SATURATE STEAM
14. CONDENSATE RETURN	25	1	100	417.5	SATURATE LIQUID
15. CONDENSATE RETURN	25	6	100	418	COMPRESS LIQUID

Fig. 2 - Heat Balance Diagram for Power Plant

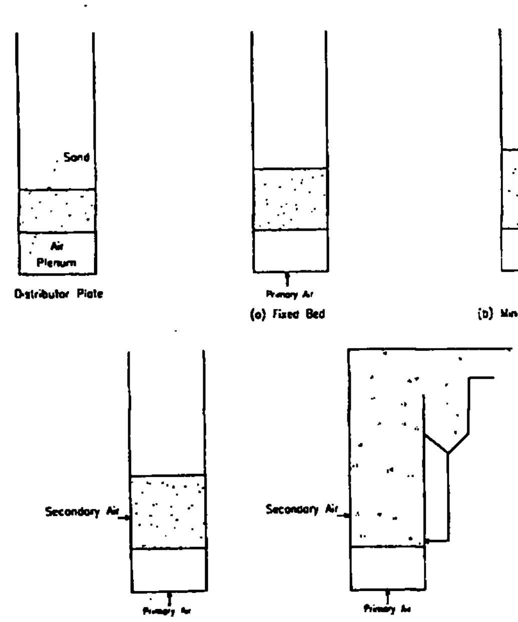


Fig. 3 - Typicol Fluidized Bed Conditions

4.2 Description of Operation

At the initial startup of a boiler, the boiler is usually fired with start up burners located above the sand bed. The fuel used for initial start up is oil. The cold sand in the fluidized bed is heated to the ignition point of the design solid fuel or fuels at which point, the design solid fuel would be introduced in to the bubbling fluidized bed.

The design solid fuel is introduced evenly onto this bubbling bed of sand from fuel feeder system located higher up in the furnace. These normally consist of one or more silos containing the solid fuel and conveyer system to deliver the fuel to furnace. As the temperature of the sand bed is at or above the ignition temperature of the solid fuel, combustion of the solid fuel takes place in and above the bubbling fluidized sand bed. The combustion of the solid fuel then maintains the temperature of the sand bed.

Above the sand bed, other air nozzles set into the furnace wall introduce more air (ìsecondary airî) into the furnace to facilitate combustion of the fuels. Further combustion of the fuel takes place in this area above the sand bed.

The rate of fuel feed to the boiler is controlled by varying the speed of the feeding chain conveyors.

The heated mixture of air, gas and ash, termed flue gas from the fuel rises up the furnace to the superheaters. In our boiler there is one boiler bank followed by three superheaters banks, termed in order of distance from the furnace bed, the secondary superheater, the second primary superheater and the first primary superheater.

The walls of the furnace are formed by cooling tubes. The lower parts of the furnace is lined with refectory material which protects the cooling tubes in that area from erosion provides thermal insulation for that part of the furnace.

The flue gas rising from the furnace bed first comes into contact with the boiler bank, the superheaters, and then enters second pass of the boiler where economizers are situated. In order of the direction of the flow of flue gas the economizers encounters are firstly, the bare tube economizer, and then finned tube economizers.

The economizers, boiler bank and superheaters are simply banks of tubes carrying first water, then a mixture of water and steam, and finally superheated steam, Their function facilitate heat transfer from flue gas to water.

The flue gases having transferred most of its heat in to the water/steam the passes through an Electro Static Precipitator (ESP).

ESP ash is then removed via ash hoppers.

4.3 Advantageous and Disadvantageous of Fluidized Bed Technology

Advantages

BFB boilers are generally accepted as an improvement over the grate fired boilers for the following reasons.

- BFB boilers are of simpler construction have no mechanical moving parts in the furnace so that the maintenance costs are lower.
- BFB boilers provide better combustion efficiency of fuels.
- Low Bed Temperatures (750C-950 oC) in fluidized bed gives following two key advantages.

  - Produce low thermal NOx due to low bed temperature 750-950 oC and in general for all fuels either bio mass or coal it is possible to use inexpensive material such as lime stone or dolomite as a sorbent to remove SO2. In case of bio mass due to low sulfur no need any limestone or dolomite to control SOx emission unlike in coal BFB case.

  - At this low temperature the ash does not melt, with good operating conditions chances for fouling boiler tubes are less.
- FB boilers have better fuel flexibility, can handle wet fuels easily, accommodate rapid load change and operate with significant variations in fuel consistency. This is one of a key factors that biomass boilers to use BFB technology.

Dis advantages

- High capital cost.
- Slightly higher auxiliary power consumption mainly due to requirement of both primary and secondary air.
- Sensitivity when handling fuels containing alkaline.

5. Specific Issues With Biomass As a Fuel

For certain fuel combinations specially risk husk (rich with SiO2) and wood chip (rich with alkaline sodium and potassium oxides) can form low melting point ash compounds (around 750 oC) than individual items i.e. eutectic point in phase diagram of K2O and SiO2 . This temperature, which is below the operating temperatures of BFB, would melt bed ash. The melted ash forms a sticky material which can easily stuck on heat transferring surfaces (boiler tubes) thus fouling boiler tubes. This eventually results reduction in efficiency, high flue gas temperature due to poor heat transfer and also high flue gas velocity due to increases in friction to flue gas flow due to tube fouling. If careful remedies are not taken on time, such as effective soot blowing, under waste case the high flue gas temperature and velocity could damage ESP and ID fan. We have experienced this practically. We found that when we fire a mixture of risk husk and wood bark it resulted more fouling in boiler tubes than we fire risk husk or wood chip alone.

Precaution has to be taken to ensure even solid fuel feeding to the furnace without pulsation in fuel feeding. Otherwise sudden variations in furnace pressure would lead to a phenomena called Furnace Breathing where combustion air flow subject to abnormal fluctuations hence variation in secondary air fan and ID fan loads.

Considering above, in order to design a proper flexible boiler, prior to design or order it is essential to define the intended type of fuel to be burned, their physical and chemical properties, moisture contents, whether fuel burn with mixing and in case of mixing fuel mixing ratios, . Otherwise it would lead to heavy repercussions particularly boiler fouling and leakage.

It is difficult and costly to design a commercial boiler to burn wide varieties of boimass together with broad range of chemical and physical properties among the same fuel and to run on an acceptable efficiency and maintain such efficiency with high availability (Efficiency can be maintained with more boiler shut downs for cleaning i.e with low availability). So a careful survey and analysis on available fuel is advisable before design.

Remedies for Boiler Fouling Due to Melting Ash

Keep more space between superheater tubes.

Widen furnace bed to give less flue gas temperate.

Frequent sootblowing.

Radiant screen tubes (bank tubes) upstream of the convection pass to reduce flue gas temperature.

Superheater design for operation on lower gas temperature. (This require more superheater material than normal)

6. Conclusions

Combustion technologies have been developed to run efficient and environment friendly biomass fueled commercial boilers. Many units are in successful operation in developed, developing and also underdeveloped countries.

The technology can be used with exploit of biomass resources in Sri Lanka to economically meet the ever-increasing demand for electricity.

FB technology, particularly BFB technology, is ideal for commercial biomass fueled boilers. However there are some specific issues to be considered when designing biomass fueled boilers.

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