FEED WATER HEATER FOR INCREASING BOILER EFFICIENCY
CASE STUDY AT PELW ATTE SUGAR INDUSTRY

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Degree of Master of Science

By

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Abstract

Sugar cane is grown in rural areas in Sri Lanka, and the residue of sugar cane production called bagasse, can be a cheap source of primary boiler fuel, when processing sugar cane. For each 100 tones of sugar cane harvested and milled, 9-10 tones of sugar is produced together with 29-33 tones of solid waste in the form of crushed cane, or bagasse. Typically, the mill uses about 53% of bagasse in a low efficiency steam cycle to produce the electricity and steam which needs for own use. Surplus bagasse is sometimes used for paper making or cattle feed but in Sri Lanka neither of these applications are effectively used. Bagasse is a major bio-mass fuel, which can be used to produce significant quantity of surplus electricity. Progressive sugar cane companies are beginning to see the advantages of creating a substantial additional cash flow by setting up cogeneration power plants fuelled by bagasse.

Using proven technology a 5000 tones/day cane mill can use its own bagasse to supply the mill with steam and power and export approximately 22 MW of electricity. Some large sugar cane mills currently have co-generation power plants that export over 25 MW. In Pelwatte sugar industry, there is 3MW electricity generation and 90T/h steam generation to meet its total demand. Modern conversion systems also ensure lower air emissions meeting latest environmental standards. Because of the harvesting of sugar cane is seasonal, maximum utilization of the co-generation plants is only achieved, if bagasse is stored for use in the off season or other biomass or fossil fuels are employed. Therefore, optimum usage of bagasse is important for minimizing fossil fuel usage. In Sri Lanka, price of fossil fuel is increasing rapidly. If the sugar factory consumes fossil fuels, then those factories are directly affected by the price changes of fossil fuels. For the existence of Sri Lankan sugar industry, and to compete with other sugar industries all over the world, optimum usage of bio-mass usage, such as bagasse is very important.

For the optimum usage of bagasse consumption, various methods can be used. But the sugar factories, which are already installed, have been equipped with some of

these methods. Later modification for optimization and saving of bagasse directly affects the whole system. To optimize bagasse usage, and to minimize fossil fuel usage, it was decided to increase existing boiler efficiency by introducing a feed water heater. But for that, extensive studies were conducted. By this modification it was revealed that an increase of 3% in boiler efficiency could be achieved thereby a saving of 54.2 million LKR could be gained annually. In addition, an obvious reduction of fossil fuel usage and reduction of emissions are the other achievements. Outcomes of this project are significant and it is bound to benefit sugar industry in Sri Lanka.

DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated. It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

UOM Verified Signature

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List of principal Symbols

u_w - Velocity of water

u_f - Velocity of flue gas

ρ - Density kg/m^3

L - Length

V - Velocity

μ - Dynamic Viscosity

Re - Reynolds numbers

N_u - Nussel number

h_f - Surface heat transfer coefficient

D - Diameter of the tube

K - Heat transfer conductivity coefficient

P_r - Prandle number

C_1 - Correction factor

m - Mass flow rate

Cs - Specific heat coefficient

θ - temperature difference

ε - Effectiveness of heat transfer

C - Constant

I - Moment of inertia

M - Bending moment

σ - Stress (nominal)

w - Force per unit area

d - Thickness of the plate

P - Force per unit area

E - Young modulas of elasticity

δ - Deflection

List of Abbreviations

ASTM - American Society of Testing and Materials Construction

ASME - American Society for Mechanical Engineers

AWS - American Welding Society

C - Carbon

CDM - Clean Development Mechanism

CO - Carbon Oxide

CO_2 - Carbon Dioxide

FD - Forced Draft

H - Hydrogen

IRR - Internal Rate of Return

IPCC - Intergovernmental Panel on Climate Change

UNFCC - United Nations Framework Convention on Climate Change

ID - Induced Draft

N - Nitrogen

NO_2 - Nitrogen Dioxide

PM - Particulate Matter

S - Sulfur

SO_2 - Sulfur Dioxide

TOC - Total Organic Compounds

VOC - Volatile Organic Compounds

Chapter 1

Introduction

1.1 Background

Annual sugar consumption in Sri Lanka is around 670,000 MT. Pelwatte Sugar Industries Limited and Sevanagala Sugar Industries Limited together are producing nearly 66,000 MT annually. This is above 10% of total consumption. Earlier Hingurana sugar factory produced around 20,000 MT of sugar annually. But this sugar factory was closed down in 1993 and now it is going to start it's production in the year of 2011. At present only Pelwatte Sugar Industries and Sevanagala Sugar Industries are being operated. These factories were installed in 1985 and 1986 respectively. Therefore the technology used by both Pelwatte and Sevanagala are older compared to the modern technology used in other sugar producing factories in the world. It is very difficult for our factories to compete with these countries, because they are using modern technology [5].

In sugar industry, research and development is a very important factor, as there are various sugar varieties frequently introduced. Therefore yield per hectare should be increased while getting more sucrose from the sugar cane. Similarly there are different types of diseases spreading out over the sugar cane and solutions should be given immediately. In case of reducing cost of production, the modern technologies can be used. These activities are used in sugar producing countries. But in Sri Lanka, considerable attention has not been given to this field. Sri Lanka is an agricultural based developing country. There are lots of bare lands in dry zone, which can not be used for other agricultural cultivations other than sugar cane. These sugar factories are located far away from the capital city, Colombo. Therefore large number of jobs has been provided by this industry. Otherwise people who live in these areas would have to come to main cities for job opportunities. There are thousands of people living in this area who have direct relationships with sugar industry.

Reduction of cost of production is a difficult task in Sri Lankan sugar industry. Lots of heavy machinery and their spares along with sensitive instruments are imported. Due to the depreciation of Rupee, cost of these imported items has been increased. In other countries, research and development in sugar industry plays a big role for reducing cost of production. Electricity which is in excess from the utilized amount in the manufacturing process is a common by-product in sugar industry today. This is a very common practice in India. But in Sri Lanka, this is not practiced, as it requires very high pressure boilers and auxiliaries to be used. Implementation of this is not possible in Sri Lankan sugar industry, because existing system is not capable enough to withstand this pressure. The other major reason is the capital cost. For the replacement of existing machineries with new ones and to produce sugar and electricity, capital cost will be very high. Investment on 1kW of electricity generation and distributing it to national grid is approximately 45 million LKR. The potential of generating electricity from Pelwatte Sugar Industries is 20 MW. For that, the capital cost will be very high and pay back period is also around eight years. IRR value is not significant; therefore nobody is interested in this replacement, other than getting maximum output from the existing plant. Nowadays, electricity generation is more profitable than sugar manufacturing. The grid connection is the main problem faced by the Pelwatta Sugar Industries as it is far away from the national grid.

Fuel price is fluctuating, with the price changes of a crude oil barrel in world market. Therefore, industries that are directly related with energy are highly affected by these price variations. To sustain with these changes, fuel usage must be minimized. In Pelwatta sugar manufacturing process, whenever the released amount of bagasse is not sufficient, furnace oil is basically used to supplement the fuel requirement. Diesel generators are used during the off season for the power supply. The annual fuel consumption is therefore at a high level. Average annual furnace oil consumption is 600MT [5]. For the existence with the changing world, cost of production must be minimized. Otherwise the Sugar Industry in Sri Lanka will not survive long.

Optimum usage of bagasse is the most important factor, in minimizing the fuel consumption in sugar industry. For the optimum usage of bagasse, boiler efficiency should be increased. When the boiler efficiency is increased, bagasse consumption will be reduced. This causes to serve surplus bagasse. There are various methods of increasing boiler efficiency such as introduction of air pre-heater, introduction of feed water heater, minimizing blow down frequency, minimizing surface loss, etc. First two methods can be achieved from the waste heat of the flue gas. For other two methods, proper boiler water treatment and complete insulation of boilers are very important. Similarly mixing commonly available bio-mass (such as Giniseria) with bagasse is also possible for saving surplus bagasse. There are lots of bare lands of the sugar cane field, especially near the river banks, which can be used for the cultivation of these bio-mass [3].

1.2 Motivation

I have been employed about ten years in the Pelwatte Sugar Industries Ltd. Pelwatte Sugar Industries is the largest sugar manufacturing company in Sri Lanka. It produces 6.5% of the total sugar consumption in Sri Lanka. Pelwatte Sugar Company is located at Buttala in Monragala district which is nearly 235km away from the capital city Colombo. This subject area which is more familiar to me and opportunity to offer a significant benefit to the organization and also to the country motivated me for undertaking this project.

1.3 Process Description

Pelwatte Sugar Industry owns sugar cane cultivation in 12,000 hectares. Both company owned and private owned lands are used to cultivate sugar cane. Sugar cane is a large grass that has a bamboo – like stalk, grows 2.5 to 4.5 meters (8 to 15 feet) high, and contains a large amount of sucrose in the stalk. Different varieties occur throughout the tropical and semi tropical regions of the world, they are the results of the diverse soil conditions, climates and mode of cultivation. Two major seasons are in area, named "Yala" and "Maha" seasons. Generally these two seasons divided by considering rain fall. During rainy seasons cane harvesting is stopped and cultivation is started. Sugar production is a continuous and 24 hour operation, therefore regular cane supply from the field to factory is essential; but during the rainy seasons vehicles cannot enter in to the field due to wet ground condition. Basically 60-80 MT per hectare is the yield of sugar cane of these agricultural lands [6].

1.4 Literature review

Scientific findings strongly suggest that there is a stronger evidence for a human influence on climate change than at the time of adopting the United Nations Framework Convention on Climate Change (UNFCC). It is likely that increasing concentrations of green house gasses have contributed substantially to the observed global warming over the Past 50 Years. The Intergovernmental Panel on Climate Change (IPCC) has now revised its earlier estimates to temperature of 1.3 - 6^0 C to an increase 1.5 - 6^0 due to the expected reduction of Sulfur Oxide emission. The IPCC report notes that the concentration of atmospheric Carbon Dioxide has now risen to over 360 parts per million (PPM) from the industrial level of about 270 PPM. Carbon Dioxide has an effective life time in the atmosphere of about 100 years, so that its global mean concentration responds to changes in emissions very slowly. Emission reductions of 60%-70% from current levels would be needed to prevent carbon concentrations from rising further. Mean sea level has risen by between 10 to 25cm. If any CO_2 emission reductions are not implemented, sea floods also can be expected in future [3].

Bio-mass can be considered to cause zero Carbon Dioxide emissions, because when the biomass is burnt it releases carbon dioxide, which was absorbed by bio-mass during its growing phase. Therefore when total cycle is considered, net emission of Carbon Dioxide is zero. Energy sources, like wind energy, tidal energy, solar, biogas can also be considered as zero emission of Carbon Dioxide. That is why developing countries are always trying to use these types of energy. Uncultivated lands owned by Pelwatte Sugar Industries Limited (especially near the river banks), can be selected as agricultural lands for "Giniseria" which can be mixed with bagasse. Then huge quantity of bagasse can be saved, minimizing petroleum consumption at the same time input energy also can be increased, as Giniseria is having more heating value than bagasse. Finally by carefully studying the rules and regulations of UNFCC, this project can be considered as a CDM (Clean Development Mechanism) project. Therefore, possibility is there to get some benefit for this project, under the concept of **"Carbon Trading"** [3].

1.5 Goals

In Pelwatte sugar plant, only air pre- heaters are available for increasing boiler efficiency. Therefore efficiencies of boilers are estimated to be in the range 65-67%. If it is possible to install a feed water heater (through which an increment of 25^0 C temperature will be possible), then the boiler efficiency can be increased up to 70%. Bagasse saving can be expected as a result of boiler efficiency increase. But for this, wide and sufficient research must be carried out. Design parameters of the boilers should not be changed. Similarly temperature of flue gas releasing to the atmosphere cannot be reduced below 175^0 C. If we do so, sulfur content of the fuel will be on the chimney, air duct and structure. This is the main reason for corrosion of the effective parts. Capacities of the existing Induced Draft (ID) and Forced Draft (FD) fans should be considered. Turbulence of flue gas inside the feed water heater and pattern of the stream lines are also critical issues. Method of harvesting and emission are also effective factors for this project. Particulate matter (PM) is a common emission, and must be removed from the flue gas to reduce atmospheric pollution.

Ash and PM (particulate matter) will deposit on feed water heater tubes. Therefore before introducing a feed water heater, adequate space must be provided to avoid friction for the flue gas flow. Arrangement should be made to remove deposited ash and particulate matters on the tubes. Otherwise, due to the obstruction for the flue gas flow, back pressure will be created inside the boiler. On the other hand this deposited ash will act as an insulation layer on the tubes reducing heat transfer rate of the feed water heater.

Chapter 2

Problem Statement

The factories of Pelwatte Sugar Industries and Sevanagala Sugar Industries were commissioned in 1985 and 1986 respectively. Therefore the technology, used by both Pelwatte and Sevanagala is older than which is used by other modern sugar producing factories in the world. Therefore, it is very difficult to compete with these countries, as they are using modern technology, with higher productivity.

Sugar cane is grown in rural areas in Sri Lanka, and the residue of sugar cane production called bagasse, can be a cheap source of primary boiler fuel, when processing sugar cane. For each 100 tones of sugar cane harvested and milled, 9-10 tones of sugar is produced together with 29-33 tones of solid waste in the form of crushed cane, or bagasse [5]. Typically, the mill uses a portion of the bagasse in a low efficiency steam cycle to produce the electricity and steam which is needed for own use. Surplus bagasse is sometimes used for paper making or cattle feed but in Sri Lanka neither of these applications are effectively used. Bagasse is a major bio-mass fuel, which can be used to produce significant quantity of surplus electricity. Progressive sugar cane companies are beginning to see the advantages of creating a substantial additional cash flow by setting up co-generation power plants fuelled by bagasse.

Because of the harvesting of sugar cane is seasonal, maximum utilization of the co-generation plants is only achieved if bagasse is stored for use in the off season or alternative biomass or fossil fuels are employed. Therefore, optimum usage of bagasse is important for minimizing fossil fuel usage. In Sri Lanka price of fossil fuel is increasing rapidly. If the sugar factory consumes fossil fuels then those factories are directly affected by the price fluctuations of fossil fuels. For the existence of Sri Lankan sugar industry, and to compete with other sugar industries all over the world, optimization of bio- mass usage, such as bagasse is very important.

In the existing two sugar factories in Sri Lanka, there are no feed water heaters installed. In Pelwatte, only air pre- heaters are available for increasing boiler efficiency. Therefore, efficiencies of boilers have been calculated as 65-67%. If it is possible to install a feed water heater (due to which feed water temperature increment is calculated as 25° C), then the boiler efficiency can be increased up to 70-74%.

Chapter 3

Boilers

3.1 Boiler types

Fuel cells, horseshoe boilers and spreader stocker boilers are used to combust bagasse. Horseshoe boilers and fuel cells differ in the shape of their furnace area but similar in design and operation. In these boilers, bagasse is gravity-fed through chutes and piles up on a refractory hearth. Primary and over fore combustion air flows through ports in the furnace walls burning begin on the surface pile. Many of these units have dumping hearths that permit ash removal while the unit is operating [6].

In more recently built sugar mills bagasse is burned in spreader stocker boilers. Bagasse fed to these boilers enters the furnace through a fuel chute and is spread pneumatically or mechanically across the furnace where part of fuel burns while in suspension. Simultaneously large pieces of fuel are spread in a thin even bed on a stationary or moving grate. The flame over the grate radiates heat back to the fuel to aid combustion. The combustion area of the furnace is lined with heat exchange tubes [6].

Boiler Diagram

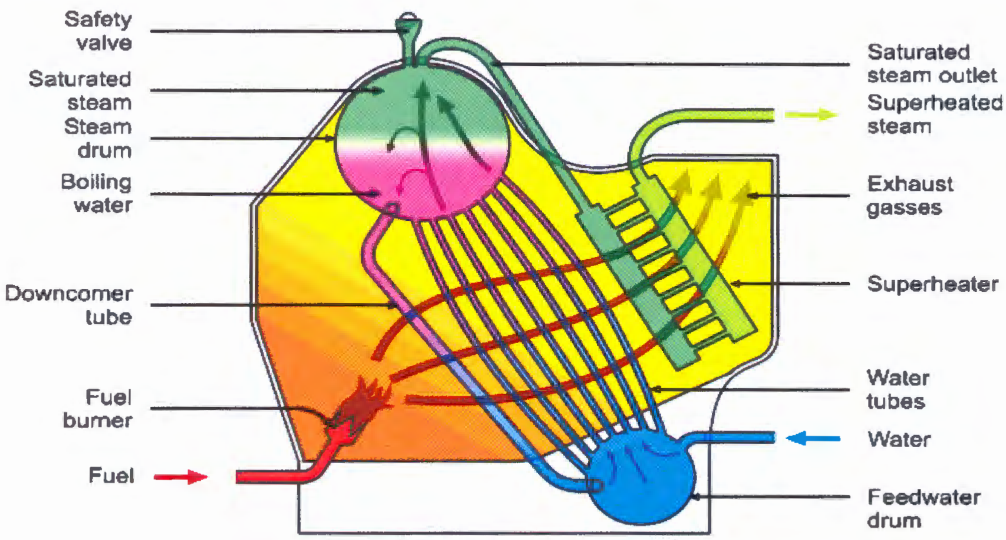


Figure 3.1

3.2 Boiler efficiency

In general, properly tuned boilers (bagasse-fired) operate in an average efficiency of 70% -80% based on gross calorific value. So, that 20-30% of energy stored in fuel is wasted. This is shared by flue gas losses (18-21%), blow down losses (2-3%), surface losses in fuel oil (2-3%) in bagasse fired boilers. The flue gas temperature is dependent on the boiler and is in the range of 250 ^{0}C to 380 ^{0}C. In the flue gas on average 40% is sensible heat and 60% is latent heat (water vapor in the flue gas) [6].

Waste heat recovery is very important in several aspects. When looking at the macro level, it will reserve the energy sources and reduce environmental damages mainly through reduction of emissions of CO_2, SO_2 & NO_2 etc. When looking at the micro level, it will serve energy and will give local environmental benefits such as reduced thermal pollution.

3.3 Methods of increasing boiler efficiency

- Increasing inlet air temperature.
- Increasing feed water temperature.
- Minimization of boiler blows down.
- Minimization of surface losses.
- Reduction of moisture content of bagasse.

In the Pelwatte boiler, 1st method had been implemented originally. This project designed for 2nd method. The boiler efficiency can also be improved by minimizing heat losses of the boiler which requires minimized boiler blow down. If boiler feed water is properly treated and blow down frequency could be reduced. Then, blow down losses could be minimized.

Surface losses of the boilers can be minimized by properly insulating the boilers and its related auxiliaries. In water tube boilers, insulation bricks are used to prevent heat losses from the surface. By replacing damaged insulation bricks and doing refractory works annually and when possible, surface losses also can be minimized. Steam outlet lines, feed water inlet lines and also furnace oil lines should be properly insulated using standard insulation materials.

Reducing moisture content of bagasse, boiler efficiency can be increased. There are various methods for doing this. Even now there is lots of research carried out in sugar producing companies all over the world. The commonly used method to reduce moisture content of the bagasse is bagasse dryer. Bagasse dryer installation is a costly exercise, if it is done on a later stage. Therefore, this is usually installed during the project implementation stage. Design of bagasse dryer in later stage is also a slightly complex exercise.

These boilers have been designed without having a feed water heater. Bagasse is the main fuel and furnace oil is used intermittently whenever the Bagasse availability is not adequate. But the price of one ton of fuel oil is nearly Rs.40,000.00. Fuel consumption of a boiler is 4.2 Tons/hr, the equivalent cost is over Rs.168,000.00/hr. Designed Bagasse rate for these boilers for their steam generation is 21 Tons/hr. Then the cane-crushing rate is 135 T/hr. The energy released by the Bagasse is used to produce 30bar and 380 ^{0}C super heated steam from 35bar, 105^{0}C boiler feed water [5].

At the same time, additional steam turbine was introduced by the Chinese management as a prime mover of a shredder. This was mainly for increasing "extraction" of juice in the sugar cane. But at the same time steam consumption was also increased. Finally, bagasse production from the cane crushing was marginally adequate and surplus bagasse was available, whenever the operation was temporarily stopped. Therefore the attention of the management was given for improving the boiler performance, while keeping the surplus bagasse. Ultimate solution for this is installing feed water heaters for the boilers [6].

3.4 Boiler operating procedures

Boiler operating procedures can influence uncontrolled emissions from bagasse-fired boilers. First, like other waste-fired boilers, bagasse boilers may use auxiliary fuels for start up. Because fuel oil is usually the start-up fuel, the initial sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) emissions are higher than when bagasse alone is fired. The duration of start-up is typically 8 hours. During this period particulate matter (PM) emissions may increase due to poor combustion conditions in the boiler while it is cold. In Pelwatte Sugar Industries Limited, bagasse-fired boilers are started up once at the start of the harvest season and are running until the end of the season unless it is absolutely necessary to stop them. During this period for the preventive maintenance, the boilers are temporarily shut down at every 7 to 10 days, for few hours [5]. When co-generating electricity is available one boiler is shut down while the other is under operation.

Bagasse boilers use an auxiliary fuel (normally fuel oil or natural gas) at times to produce the total energy needed for the facility to sustain good combustion with wet bagasse. But this can be minimized if hot water is used as imbibition water. Due to the presence of sugar trace in 3rd and 4th evaporator's condensate, that water cannot be used as boiler feed water. This hot water can be used as imbibition water. The researches have proven that hot water imbibition has increased sucrose extraction while reducing moisture content of bagasse [6]. There are so many methods which are used to reduce the moisture content of bagasse but these should be installed at the boiler installation, as the later introduction is a costly implementation. But in Pelwatte Sugar Industries Limited, the engineering department did this valuable design considering careful modification. This was successful in reducing the moisture content of bagasse by 2 % giving more surplus bagasse.

During start up combined oil and bagasse firing increases SO_2 and NO_2 emissions. Auxiliary fuel is used whenever additional heat input is required, if the supply of bagasse to the boiler is interrupted. During these periods, SO_2 and NO_2 emissions increase. Typically, less than 15 percent of the total annual fuel heat input into the boiler is in the form of fossil fuels. Soil characteristics such as particle size can affect the magnitude of PM emissions from the boiler. Mal-operation can also influence the bagasse ash content. (i.e. no proper filtering when preparing the cane).

3.5 Emissions

The complete combustion of bagasse can be considered of as a two stage process primary and secondary combustion. Primary combustion refers to the physical and chemical changes occurring on the fuel bed. It consists of drying devolatization ignition and burning of the bagasse. Secondary combustion refers to the oxidation of the gases and particulate mater released by primary combustion. Secondary combustion is aided by high temperature sufficient air and turbulence in the gas stream. The turbulence must be intense and last long enough to ensure adequate mixing at elevated temperature. This turbulence can be created by forced and induced draft fans. Process time, temperature, turbulence and air require a delicate balance for complete combustion. A disturbance in one or more of these variables can reduce combustion efficiency and result in measurable increases in emissions of Carbon Monoxide (CO) and other organic compounds (i.e., the products of incomplete combustion). As a class, these volatile organic compound emissions are generally measured either as volatile organic compounds (VOC) or total organic compounds (TOC) [3].

3.6 Control of emissions

The primary concern in bagasse-fired boilers is particulates. Currently there are four basic control devices used to reduce particle emissions [3].

- Mechanical Collectors (or cyclones)
- Wet Scrubbers
- Fabric Filters
- Electrostatic precipitation

Before 1970, few bagasse fired boilers were controlled with devices other than mechanical collectors in Hingurana sugar factory. Pelwatte Sugar Industry was started in 1985. From the year 1985 to 2002, no any emission controlled system has been installed. But with the passage of more stringent air emission standards, wet scrubber was installed in mid 2002 but this was only for heavy particle removal.

Mechanical collectors or cyclones use centrifugal separation to remove PM from flue gas streams. At the entrance of the cyclone a spin is imparted to the particle-laden gas. This spin creates a centrifugal force which causes the PM to more away from the axis of rotation and towards the walls of the cyclone. Particles which contact the walls of the cyclone tube are directed to a dust collection hopper where they are deposited.

In a typical single cyclone, the gas enters tangentially to initiate the spinning motion. In a multitude cyclone (or multi cyclone,) the gas approaches the entrance axially and has the spin imparted by a stationary "spin" valve fired in its path. This allows the use of many small higher efficiency cyclone tubes operating in parallel to the gas flow stream with a common inlet and outlet header.

One variation of the multitude cyclone is to place two similar mechanical collectors in series. This system is often referred to as a dual or double mechanical collector. The collection efficiency of the dual mechanical collector is theoretically improved over that of a single mechanical collector. Mechanical collectors have been reported to have PM collection efficiencies of 20 to 60 percent. Particulate emissions from bagasse-fired boilers are considered to be abrasive and can cause erosion within the mechanical collector. Such erosion reduces PM collection efficiency unless corrective maintenance procedures are employed.

A wet scrubber is a collection device which uses an aqueous stream or slurry to remove matriculate and /or gaseous pollutants. There are three basic mechanisms involved with collecting particulate matter.

- Interception
- Inertial impaction and
- Diffusion of particles or droplets

The interception and inertial impaction effects dominate at large particle diameters, the diffusion effects dominate at small particle diameter.

Wet scrubbers are usually classified by energy consumption. Low-energy scrubbers represented by spray chambers and towers have pressure drops of less than 1 k pa (5 inches of water). Medium energy scrubbers such as impingement scrubbers have pressure drops of 1 to 4 pa (5 to 15 inches of water). High energy scrubbers such as high pressure drop venture scrubbers have pressure drops exceeding 15 inches of water. Greater removals of particulate maters are usually achieved with higher energy scrubbers.

Currently the most widely used wet scrubbers for bagasse-fired boilers are impingement and venture scrubbers. An impingement scrubber (also known as an orifice self induced spray or entrainment scrubber) features a shell that retains liquid so that gas introduced to the scrubber impinges on and skims over the liquid surface to reach the gas exist duct. Atomizing liquid is entrained by the gas and acts as a particle collecting and mass transfer surface. Particle collecting results from inertial impaction caused by both gas impinging on the liquid surface and by the gas flowing around the atomized drops.

In a typical venture scrubber the particle laden gas first contacts the liquor steam in the core and throat of venturi section. The gas and liquid streams then pass through the annular orifice formed by the core and throat, atomizing the liquid in to droplets which are impacted by particles in the gas stream. Impaction results mainly from the high different velocity between the gas stream and the atomized droplets. The droplets are then removed from the gas stream by centrifugal action in a cyclone separator.

Wet scrubbers have reported PM collection efficiencies of 90 percent or greater. Operational problems can occur with wet scrubbers due to clogged spray nozzles, sludge deposits dirty recirculation water improper water levels and unusually low pressure drops. The spray impingement scrubber is in greater use due to lower energy requirements and less operating and maintenance problems.

Chapter 4

Theoretical Development

Assumptions

- Use of the boiler parameters as actual.
- Calculations are based on log book readings.
- Continuous process (no breakdowns).
- Every machine operates accurately.
- Use of same furnace oil.
- No fuel mixing.

4.1 Data analysis

Furnace Oil, Diesel & Bagasse Consumption with total Cane from 1991 to 2008 [5]

Year	Cane Crushed (Tons)	Furn. Oil used (Tons)	Diesel used (Tons)	Bagasse (Tons)	Electricity (MWh)
1991	193,201	710	600	63,760	6,008
1992	192,506	647	610	63,530	5,986
1993	384,975	673	500	127,000	11,972
1994	343,975	630	525	113,510	10,697
1995	432,866	728	475	142,850	13,462
1996	570,672	558	400	188,320	17,747
1997	409,816	707	525	135,240	12,745
1998	448,347	791	475	147,950	13,943
1999	476,675	614	460	157,300	14,824
2000	547,900	536	400	180,800	17,039
2001	561,742	654	410	185,370	17,470
2002	504,208	639	450	166,390	15,680
2003	531,684	485	430	175,450	19,645
2004	557,919	498	420	184,110	17,351
2005	500,609	595	450	165,200	15,568
2006	328,659	624	575	112,500	10,221
2007	266,734	373	650	88,020	8,295
2008	471,290	407	470	155,520	14,657

Table 4.1

Furnace Oil, Diesel, Consumption with total cane from 1991 to 2008

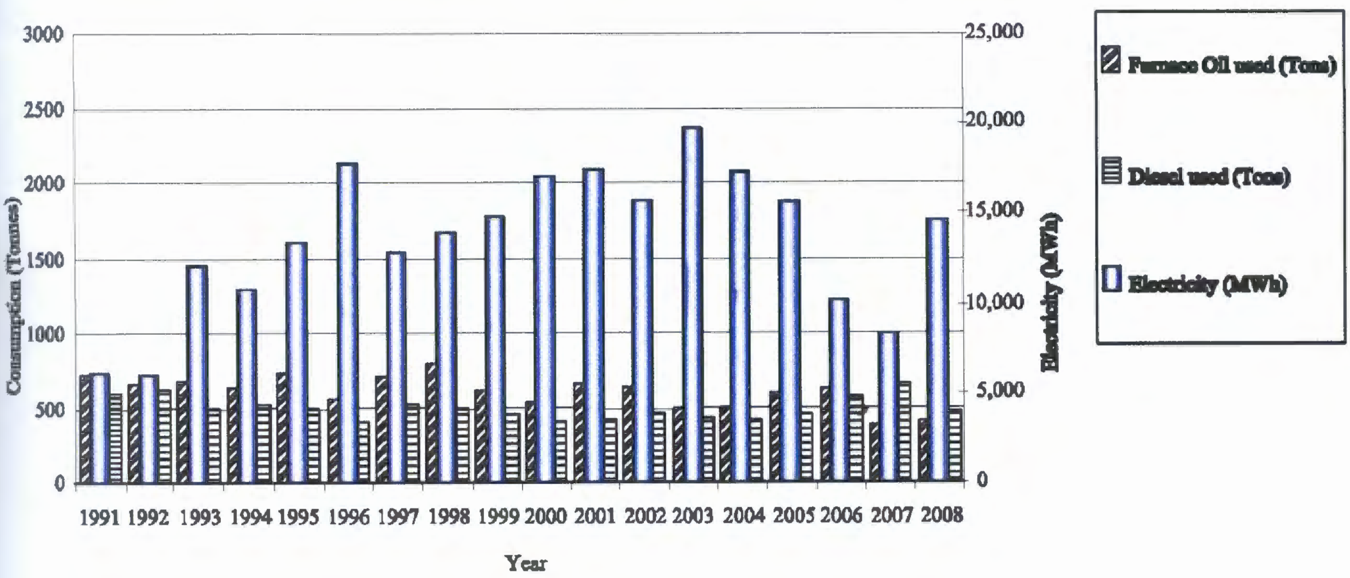


Table 4.2

Utilization of Process Data

Average Crushed cane		-	429,100 T/y
Average Sugar production		-	42,910 T/y
Average Diesel consumption		-	500 T/y
Average Furnace oil consumption		-	600 T/y
Average Electricity Generation		-	13,571 MWh/y
Bagasse consumption		-	141,880 T/y
Required water quantity		-	388,800 T/y
Cost of Diesel		-	73.40 Rs/l
Cost of Furnace oil		-	31.90 Rs/l
Cost of Bagasse (labor cost)		-	750 Rs/T
Specific fuel consumption,	Furnace oil	-	1.50 kg/kWh
	Bagasse	-	7.40 kg/kWh
Cost of Electricity,	Furnace oil	-	59.36 Rs/kWh
	Bagasse	-	5.56 Rs/kWh

Feeding of the Bagasse to the Boiler

Figure 4.1

4.2 Analysis of selected fuels

Fuel	C	H	O	N	S
Rice straw	39.2	5.1	35.8	0.6	0.1
Rice husk	38.5	5.7	39.8	0.5	0
Corn cob	46.2	7.6	42.3	1.2	0.3
Baggase	**46.4**	**5.4**	**42.6**	**0.7**	**-**
Peanut shell	45.3	5.6	45.3	0.5	-
Cotton stalk	50.8	6.4	41.8	0.4	-
Wood	52.9	6.3	39.7	0.1	-
Lignite	64.0	4.2	19.2	0.9	1.3

Table 4.3

Source : U.S. Environmental protection agency [3]

Ultimate analysis of selected fuels

Fuel	Volatile matter	Fixed Carbon	Ash
Rice straw	54.1	24.8	21.1
Rice husk	63.3	14.0	22.7
Corn cob	75.6	15.5	8.9
Bagasse	**74.0**	**19.3**	**6.7**
Peanut shell	72.8	20.1	7.1
Cotton stalk	75.8	18.9	5.3
Wood	77-87	13-21	0.1-2.0
Lignite	43.0	46.6	15

Table 4.4

Source : U.S. Environmental protection agency [3]

4.3 Overview of existing Boiler

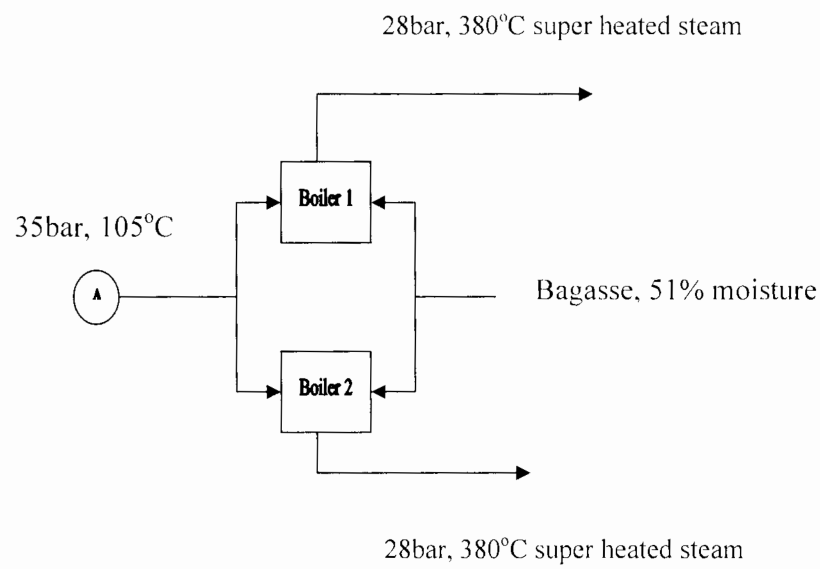


Figure 4.2

Side elevation of the Boiler

Figure 4.3

Front elevation of the Boiler

Figure 4.4

4.4 Steam flow Diagram

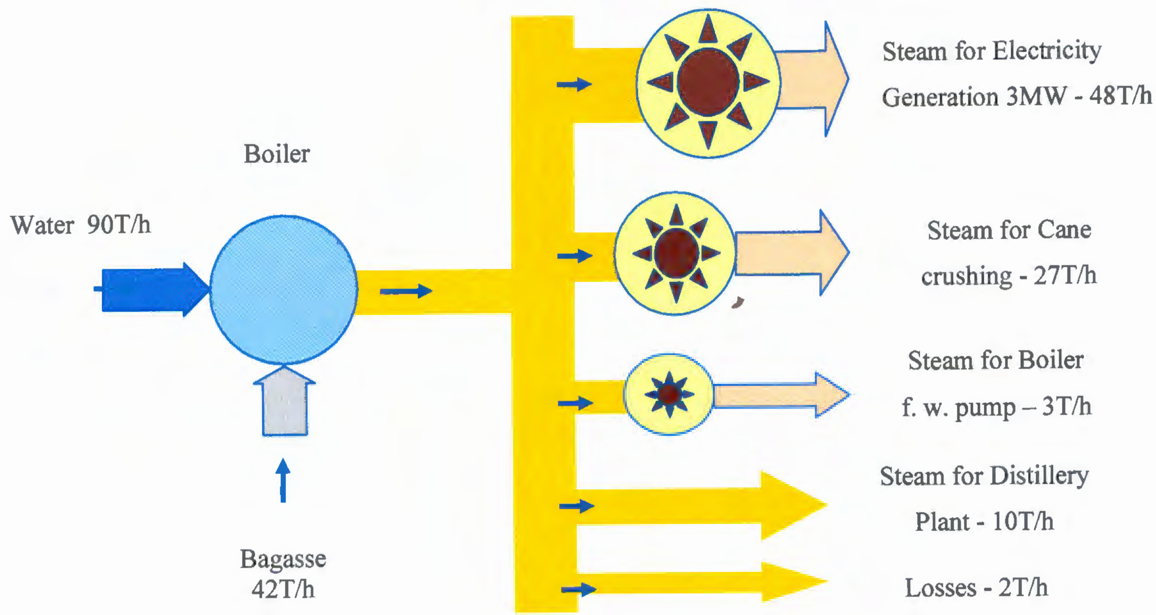


Figure 4.5

4.5 Standards

The following specifications and codes were studied for procedures & material parameter values in this feed water heater design.

Steels & Material selection

ASTM American Society of Testing and Materials Construction [2]

Welding

ASME American Society for Mechanical Engineers [2]

Welding rods

AWS American Welding Society [2]

Chapter 5

Proposed Solution

5.1 Designing of Feed water heater

Following characteristics must be considered in feed water heater design.

1. Strength	5. Utility	9. Wear	13. Volume
2. Reliability	6. Cost	10. Friction	14. Maintenance
3. Thermal Properties	7. Flexibility	11. Size & shapes	15. Safety
4. Corrosion and Erosion	8. Weight	12. Control	

Required parameters for the designing of F.W. Heater

Heat source	- Flue gas
Steam pressure	- 30 bar
Steam flow rate (max.)	- 90,000 kg/hr
Steam temperature	- 380 +/-10°C
Flow rate of air	- 3,500 m^3/min
Inlet water temperature	- 105 °C
Furnace outlet temperature	- 920 °C
Boiler outlet gas temperature	- 340 °C
Air preheated outlet air temperature	- 200 °C
Calorific value of Bagasse	- 8,316 kJ/kg
Calorific value of Furnace oil	- 42,370 kJ/kg

The following parameters must be determined for the feed water heater designing

- Specific location
- Materials
- Dimensions of the tubes
- Dimensions side plates
- Space required
- Nos. of tubes required
- Diameter of Bolts
- Weight of the heater

5.2 Proposed feed water heater diagram

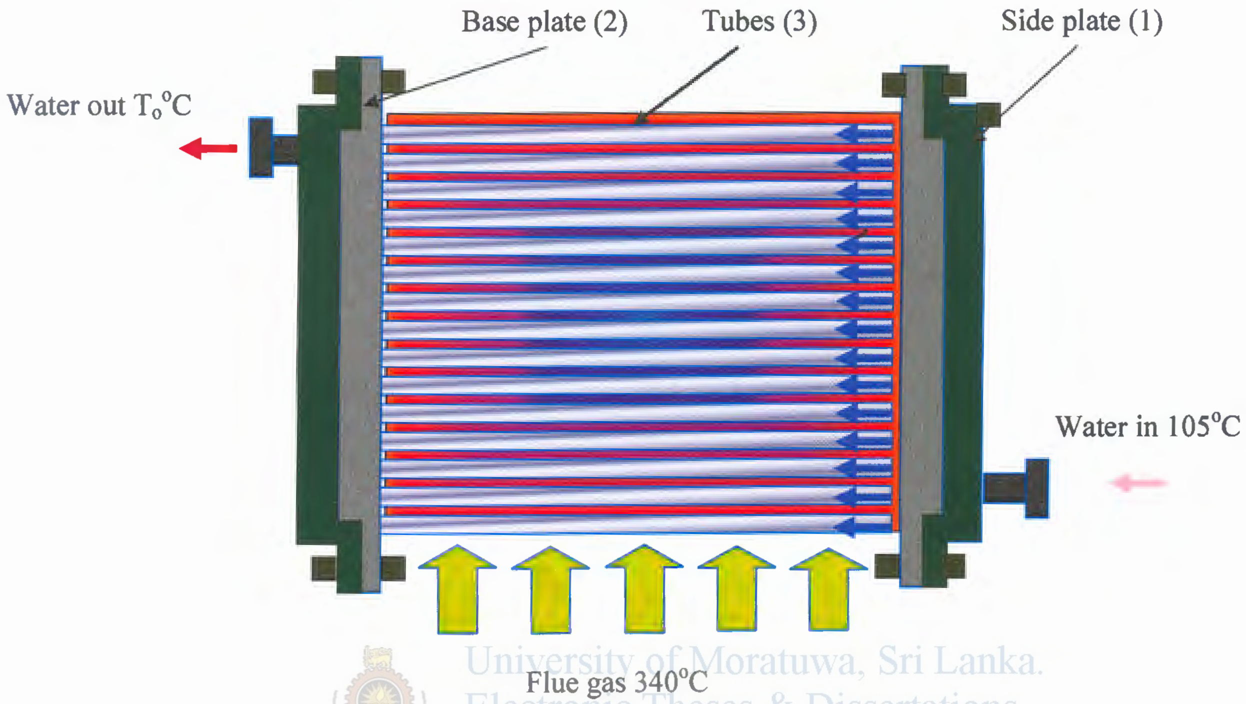


Figure 5.1

5.3 Location of the Feed Water Heater

Generally, efficient feed water heaters should be installed inside the boiler before coming to the air pre heater. It should be done with original design and installation. However, carefully selection and identification of the location is very important. Friction losses can be avoided by the selection of good quality pipes.

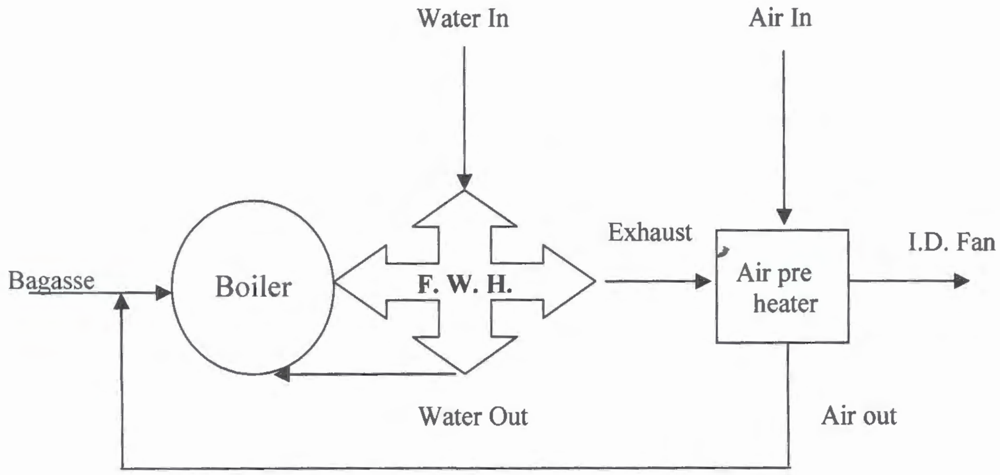


Figure 5.2

The existing arrangement of the feed water to the Boiler Drum

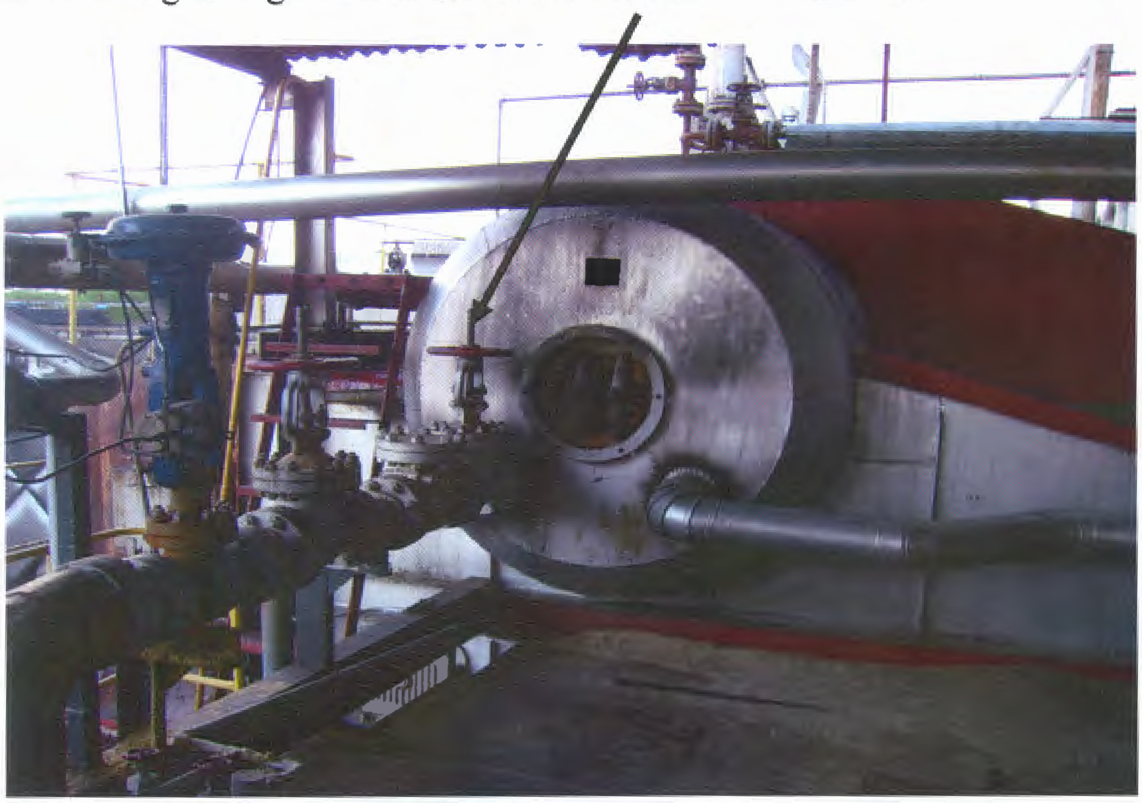


Figure 5.3

Proposed location of the feed water heater

Figure 5.4

Air pre-heater tubes

Figure 5.5

5.4 Materials for heater tubes

Following ratings should be considered when selection of materials.

1. Flue gas temperature (max.) 400 ^{0}C
2. Water pressure (max.) 40 bar
3. Water temperature (max.) 140 ^{0}C

Carbon steel schedule 40 satisfies the above Conditions. Thickness of 3.5mm was selected [4].

5.5 Diameter of the tubes

Generally, following sizes of the tubes are available for the heaters.

1. 25mm outer diameter
2. 50mm outer diameter
3. 75mm outer diameter
4. 100mm outer diameter

↑ Increase heat transferability

↓ Easier for removal of Scale

By considering above factors, 75mm outer diameter was selected as the Best.

Determination of flow conditions

Dimensions of Tubes

Outside diameter of a tube	- 75 mm
Inside diameter of a tube	- 68 mm
Length of a tube	- 9000 mm
Thickness	- 3.5 mm

Consider flow rate of a single tube,

Flow rate of water	- 12.5 kg/sec
Specific volume of water	- $1.244*10^{-3}$ m^3/kg at 35 bar
Density of water at 35 bar	- $1/1.244*10^{-3}$ m^3/kg = 803.85 kg/m^3
Cross sectional area of a tube	- $3.14* d^2/4$
	- $3.14* 0.0752 /4$ m^2

Velocity inside the Tube is "u_w" considering a uniform flow,

$9*3.14*0.075/4m^2\, u_w = 1.244*10^{-3}\, m^3/kg * 12.5\, kg/sec$

Velocity of water, u_w = 1.17 m/sec

Cross sectional area of duct = $8.7*0.9\, m^2$

= $7.83\, m^2$

Air low rate of I/D fan = $3500\, m^3/min$

Therefore, velocity of flue gas assuming a uniform flow condition, "u_f"

"u_f" = 3500/60*1/ 7.83

Velocity of flue gas "u_f" = 7.5 m/sec.

Reynolds number

Reynolds number can be defined for a number of different situations where a fluid is in relative motion to a surface. These definitions generally include the fluid properties of density and viscosity, plus a velocity and a characteristic length or characteristic dimension.

Reynolds numbers

$Re = \rho LV / \mu$, [1]

Parameter	Flue Gas	Water
Density kg/m^3	0.60	803.85
Length m	0.25	9
Velocity m/s	7.50	1.17
Dynamic Viscosity (kg/ms)	$2.927*10^{-5}$	$0.284*10^{-3}$

$Re_f = 0.60*0.25*7.5/2.927*10^{-5} = 3.84*10^4$

$Re_w = 803.85*9*1.17/0.284*10^{-3} = 2.98*10^7$

$0 < Re < 5 * 10^5$ - Lamina flow [1]

$2 * 10^5 < Re < 10^8$ - Turbulent flow [1]

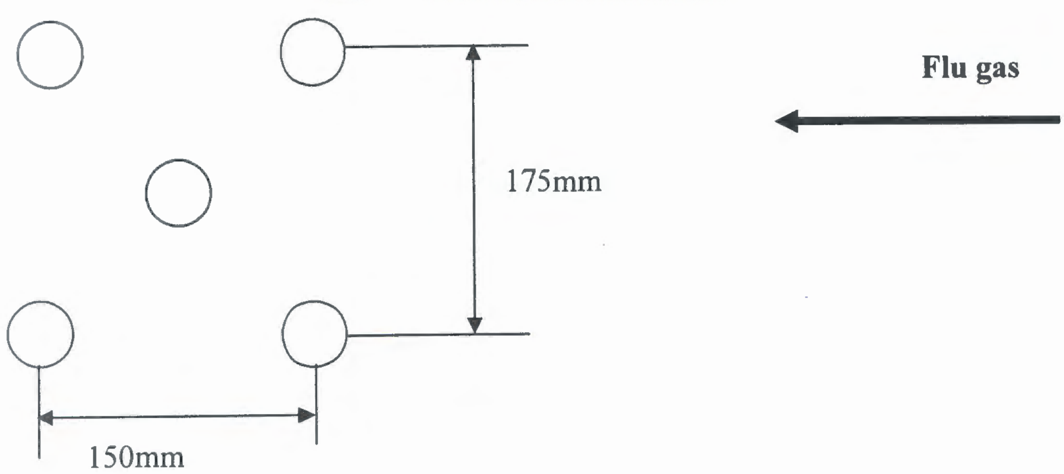
5.6 Calculation of heat transfer coefficients

Conduction and convection of heat are considered for the calculations, and all the equations used were cross flow over the cylinder equations. NTU method used to calculate the effectiveness of the heat exchanger.

Further increasing of heat transfer is possible by increasing the area of heat transferring, but it has not been considered due to the additional weight coming on to the structure, reduction of air flow rate and to keep required temperature of exhaust gas for air pre-heater.

Flue gas,

Flue gas is passing through the bunch of tubes, which are staggered, and the flue gas is crossing over the tubes [1].



$b/d = 150/75 = 2$

$a/d = 175/75 = 2.33$

Figure 5.6

Select, $C_l = 0.482$ $Re_f = 3.84 * 10^4$

$n = 0.556$

$Pr = 0.68$

$N_u = h_f D/k$ Where, N_u - Nusselt number

h_f - Surface heat transfer coefficient

D - Diameter of the tube

k - Heat transfer conductivity coefficient

P_r - Prandle number

C_l - Correction factor

$N_u = hD/k = 1.13C_l * (Re_f)^n * Pr^{1/3}$ Valid for $2000 < Re_f < 40{,}000$

By substituting above values together with $k = 3.930 * 10^{-2}$ W/m.K

$$h_f = 1.13 * 0.482 (3.84 * 10^4)^{0.556} * 0.68^{1/3} * 3.930 * 10^{-2}/0.075$$

$$h_f = 171.3 W/m.K$$

Water,

Inside the Tube [1],

$Re_w = 2.98 * 10^7$

$N_u = h_w/Dk = 0.023 (Re_w)^{0.8} * Pr^n$

$D = 0.068$ m

$k = 0.682$ W/m.K at 100^0C

$Re_w = 2.98 * 10^7$

$Pr = 1.76$

$n = 0.4$

$$h_w * 0.068/0.682 = 0.023 * (2.98 * 10^7)^{0.8} * 1.76^{0.4}$$

$$h_w = 275 * 10^4 W/m.K$$

$$h_f = 171.3 W/m.K$$

5.7 Calculation of number of tubes required for the feed water heater

Logarithmic Mean Temperature Difference (L.M.T.D), [1]

$$\text{L.M.T.D} = (\theta_i - \theta_o) / \ln(\theta_i / \theta_o)$$

Where $\theta_i = t_i - t_o$ and $\theta_o = T_o - T_i$

m – mass flow rate

C – s. heat coefficient

θ – t. difference

$$m_w * C_w * (T_i - T_o) = \varepsilon * m_f * C_f * (t_o - t_i)$$

Where, ε - Effectiveness of heat transfer

$t_{o\,min}$ - 270°C (limitation)

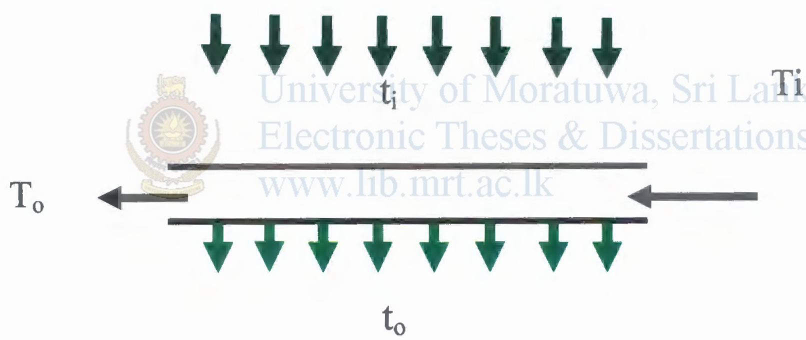


Figure 5.7

For cross flow of both streams unmixed,

$$\varepsilon \sim 1 - \exp\{C\,(NTU)^{0.22}\,(\exp(-C(NTU)^{0.78}\ [-1]\}$$

Where, $NTU = UA/C_{min}$

NTU = Number of transfer Units.

C_{min} - Specific heat transfer coefficient

C - Constant

$U = [1/h_f d_f + 1/k * \ln(d_0/d_i) + 1/h_w d_w]$

A = Heat transferring area.

$\varepsilon \approx 0.4$

For flue gas,

C_p = 1.026 kJ/kg.K

ρ = 0.6 kg/m^3

m = V * ρ = 3500/60 * 0.6 = 35 kg /sec.

For water,

C_p = 4.2 KJ/kg.K

ρ = 803.85 kg/m^3

m = V * ρ = 45/3600 * 803.85 = 10.05 kg/sec.

Mass flow rate of flue gas = 35 kg/sec

Mass flow rate of water = 10.05 kg/sec

Velocity of water = 1.17 m/sec

Velocity of air = 7.50 m/sec

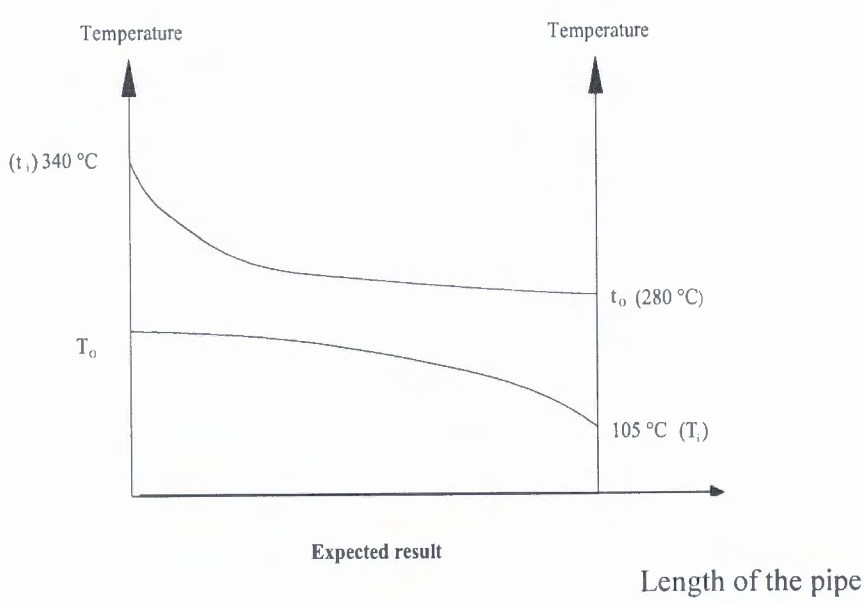


Figure 5.8

Consider the following table, Energy release and absorption

Temperature Difference (ɵ)	Heat emitted $m_f*C_f*(ɵ)$	Heat absorbed $m_w*C_w*(ɵ)$
1	44.1	35.9
5	220.5	179.5
10	441	359
15	661.5	538.5
20	882	718
25	1102.5	879.5
30	1323	1077
35	1543.5	1256.5
40	1776	1436
45	1984.5	1615.5
50	2205	1795
55	2425.5	1974.5
60	2646	2154
65	2866.5	2333.5
70	3087	2513

Table 5.1

Effectiveness of the heat transfer (є) is 0.4.

Therefore, $m_w * C_w * (ɵ) = 0.4 * m_f * C_f * (ɵ)$

When the temperature difference of flue gas is expected to be 60^0 C,

2646 * 0.4 = 1058.4 kW

Now, this energy is enough to raise the feed water temperature over 25^0 C

$t_i = 340^0$ C $T_i = 105^0$ C

$\mathbf{t_o = 280^0 C}$ $T_o = 130^0$ C

L.M.T.D = [(340 - 280) - (105 - 130)] / ln (60/25)

= 85 / 0.875

L.M.T.D. = 97.1°C

Number of tubes for the heat exchanger [1]

$$q = \frac{L.M.T.D.}{1/n * \pi L\,[1/h_f d_f + 1/k * \ln(d_o/d_i) + 1/h_w d_w]}$$

$q = 97.1 / X$,

where,

$X = 1/n * \pi 9\,[1/171.3 * 0.075 + 1/42.9 \ln(0.075/0.068) + (1/275 * 10^4 * 0.068)$

$X = 1/n * 28.3 * 0.08$

$n = 880 * 10^3 * 0.08 / (97.1 * 28.3)$

$n = 25.6 \sim 26$

Therefore, nos. of tubes for the "Cross Flow Heat Exchanger" is **26.**

5.8 Conditions of feed water after heating

temperature - 130oC

pressure - 35 bar ← Sub saturated water

Conditions of the water in the Boiler Drum

temperature - 241oC

pressure - 30 bar ← Saturated water

States of water with temperature

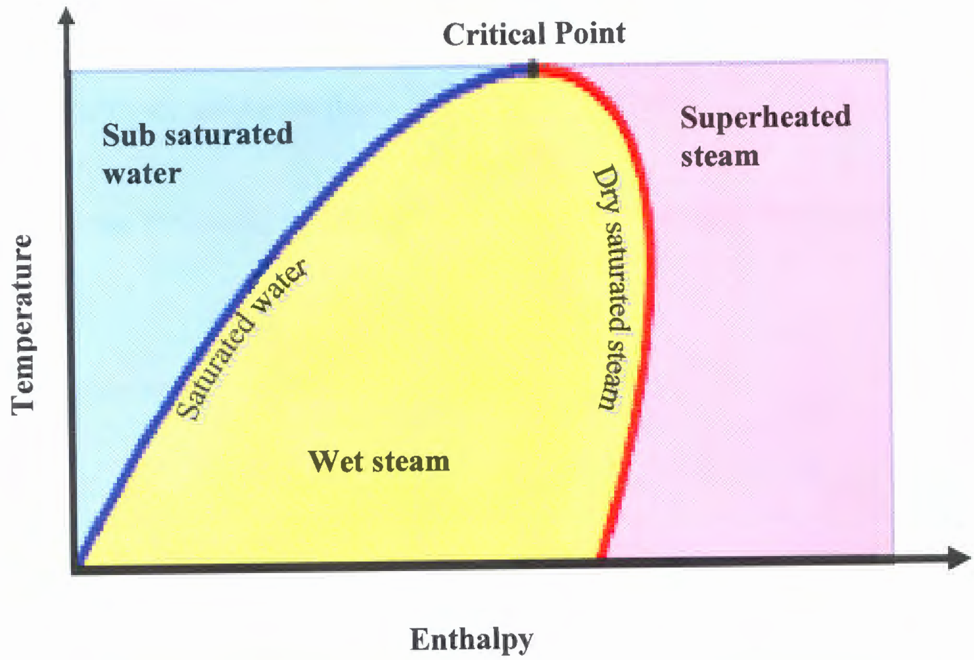


Figure 5.9

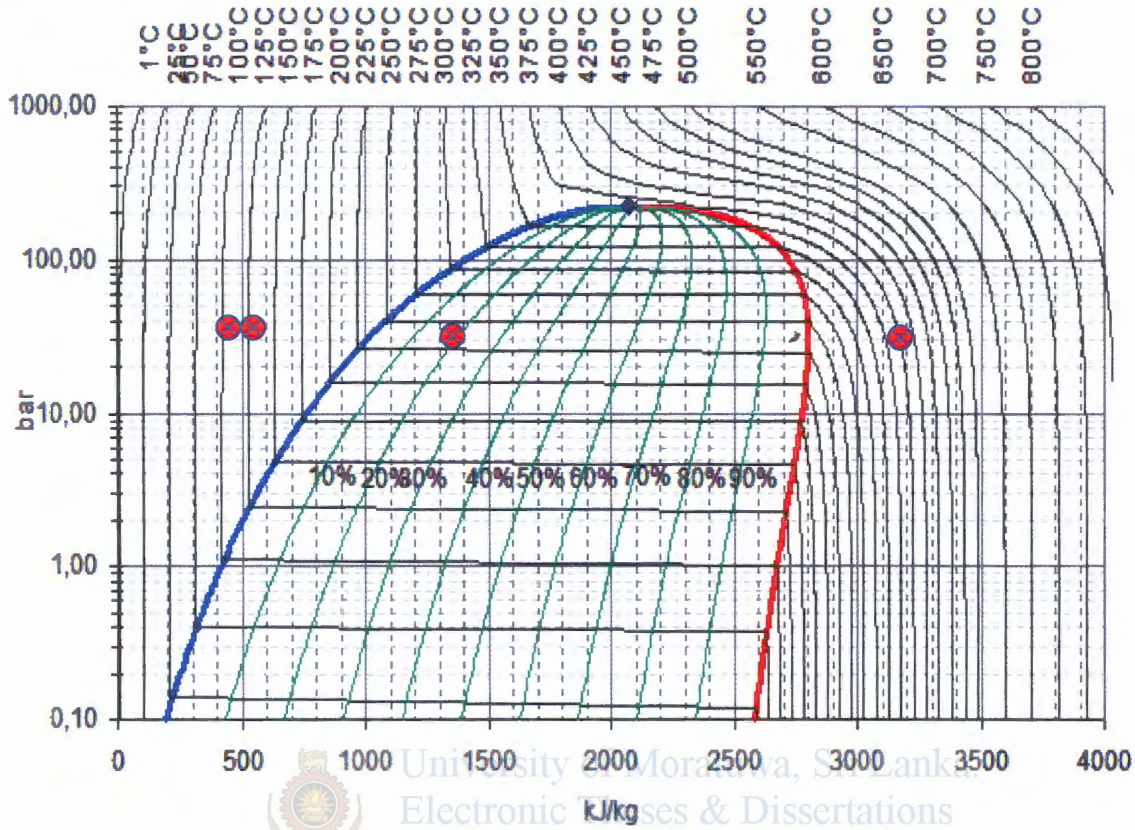


Table 5.2

5.9 Dimension of the Heater

Area of existing air pre-heater tubes $= \pi * 0.075^2 * 1100/4$

$= 4.86\ m^2$

Additional area increasing = Diameter of a Tube * L * nos. of effective tubes in line

$= 0.075 * 9 * 16$

$= 10.8\ m^2$

Total area increasing $= 4.86\ m^2 + 10.8\ m^2$

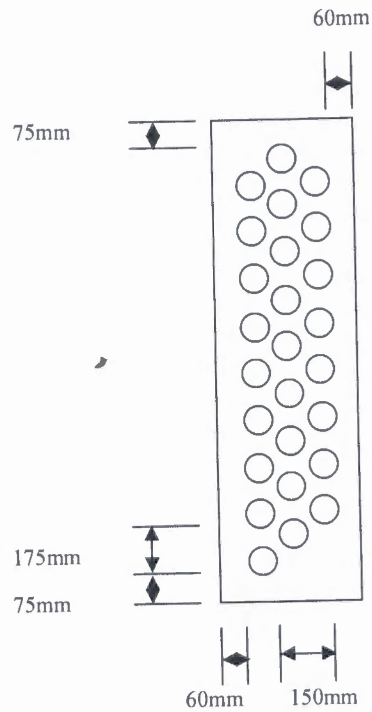
$= 15.66\ m^2$

Therefore, length * height of the " cross flow heat exchanger" to be equal to above value

$L * H = 15.66\ m^2$

$H = 15.66\ m^2 / 9.0\ m$

$= 1740\ m$



By referring to this figure,

Height of the economizer = 75*2mm + 8 * 175mm + 75*2mm

= 1700 mm < 1740 mm

Therefore, the condition is satisfied.

Width - 345mm

Height - 1700mm

5.10 Side plate's thickness calculation

Considering the part of the side plate,

Force on the plate $= 35 kg/cm^2 * 0.525 * 0.345$

$= 350 * 0.525 * 0.345 *$

$= 6.3 * 10^5 N$

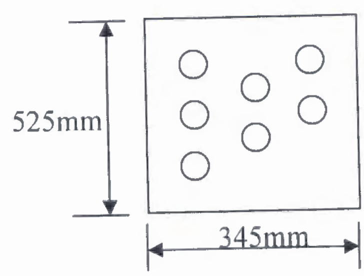


Figure 5.10

By using Bending formula, $M/I = \sigma/y$

$I = bd^3/3$ and $y = d/2$

Therefore, $M = w L^2/8$

I - Moment of inertia

M - Bending moment

σ - Stress (nominal)

w - Force per unit area

d - Thickness of the plate

For shear/yield stress of mild steel, $\sigma = 372\ MN/m^2$

By considering uniform distribution of force over the plate,

Where, $M = 6.3 * 10^5 * 0.345^2/0.525^2 * 8$

$w = 6.3 * 10^5/0.525$

$M = 1.6 * 10^4\ Nm$

$I = 0.525 * d^3/3$ and $y = d/2$

By substituting these values of bending formula,

$1.6 * 10^4 * 3/(0.525 * d^3) = 372 * 10^6 * 2/d$

$d^2 = 1.6 * 10^4 * 3 * 1.5/(0.525 * 372 * 10^6 * 2)$

$d = 13.6\ mm$

Therefore selected plate thickness for side plate is 15mm and thickness of the base plate is 20mm, where safety factor is selected as 1.5.

5.11 Diameter of Bolts

Force applying on a single plate $= 6.3 * 10^5 /2 = 3.15 * 10^5$

Tensile strength of the bolt $= 480\ MN/m^2$

Bolt diameter $= d$

Number of bolts considered $= 10$

$3.15 * 10^5 / (10 * \pi d^2 /4) < \sigma$ [2]

$3.15 * 10^5 * 4 * 3/(480 * 10^6 * \pi * 10) < d^2$

$9.1mm < d$

The selected bolt diameter is 16mm. where safety factor is considered, as 1.7. Then the length of the bolts for side plates to be 100mm.

5.12 Deflection of the tubes

δ = PL / AE [2]

p = $\pi * 0.068^2/4 * 3 * 873 + \pi (0.075^2 - 0.0686^2)/4 * 3 * 7700$

= 9.5+16.8 = 26.3kg

= 263N

δ = $263 * 3/[\pi * (0.075^2 - 0.0686^2)/4 * 200 * 10^9]$

= $\underline{5.5 * 10^{-6} m}$

P - Force per unit area

E - Young modulas of elasticity

L - Length

δ - Deflection

Therefore deflection of the tubes can be neglected under this condition.

5.13 Weight of the heater

Material of the Boiler tubes is "Carbon steel "with ASTM, out side diameter is 75mm and thickness of the tube is 3.2mm.Therefore inside diameter of the tube is 68.3mm.

Weight of a tube = $(0.075^2 - 0.0686^2)/4 * 9 * \rho$

= 50.4 kg. Considered $\rho = 7700 kg/m^3$

Total weight of tubes = 50.4 * 26 = 1310.4 kg

Weight of base plate = 1.8 * 0.45 * 0.020 * 7700 kg

= 125 kg

Weight of side plate = 1.75 * 0.45 * 0.015 * 7700kg

= 91kg

Weight of feed water = $0.0686^2/4 * 9 * 1000 * 26$

= 275kg

Total weight of plates = 125 * 2 + 91 * 2 + 2 * 1.65 * 0.3 * 0.012 * 7700

$= 523kg - [(\pi * 0.0762^2/4) * 0.02 + (\pi * 0.0762^2/4) * 0.015$

$+ (\pi * 0.0762^2/4) * 0.012] * 7700 * 10 * 2$

= 523 kg - 172kg

= 351kg

Total weight of the Feed water heater is 1310 + 351 + 275 = 1936kg

5.14 Design of mounting plates

Weight of the Feed water heater = 1936kg

Number of mounting plates = 4

Force coming on each plate = 19360/4 N

= 4840 N

$4840 / w * t < 300 * 10^6$ [2]

$4840 / 0.3 * 300 * 10^6 < t$

$0.1mm < t$

Therefore, selected dimensions of the mounting plates are as follows. The relevant drawings are attached in the appendix.

Height = 1.7m

Width = 300mm

Thickness = 12mm

Chapter 6

Results and Analysis

6.1 Water heat recovery & Bagasse saving

Feed Water

Existing feed water temperature = 105 ^{0}C

Feed water temperature from the F.W.H. = 130 ^{0}C

Temperature increment due to F.W.H. = 25 ^{0}C

Maximum designed feed water rate is 45,000kg/hr per boiler. After installing the Feed Water Heater, according to the calculations. Temperature of feed water can be increased up to 130°C

Heat recovery from the F. W. H., $q = m. c.(t_2 - t_1)$

$= 45{,}000/3600*4200*(130\text{-}105)$

q = 1.312MWh

Calorific value of the Bagasse is 8314kJ/kg, Therefore required heat energy to produce 30bar, 380°C super heated steam from 35bar, 105°C feed water

$= m * h$ $h_{105} - 450$kJ/kg

$= 45{,}000/3600*4200*(h_{380} - h_{105})$ $h_{380} - 3200$kJ/kg

= 34.375MWh

To provide this energy, required Bagasse rate is 5.85kg/s. If the feed water temperature is increased by 25°C,

Heat energy required $= 45{,}000/3600*4200*(h_{380} - h_{130})$ $h_{130} - 554.96$kJ/kg

= 33.063MWh

Energy saving = 34.375 – 33.063

= 1.312 MWh

Bagasse saving = 5.85/34.375*1.312 = 0.223 kg/sec.

= 0.223*3600

= **804 kg/hr.**

The outcome of this research project is reduction of fuel consumption by increasing boiler efficiency. Following results can be expected as a result of boiler efficiency increase.

Energy saving due to feed water heater = 1312 kWh

Energy saving per 24 hrs. = 31.5 MWh

Bagasse saving due to feed water heater = 804 kg/hr.

6.2 Comparing of Bagasse price with the price of furnace oil

Energy of 5 kg of Bagasse = Energy of 1 kg of furnace oil [5]

Price of 1 kg of furnace oil = Rs.40.00

Therefore, price of 1 kg of Bagasse = Rs.8.00

Money saving due to the f. w. heater = 804*8.00

(for one Boiler) = Rs.6432/hr

For 24 hours operation = Rs.154,368/day

6.3 Calculation of efficiency improvement

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Energy of super heated steam}}{\text{Energy of Bagasse}}$$

$$= \frac{36{,}600 \text{ kg/h} * 3200 \text{ kJ/kg}}{21{,}060 \text{ kg/h} * 8.316 \text{ kJ/kg}}$$

Enthalpy of super heated steam at 380 ^{0}C is 3200 kJ/kg

Calorific value of Bagasse is 8.316 kJ/kg

= 67%

Energy saving due to feed water heater is 1312 kWh. Then, the Bagasse saving is 804kg/h.

$$\text{New efficiency} = \frac{36.600 \text{ kg/h} * 3200 \text{ kJ/kg}}{20.256 \text{ kg/h} * 8,316 \text{ kJ/kg}}$$

$$= 70\%$$

Boiler Efficiency

Existing Boiler efficiency = 67%

Increase in efficiency = 3%

Boiler efficiency, due to F.W.H. = 70%

6.4 Calculation of material cost & labor cost for a single unit

Item	Description	Quantity	Unit Price Rs.	Cost Rs.
Base plates	MS 2400 * 1200, 20mm thickness	01 No	40,000.00	40,000.00
Side plates, m. plates	MS 2400 * 1200, 15mm thickness	01 No	34,000.00	34,000.00
Water tubes	Schedule 80, 75mm O*9m	26 Nos.	20,000.00	520,000.00
Feed water pipes.	Schedule 80, 100mm O*6m	01 No	22,000.00	22,000.00
Glass wool	2400 * 1200, density 48g/m^3, 50mm thick.	3 Nos.	6,000.00	18,000.00
Nuts & Bolts (For side co.)	(High tensile) 16mm O* 100mm	60 Nos.	115.00	6700.00
Nuts & Bolts (For mounting plates)	(High tensile) 20mm O* 65mm	24 Nos.	140.00	3360.00
Aluminum foil	1m width	10 m	600.00	6,000.00
Pop reverts	3mm O * 75mm	70 Nos.	1.50	105.00
High pre. packing sheets.	2400 * 1200, 3mm thickness	01 No	18,450.00	18,450.00
Valves 4"	PN 16, Class 125, BS 2901	04 Nos.	25,400.00	101,600.00
"I" beam	150mm * 100mm, 6m Thick. 8mm	01 No	30,000.00	30,000.00
Total cost for the materials				**800,215.00**

Table 6.1

Job Item	Designation	Man Hours	Cost (Rs/Hours)	Cost (Rs)
Machining	Forman	32	140.00	4480.00
	Machinist	32	120.00	3840.00
	Helpers (2)	32 * 2	100.00	6400.00
Fabrication	Forman	24	140.00	3360.00
	Welder	24	120.00	2880.00
	Fitter	24	120.00	2880.00
	Helpers (3)	24 *3	100.00	4800.00
Assembling & Installation	Forman	24	140.00	3360.00
	Welder	24	120.00	2880.00
	Fitter	24	120.00	2880.00
	Helpers (3)	24 * 3	100.00	7200.00
Testing	Operator	8	140.00	1120.00
	Fitter	8	120.00	960.00
	Helper	8	100.00	800.00
Labor cost for the Feed water heater.				**Rs. 47,840.00**

Table 6.2

Calculation of fabrication cost for a single unit

Total cost for materials = Rs. 800,215.00

Total labor cost = Rs. 47,840.00

Total cost for the feed water heater = Rs. 848,055.00

6.5 Fabrication

The unit can be fabricated using available materials at the plant. Required materials with their specifications can be found without any difficulty. Close supervision is necessary during the fabrication. All the steam tubes to be expanded using "Tube expander" and during these operations base plates must not be damaged. All the limitations should be kept and limits and tolerances should not be violated. Any mistakes during the fabrication could cause for water leaks, due to high- pressure operation.

Holes for the water tubes to be drilled on the base plates and the center plates. This can be done using 76 mm drill bit or directly holding on heavy lathe machine available at Pelwatta Sugar factor workshop. Welding procedures to be followed multiple welding and finally this welding should be examined using "Ultra sonic flow detector available at factory. Appropriate welding rods should be selected to suit the material and plate thickness.

6.6 Installation

The unit should be tested before the installation. By pressurizing the unit using water by hydraulic pump up to 45 bars is sufficient for testing. By using a movable crane this unit can be kept at the designed location. Assembling can be done, where the economizer is mounted and then tube expansions can be carried out there. 5 Ton chain block to be used for the handling purposes. Approval to be taken from an authorized Boiler inspector before the installation; inspection reports regarding calculations, thickness testing, and welding testing certifying by qualified Non destructive Tester Will be very helpful for this. Re-modification of existing air duct to be done before modification, such as extending height of the air duct by 0.6m, boiler fire brick wall extending etc.

Chapter 7

Conclusions

Main objective of this project was to look in to the process of the sugar industry thereby to study on the possible efficiency improvements in the boiler which is a component of the process. Through the results obtained in this study it is concluded that efficiency improvement & energy saving is achievable by the modification of the boiler process by introducing a feed water heater. With assumptions and approximations mentioned in each stage of the evaluation following improvements are possible.

- 1608 tons/hr, Bagasse can be saved.
- Feed water temperature can be increased by 25 ^{0}C.
- This will increase boiler efficiency by 3%.
- Final boiler efficiency will be 70%.
- Therefore no any furnace oil is required to run the plant.
- Using surplus bagasse, steam turbine can be run to produce electricity during off season (90 days).
- This will reduce diesel consumption by 350 MT.
- Emissions also can be reduced.
- Cost for implementation of Feed Water Heater is 2.7 million LKR.
- Annual saving is 54.2 million LKR.

Finally, above improvements will be significant for the organization to enhance its productivity. The outcomes due to this project are also significant and benefit to my country and to the nation.

7.1 Time Plan

	Feb '09	Mar '09	Apr '09	May '09	Jun '09	Jul '09	Aug '09	Sep '09	Oct '09	Nov '09	Dec '09
Background Study of the Sugar process	■										
Analysis of the past plant data in the Sugar		■	■								
Analysis of the present plant data in Sugar the process			■	■	■						
Results Analysis & Building up the Required design					■	■	■	■			
Study on further Developments									■		
Writing the Dissertation										■	
Presentation Materials & Presentation											■

7.2 References

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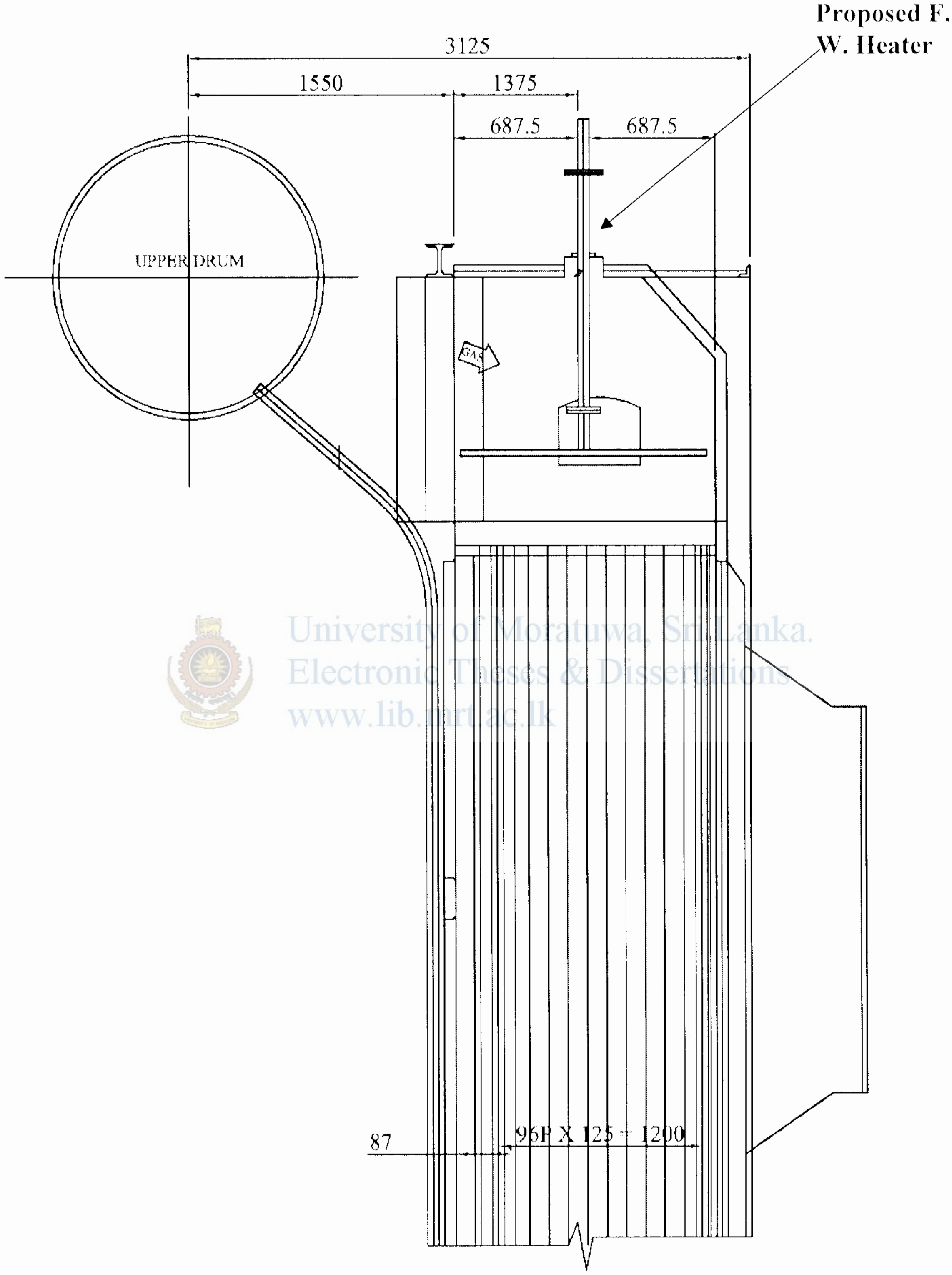
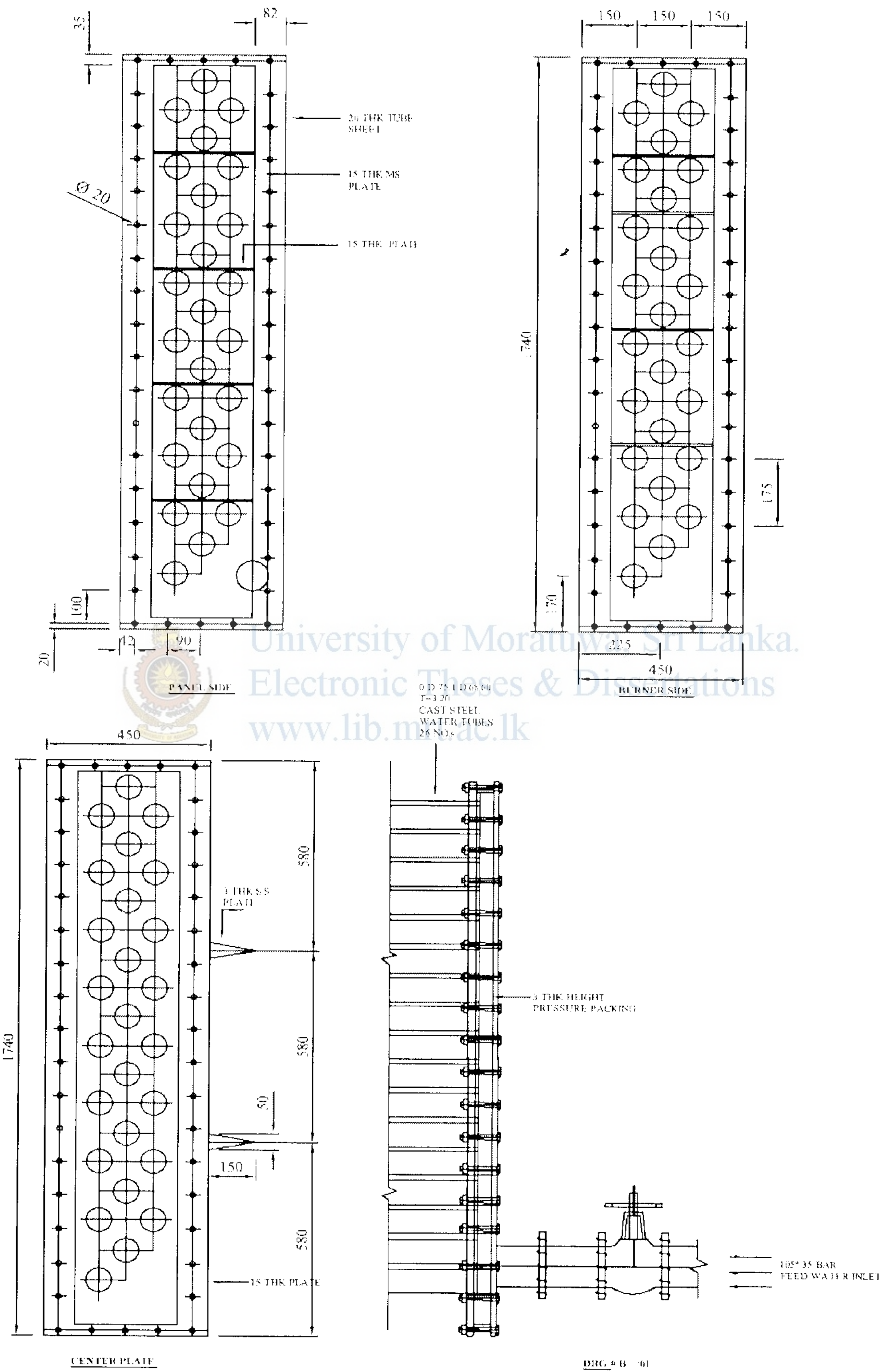
Air Pre-Heater Assembly Drawing



Drawing of the Base Plates



Feed Water Heater Assembly Drawing