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

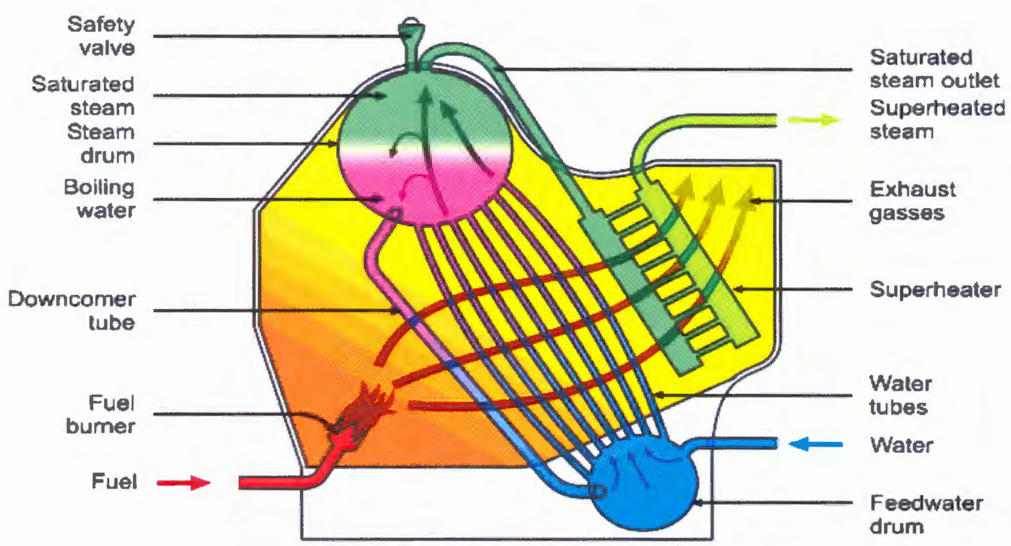

Figure 3.1

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.