Annex-1

CASE STUDY- 1

Innovative Bagasse Flash Dryer scheme for increasing thermal efficiency of HP Boiler through stack flue gas -waste heat recovery in Balrampur Chini Mill

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ABSTRACT

Thermal efficiency of all Boilers firing high moisture fuels [Bio and fossil] are of a low order primarily due to high moisture content in fuel thereby lowering steam economy. To counter this energy loss, an innovative Bagasse Flash Dryer scheme had been conceived and had been put into successful commercial operation. Two Case studies had been taken up for illustrating the quantum increase in Energy gains in the 3Es - Energy Conservation Emission reduction and Cleaner Environment.

The Bagasse dryer scheme envisages the lowering of moisture in Bagasse as received through direct mixing of warm flue gas leaving the Bagasse fired HP Boiler with Mill wet Bagasse. The dried bagasse is then separated from flue gas stream through specially designed Cyclonic Separators. The low grade heat in warm moist flue gas is exchanged for drying the fresh incoming wet bagasse. The dried bagasse with lowered moisture and higher heating value would be fired in the boiler resulting in significant increase in HP steam generation to the tune of 7 to 9 % through lowering of moisture in as fired bagasse by ~20 %. Consequently, there would be increased power and LP steam available for process and export to grid from the integrated extraction condensing steam turbo-generator. Alongside, the high emission reduction achieved through increased green energy displacing fossil energy is only to be expected. To cap it all through this scheme, the reduction in particulates in flue gas ensures cleaner environment. .

The concept can be easily replicated in all Bagasse fired boilers in particular, but also in boilers firing high moisture content biomass [viz. Bagasse pith, saw dust , chipper dust etc.] in general. The stage is set for enhancing steam economy and reducing carbon emission further through increasing the boiler thermal efficiency and reducing heat rate further.

1.0 INTRODUCTION

Balrampur Chini Mill (BCML), in its quest for maximizing utilization of in plant Energy resource had installed HP Boiler using the as milled high moisture bagasse as fuel. In order to maximize Green energy -Steam and power for process use, bagasse fired HP Boiler along with matching extraction condensing steam turbo-generator had been installed and is being in successful operation all these years.

2.0 BOILER DESCRIPTION- BCML

Milled wet bagasse is directly fed to the HP Boiler. The steaming conditions of the Cogen HP Boiler and other related parameters are elicited in Table -1.

TABLE -1

BAGASSE FIRED HP BOILER

Parameter	Design Value	Units
Fuel	Bagasse	
Moisture in Mill Bagasse	50	%
Steam Evaporation [MCR]	80	TPH
Steam outlet Pressure	87	Ksc
Steam outlet temperature	515	ºC
Feed Water Temperature from HP heater to Economizer	180	ºC
Draught system	Balanced- FD & ID Fans	
Flue gas temperature at APH out	145	ºC
APC Device	ESP	
Back end Equipment	Economizer& APH	
SH Steam temperature Control	Inter-stage Attemperation between PSH & SSH	
Air Distribution-Multistage	PA & SA	

Balanced draught system is in place with air for combustion. Combustion air is split as primary at lower level and Secondary air at an elevation from the walls of the combustion chamber. With proper apportioning of PA and SA, the combustion of fuel is ensured. Combustion chamber is of membrane walled tubes housed all around as an air tight fit. Hot flue gas leaving the furnace top is passed through Super heater coils - Primary and Secondary for generating superheated steam. Inter-stage attemperation spray is employed for controlling steam outlet temperature at the design rating.

Boiler feed water constitutes Turbine return condensate, process indirect hot condensate and balance fresh treated DM water of high quality. Feed water is heated along with deaeration in the pressurized deaerator. The heated deaerated feed water is heated further in HP heater before the same is led to the economizer. The flue gas flows through Economizer wherein the high temperature feed water is preheated further before leading the same to the Steam drum.

Hot flue gas leaving the economizer is passed through tubular APH wherein the air from ambient is preheated before the same is led as hot combustion air onto the Combustion chamber of the boiler. Warm flue gas leaving the air preheater is passed through ESP for de-dusting, before the de-dusted flue gas is sent to the connected tall stack with the help of ID fan.

3.0 INNOVATIVE MILLED BAGASSE FLASH DRYER –CONCEPTUALIZATION

As ENVIROPOL found out that there is significant heat loss all due to warm moist flue gas discharge to surrounding environment through stack, it was decided by the team to develop an energy -enviro friendly scheme which can recover the at least the sensible heat available in otherwise wasted thermal energy to the surrounding environment. The Innovative Waste Heat Recovery Enviro friendly scheme on the form of Flash Bagasse Dryer unit [Fig.1] is discussed in the following section.

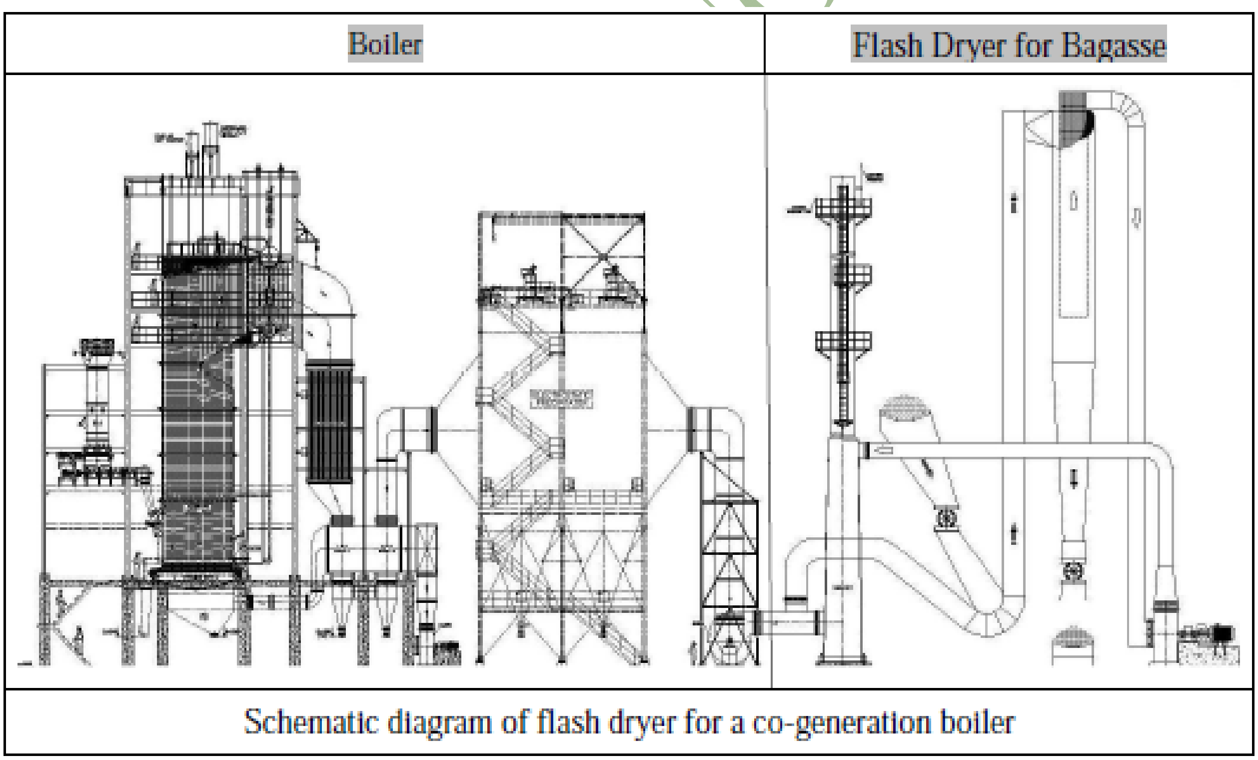

Fig.1 Boiler Side View with Bagasse Dryer

3.1 BAGASSE FLASH DRYER -INNOVATIVE PRODUCT-WORKING PRINCIPLE

In this process of bagasse drying, the waste heat from the available flue gas is used as a heating /drying medium. The warm exit gases are drawn from the boiler and allowed to pass through the flash tower under induced or forced draft maintaining pre-calculated velocities and Average Particle Retention Time (APRT).

Bagasse is fed at controlled rate through sealed air lock feeder at the bottom of the flash tower [Fig.2] and allowed to inter mix with hot flue gas. It is then carried up-ward in co-current mode with the hot flue gas. During the process, the moisture present in bagasse keeps on evaporating gradually till flue gas reaches to a predicted temperature.

Fig. 2 Actual site photo-Bagasse Drier

The dried bagasse (Fig3) is the separated from the gas stream using specially designed high efficiency cyclonic separators. The mill bagasse acts as a good scrubbing agent and clean the gas entrapping suspended particulate matters present in the flue gas.

The clean flue gas is removed through booster fan before letting it out through chimney. The dried bagasse is continuously removed through sealed air lock valves from the bottom of the cyclone and conveyed back to the fuel feeding system of the boiler (Fig-4-DCS snap shot showing the complete flow diagram).

Fig.3 Wet & Dried Bagasse

Fig. 4 DCS snap shot of Dryer in operation

3.2 PERFORMANCE TEST- DATA COLLECTION

The said bagasse dryer at BCML was installed and commissioned in Nov 2020. The following were the design input and output conditions [Refer Table -2].

TABLE -2

DESIGN INPUT PARAMETERS		
Description	**Unit**	**Value**
Boiler Steam Generation Capacity	TPH	80
Bagasse Dryer Capacity	TPH	31
Bagasse moisture at inlet	%	49
Temperature of inlet flue gas (*)	Deg C	**140**
Quantity of inlet flue gas	m^3/sec	60
Particle size distribution		Standard
Quantity		1 Set
DESIGN OUTPUT PARAMETERS		
Predicted moisture in Bagasse at outlet	%	**39.5±0.2**
Predicted flue gas temperature at outlet	Deg C	**70±2**
Predicted pressure drop across dryer	Mmwc	**135±10**

Series of performance Tests were conducted at varying available steam load conditions of the boiler, last being the test conducted for capacity test of dryer on 2nd April 2021 for 24 hrs continuous duration. The data collected from the same Test are given in Table -3

TABLE -3

PERFORMANCE TEST DATA - FLASH BAGASSE DRYER

DRYER COMMISSIONING PARAMETERS

S. No.	DATE	TIME	F. G. TEMPERATURE (Deg C)							F.D . AIR Temp (Deg C)	DRAUGHT in MMWC				LOAD								Power Consum					APH F.G. Bypass Damper opening %	Motorised actuator 02	
			APH Outlet	ESP Outlet	Actual Dryer Inlet	Design Temp at Inlet of Dryer	Actual Dryer Outlet	P.G.Design Temp. at Outlet (Deg C)	Furnace		Dryer Inlet	Dryer Outlet	Actual Pressure Drop (MMWC)	P.G.Pressure Drop Across Dryer	Both ID Fan (RPM %)	SA Fan Air Quantity (M3/Hr)	FD Fan Air Quantity (M3/Hr)	BIDF (RPM%)	Design Boiler Steam Load (TPH)	Boiler Steam Load in TPH	Design Bagasse Input Load (TPH)	Actual Bagasse Load in TPH	Bagasse Dryer system with New Belt Conveyor system	Actual Dryer Inlet	P.G. Moisture Drop of Bagasse at Outlet(%)	Actual Dryer Outlet	Diffrence		Slat 01	Slat 02 Boiler Side
1	03.04.2021	7:00	143	141	130	140	65	70±2	668	128	145	45	100	135±10	64	54	70	93	80	67	31	30	4238	47.9	9.5±0.2	38.22	9.68	100	No	Yes
2		8:00	144	142	131	140	68	70±2	660	130	144	47	97	135±10	63	54	69	93	80	66	31	30			9.5±0.2			100	No	Yes
3		9:00	141	139	129	140	65	70±2	658	129	138	38	100	135±10	57	54	69	93	80	66	31	29			9.5±0.2		0	100	No	Yes
4		10:00	142	140	130	140	67	70±2	680	130	140	39	101	135±10	58	52	71	93	80	68	31	31			9.5±0.2			100	No	Yes
5		11:00	142	140	130	140	69	70±2	690	131	141	40	101	135±10	59	53	70	93	80	69	31	30			9.5±0.2		0	100	No	Yes
6		12:00	144	141	130	140	67	70±2	683	134	136	39	97	135±10	64	53	71	93	80	69	31	29			9.5±0.2			100	No	Yes
7		13:00	147	143	134	140	66	70±2	669	136	141	40	101	135±10	72	53	73	93	80	70	31	30			9.5±0.2		0	100	No	Yes
8		14:00	143	145	135	140	70	70±2	672	135	140	42	98	135±10	67	52	71	93	80	68	31	32			9.5±0.2			100	No	Yes
9		15:00	144	142	132	140	68	70±2	677	134	143	43	100	135±10	58	53	66	93	80	68	31	28			9.5±0.2		0	100	No	Yes
10		16:00	142	140	130	140	68	70±2	695	136	138	30	108	135±10	53	53	63	93	80	68	31	30			9.5±0.2			100	No	Yes
11		17:00	142	140	130	140	69	70±2	705	135	142	33	109	135±10	56	53	66	93	80	69	31	29		47.63	9.5±0.2	38.09	9.54	100	No	Yes
12		18:00	141	140	129	140	70	70±2	708	134	139	41	98	135±10	61	54	68	93	80	68	31	27			9.5±0.2			100	No	Yes
13		19:00	140	138	128	140	73	70±2	681	133	141	36	105	135±10	60	55	67	93	80	68	31	29			9.5±0.2		0	100	No	Yes
14		20:00	143	140	129	140	66	70±2	675	135	138	33	105	135±10	63	53	67	93	80	70	31	31			9.5±0.2			100	No	Yes
15		21:00	141	139	128	140	66	70±2	687	132	143	50	93	135±10	66	53	64	93	80	66	31	30			9.5±0.2		0	100	No	Yes
16		22:00	140	138	127	140	67	70±2	663	130	144	34	110	135±10	62	53	64	93	80	70	31	28			9.5±0.2			100	No	Yes
17		23:00	141	138	127	140	70	70±2	682	131	156	41	115	135±10	71	55	67	93	80	69	31	28			9.5±0.2		0	100	No	Yes
18		0:00	139	136	125	140	68	70±2	665	130	142	38	104	135±10	58	55	65	93	80	69	31	29			9.5±0.2			100	No	Yes
19		1:00	138	136	125	140	74	70±2	664	129	140	45	95	135±10	57	54	65	93	80	68	31	29			9.5±0.2		0	100	No	Yes
20		2:00	140	138	127	140	75	70±2	670	131	153	48	105	135±10	62	54	65	93	80	71	31	30			9.5±0.2			100	No	Yes
21		3:00	140	137	127	140	72	70±2	680	131	156	54	102	135±10	76	54	67	93	80	72	31	28			9.5±0.2		0	100	No	Yes
22		4:00	140	138	127	140	66	70±2	674	132	155	49	106	135±10	68	55	67	93	80	69	31	28			9.5±0.2			100	No	Yes
23		5:00	140	138	128	140	68	70±2	667	130	159	51	108	135±10	72	56	68	93	80	70	31	30		47.53	9.5±0.2	38.58	8.95	100	No	Yes
24		6:00	0:00	0:00	0:00	140	67	70±2	678	129	154	43	103	135±10	70	56	70	93	80	68	31	30			9.5±0.2			100	No	Yes
Average			142	139	129		69		677	132	145	42	103		63	54	68	93		69		705.00								

3.3 PERFORMANCE TEST- DATA ANALYSIS

Data analysis was carried out after the test and following were the recorded output:

1- The dryer was running during the test with bagasse load varying from 29-36 TPH (Avg Load- 32.25 TPH. as against design load of 31 TPH)

2- The available steam load on H.P. boiler was varying between 67 to 78 TPH (Avg load 71 TPH as against boiler design of 80 TPH)

3- It transpired that the dryer was producing more dried bagasse than it was actually required for that boiler load, as a part of dryer capacity test. About 5.2 TPH of dried bagasse was going to the yard with surplus mill bagasse (it is not a standard operating protocol but as part of dryer capacity test, it was allowed seeing the steam demand of the plant during the testing period).

4- The total weight of dried warm bagasse from the dryer was noted as 27.2TPH at reduced moisture. Out of this,22.0TPHof dried bagasse was consumed in the boiler to produce 71 TPH of steam on 24 hrs average basis.

5- This represents that an evaporation rate of boiler with dried bagasse as 3.22kg of steam /kg of bagasse considering the reduced weight due to moisture evaporation

6- The test also reflected that even at reduced flue gas volume (equivalent to 71 TPH boiler steam load as against design condition of 80 TPH) and reduced flue gas temperature (133^{0}C as against design condition of 140^0 C), the dryer was able to dry more than designed quantity of bagasse (32.25 TPH as against designed value of 31.0 TPH) even while maintaining designed outlet flue gas temperature as 70^{0}C and moisture reduction of 9.63 per cent points(equivalent to 20 % reduction over 47.7 % moisture in mill bagasse).

7- The above finding represents that the actual results were better than the guaranteed figure. Considering a conservative approach adopted for committing the guaranteed values and even after taking scope of some error in on line weight measurements of bagasse, there is still a room for further improvement.

8- All data compiled are tabulated and shown below in Table-4.

TABLE- 4

BCML - BAGASSE FIRED HP COGEN BOILER

Parameter	Boiler- Design	With Dryer	Units
Steam Generation	80	*71 /87	TPH
Main Steam Pressure	86	86	kscg
Main Steam Temperature	515	517	^{o}C
Feed water Temperature	180	186	^{o}C
Flue gas outlet temp	133	72	^{o}C
Fuel	Bagasse	Bagasse	
Moisture Content	48-50	38.0	%
GCV of Fuel	2375 - 2270	2825	Kcal/kg
Fuel Temperature to Boiler	30	50-65	^{o}C

(*) On the day of testing, steam demand was only 71 TPH on 24 hrs. average basis. However the Boiler steam generation capacity enhanced to about 87 TPH on account of reduced moisture in bagasse

4.0 QUANTUM INCREASE IN ENERGY GAINS

Through installation of the flash bagasse dryer at the backend of the bagasse fired boiler, Moisture in bagasse is partly removed before the dried heated bagasse with increased GCV is fired in the combustion chamber. Additional energy gain which gets unnoticed is one of fuel being preheated from ambient to 65-70^{0}C. Excess dried heated bagasse, if any, through the bagasse dryer needs to be included in the energy gains. Thermal efficiency of the boiler is increased by around 7to 8 % [6per cent points].

As reflected from the test, the total power consumption during the bagasse dryer capacity run was recorded as 4184 KW over a period of 24 hrs i.e. 174 kWh on bagasse dryer booster fan and accessories. At the same time, overall reduction of about 35 kWh was observed in auxiliary power consumption of boiler related to ID, FD, SA fans and bagasse feeding equipment of boiler on account of reduced flue gas volume ,draught and weight of bagasse. Accordingly, the net power increase is calculated as 139 kWh.

Considering the increase in thermal efficiency of the boiler, the gross mill bagasse saving is calculated at 2.4TPH which is very close to the actual savings validated by end user. This saved bagasse can produce extra HP steam to the tune of 6.5 TPH considering 2.5as reported evaporation rate of boiler on mill bagasse.

With reported specific steam consumption of 3.8 kg/KWh [in condensing mode exclusively for power generation] of installed HP turbine, the saved bagasse is capable to produce additional green power of 1700kWh. Considering, extra power consumption of 139kWh, the net extra power availability for the grid works out to1561kWh.

The performance test results are summarized in Table –5.

TABLE -5

BCML- PERFORMANCE WITH DRYER

Parameter	Without Dryer in operation	Energy Gains with Dryer	Increase/ Reduction
Bagasse Moisture	47.63 %	38 %	9.63 pp [20%]
Bagasse GCV	2375 kcal/kg	2810 kcal/kg	18%
Boiler Thermal Efficiency	70 %	76 %	6 % point
Steam Economy Upgrade	2.4 -2.5	3.1- 3.2*	11-12%
Flue Gas Temp to Stack	133°C	72°C	61°C
Excess Air Reduction			~20%
CO_2 Reduction			33-35 t/CO2e/day
SPM reduction in FG			80- 90%
NOx reduction est.			15-20%
N2O reduction est.			5-10%

(*) Considering reduced weight of bagasse after dryer.

4.0 RETURN ON INVESTMENT

If we follow the power generation route, the net saving works out to INR 1, 12,390per day considering current power tariff of INR 3.0 /kWh to the grid.

The savings, on account of sale of bagasse to other industry is calculated to INR 92,400per day considering the current rate of bagasse as INR 1750 / Ton.

The above figure represents a Return on Investment well within less than 500 working days.

5.0 OVERALL PERFORMANCE ANALYSIS

- The waste sensible heat in the flue gas escaping to the stack and the same being used for removing partly the moisture in fuel.
- The fuel is preheated by about 45^0 C which also adds marginally to boiler performance. However, in order to leverage the energy gains on a sustained basis, heat in the dried warm bagasse which is presently getting dissipated due to storage in the open could be conserved.
- Flexibility exists for saving balance excess bagasse not required for safe storage in the yard for use at a later stage of use in the HP boiler-especially during lower cane crushing period specifically for power export to grid.
- Particulate reduction in flue gas after Bagasse dryer in place ensures cleaner environment.
- Lowered excess air coupled with staged air combustion and preheated dried fuel admission is expected to contribute to NOx reduction to the tune of ~20%
- However, Net Station power consumption due the additional Bagasse Flash Dryer unit consumption of ~140 kW after taking into account reduction in flue gas and air flows through the Boiler circuit.
- **RORT is < 1.4 years [Crushing Months]**
- Furnace combustion temperature is expected to be marginally higher due to lowered moisture and higher GCV fuel fired as compared to the design stage. This would relate to reduction in N_2O[high potent GHG] further contributing to Emission reduction.
- With increase in specific energy gains through increase in Steam economy [Specific steam evaporation], the emission reduction through fossil energy offset. With improved heat rate and thermal efficiency enhancement of the boiler with bagasse dryer in place is estimated at around 1000 t CO2e/ month during crushing season.

6.0 REPLICATION

This Innovative scheme can be replicated in all boilers firing milled wet bagasse in general, but also can be used for boilers firing other monstrous agro wastes viz., Bagasse pith, saw dust etc.

Potential is very high considering the large number of sugar Mills and other agro waste fuel fired boilers in many other process plants in diverse Industrial sectors.

7.0 WAY FORWARD

Having achieved the breakthrough in tapping the stack gas waste heat through the innovative Bagasse Flash dryer , development is under way to improve the heat rate of the boiler further with increased waste heat recovery, thereby contributing truly to the dictum of 3 Es-Energy Conservation, Cleaner Environment and Emission reduction-all in one.

ACKNOWLEDGMENT

Team Enviropol, are grateful to the Management of BCML for providing opportunity to install Flash Dryer on their high pressure cogeneration boiler.

We also wish to acknowledge and express gratitude to very dynamic &energetic team of their plant for their active cooperation and assistance rendered right from installation to steady state successful operation of the Bagasse Dryer integrated to the HP Boiler.

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