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KTH Industrial Engineering and Management

FACULTY OF ENGINEERING AND SUSTAINABLE DEVELOPMENT

WASTE FROM INSTANT TEA MANUFACTURING AS A FUEL FOR PROCESS STEAM GENERATION

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Master's Thesis in Sustainable Energy Engineering

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Examiner: Prof. Andrew Martin
Supervisor: Prof. Andrew Martin

Declaration

The work submitted in this thesis is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any other degree and is also not being concurrently submitted for any other degree.

D. H. G. S. R. Somasundara

Date

We/I endorse declaration by the candidate.

	Master of Science Thesis EGI 2010:OUSL	
KTH Industrial Engineering and Management	**Waste from instant team manufacturing as a fuel for process steam generation**	
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Approved March 2017	Examiner Prof. Andrew Martin	Supervisor (KTH) Prof. Andrew Martin
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Abstract

An existing furnace oil fired boiler is used to supply process steam to an instant tea manufacturing factory. The instant tea is manufactured the Broken Mixed Fannings (BMF) through extraction and other required processes. The average steam consumption of the plant is 6000 kg/h at 10 barg pressure. During the process, tea waste is generated at a nominal rate of 50,000 kg/day, about 2000 kg/h at around 70% MC content on wet basis. At the moment this waste tea is either dumped in the surrounding area by spending money or sent to landfilling purposes, which create environmental issues.

The tea waste coming out at 70% MC wet basis, is looked at to press through continuous belt press to reduce the moisture content to about 55% on wet basis. The water removed from this pressing process is sent to effluent treatment plant at the factory. The output from the belt press is sent to a steam operated The average generation of tea waste from the instant tea manufacturing process process is about 2000 kg/h, after pressing in the belt press an output rate of about 1,400 kg/h at 55% MC.

This amount of tea waste at 55% MC is sent to a rotary steam tube dryer and the MC is reduced from 55% to 30% and the output rate from the steam tube dryer is about 857 kg/h. The amount of steam consumed by the rotary steam tube dryer at 6 barg pressure is 760 kg/h. Then the tea waste from the rotary tube dryer is mixed with firewood of 30% MC and fed to the boiler to generate process steam, out of which 857 kg/h steam at 6 barg pressure is sent back to the rotary steam dryer.

From tea waste alone, a steam amount of 2,472 kg/h can be supplied after giving steam to the rotary steam dryer. The balance steam amount of 3,528 kg/h for the process requirement is supplied by burning additional firewood at 30% MC content. The tea waste fuel and firewood in combination have an overall moisture content of 30% on wet basis. The boiler is rated at 10,000 kg/h F & A 100 deg C with an actual generating capacity of about 9000 kg/h at 10 barg operating pressure at 70 deg C feed water temperature.

By implementing the combination of belt press, rotary steam tube dryer and firewood boiler in place of the existing furnace oil fired boiler, an annual monetary saving of 168 Mn SLR/year can be achieved with a simple payback period of 21 months which is a highly feasibly project.

Acknowledgement

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Most importantly I express my heartiest thanks to Ruchira Abeyweera of OUSL for his guidance, assistance and continuous encouragement which paved the path to successfully complete this thesis. If his strict follow up was not there, this thesis would have not been a reality. The motivation given by my friendly colleagues, Kumudu Amarawardena and Asela Abewardena, is always heartily remembered. The support, words of encouragement and backup given by fellow director of the company, Indrawansha Rajapaksha, during his busy schedules of work and studies, is always very much appreciated.

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1 Introduction

Instant tea is produced using extraction process of processed black tea; undried fermented leaves or waste tea. The raw material used for instant tea production is called Broken Mixed Fannings (BMF). The BMF production in 2006 was 30,000 tonne as a waste product at the black tea production of 300,000 tonne in the same year (Sri Lanka Tea board).

At present only one company in Sri Lanka uses BMF, who consumes about 9000 tonne of BMF per year and produces about 2000 tonne of instant tea. Tea waste with water, generated at the pressing process is about 15,000 tonne per year at moisture content of 70% on wet basis (approximately 50 tonne per day at 70% (wet) moisture content). The company has no facility to use all the tea waste such that a major portion is dumped on bare lands nearby. Because of the fibrous property of this tea waste is not suitable for land filling, hence the disposal has become a major environmental problem to both the company and the area.

The tea waste is a biomass that can be used as a source of energy. However, higher percentage of moisture, in the range of 70%, pauses a major problem with regard to direct combustion such that proper flame temperature is difficult to achieve. In order to achieve sufficient combustion the moisture content has to be reduced to below 50% (wet basis). Based on the preliminary analysis the higher calorific value (HCV) of waste tea at 50% moisture content is about 9 MJ/kg while the lower calorific value (LCV) is about 7.3 MJ/kg.

The major utility used in this process is steam, which at present is supplied using a furnace oil fired boiler. The steam consumption is about 8.2 tonne per hour with corresponding furnace oil consumption of about 5.5 million liters per year. At the prevailing furnace oil price the fuel bill for steam generation is about Rs. 250 Mn per year. Compared to electricity usage in the process, this corresponds to about two folds of electrical energy use.

2 Objectives

- To study the feasibility of using tea waste produced in the pressing process of instant tea production, as a fuel to a process heat boiler.
- To decide on an efficient and economical pressing and drying processes to reduce the moisture content of tea waste from 70%(wet) about 30% MC (wet) using mechanical pressing, waste heat or other source of energy
- Study the most appropriate combustion technology for burning tea waste at moisture content of about 30% (wet) in a process heat boiler combustion chamber
- Study maximum possible steam generation capacity through the use of waste, part of which can be supplied to the process for reducing furnace oil consumption and monetary saving.

3 Methodology

Tea waste from the extraction process is tested for composition. Ultimate test is done to find out Carbon, Hydrogen and other major components. The calorific value is tested through bomb calorimeter. The samples are tested through filter press to check the maximum possible moisture reduction through mechanical means. The requirement is to achieve the minimum possible moisture content by mechanical pressing, eg. From 70 % MC to about 55 % MC, subsequently tea waste is dried from 55% MC to 45% MC by steam dryer. Steam required for steam dryer is supplied from the same process boiler.

The properties of fuel mixture of tea waste as a fuel at 45% MC and firewood of 30% MC, are calculated to find out the total equivalent moisture content and the corresponding calorific values. Since the boiler F & A rating, operating pressure and feed water temperatures are known and decided, it is possible to calculate the required firewood while using dried tea waste to fire in the boiler.

The main requirement of the project is to replace the existing furnace oil fired boiler, by a solid fired boiler in which the dried tea waste is used a fuel as well as firewood as a supplementary fuel. The total saving in installing the firewood fired boiler, is calculated and the recovery period of the investment is presented.

4 Analysis

1. Analyze tea waste generation process, composition, calorific values and capacity variations

Table 1 : Composition of Tea waste on wet basis – Ultimate analysis

Parameter	Percentage /(%)
Carbon, C	18.32
Hydrogen, H	1.20
Sulphur, S	0.06
Nitrogen, N	0.55
Oxygen, O	8.64
Ash, A	0.71
Moisture content, MC	70.52
Total	100.00

Source: Test done at the ITI, Colombo

Table 2: Moisture content test results

Parameter	Sample 1	Sample 2	Sample 3	Average
Moisture content, wet basis /(%)	71.10	71.20	72.20	71.50

Source: Test done at the environmental laboratory, faculty of Engineering, University of Peradeniya

Table 3: Gross Calorific Value test results

Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Average
Gross Calorific Value /(MJ/kg) (Dry)	19.00	18.79	17.97	18.20	18.49

Source: Test done at the department of Mechanical Engineering, faculty of Engineering, University of Peradeniya

2. Study and identify the best process to reduce moisture content from 70% to about 50% for proper combustion by either mechanical or thermal means

Mechanical process

Following test is done to measure how much moisture can be removed by manual press.

Table 4: Filter pressing results

Parameter	Value
Moisture content /(%)	71
Moisture content after manual press /(%)	48

This means it is possible to use additional screw press to reduce the moisture content of 71% to about 55% on a conservative basis.

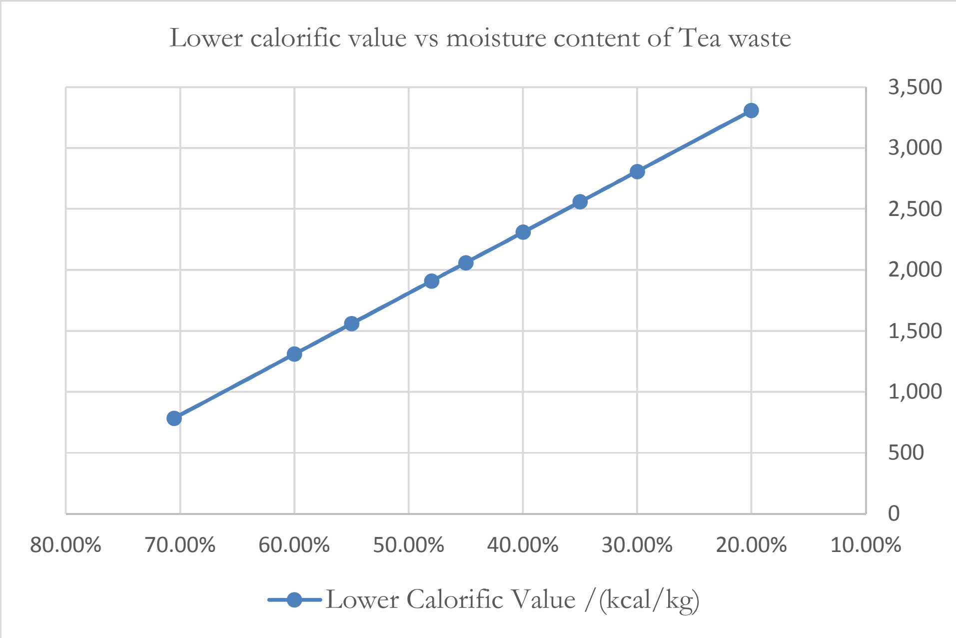

Figure 1: Lower calorific value of tea waste at different moisture content on wet basis

Table 5: Usable steam generation for process at different MC levels of tea waste

Initial MC /(% wet)	Final MC /(% wet)	Evaporated water /(kg)	Fuel generation rate for combustion /(kg/h)	Possible steam generation, Actual /(kg/h)	Steam for drying /(kg/h)	Usable steam for process /(kg/h)
55%	45%	248	1,117	3,096	297	2,799
55%	40%	341	1,024	3,183	408	2,774
55%	35%	420	945	3,256	503	2,753
55%	30%	487	877	3,318	583	2,735

According to table 5, the usable steam generation shows a reduction when drying from 55% MC level to 30% MC level than 55% MC level to 45% MC level. Our main objective is to have maximum possible usable steam for process at the maximum MC level of tea waste mixture which can be combusted in the boiler.

Table 6: Final MC level of tea waste and additional wood fuel mixture at different MC levels of tea waste

Initial MC /(% wet)	Final MC /(% wet)	Percentage of Usable steam/Actual steam /(%)	Balance steam from direct fuel /(kg/h)	Additional firewood, 30% MC /(kg/h)	Mixing ratio (Tea waste/(Tea waste+Additional fuel)	Final MC of fuel mixture /(%)
55%	45%	90	6291.64	1557.1805	42	36
55%	40%	87	6316.71	1563.3856	40	34
55%	35%	85	6337.92	1568.6361	38	32
55%	30%	82	6356.11	1573.1366	36	30

Table 6 shows the final moisture content of fuel mixture comprising of dried tea waste and additional fire wood fuel. Looking at the percentage of usable steam generation that can be supplied to process, to the total actual possible steam generation, when reducing MC level from 55% to 45% shows the highest value. Final moisture content of the fuel mixture is also 36% which is combustible at the boiler with acceptable flame temperature levels. Present improved grate firing boilers will accommodate MC levels as high as 45% of firewood or fuel mixtures, without considerable effect to the flame temperature.

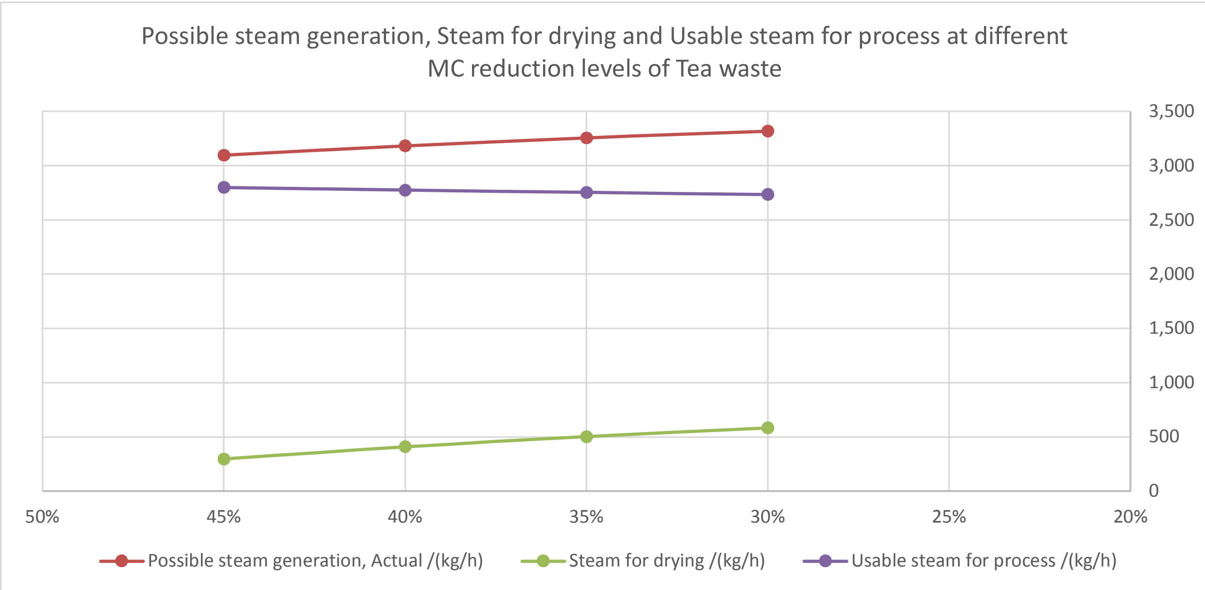

Figure 2: Possible steam generation, steam for drying in rotary dryer and usable steam for process at different moisture reduction levels from 55% MC on wet basis of tea waste

Figure 2 shows the variation of possible steam generation, steam used for rotary dryer to evaporate water of tea waste to reduce to the required moisture content level and usable steam for process, at different moisture content level from 55% MC on wet basis of tea waste. With varying achieved moisture content level, the usable steam for process shows a decrease in value which is not economical in the long run, since the main objective is to have maximum possible usable steam for process. Therefore the final moisture content of tea waste after rotary dryer is selected as 45% on wet basis and the moisture content of fuel mixture is 36% as selected from Table 6.

5 Proposed plant

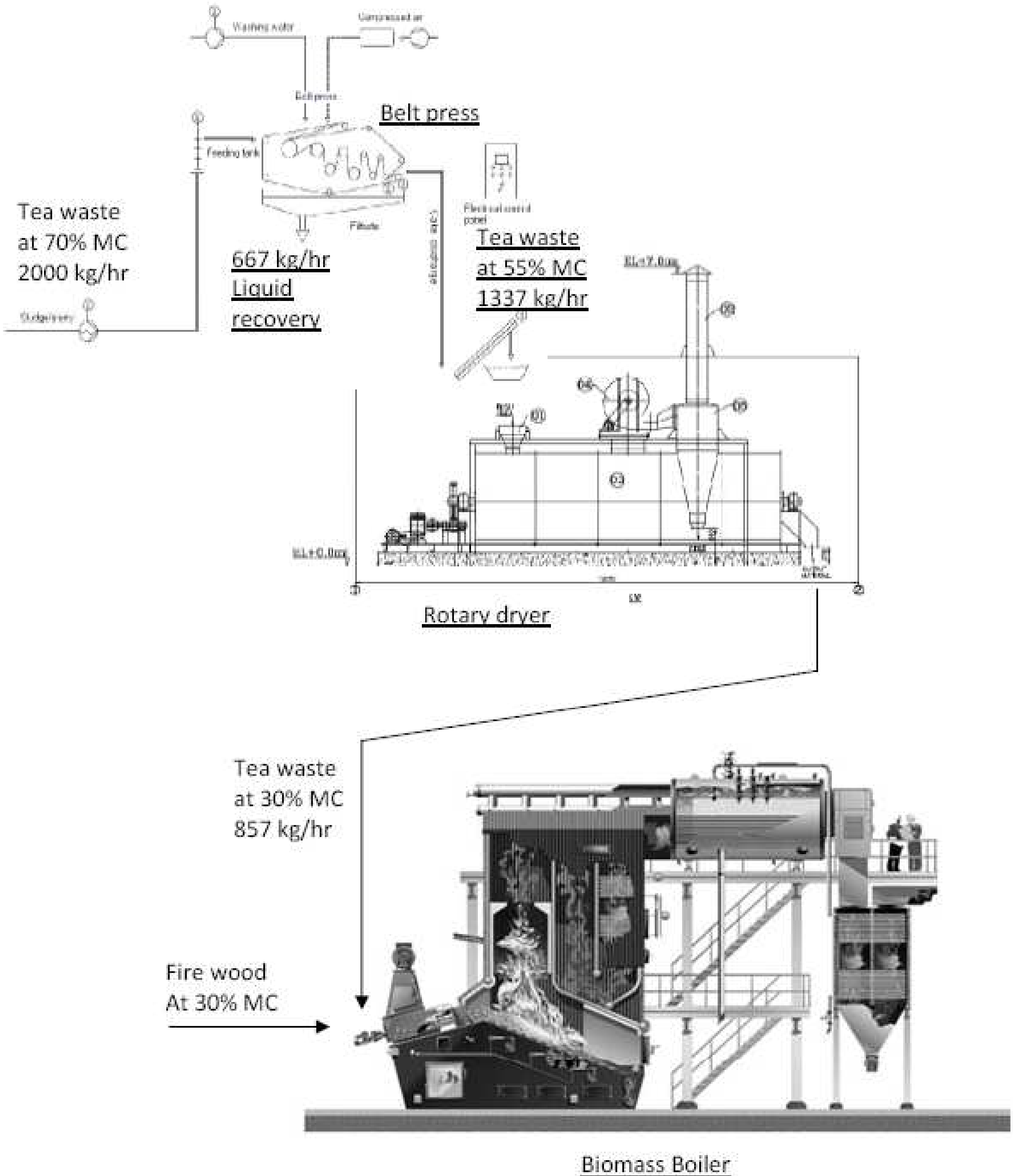

Figure 3: Proposed configuration of plant

The proposed plant in Figure 3, comprises of a belt press, rotary steam tube dryer and a firewood fired boiler which is a step grate type automatic feeding. Details of belt press, dryer and boiler are given below.

5.1 Belt press

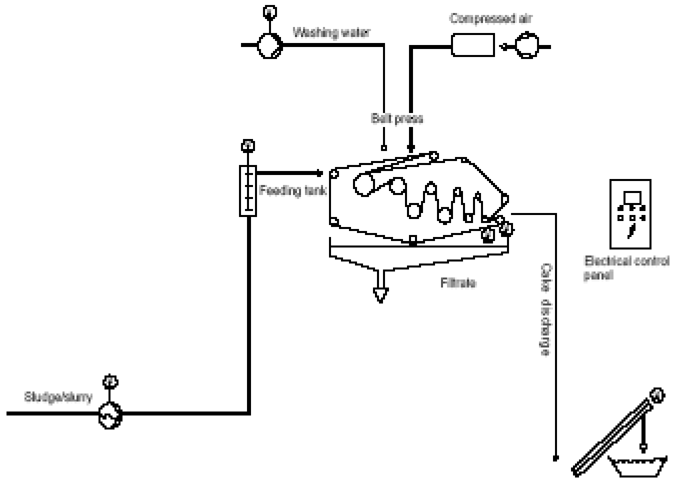

Figure 4: Belt press configuration

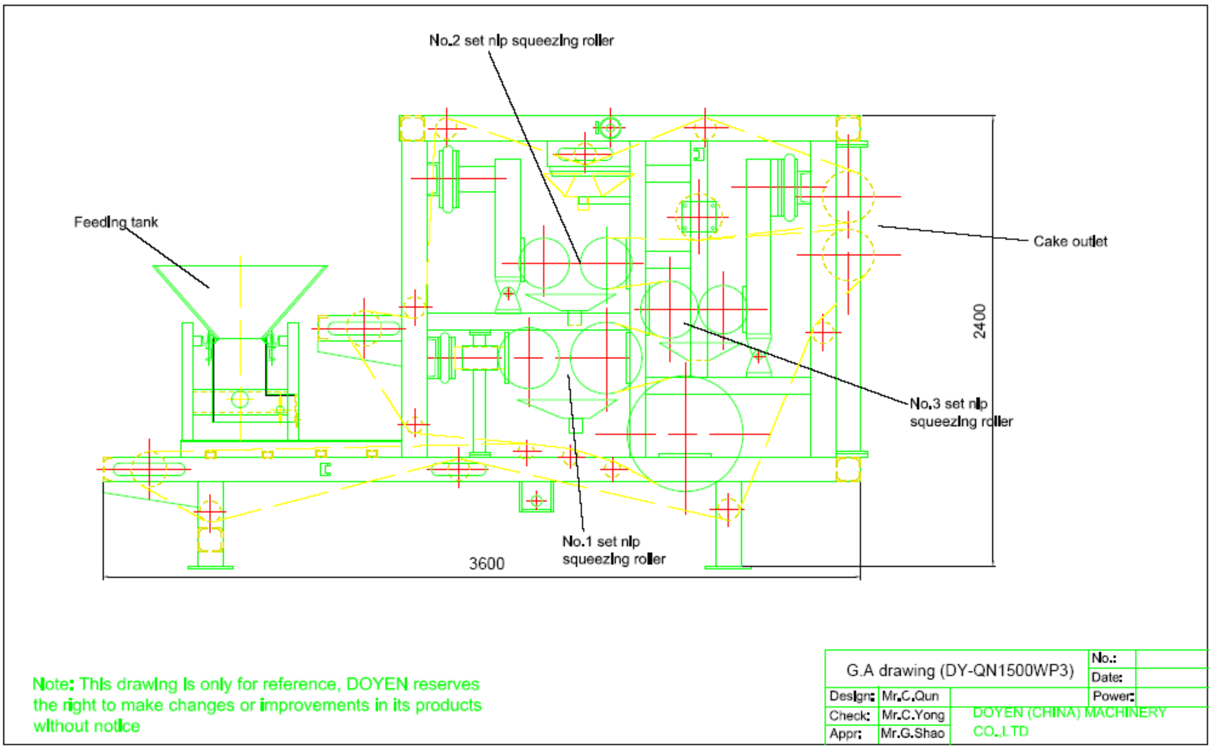

Figure 5: Belt press drawing

5.1.1 Specifications

In the production of ethanol, a valuable by-product of the spent grain is produced. Whether the spent grain is from corn, wheat, barley or rye, it has a high value once dried. The main use of the dried mash is in the animal feed industry where the product is used to supplement e.g. ruminant diets.

DY-DYQ series powerful type belt press is a new typ e dewatering equipment specially developed in light of actual need of spent grain dewatering by successfully absorbing the advanced techniques of pressure filter home and abroad through many years research and testing. It is the best choice for dewatering of spent grain like wheat beer brewery mash,etc. This equipment has the characteristics as continuous working, good dewatering effects, lower power consumption, lower noisy, easy for operation and maintenance. It is a very good processing equipment of high moisture spent grain before drying with energy saving greatly.

Typically, our spent grain press receives materials ranging from 75 - 85 % feed moisture content and produces a final product of 50 - 65 % cake moisture. Performance depends on the nature of the materials being processed.

2.Key Advantages:

- Continuous and fully automatic operation
- High reduction of slurry volume for saving of transport cost
- High dewatering performance due to an convenient arrangement of the rollers
- Construction with a special concentration system, available to press original slurry directly l.
- Reinforce structure design
- The frame is made of high quality square steel pipe(10#-12#) with sandblast and high strength fluorin-carbon finish makes anticorrosive ability keep more than 8 years.
- High quality bearing with full airproof bearing seat, available to run more than 3 years.
- Extrusion and transmission rollers are made of seamless steel pipe with anti-wearing rubber outside, available to work more than 5 years.

An essential advantage of our belt press compared to other dewatering press is the possibility to get the lowest moisture content of press cakes with special patent 3 sets nip squeezing rollers.

3. Technical parameters

- Installed power: 9KW.
- Size:3600(L)X1890(W)X2300(H)mm, weight: 5500 kgs (reference)
- Belt width:1000 mm.
- Belt speed: 1-9m/min
- Air consumption: 0.10 m3/hour Water consumption: ≤5m3 /h
- Belt tension pressure: 0.3-0.5 MPA
- Best wash hydraulic pressure:0.5-0.8 MPA
- Capacity: 2-3 tons/hour (inlet material)
- Waste tea cake moisture content: 48% - 52%

Input: Tea waste at 70% MC (wet basis) (Approx. 2000 kg/h)
Output: Tea waste at 50% MC (wet basis) Approx 1153 kg/h-1250 kg/h)

5.2 Rotary steam tube dryer

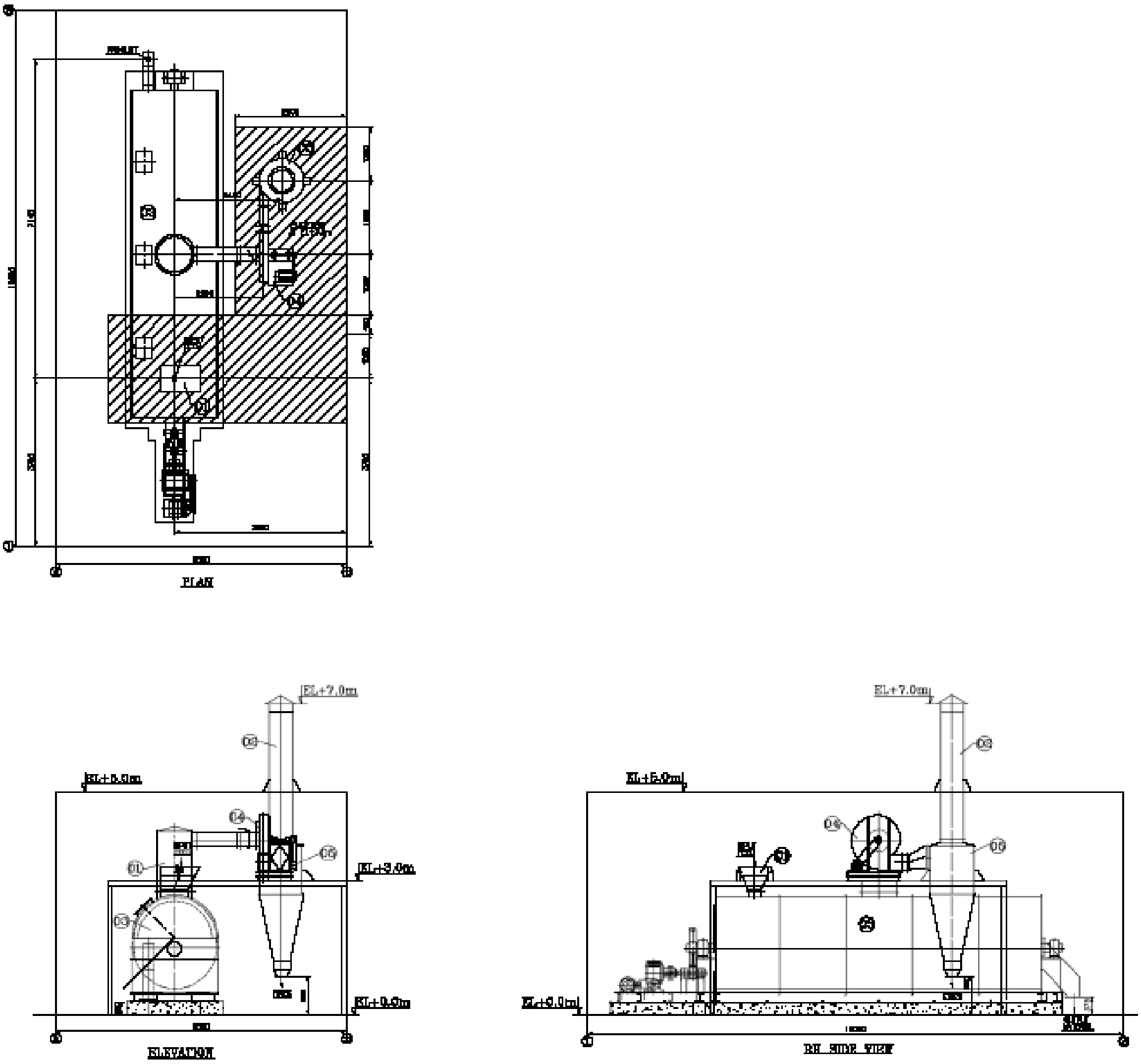

Figure 6: Rotary steam tube dryer

5.2.1 SPECIFICATIONS

MATERIAL TO BE DRIED	:	Waste tea leaves + Stems after extraction
CAPACITY		
Input Feed Rate	:	1500 Kg/hr
Evaporation Rate	:	429 Kg/hr
Output Rate	:	1071 Kg/hr

INPUT FEED PROPERTIES

Feed Moisture Range	:	50 % w/w
Avg. Feed Moisture (Design)	:	50 % w/w
Feed Solvent	:	Water
Feed Temp.	:	Ambient
Feed Nature	:	Non Corrosive, pH – to be confirmed

OUTPUT PROPERTIES

Material Moisture	:	≤ 30 % w/w
Material Temp.	:	≤ 75 °C (outlet of Dryer)

OPERATING CONDITIONS

Drying Media	:	*Dry saturated steam Indirect conduction heat transfer*
Utilities Used For drying	:	*Steam @ 6 bar (g)*

5.2.2 SITE CONDITIONS (Assumed)

Ambient Temperature	:	Min. : 21°C Max. :36 °C (Avg : 30°C assumed)
Humidity	:	Minimum 20 % RH, Max. 80%RH (Avg. 70% RH at 30°C assumed)
Altitude	:	< 400 M From MSL
Installation	:	Indoor
Area Classification	:	Non Hazardous / Non Explosive / Non Flameproof

5.2.3 UTILITIES

Power	: Voltage : 415V / 4 wire, 3 Phase,Frequency : 50 Hz.		
	Equipment	**:**	**Motor Rating**
	Tube Bundle dryer	:	18.60 kW
	Exhaust Fan	:	7.50 kW
	Connected Power	:	**26.10 kW**
	Consumed Power	:	**17.80 kW**
Steam	Dry Saturated Steam at 6 bar (g)		
	Normal Consumption for Dryer	:	690 kg/hr
Tolerance	Utilities are specified at average ambient condition.	:	+/- 10 %

5.2.4 SYSTEM DESCRIPTION

Wet Waste Tea Leaves are to be fed at controlled rate into the Charging Hopper of the Dryer through suitable belt conveyor. (Client's Scope).

The dryer is conduction type dryer & comprises of rotating Tube Bundle housed in a stationary housing. Steam is admitted into the tubes through Rotary joint from one end of the Tube Bundle and the condensate is collected out from the Tube Bundle through Rotary joint and suitable siphon arrangement from other end of the Tube Bundle. The Tube Bundle is provided with suitable flights mounted in the spiral fashion on the periphery for effective showering of the material on to the tubes for effective heat transfer & drying of the material. On the discharge port of the dryer, a suitable manually adjustable weir is provided to adjust the material residence time in the dryer. Dried material is discharged through outlet discharge port.

Ambient air is sucked from the openings provided on the housing and the vapours with fines are exhausted by means of Exhaust fan. Fines, if any, getting carried over are partially separated in a Cyclone Separator and remaining are vented to atmosphere along with exhaust air.

SCOPE OF SUPPLY

- **Charging Hopper** : 1 No

Capacity	:	0.5 m^3
Type	:	Rectangular Cross section.
Length, m	:	0.5 mtrs
Material Of Construction		
Casing	:	SS 304
Externals / Stiffeners	:	Carbon Steel.

- **Dryer Assembly** : 1 No

Type	:	Rotating Tube bundle in stationary housing.
M.O.C. of tubes	:	Carbon Steel, Seamless
M.O.C. of Rotor	:	Carbon Steel.
Operating RPM	:	@ 7.2 rpm
Tube Bundle rotating length	:	8 Mtrs. Including shafts
Housing type	:	Stationary housing.

Housing Construction	:	SS 304 with Carbon steel externals, stiffeners & flanges. Segmental housing with two halves suitably bolted/welded with provision for end covers removal.
End bearings type	:	Spherical roller bearings
Steam inlet & outlet	:	Through Rotary joints
Showering mechanism	:	With the help of lifters on the periphery of rotating tube bundle
Drive Rating	:	18.6kW x 4 pole motor.
Drive	:	V-belts & pulleys between motor to gear box, Gear Coupling between drive gear box output to drive pinion. Bull Gear drive from drive pinion to dryer rotor.
Drive Accessories		Gear guard, Belt guard, Coupling Guard.
Dryer accessories	:	Manually adjustable weir, Fresh air intake nozzles, vapour outlet nozzles.

• **Exhaust Fan**	:	1 Set
Type	:	Centrifugal , Belt driven
Make	:	Laxmi Projects / Patel Airflow
Operating speed	:	≤ 1800 RPM
Static Efficiency	:	≥ 65%
Drive motor	:	TEFC, IP 54, F Class, 7.5 KW
Material Of Construction	:	
Impeller & Housing	:	Carbon steel Epoxy Painted
Shaft	:	En8
Base Frame, externals	:	Carbon steel Epoxy Painted
Accessories	:	Single base frame, outlet flap damper, access door, drain plug, V-belt pulleys, shaft, bearings, belt guard, anti-vibration pads etc.

• **Cyclone Separator**	:	1 No.
Type	:	Tangential Entry , Mono
No. of units	:	1 No.
Material Of Construction	:	

Product Contact Internals	:	Carbon steel Epoxy Painted
Externals / Flanges	:	Carbon steel Epoxy Painted
Accessories	:	Support bracket, Cleaning Nozzles .

- **Heating Coil** : 1 Lot of MS Coiled pipe around cyclone body to prevent condensation

- **Interconnecting Ducting** : 1 Lot

Interconnections between Dryer, Cyclone, Fan		
Material Of Construction	:	
Product Contact Internals	:	Carbon steel Epoxy Painted
Externals / Flanges	:	Carbon steel Epoxy Painted

BATTERY LIMITS

- Input Feed : At the inlet of Feed Hopper at controlled rate through necessary belt conveyors.
- Output : At the Outlet of Dryer & Cyclone.
- Power : To individual drive motors through suitable starters.
- Steam : At the Inlet of Rotary Joint through suitable Flexible Hose, PRV, Isolation Valve, etc.
- Condensate : At the outlet of Dryer Rotary Joint through suitable Flexible Hose, necessary steam traps, strainers etc.
- Exhaust Air : At outlet of Cyclone Separator

5.3 Step grate firewood fired steam boiler

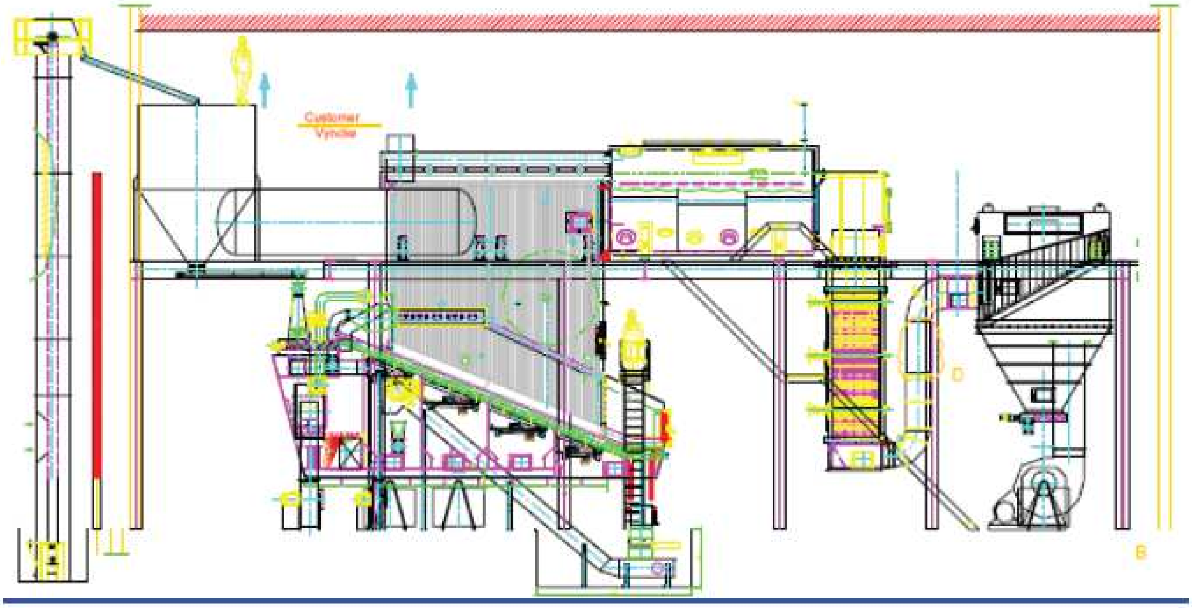

Figure 7: Principal layout of boiler plant (Dynamically air cooled steam grate boiler)

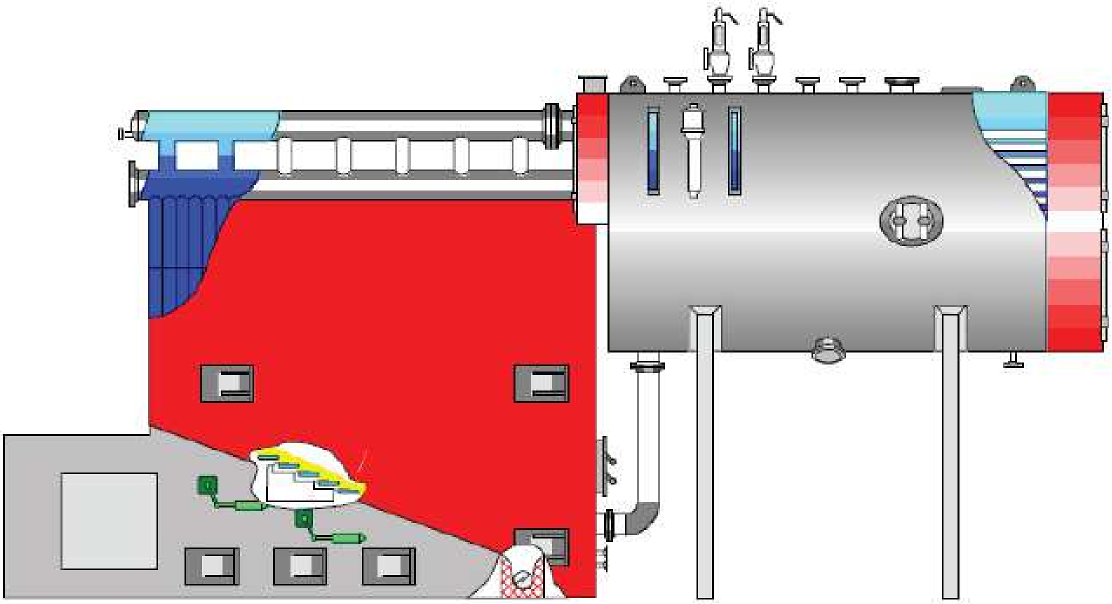

Figure 8: Boiler configuration

Figure 9: Typical layout of complete boiler

MAIN BOILER

The main boiler is a **combined water tube - fire tube steam boiler** type, consists of these major components:

1. A **furnace**
2. A large water tube **radiation part**,
3. A **convection part** with horizontal fire tube bundle
4. An **economizer**

The water tube radiation part is connected to the convection part on the waterside with down-comers and with riser tubes on the steam side.

A. THE FURNACE

The furnace is completely **integrated** in the boiler: the sidewalls and the roof of the furnace are completely cooled by the membrane walls of the boiler. The membrane walls of the furnace are partially covered by refractory. The amount of the concrete is however restricted to a minimum in order to minimize the investment and the maintenance costs and to maximize boiler availability. The integration of the furnace into the boiler helps to control the combustion temperature. Furthermore it reduces excessive slagging of the ashes on the sidewalls of the furnace. As a result, the **BOILER** is extremely efficient for the combustion of fuels with high lower heating values and fuels characterized by low ash fusion temperatures.

One door is mounted into the rear wall of the furnace and makes the boiler easily accessible. An adequate inspection glass mounted in the rear wall gives an inside view of the combustion process in the furnace.

B. THE RADIATION PART

Two internal membrane screens divide the radiation part of the boiler into 3 empty passes. The flue gases arising from the combustion grate enter the first empty pass. In this first empty pass, the burnout of the flue gases takes place. The injection of secondary air at a high velocity at the inlet of first empty pass strongly stimulates the burning out of the flue gases. During the residence in the 3 empty passes, the flue gases are cooled down by radiation up to a temperature that is far below the ash fusion point of the ashes.

This in order to lower the risk of ash fusion in the fire tubes of the convection part. Accessibility is assured through a manhole in the water tube screen. The combi boiler contains much more water than the standard water tube boiler due to the voluminous steam drum. This huge quantity of boiling water is potential energy and the source of constant pressure.

C. THE BOILER DRUM

In the fire tube part, the flue gases enter the fire tubes where they are rapidly cooled down by convection. The fire tube part is executed as a single pass heat-exchanger. The large water content in the convection drum, a large evaporation surface and the modulating feed water control results in a quick response when the steam production shows a peak load. The voluminous drum assures dry steam without complicated or expensive secondary measures as steam dryers. The optimal combustion and the carefully chosen flue gas velocity in the fire tubes reduce the fouling of the fire tubes to a minimum. Accessibility is assured through a door(s) the cleaning doors on the smoke box at the end of the drum.

D. THE ECONOMISER

In the Economiser, the flue gases are further cooled down to the outlet temperature of the boiler. The economizer makes better use of the heating surface than the convection drum, because the temperature of the feeding water through the economizer is far lower than the saturation temperature of the water in the convection drum. The in-line arrangement (opposed to staggered arrangement) of the tubes in cross flow with the flue gases (also called square pitched tubing) allows the installation of soot blowers for regular cleaning of the economizer tubes. The in-line arrangement is also less prone to fouling than the staggered arrangement.

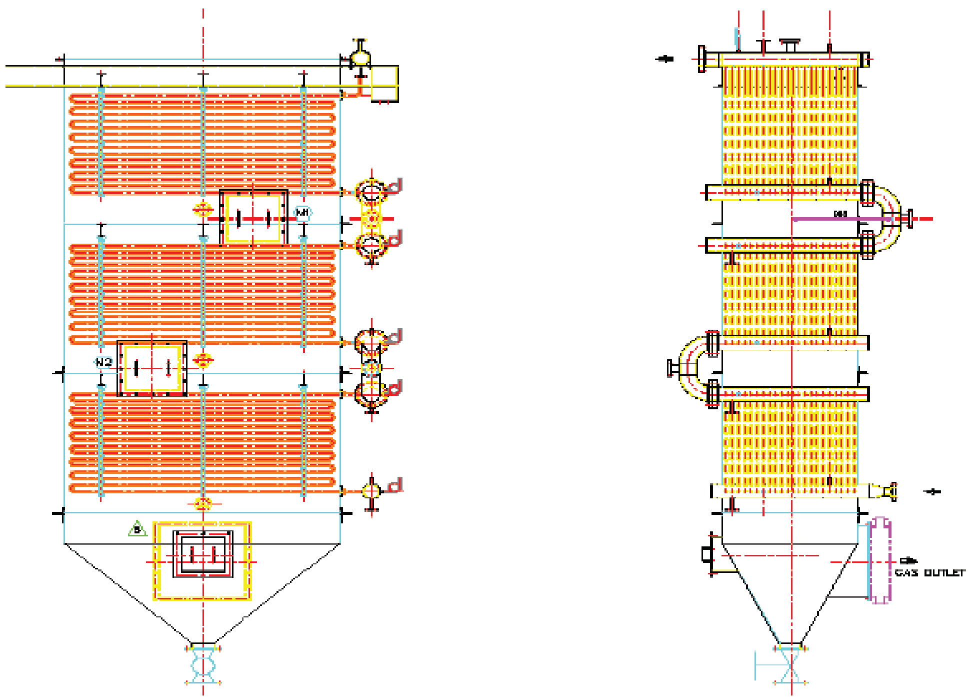

Figure 10: Layout of the economizer

5.3.1 Technical specification of boiler

TECHNICAL SPECIFICATIONS OF BOILER

Boiler General Details	
Type of boiler	Water + Smoke Tube Type
Model	**Modupac**
Type of Grate	**High Chromium DAS with three Zone Combustion and Electronic Air to Fuel Ratio Control.**
Steam Generation	10000 kg/hr (F&A 100°C)
Boiler Operating Pressure	10.54 kg/cm^2
Steam Pressure	
Safety Valve Set Pressure	10.5 / 10.25 Kg/cm^2
Feeding Cut - Off Pressure Switch Setting	10.5 Kg/cm^2
Boiler Thermal Efficiency as per BS 845 Part I	**80 % (+/- 2 %)**
Steam Side Turndown	**40% to 100%**

Boiler Water Concentration Limits (for dryness fraction of 0.98)

Hardness as $CaCO_3$	(ppm)	Not Detectable
Total Dissolved Solids	(ppm)	3500 max.
Suspended Solids	(ppm)	50
Alkalinity as $CaCO_3$	(ppm)	1200 max
pH value		8.5 - 9.5
Free CO_2	(ppm)	nil
Dissolved Oxygen	(ppm)	nil
Silica	(ppm)	<140
Phosphates as PO_4	(ppm)	50 - 100
Sodium Sulphite as SO_3	(ppm)	30 - 70

Mechanical Details of the Boiler	
Convection Tubes Thickness (mm)	3.66
Tube Diameter (mm)	76.2
Effective Length (m)	5.0
Material of Construction	SA 515/516 Gr 70 / IS 2002 Gr II
Feed Water Arrangements	
No. of Pumps	2
Stand by Water Pumps	1
Type of Pumps	Multistage, Centrifugal

Capacity of each Pump (m^3/hr)	15
Head of each Pump (MWC)	140
Valves in Water Feed Piping	
Stop Valve at pump outlet	Yes
Non - Return Valve at pump outlet	Yes
Pressure Gauge at pump outlet	Yes

Flue Gas Ducting (Recommendations)

Plate Thickness (mm)	5 mm

Automatic Water Level Controls

Qty (nos)	1
Alarm and Signal provided for	
Low Level	Yes
High Level	Yes

Boiler Mountings and Fittings	**Qty.**	**Size**
Steam Stop Valve	1	150NB
Safety Valve Exhaust	2	80/100NB
Feed Check Stop valve	2	40NB
Feed Check Valve	2	50NB
Blow Down Valve	1	50NB
Auxiliary steam stop Valve	1	25NB
Steam Pressure Gauge	1	200mm

6. Results

Table 7 comprises of the detail calculation of the savings possible by introducing tea waste belt press, rotary steam dryer and biomass boiler fired by tea waste and supplementary fire wood.

Table 7: Tea waste and fire wood fired boiler to generate steam in place of existing furnace oil fired boilers

Parameter	Value	Unit	Remarks
Average Generation	50,000	kg/day	
	2,083	kg/h	
Considered amount (At 70% (wet basis) MC)	2,000	kg/h	
Dry content	600	kg/h	
Water content	1,400	kg/h	
De-watering capability of belt press, 70% to	50%	MC (wet)	
Considered de-watered MC value of belt press	55%	MC (wet)	
Dry content	600	kg/h	
Water content	733	kg/h	
Dewatered amount	667	kg/h	
	4,000	tonne/year	
Possible value of DS in the liquid	1%	kg/kg	
Total production of powder	40	tonne/year	
Present average annual production	1839	tonne/year	
Increase in production due to recovery	2.18%	Kg/kg	
If dried by rotary tube steam dryer to	30%	MC (wet)	
Water to be evaporated	476	kg/h	
Tea waste output of dryer	857	kg/h	
Initial temperature of tea waste before dryer	50	deg C	
Energy to be supplied for evaporation of water	590	kcal/kg	
Energy required for evaporation	280,952	kcal/h	
Thermal efficiency of Rotary tube steam dryer	75%		
Energy to be supplied by steam	374,603	kcal/h	
Steam pressure	6	kg/cm2.g	
Enthalpy of steam	659	kcal/kg	
Enthalpy of evaporation	493	kcal/kg	
Steam consumption for rotary tube steam dryer	760	kg/h	
Tea waste			
Gross Calorific Value of tea waste at 0% MC	4,296	kcal/kg	
Moisture content after dryer	30%	MC (wet)	
Gross Calorific Value after dryer	3,007	kcal/kg	
Net Calorific Value after dryer	2,798	kcal/kg	

Table 7:(Contd)

Parameter	Value	Unit	Remarks
Boiler efficiency with economizer and air pre-heater	80%	(Gross basis)	
Operating pressure	10	kg/cm2.g	
Enthalpy of steam	664	kcal/kg	
Feed water temperature	70	deg C	
Enthalpy of feed water	70	kcal/kg	
Steam generation	3,232	kg/h	
If dryer is drying from 55% MC to 30% MC, then available for the process	2,472	kg/h	
Average process steam consumption	6,000	kg/h	
Balance amount to be supplied from fire wood	3,528	kg/h	
Moisture content of firewood	30%	(Wet basis)	
HHV at as received	3,007	kcal/kg	
Firewood consumption	871	kg/h	
	522,391	kg/month	
Estimated operating hours	600	h/month	
Electricity cost (Including kVA cost)	14.50	Rs./kWh	
Fire wood cost	7.00	Rs./kg	
Firewood consumption (at 30% MC (wet))	522,391	kg/month	
Firewood bill	3,656,734	Rs./month	
Electricity cost for belt press	174,000	Rs./month	
Electricity cost for rotary tube dryer	261,000	Rs./month	
Electricity cost for boiler	1,583,400	Rs./month	
Skilled worker wage	1,000	Rs./day	
Unskilled worker wage	750	Rs./day	
No of working days	30	days/month	
Skilled worker for belt press(1 No/8 hr x 3 shifts per day)	90,000	Rs./month	
Unskilled worker for belt press (2 No/8 hr x 3 shifts per day)	135,000	Rs./month	
Skilled worker for rotary dryer (1 No/8 hr x 3 shifts per day)	90,000	Rs./month	
Unskilled worker for rotary dryer (1 No/8 hr x 3 shifts per day)	67,500	Rs./month	
Boiler operator for boiler (1 No/8 hr x 3 shifts per day)	0.00	Rs./month	Existing boiler operators will be trained and allocated
Unskilled worker for boiler (4 No/8 hr x 3 shifts per day)	270,000	Rs./month	
Water cost for belt press	21,600	Rs./month	

Table 7: (Contd)

Parameter	Value	Unit	Remarks
Compressed air	10,000	Rs./month	
Contingencies	100,000	Rs./month	
Total fuel + utility + labour cost	6,461,014	Rs./month	
	77,532,172	Rs./year	
	78	Mn Rs./year	
Total saving of furnace oil when steam is generated by tea waste + fire wood	292	Mn Rs./year	
Saving in elimination of disposal cost (disposal cost Rs. 320/tonnex120000 tonne/year)	3.8	Mn Rs./year	
Saving of cost of handling tea waste (6 unskilled per day)	1.6	Mn Rs./year	
Belt press and accessories (Input rate 2500 kg/hr at 70% MC, Output rate 1667 kg/h at 55% MC)	28	Mn Rs.	
Rotary tube steam dryer and accessories (Input rate 1667 kg/hr at 55% MC, Output rate 1072 kg/hr at 30% MC)	60	Mn Rs.	
Boiler and plant accessories (Based on already done estimate by client*115%) (10 TPH F & A 100 deg C, 10.54 kg/cm2.g)	207	Mn Rs.	
Total capital investment	295	Mn Rs.	
Life time of belt press	10	years	
Life time of steam dryer	10	years	
Life time of boiler	15	years	
Depreciation for belt press	3	Mn Rs./year	
Depreciation of steam dryer	6	Mn Rs./year	
Depreciation of boiler	14	Mn Rs./year	
Maintenance cost of belt press (10% cost)	3	Mn Rs./year	
Maintenance cost of steam dryer (10% of cost)	6	Mn Rs./year	
Maintenance cost of boiler (10% of cost)	21	Mn Rs./year	
Total monetary saving	**168**	**Mn Rs./year**	
Payback period	**21**	**Months**	

Summary

Table 8: Summary of the calculation in table 7

Parameter	Value	Unit
Existing furnace oil fired steam generation		
Present furnace oil + handling + disposal cost	298	Mn Rs./year
Proposed tea waste + fire wood fired steam generation		
Capital cost (Belt press + rotary steam dryer + boiler)	295	Mn Rs.
Fuel cost	44	Mn Rs./year
Electricity + Compressed air + water (belt press) + Labour cost	34	Mn Rs./year
Maintenance cost	30	Mn Rs.year
Depreciation	23	Mn Rs./year
Monetary saving in fuel	168	Mn Rs./year
Payback period	21	Months

7. Conclusion

The belt press is effectively used to reduce the moisture content of tea waste from about 70% MC to 55% MC before feeding the steam tube dryer. The average generation of tea waste from the process is about 2000 kg/h, after pressing in the belt press an output rate of about 1,400 kg/h at 55% MC. This amount is fed to dryer and the MC is reduced from 55% to 30% and the output rate from the steam tube dryer is about 857 kg/h. The amount of steam consumed by the rotary steam tube dryer at 6 barg pressure is 760 kg/h. Then the tea waste from the rotary tube dryer is mixed with firewood of 30% MC and fed to the boiler to generate steam, part of it fed back to the rotary steam dryer. From tea waste alone, a steam amount of 2,472 kg/h can be supplied after giving steam to the rotary steam dryer. The balance steam amount of 3,528 kg/h for the process requirement is supplied by burning additional firewood at 30% MC content. The boiler is rated at 10,000 kg/h F & A 100 deg C with an actual generating capacity of about 9000 kg/h at 10 barg operating pressure at 70 deg C feed water temperature.

By implementing the combination of belt press, rotary steam tube dryer and firewood boiler in place of the existing furnace oil fired boiler, an annual monetary saving of 168 Mn SLR/year can be achieved with a simple payback period of 21 months.

8. Recommendation

It is highly recommended to recover waste tea as fuel and install waste tea + firewood fired biomass boiler to cater for the total steam demand of the plant while keeping about 25% margin for future expansions.

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