A STUDY OF ENERGY USE AND SAVING OPPORTUNITIES AT A TOBACCO GREEN LEAF THRESHING PLANT

By

KIFALU, Hilarious Ruwa

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DECLARATION

A. Student's declaration

I confirm that this project is my work and has never been submitted before for examination purposes or any other purpose

Hilarious Ruwa Kifalu, F56/71279/2007

Signature:...

Date: 15/07/2011

B. Supervisors' Declaration

I confirm that the above student carried out this project work under my supervision for the entire period of the project.

Dr. A. A. Aganda

Signature: alex aganda

Date: 19/7/2011

Dr. J. A. Nyang'aya

Signature:...

Date: 19.7.2011

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ABBREVIATIONS AND ACRONYMS

A	Ampere
BAT	British American Tobacco
BEE	Bureau of Energy Efficiency
Cst	Centistoke
ECM	Energy conservation measure
ECO	Energy conservation opportunity
ER	Evaporation ratio
GLT	Green Leaf Threshing
HFO	Heavy furnace oil
HMI	Human machine interface
h	Hour
K	Kelvins
Ksh	Kenya shilling
kg	Kilogram
kJ	Kilo joule
kWh	Kilo watt hour
l	Litre
MCC	Motor control centre
MJ/kg	Mega joule per kilogram
OEM	Original equipment manufacturer
ppm	Parts per million
RO	Reverse osmosis
TDS	Total dissolved solids
USD	United states dollar
V	Volt
VFD	Variable frequency drive

ABSTRACT

This study was carried out to analyze the energy use patterns at a Tobacco Green Leaf Threshing Plant (GLT) in order to understand energy consumption trends and patterns. The main aim of this was to identify energy conservation opportunities (ECO) and respective energy conservation measures (ECM) that can be put in place where possible to conserve energy and in relation to best practice in this type of industry.

Energy costs in the GLT are a major manufacturing cost contributing up to 22% of total manufacturing costs. With the GLT already operating at higher costs than projected plan, the finding of this study will greatly help the GLT to reduce its operational costs and be competitive.

In the assessment of energy use it was observed that the GLT has been consuming energy at higher rates of 4MJ of heavy furnace oil and 1.1MJ of electricity per kilogram of production compared to target benchmarked standards of 3.3MJ and 0.84MJ per kilogram of production. Also observed was that even as the GLT has been putting in measures to conserve energy such measures were not well planned and coordinated.

Observations and measurements were made on process behaviors of energy distribution and user systems. Several ECO's were identified and respective ECM's recommended with estimate investments required and expected payback periods

It was found that the proposed ECM's have potential to save the GLT 114,971 kWh per year equivalent to Ksh 1,429,412 per year, which is a 2% reduction from 2010 total electricity usage with an estimate investment of Ksh 2,204,400 and 270,485litres of HFO per year equivalent to Ksh 11,623,835 which is a 17% reduction from 2010 total HFO usage with an estimate investment of Ksh 6,862,200.

Other recommendations were also made on what else can be done as future projects to further reduce energy use.

CHAPTER ONE

INTRODUCTION

In this chapter an overview of the tobacco industry is presented and its significance in the national economy in revenue generation and gross domestic product. A view of the impact of energy in tobacco manufacturing is shown that outlines the need to carry out this study

1.1 Overview of tobacco manufacturing

Tobacco is a horticultural crop grown through small scale farmers in the country. Tobacco is first grown on seedbeds and then transplanted to the fields. In Kenya the tobacco crop is a rain fed crop and is grown in both the long and short rain seasons. Once the tobacco plant reaches maturity its leaves are harvested and dried, a process referred to as 'curing'. The cured tobacco is then graded depending on colour appearance and leaf body. This colour appearance is related to the chemistry of the leaf, where the active chemicals are nicotine and sugars required for smoking characteristics of cigarettes. Tobacco is then sold in local markets to various tobacco companies where the manufacturing facility under this study is one of such companies. The growing operation is a labor intensive process and also uses a lot of energy through wood fuels during 'curing' (tobacco drying in the fields). Tobacco farmers spend a lot of input costs to produce good farm yields and in return expect to earn high yields through sales of tobacco.

Tobacco leaf purchased from farmers is then transported from growing regions to a tobacco manufacturing plant (Green Leaf Threshing Plant). During tobacco manufacturing the leaf is separated from the stem (mid rib) in a process referred to as 'green leaf threshing'. The leaf is separated from the stem because in the next process of cigarette manufacture, the leaf and stem are subjected to different inclusion levels and conditions. The leaf and stem are then dried and packed separately and transported to cigarette manufacturing plants.

The processed leaf (threshed leaf) and stem at the cigarette manufacturing plant is cut into fine strands and assembled into cigarettes using special perforated cigarette paper and filters. The cigarettes are packed in packets of twenty cigarettes each and sold to retailers who sell to consumers. Revenue generated from sale of cigarettes is used to pay for all tobacco processes from the farmers who grow the leaf to the leaf threshing and cigarette manufacturing processes. Revenue from cigarette sales has played an important role in the Kenya's gross domestic product (GDP) contributing revenue to the exchequer and earnings to farmers.

According to the tobacco leaf and cigarette manufacturing plants (under this study) annual financial results for the year 2010, revenue from cigarette sales generated Ksh 955 million in income taxes[1] as payment to the exchequer and Ksh 622.2 million as direct payment to farmers[2]

The processes of leaf and cigarette manufacturing are energy intensive and the efficient energy usage during these processes affects revenue generation, income to farmers and the country's GDP

The tobacco green leaf threshing is one part of the process of tobacco manufacture which is the scope of this study.

1.2 Green leaf threshing and energy use

The tobacco Green Leaf Threshing (GLT) plant consumes a significant amount of energy required for product manufacturing. It involves softening the tobacco leaves using steam in a process called conditioning so that it does not shatter during the separation of leaf from stem in the leaf threshing process and drying the tobacco leaves using steam heated air. The manufacturing plant is all run through electrical motors and appliances

The GLT plant used 22% of 2010 total manufacturing costs on energy which amounts to a total of Ksh 131 million for the year 2010. Of the total energy costs 45% was on electricity, 51% on furnace oil and the balance on diesel [2]. The energy costs in Kenya have been rising over the years that have made manufacturing costs in Kenya to escalate. The high energy cost makes it difficult for manufacturing companies in the country to compete effectively with other manufacturers globally. There has been a steady rise in heavy furnace oil (HFO) price from May 2009 towards 2010 to peak at Ksh 45.44 in May 2010. Monthly average prices are at Ksh 35.93/l in 2009 and 42.97/l in 2010[3]. Electricity price has also been rising from July 2009 towards December 2009 to peak at 17.26 Ksh/kWh in November 2009. There was a decrease in electricity price in the year 2010. Monthly average prices are at 12.93 Ksh/kWh in 2009 and 12.43 Ksh/kWh in 2010 [4].

According to the Kenya Association of Manufacturers (KAM), Kenyan manufacturers are paying between Ksh10 and Ksh15 per kWh of electricity compared to their competitors in China and India who pay between USD 0.0312 and USD 0.0475 which is equivalent to between Ksh 2.50 and Ksh 3.80 per kWh of electricity [5] at an exchange rate of Ksh 80 to one USD.

To reduce energy use it is necessary and urgent that an analysis is made on how energy is utilized in the plant processes. The aim of this project was to study the current energy use at the GLT plant, analyze and identify opportunities for improvement in efficient and economical usage of energy to minimize waste and reduce manufacturing costs. The high energy use may be due to energy inefficient equipment, poor process controls and maintenance. The study involved an investigation, initially using simple observations of the equipment and then measurements. The study was made to understand the historical energy use intensities, most appropriate way for energy conversion systems, efficient energy usage processes and equipment and waste energy recovery.

The findings of this study will be useful to the GLT plant in efficient energy use and cost savings and also to other manufacturing plants that use similar technology in selected plants. The findings will demonstrate available savings and investment returns in the case where such investments will be required.

1.3 Statement of the problem

The study GLT Plant uses electricity and HFO for steam generation. According to the GLT plant energy consumption [3,4] the current 2010 average energy usage stands at 3.97 MJ of HFO/kg of tobacco processed and 1.1 MJ of electricity/kg of tobacco processed compared to the targets of 3.3MJ of HFO per kg of tobacco processed and 0.84MJ of electricity per kg of tobacco processed[6]. The targets are arrived at from global benchmarking of the companies sister GLT's. This means the GLT plant is less efficient in its manufacturing processes than expected practice. Attempts must be made to improve the energy efficiency of the plant. The price of HFO and electricity has been rising over the years and currently stands at an average of Ksh 42.97/l of HFO and Ksh 12.43/kWh of electricity for the year 2010 [3, 4] and therefore increasing manufacturing costs. There is need for better efficient energy use. For the year 2010 manufacturing costs at the GLT stood at Ksh34.3/kg of tobacco versus a company plan target of Ksh27.20/kg of tobacco processed [6]. This reduces revenue and profitability of the GLT Plant. The lower profitability will also result to higher retail costs of the GLT products and will as a result loose competitiveness with competitor plants. It is crucial that energy use is analyzed and reduced to improve energy efficiency

1.4 Objectives

The objectives of this study was

a. To study the historical data to establish typical energy consumption rates and intensities
b. To make a plant survey thorough inspection and observation on the status and condition of the equipment in the plant in relation to energy use
c. Identify energy conservation opportunities (ECO)
d. Recommend energy conservation measures (ECM)

CHAPTER TWO

LITERATURE REVIEW

In this chapter a review is presented on what is already known on this subject. A detail of what is known as acceptable industry practice is shown with highlights of common industry inefficiencies. A review of what has already been done at the GLT site and other similar operations in energy saving measures is also presented. Also shown in this chapter is the company's strategy in global energy reduction targets.

2.1 Boiler and steam distribution

2.1.1 Fuel (heat) system

The most common source of energy in the Kenyan industries for steam generation is combustion of fuels in a furnace. The fuels can either be solid, liquid or gas.
Solid fuels in Kenyan industry used for boiler steam generation range from coal, wood, sugarcane bagasse, coffee and rice husk, saw dust etc depending on availability at point of use. Liquid fuels range from fuel oil, petroleum oil, kerosene and dirty fuels (used oils, thinners & paint waste etc). Gas fuels range from liquefied petroleum gas (LPG) and natural gas. Generally fuels mostly contain carbon, hydrogen, sulphur (as main combustible components) & oxygen and ash. When evaluating a fuel only the carbon and hydrogen is normally considered. Fuel oils generally consist of carbon at 84% to 90%, hydrogen at 5% to12%, oxygen and nitrogen 3-4% and sulphur up to 4% depending on source [7, 8, 9].The most important component when evaluating a fuel is the heating value which is the quantity of heat generated by combustion of the fuel per unit mass or volume. The lower heating values (LHV) for most fuel oils range from 35.58 to 41.87 MJ/kg [7]. The relationship between lower heating value (LHV) and higher heating value (HHV) is that LHV takes into account energy used in the evaporation of moisture in fuel and generation of water from hydrogen and oxygen in fuel. This energy can be recovered through condensation of the water vapour in flue gas through heat recovery systems. If a fuel has no moisture then the LHV will be equal to the HHV [7] [10].

According to Beer [10], the relationship between LHV and HHV can be expressed using the International Energy Agency (IEA) equation as [10]

$$LHV = HHV - (0.2121 \times H + 0.02442 \times H_2O + 0.0008 \times O) \quad \text{...(2.1)}$$

Where LHV and HHV are in MJ/kg, and H, H_2O and O are in %.

Fuel oils are classified in terms of heating value, viscosity and density in the range of fuel oil number 1(FO1) to fuel oil number 6 (FO6). In the Kenya market FO1 to FO4 are classified as industrial diesel oil (IDO) and FO5 and FO6 classified as heavy furnace oil (HFO) [7]. Table 2.1 shows values of the range of LHV, viscosity and preheat temperatures preparations of various fuel oils and also respective classification in the Kenyan market.

Table 2.1 Properties of various fuels in Kenya

Trade number	Preheat temperature °C	Viscosity Cst. 38°C	LHV Btu/gal	**Comments in Kenya market**
FO1	Volatile fuel oil	1.6	137,000	IDO hell light
FO2	Moderately volatile	2.7	141,000	IDO amber
FO3	No preheating required			IDO
FO4	No preheating required	15	146,000	IDO black
FO5	75°C to 105°C	50	148,000	HFO black
FO6	100°C to 120°C	360	150,000	HFO black

As shown in Table 2.1, FO1 to FO4 do not require preheating as the fuels are already light, viscous and volatile. However FO5 and FO6 require pre-heating ranging from 75°C to 120°C. This is normally achieved through electric heaters or using a steam heat exchanger once steam has been generated. Gas or other light fuels can also be used for pre-heating. The heated oil allows the oil to be pumped to furnaces due to lowered viscosity, allows attainment of required ignition temperatures and helps in mechanical atomization of fuel in the boiler burners for efficient combustion. Combustion of fuel oil is achieved by burning the oil in the presence of air. Mechanically atomized fuel oil is mixed with air supplied through boiler draught fans to form an aerosol. During combustion heat is released through the chemical processes of combustion of carbon, hydrogen and sulphur and also during the reaction of hydrogen and oxygen. The air required to achieve complete combustion is referred to as 'stoichiometric air'. 1 kg of fuel oil containing 86% carbon, 12% hydrogen and 2% sulphur would require 14.1 kg of air for a complete combustion [9]. In practice the combustion is not perfect and some additional air referred as 'excess air' must be allowed to ensure combustion is complete and the fuel oil has given out all its heat content. If too much excess air is added then there exist heat losses in heating the additional cooler air. The amount of excess air varies by type of furnace and fuel on combustion. Control of excess air is achieved by monitoring and controlling the amount of oxygen or carbon dioxide in the flue gas. A good combustion system using heavy furnace oil (HFO) should aim at limiting the excess air to ranges of 12% to15% [8, 9] and oxygen in flue gas to 2% to 3% [8, 9]

Excess air can be expressed using the following relationship [8, 9]

Excess air % =%O2/(21-O2%) x 100 ....(2.2)

The heat in flue gas is passed into boiler tubes and passages that run through boiler water to transfer heat from flue gas to steam. The efficiency of transfer depends on conductivity of the boiler tubes. Tubes that have deposits (scales on the water side or soot on the flue side) will have a lower heat transfer and high heat losses through high exit flue gas temperature. A boiler efficiency loss of 1% is estimated for every 22°C temperature rise in flue gas due to deposits [9]. A 3 mm soot deposit layer can cause a 2.5% increase in fuel consumption [9]

The flue gas should exit the boiler stacks at as low temperatures as possible. High temperatures indicate poor heat transfer in the boiler while too low flue gas temperature can lead to sulphur dew point corrosion. Stack temperatures higher than 200°C show potential for waste heat recovery [8, 9]. Normally most boilers operate at between 200°C to 300°C [9] flue gas exit temperatures. This energy can be recovered through an economizer to preheat feed water or combustion air. A boiler with exit flue gas temperature of 260°C can preheat feed water in an economizer to increase temperature by 15°C that can increase boiler efficiency of the order of 3%. This would reduce the flue gas temperatures back to 200°C [9]. Raising the combustion air by 20°C in an air pre-heater can increase boiler efficiency by 1% [9].

Above the heat losses previously stated, other losses exist due to boiler surface radiation where the boiler surface insulations are missing or damaged. The expected boiler surface radiation is normally a fixed loss estimated at 1.5% of gross calorific value for modern boilers but can increase to 6% if boiler is run at 25% output [9]. In summary the combined heat losses for the boiler heat system relate to the overall boiler efficiency. The boiler efficiency (efficiency of combustion and heat transfer) can be expressed as

Boiler efficiency = 100% - (boiler heat losses) known as the indirect method............(2.3)

In the indirect method the principal boiler losses include loss of heat due to dry flue gases, moisture in fuel and combustion air, combustion of hydrogen, unburned products and heat surface radiation & convection

The following expressions can be used to show the relationship of the heat losses [8, 9]

Heat loss in dry flue gas
=mg x Cp x (Tf-Ta)/1kg x HHV x 100 ....(2.4)

Where mg is mass of moisture in flue gas
Cp is specific heat capacity of flue gas
Tf – Ta is difference in flue gas and ambient temperature
HHV is the higher heating value of the fuel

Combustion of hydrogen and evaporation of moisture
=mg x Cp x (Tf-Ta) + mg x hfg/1kg x HHV x 100..(2.5)

Where mg is mass of moisture in flue gas
Cp is specific capacity of steam
Tf – Ta is difference in flue gas and ambient temperature
hfg is the enthalpy of steam in flue gas = enthalpy of steam in flue gas – enthalpy of water at ambient temperature
HHV is the higher heating value of the Fuel

Evaporation ratio (ER) is defined as the quantity of steam generated in kilograms per fuel combusted in kilograms

2.1.2 Water system

In the boiler water system, water is heated to generate steam. During evaporation of steam the boiler impurities in water remain in the boiler and increase in concentration, with the heavier particles settling at the bottom of the boiler and lighter particles floating at the water top surface.

The process of 'boiler blow down' regulates the concentration of impurities in water by blowing off some amount of water from the boiler to reduce impurities and feed water used to make up for the lost water due to blow down.

A low blow down rate will increase dissolved impurities that will cause deposits and scale formation in the boiler. The scales in the boiler tubes will lead to poor heat transfer to the water and will resulting to heat loss through the flue gas and reduce boiler efficiency. The poor heat transfer can also result to overheating of the boiler tubes leading to tube failure. The high impurities floating at the water surface will also result to foaming that leads to carry over of water in steam affecting steam quality.

A high blow down rate will result to excessive loss of heat in boiler water and higher heating fuel usage resulting to lower boiler efficiency. More water treatment chemicals will also be required due to increased usage of make up water.

For packaged and economic boilers (similar to the boilers in the scope of this study) the recommended manufacturers maximum total dissolved solids (TDS) in the boiler water is 3000 parts per million (ppm) [8, 9]. To maintain boiler TDS at permissible levels blow down is carried out both at the bottom and at the water surface of the boiler as follows:

A large diameter valve connected at the lowest point of the boiler is opened for a short time. As a rule of the thumb, this is opened 'once an eight hour shift for two minutes' [8, 9] referred to as 'intermittent blow down'.

A small diameter pipe is connected near the water surface and continuously releases a small volume of boiler water that is also continuously replaced by feed water. This is referred to as 'continuous blow down'.

As best practice blow down can be automated that only sufficient amount of water is blown off to maintain boiler TDS at preset levels.

The estimated amount of blow down rate can be expressed as [8, 9]

$$\text{Blow down \%} = \frac{\text{Feed water TDS x make up water \%}}{\text{Maximum permissible boiler water TDS}} \qquad \text{(2.6)}$$

To reduce effects of impurities in water on boiler efficiency feed water can be treated both internal and external of the boiler. Internal treatment is done to chemically convert scale forming impurities to free flowing sludge's that can be removed during blow down. The type of chemicals used varies depending on types of impurities present in the feed water. They include sodium carbonate, sodium aluminate, sodium phosphate, sodium sulphite [9]. External treatment is done to remove suspended, dissolved solids (especially calcium and magnesium ions responsible for scale formation) [9] and dissolved gasses. The external methods used include ion exchange, demineralisation, reverse osmosis and de-aeration [9].

A good water system is one that maximises the use of return condensate from the steam system. In this system less feed water is used and as a result less impurity introduced in the boiler. Condensate recovery will be discussed further in section 2.1.3.

2.1.3 Steam distribution system

Steam generated in the boilers is collected and piped to end user equipment. Depending on steam quality requirements, steam pressure may be lowered using pressure reducing valves installed in the steam distribution system. During steam distribution energy is lost by heat transfer in the pipes resulting to steam condensation. The heat loss is a result of high temperature steam heating cold pipe lines to working temperature and thereafter steady heat loss through radiation and convection. The condensate formed must be removed through steam trapping to avoid risk of lowering steam quality and water hammer. A 100 mm well lagged pipe of 30 m length carrying steam at 7 bar can condense 10kg of water in one hour unless it is removed by trapping [8, 9]. Steam piping should then run with a fall of no less than 12.5mm in 3 m in the direction of flow to allow condensate to flow out. The condensate should be drained out every 30 to 50 m at the lowest point of pipe network [9].

There are three main designs of steam traps to remove condensate. They are mechanical type which operates using density differences between condensate and steam/air, thermostatic type which operates using temperature differences between condensate and steam and thermo-dynamic (disk/orifice) type which operates using flow differences between condensate and steam. Steam traps also help in removal of gasses trapped in the steam by automatic venting, especially during start up. A good steam trap installation should have a steam separator and a strainer to prevent dirt and scale in trap upstream of the trap. Steam traps require regular monitoring and maintenance to ensure all parts move freely and avoid trap stuck in closed or open position. It's also recommended that traps should be installed to individual condensate source. Group trapping is less efficient [9].

Steam lines require to be lagged to avoid loss of heat energy. Common lagging materials include asbestos, magnesia asbestos, corrugated asbestos, fibre glass, aluminium foil, mineral wool and slag wool [8]. The use of asbestos in industry is however currently discouraged due to health risk. A 5 inch pipe at a temperature of 400°C and an ambient temperature of 21°C will save heat loss by up to 95% if lagged with fibre glass [8]. Steam system lagging should include steam line accessories and flanges to reduce heat loss. One uncovered flange is the equivalent of 0.6 metre of its bare pipe [9]. A 0.15 metre diameter steam pipe with 5 un-lagged flanges will result to heat loss equivalent to 3000 litres of oil in a year. [9].

Heat loses through surface heat transfer to air can be expressed using the following relationship

Heat $Q = hA(T2-T1)$..(2.7)

Where

h = Heat transfer coefficient in W/m²K= 15 for steel [9]

A = Total surface area in m²

T2-T1 = Temperature difference between surface and air in K

Condensate trapped from the steam system should be recovered as much as practically possible and pumped back to the boiler feed water tank. The main benefit of condensate recovery is heat energy recovery in the condensate as preheated boiler water. Condensate at 7 bar contains 721 kJ/kg of energy which is 26% of original energy contained in steam of 2769 kJ/kg at the same pressure [8]. A 60°C rise in boiler feed water can result to 1% saving in boiler fuel [9]. Other benefits include reduced usage of make up water and less impurity in boiler water, reduced chemical treatment of boiler water, and reduced blow down rates.

Other energy losses in a steam system are steam leaks and flash steam. It is estimated that a 3mm hole on a steam pipe carrying steam at 7 bar can leak steam equivalent to 33000 l of fuel oil in a year [9]. Condensate at high pressure releases flash steam when released at atmospheric pressure. 13.4% of flash steam is produced by hot condensate at 7 bar when released at atmospheric pressure [9]. The flash steam contains residual energy that can be recovered. This can be achieved in waste heat recovery systems. Waste heat recovery systems vary in design and application depending on source of waste heat. Typical waste heat recovery system efficiency range is of the order of 60-80% [8].

2.2 Electrical system

2.2.1 Electrical load and tariffs

Electricity is commonly supplied to industries at various voltages depending on size of industry. The tariffs structure varies depending on supply voltage. Electricity supplied at 11 kV is billed as per tariff method C12 which includes a fixed charge of Ksh 2,500, a charge of Ksh 4.73 per unit consumed and a charge of Ksh 400 per kVA of demand [11] .Demand is billed as the highest continuous peak for 30 minutes during the billing period [11]. Above these charges other surcharges and penalties exist depending on circumstances at electricity generation and end usage. These include unavoidable surcharges as fuel and foreign exchange rate fluctuation adjustments, rural electrification programme (REP) and energy regulatory commission (ERC) levies and avoidable penalties as power factor correction and maximum demand excess of contractual levels

According to the Kenya Power and Lighting Company tariffs, for consumers charged under method C12 - the payment for electrical energy consumed and chargeable kVA of demand in each billing priod (exclusive of VAT, fuel cost, foreign exchange rate fluctuation adjustment, REP and ERC levies) shall be increased by 2 per cent for each complete 1 per cent by which the power factor is below 0.90 [11].

Time of day tariffs are also applied depending on time of usage where lower tariff rates are offered during off peak usage periods

Electricity load management then is important that electricity is used in a way that attracts the best rates and avoids any avoidable penalties. Load management includes rescheduling loads such that optimum loads are used at any one given time. This may include sequencing motor start ups to avoid simultaneous high loads of different motors starting at the same time. Scheduling different high load operations to different shifts can also result to lower demand. Shedding off non essential loads also reduces electricity load. This may include running motors when there is no production during breakdowns, operation changes and cleaning or lighting during the day where natural light could have been used. Demand can also be reduced through reactive power compensation through use of capacitor banks to maintain optimum power factor. A good electrical system should have a power factor (PF) close to unity. It is recommended that PF correction be done as close as possible to the electrical load [9]. Electricity power is expressed using the following relationship

$$\text{Power (kW)} = \sqrt{3} \times \text{Voltage (V)} \times \text{Current (A)} \times \text{PF} \quad (2.8)$$

2.2.2 Electrical drives

There are various designs of electric motors however induction motors are most commonly used in industrial applications. Two important attributes of induction motors are efficiency and power factor. Efficiency is defined as ratio of the mechanical output at the output shaft to the input power on its terminals. The induction motors are also characterized by a power factor less than unity. A good motor should have as high an efficiency and power factor close to unity [9]. The efficiency of motors is determined by presence of two types of losses as fixed losses due to magnetic core losses and variable losses due to resistance in current flow in the stator and rotor proportional to the square of the current with respect to the wiring material resulting to heat loss.

Energy efficient motors are designed to incorporate thicker wires to reduce current resistance, a longer core to increase active material made from low loss silicon steel, thinner laminations, smaller air gaps between stator and rotor, superior bearings and smaller cooling fan to reduce mechanical loads. Energy efficient motors as a result operate at 3 to 4% higher efficient than standard motors [9].

A common practice in industry is overrated motor capacity that results to motor under loading. This is a result of original equipment manufactures (OEM) designing motors with large safety factor and underutilization of motors in user applications.
Under loading of motors is common in industry contributing to lower motor efficiency and power factor. It is recommended to downsize motor duty and for the case of high torque requirements at start up, then other options as star to delta or soft start can be applied. It is also recommended to always install energy efficient motors. During replacement to downsize capacity or replacements with energy efficient motors, economic analysis needs be done on case by case basis.

2.2.3 Lighting and illuminance

The power consumption on lighting in industry varies from 2% to 10% [9] depending on type of industry. Different industrial applications demand different levels of illuminance. Illuminance is measured in lux and is presented as an example, (30-50-100) where 50 is required average, 30 is minimum illuminance and 100 is maximum illuminance [9].

According to the Bureau of Energy Efficiency India, a process plant running on remote control recommended illuminance in lux is 30-50-100 while one with permanently occupied work stations is 150-200-300. For process plants requiring fine and close inspections similar to the plant in this study, the recommended illuminance in lux is 300-500-750 [9]. Higher illuminance will be required for workstations performing close inspections of small objects of up to 1000 lux with thresholds of 10,000 lux for medical surgery rooms [12].

The efficacy of lighting lamps is given as the amount of lumens per watt of electricity usage and its rated lamp life. An incandescent lamp is rated at average of 14 lux/W with a life of 1000 h while a compact fluorescent lamp at 60 lux/W with a life of 8000 to 10000 h which shows that this is superior to incandescent lamp in energy efficiency. A fluorescent lamp similar to the lights in use at the plant in this study is rated at average of 50 lux/W with a life of 5000 h [9].

Fluorescent lamps with high frequency electronic ballast use 35% less energy than those with electromagnetic ballast [9]. Other advantages offered by use of electronic ballast are that it lights instantly, does not consume power when lamp is faulty (flickering), operates well in low voltage load, improvements in power factor and has longer life rating.

2.3 Compressed air system

Compressed air systems generally account for a significant amount of energy loss. It is estimated that only 10 to 30% of total energy input into a compressor prime mover is used at intended end user equipment as delivered air with the rest lost to unusable heat losses, piping losses, noise and misuse [9]. The efficient operation of compressor systems is then important to maximize on positive energy conversion.

The location of an air compressor and the air drawn in the unit significantly affects the energy efficiency of the compressor. The efficiency improves with cooler, cleaner and dryer air at intake. As a rule of thumb, for every 4°C rise in inlet temperature results in higher energy consumption by 1% to achieve an equivalence output [9]. It is good practice to draw intake air into the compressor from outside air as the air in the compressor room is normally higher than ambient temperature due to heat generated by compressors during operation and hot exhaust air from compressor radiators.

The relationship between power consumed by a compressor and inlet air temperature can be expressed as [13]

$$W2 = W1 \times \{1 + 0.00341(T2 - T1)\} \quad \text{(2.9)}$$

Where

W1 is power consumed by compressor at air inlet temperature T1

W2 is power consumed by compressor at air inlet temperature T2

Air intake should be clean to avoid dust intake in the compressor. Dust in the compressed air system causes abrasion to compressor moving parts and premature failure in performance. It is recommended that suitable air filters be installed, regularly cleaned and pressure drop across the filter monitored. As a rule of thumb, for every increase in 'pressure drop' of 250mm water gauge across the suction path due to choked filters, the compressor power consumption increases by 2% for the same output. [9]

Compressors are set to deliver a range of pressure from the loading point to the unloading point. A compressor of similar capacity but delivering higher pressure consumes more energy. Likewise, reducing the delivery pressure of a same capacity compressor will result to energy savings. A reduction in delivery pressure in a compressor by 1 bar would reduce energy consumption by 6% to 10% [9]. It is recommended to generate separately high and low pressure air if both are required.

Compressed air pressure should be generated close to the point of use to minimize distribution losses. The size and design of distribution pipes and pipe fittings can be a source of energy waste if not properly done due to frictional losses resulting to high pressure drops. Filter units should also be free of choking to avoid pressure drops across the filter. Typical acceptable pressure drops in industrial practice is 0.3 bar at farthest point of main header and 0.5 bar in the distribution system [9].

Compressed air generation is expensive and should be applied for use only if other energy sources are inadmissible, otherwise misuse will occur. Misuse includes activities such as body cleaning, floor cleaning, equipment cleaning and equipment cooling which should be discouraged. Low pressure air from blowers can be used in place of compressed air which consumes less energy where applicable like in equipment cleaning. A brush in this instance could also do the job. If absolutely necessary, it is recommended to fit pressure regulated blow guns to keep air pressure to recommended maximum of 2 bar [9]. A ¼ inch orifice releases 100.9 CFM of compressed air at 7 bar [14]. Applications like pneumatic powered tools should be discouraged where electric powered tools can be used unless the use of electricity is inadmissible especially for safety reasons. A 6000 rpm 150 mm pneumatic grinder will consume 102 m^3/h of air at 6 bar generated by 10 kW energy input in comparison to an electric motor power requirement of 1.95 to 2.9 kW to drive the same size grinder [9]

Compressed air leakages form a major part of energy losses in industry. Compressed air leakages mostly occur at receivers, relief valves, pipe and hose joints, valves and fittings, quick release couplings, pneumatic tools and equipment due to poor maintenance practices and improper installations. As a rule of thumb, leakage should not exceed 5% of compressor capacity [8]. A 5 mm diameter hole can leak 27 l/s of compressed air at 6 bar wasting 8.3 kW of power used for generation [13]. Normal poorly maintained systems can have leakages of 20 to 30% of compressor capacity [13, 14]. It is not uncommon to have leakages of 40 to 50% in some industries [9]

Compressed air leakages can be expressed as [9, 14]

$$\text{Leakage } \% = \{ (T \times 100) / (T + t) \} \qquad (2.10)$$

Where

T = Time on 'Load' in minutes and t = Time on 'Unload' in minutes

2.4 History of energy review state at the GLT

A number of attempts have been made in the recent past years to improve energy efficiencies, not only in the study plant, but in others under the same scope. Examples of initiatives that have been made include

- Usage of translucent sky lights during day time operations observed in the GLT plant roof.

Year 2006

- Replaced 400W high bay lights bulbs with twin tube 40W fluorescent tubes [15]
- Replaced boiler 1 Harmworthy burner model AW1 with Harmworthy burner model ERO (2006) [15].

Year 2007

- Replaced pneumatic product conveyance system with open band conveyor system reducing motor demand by 250kW [15].

Year 2008

- Installed wind driven ventilation fans (first phase) [15].
- Installed a new 'Ogden' condensate pump and condensate return line to the boilers to improve condensate recovery and boiler feed water temperatures [15].

Year 2010

- Energy management committee formed [16].
- Started electricity sub metering by area [16].
- Replaced boiler 3 Harmworthy burner model AW1 with Harmworthy burner model ERO [15].
- Replaced all mechanical ball float traps with orifice traps (120 in number) [15].

However these activities have not been coordinated and their impact measured.

2.5 Case study BAT Korea plant

A thorough study of energy use was conducted in the GLT's sister company BAT Korea [17] in 2004 that resulted in energy savings from measures done. Table 2.2 shows various measures carried out and benefits realized against investments made.

Table 2.2 2004-2008 Energy initiatives and savings in BAT Korea

Items	Description	Investment	Annual savings	Status
		USD	USD	2008
1	Reduced air pressure for humidifiers	6,800	5,700	Complete
2	Electricity peak control	0	15,000	Complete
3	Lighting control	7,000	12,570	Complete
4	Lighting improvements	0	15,600	Ongoing
5	Steam main line MOV installation	30,000	78,000	Complete
6	Improve boiler operating procedure & heat insulation	1,300	22,000	Complete
7	Energy efficient motors	20,000	3,100	Ongoing
	Total annual savings complete	45,100	133,270	Complete
	Total expected annual savings ongoing	20,000	18,700	Ongoing

A total annual benefit of USD 133,270 is being realized versus an initial total investment of USD 45,100.

2.6 BAT group energy strategy

In view of the high energy costs the global company group has put in place strategies and proposed energy reduction of 6.7% in 2012 using the 2007 levels as baseline [18]. Figure 2.1 shows historical data in energy consumption intensities in GJ per million cigarettes production from 2002 to 2009 and the group target in 2012 [18]

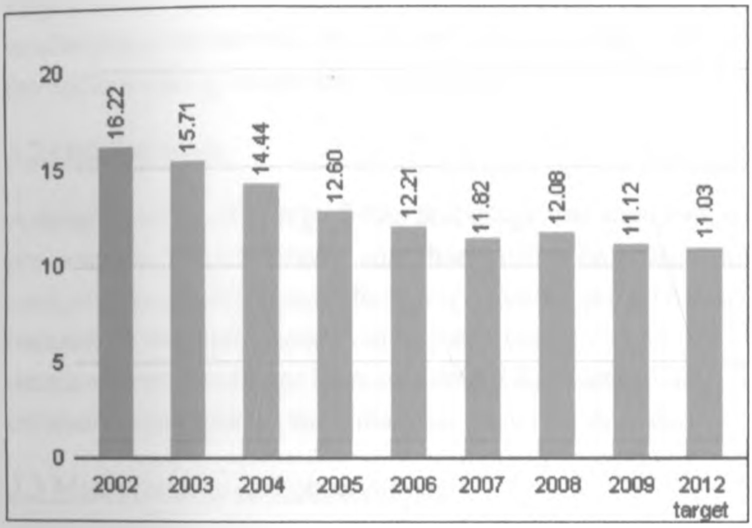


Figure 2.1 2002-2012 Global energy usage trends

The historical data from Figure 2.1 shows group energy use reduced by 7.95% to 11.12 GJ per million cigarettes in 2009 from 12.2 million GJ per million cigarettes in 2008.

According to the British American Tobacco global environment report, the group targets energy use of 11.03 GJ per million cigarettes equivalent produced by 2012. This is 6.7 per cent lower than the 2007 baseline of 11.82 GJ per million cigarettes equivalent produced [18]

CHAPTER THREE

METHODOLOGY

In this chapter the methods employed and procedures followed are outlined that include the various tools used.

3.1 Review of historical trends on consumption rates

First a review of historical trends was carried out using data from energy bills and plant production to understand the past and current energy use patterns and intensities and relate this to the various energy consuming processes.

3.2 Detailed study

A detailed study of energy flows and usage was then carried out on the current systems by process area. Measurements and observations on energy flow and usage were carried out and compared to expected manufacturing practice and technical performance by process. The measurements were carried out as per procedures laid out in section 3.3. Where such measurements could not be made, calculated values using engineering formulae and estimates/assumptions were made as shown in this report.

3.3 Measurements and observations

Measurements and observations were carried out on accessories and processes in the energy flow to provide basis of assessment for the performance and effectiveness of the manufacturing process in regard to efficient transfer and use of energy. The measurements and observations include the following

Boiler data

The boiler data was read directly from name plate details. This included the maximum continuous rated steam pressure and flow capacity. The steam normal supply pressure was read directly from steam pressure gauges fitted on the front face of the boiler. The steam temperature was obtained by conversion from steam tables [19] using the boiler saturated pressure read from the pressure gauge as reference.

Fuel data

Fuel costs and consumption was taken from monthly usage [3] for the two running boilers as there were no individual fuel flow meters for each boiler. A weighted average was made as a ratio of boiler capacity rating to arrive at individual monthly fuel usage. The monthly fuel usage was then calculated to hourly consumption based on the average run time of the factory plant.

Fuel composition was taken from a test certificate of fuel analysis carried out by Inspectorate (EA) Ltd [19] for the composition of sulphur, ash and moisture in fuel. Carbon, hydrogen and oxygen in fuel was estimated using expected composition ranges at 84%, 12% and 9% respectively [7,8, 9]. Net calorific value was taken from the test certificate report [20]. Gross calorific value of the fuel was calculated using equation 2.1

Flue gas data

Flue gas data on oxygen and temperature for boiler 3 was read directly from the human machine interface (HMI) of installed flue gas analyzer in the boiler. Flue gas analysis for boiler 1 was measured using an electronic flue gas analyzer model NU-WAY-NC-388 as this boiler does not have a directly installed analyzer. Only two readings were taken from the analyzer as it later broke down for the rest of study period. Excess air in flue gas was calculated using equation 2.2

Analysis of losses

An analysis of losses through boiler flue gas was calculated as losses through dry flue gas using equation 2.4, heat losses through combustion of hydrogen and heat losses through evaporation of moisture in fuel using equation 2.5. All other heat losses through radiation and convection were estimated at 1% [8].

Boiler efficiency

The sum of these losses was subtracted from ideal efficiency of unity to get the boiler efficiency using equation 2.3. Using the boiler efficiency and gross calorific value of fuel the evaporation ratio of the boilers was calculated that was used to compare variance of current energy use versus energy use at evaporation ratio of recommended manufacturer 'excess air levels'.

Energy flow through hot surfaces

Hot surface temperatures versus ambient temperature were measured using an infrared thermometer model 'Raytek Raynger ST' with a temperature range of 600°C. The area of emitting hot surfaces was calculated from measured lengths using a tape measure. The energy lost was calculated using the equation 2.7. Using the gross calorific value of fuel, the energy loss was related to volume of fuel and financial analysis done on actual cost of energy loss.

Boiler water quality analysis

The volume of makeup water was measured using a flow meter installed at the boiler feed water tank .Water quality analysis was carried out over three months with one test per month. Total dissolved solids (TDS) were measured using a conductivity meter model 'HACH Sension5'. The meter was temporarily acquired from Aquachem (Kenya) ltd. TDS was measured for boiler feed water, boiler water and condensate. The TDS was used to calculate estimate blow down rates for the boilers using equation 2.6. The blow down rates was then compared to an ideal situation where treated water is being used. An example of the reverse osmosis (RO) process was used for this case. The water treatment capability for RO plants was taken from a data sheet report from Davis and Shirtliff Kenya ltd [21]. Differences in heat losses were then computed between the current blow-down rates to maintain boiler TDS at recommended levels versus expected blow down rates using the ideal situation.

Electricity data

Electricity consumption and cost was taken directly from invoice figures as read on the GLT power meters. [4] This included, power factor and all respective surcharges

Factory lighting

The factory lighting was measured using a lux meter model 'Iso-Tech ILM350'. The readings were compared to expected industry standards for a manufacturing facility [9]. The lamps power rating was read from the tubes fittings. The total number of lights in the factory was counted and power usage estimated. It was assumed that all lights were working properly. The total power usage for lighting was compared with equivalent of recommended practice of using electronic ballast control gear versus currently installed electromagnetic ballast. Energy and cost savings were calculated.

Compressed air system

The compressed air plant details were read directly from the name plate of compressors. The compressed air pressure and temperature was read from the pressure indicators in the human machine interface (HMI) display unit for compressor 1 and gauges mounted on compressor 2. The actual power usage was calculated from measured values of voltage and current. A split core meter model FLUKE 355 AC/DC was used to measure the current and voltage. During calculation of power a PF of 0.9 was assumed. Equation 2.8 was used to calculate power. The duration for loading to unloading and unloading to loading of compressors was measured using a stop watch model MR-8501

3.4 Analysis of opportunities

An analysis of identified energy conservation opportunities (ECO's) to save and conserve energy was carried out. Energy conservation measures (ECM's) were made against the various ECO's identified. Quantified expected reduction in energy consumption and expected savings in costs in all the energy flows under study by process usage were made. A simple business analysis in terms of estimate investment required and payback time was then made using the following expression

Simple payback period (months) = Total investment/ Total monthly cost benefit…….(3.1)

3.5 Assumptions

The records provided on previous trends are true reflection of actual consumption and the estimates from available known literature is a true reflection of expected industry practice.

All assumptions made where measurements could not be made are a true reflection of expected performance

3.6 Limitations

Due to nature of controversy of the tobacco industry, companies are restrictive in access of information and acquiring comparative references had limitations.

Lack of some required metering devices, for example steam flow meters, limited monitoring of some data. Such data were then calculated from principles of engineering and assumptions as shown in the report.

CHAPTER FOUR

RESULTS AND ANALYSIS

In this chapter, results of this study are presented. The historical energy consumption is analyzed, energy losses are identified and illustrated and ECM'S suggested. An estimate investment for each ECM suggested is given and payback period calculated using the simple payback method.

4.1 GLT plant processes overview

The processing operation is carried out in the GLT with a production capacity of 8000kg/h. Actual average throughput is 5500 to 6000kg/h.The process involves receiving and weighing tobacco bales from the leaf growing centers after which the tobacco is stored in warehouses. Tobacco leaf from growing regions/farmers is received in 60 to100 kg bales at moisture content of 15 to 17%. The unprocessed tobacco is referred to as 'green tobacco'. Tobacco is stored in pallets in the warehouses that allow a free flow of air to keep the tobacco cool. Hot temperatures will result to changes in chemical properties and appearance of the green tobacco. Tobacco is then removed from the storage areas and laid down for pre-processing inspection before it is issued to the manufacturing process. During inspection tobacco grade validation is carried out to allow for processing. Any tobacco bale that fails to conform to the running grade is re-graded and returned back to storage, to be processed during running of reassigned grade. Any damaged tobacco is discarded and disposed.

During processing the tobacco is separated from the stem (mid rib) and packed separately as 'lamina' (the leaf part of the tobacco leaves) and stem. The processed and packed tobacco product is now referred to as 'dry tobacco' and is taken to storage awaiting shipment to end user customer. The processing operation at the GLT is seasonal. On average the GLT runs for approximately nine months in a year in a three shift system of eight hours each. The processing season normally start from May/June and run through to February/March dependent on the crop size. During out of crop season, the GLT plant is shut down for annual overhaul maintenance. During this time there are no production activities and energy consumption is largely for lighting and repair works being carried out in the plants through powered tools like weld machines, grinders etc.

Tobacco processing is done in two separate ways as shown in Figure 4.1. In the first method, the tobacco leaf is first 'tipped'(a process where the tip of the leaf is cut off to bypass the threshing process as this portion has a smaller stem content) and the bundle tie leaf is opened through a process called 'bundle bursting'. The leaf is then first conditioned with steam to a moisture content of 19 to 20% and temperature of 45 to 55°C by way of hot air draught and moisture (steam and pressurized water mist) to soften and open it to enable a sorting-process where damaged leaf and foreign particles are removed from the tobacco. The leaf is re-conditioned to a moisture content of 20 to 22% and temperature of 50 to 60°C in preparation for the threshing process. During conditioning steam is applied directly to the tobacco through steam nozzles and through heat exchangers (radiators) to generate hot air draught. In the threshing process the leafy part of tobacco (lamina) is separated from the mid rib (stem) in the threshing plant. The mixture of lamina and stem is then conveyed to air classifiers where lamina is separated from the stem in the air flow classifiers by way of air winnowing (the lighter lamina is carried up the classifier chamber by the airflow while the heavier stem is collected at the bottom of the classification chamber). The lamina and stem are then dried separately on perforated apron bed driers using hot air draught through steam heat exchangers to a moisture content of12 to13% at 40 °C for lamina and moisture content of 8 to 12% at 50 °C for the stem. The lamina and stem is then separately packed in 200kg cases and dispatched to the dry tobacco stores.

In the second method, the tobacco goes through a similar process of conditioning and drying as in the first method, however the leaf is not threshed to separate lamina from stems. Instead two processes are carried out as follows

The leaf is manually removed from the stem in a process called 'stripping' or the leaf butt which is stemmy is cut off in a process called 'butting'. In both cases the tobacco is packed as in the first method in 200kg cases.

Figure 4.1 shows a process flow block line diagram of the two processing methods described.

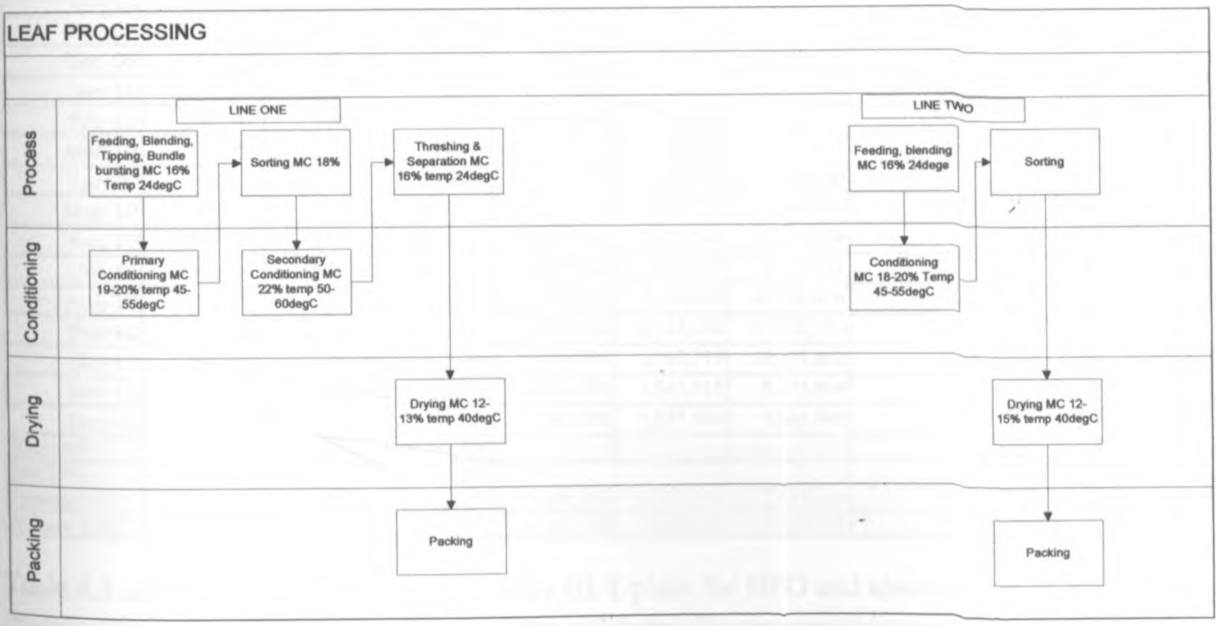


Figure 4.1 GLT Process flow

4.2 Energy use

The primary sources of energy are oil (HFO) and electricity. HFO is used to generate process steam as a secondary source for conditioning and drying processes while electricity is used to run motors and for lighting.

Another source of energy is diesel for forklift trucks, vehicle fleet and standby generator sets. (This however is not part of this study)

4.3 Review of historical energy usage trends and intensities

Table 4.1 Energy use profile (HFO and electricity)

Month	Production (kg)	HFO (l)	Electricity (kWh)	HFO (MJ)	Electricity (MJ)	Total energy (MJ)	HFO (MJ/kg)	Electricity (MJ/kg)	Total energy (MJ/kg)
Jan-09	839,635	57,424	199,480	2,703,844	835,343	3,539,188	3.22	0.99	4.22
Feb-09	1,749,277	133,485	467,130	6,285,223	1,956,156	8,241,379	3.59	1.12	4.71
Mar-09	1,347,325	90,890	346,760	4,279,611	1,452,094	5,731,705	3.18	1.08	4.25
Apr-09	0	0	98,250	0	411,432	411,432			
May-09	0	1,876	100,570	88,333	421,147	509,480			
Jun-09	827,064	83,262	347,400	3,920,442	1,454,774	5,375,216	4.74	1.76	6.50
Jul-09	1,626,639	144,928	427,310	6,824,024	1,789,405	8,613,429	4.20	1.10	5.30
Aug-09	1,811,253	187,169	602,994	8,812,967	2,525,101	11,338,067	4.87	1.39	6.26
Sep-09	2,423,205	182,202	532,418	8,579,093	2,229,556	10,808,649	3.54	0.92	4.46
Oct-09	1,787,529	214,754	574,930	10,111,823	2,407,580	12,519,403	5.66	1.35	7.00
Nov-09	2,365,533	184,970	346,074	8,709,426	1,449,221	10,158,647	3.68	0.61	4.29
Dec-09	2,022,109	146,270	390,060	6,887,212	1,633,417	8,520,630	3.41	0.81	4.21
Jan-10	2,345,048	151,765	459,336	7,145,948	1,923,518	9,069,465	3.05	0.82	3.87
Feb-10	1,088,041	119,567	413,568	5,629,885	1,731,859	7,361,745	5.17	1.59	6.77
Mar-10	-	0	99,310	0	415,871	415,871			
Apr-10	-	0	93,070	0	389,740	389,740			
May-10	1,465,137	110,812	389,656	5,217,651	1,631,725	6,849,376	3.56	1.11	4.67
Jun-10	2,785,765	176,842	590,742	8,326,714	2,473,794	10,800,508	2.99	0.89	3.88
Jul-10	2,179,556	176,223	503,790	8,297,568	2,109,673	10,407,241	3.81	0.97	4.77
Aug-10	1,753,008	169,850	566,174	7,997,491	2,370,913	10,368,404	4.56	1.35	5.91
Sep-10	2,963,688	199,629	557,430	9,399,654	2,334,296	11,733,950	3.17	0.79	3.96
Oct-10	1,698,343	172,199	521,486	8,108,095	2,183,777	10,291,872	4.77	1.29	6.06
Nov-10	1,603,432	140,805	392,328	6,629,890	1,642,915	8,272,804	4.13	1.02	5.16
Dec-10	1,542,504	147,565	442,654	6,948,188	1,853,660	8,801,848	4.50	1.20	5.71
Sum 2009	16,799,570	1,427,230	4,433,376						
Sum 2010	19,424,522	1,565,257	5,029,544						
Average 2009	1,399,964	118,936	369,448	5,600,166	1,547,102	7,147,269	4.01	1.11	5.12
Average 2010	1,618,710	130,438	419,129	6,141,757	1,755,145	7,896,902	3.97	1.10	5.08

Table 4.1 shows the energy use profile at the GLT plant for HFO and electricity from January 2009 to December 2010. It shows production in kg and the corresponding energy usage of HFO in l and electricity in kWh. Energy consumption has been converted to energy units of MJ using

the following conversions where the total energy used is shown in the last column in MJ per kg of production

1 MJ = 0.2778 kWh

HHV of HFO = 43.65 MJ/kg = 47.09 MJ/l. (Density of fuel is 0.927 [20])

Plotted in Figure 4.2 is the relationship between electricity use in MJ and production in kg between January 2009 and December 2010.

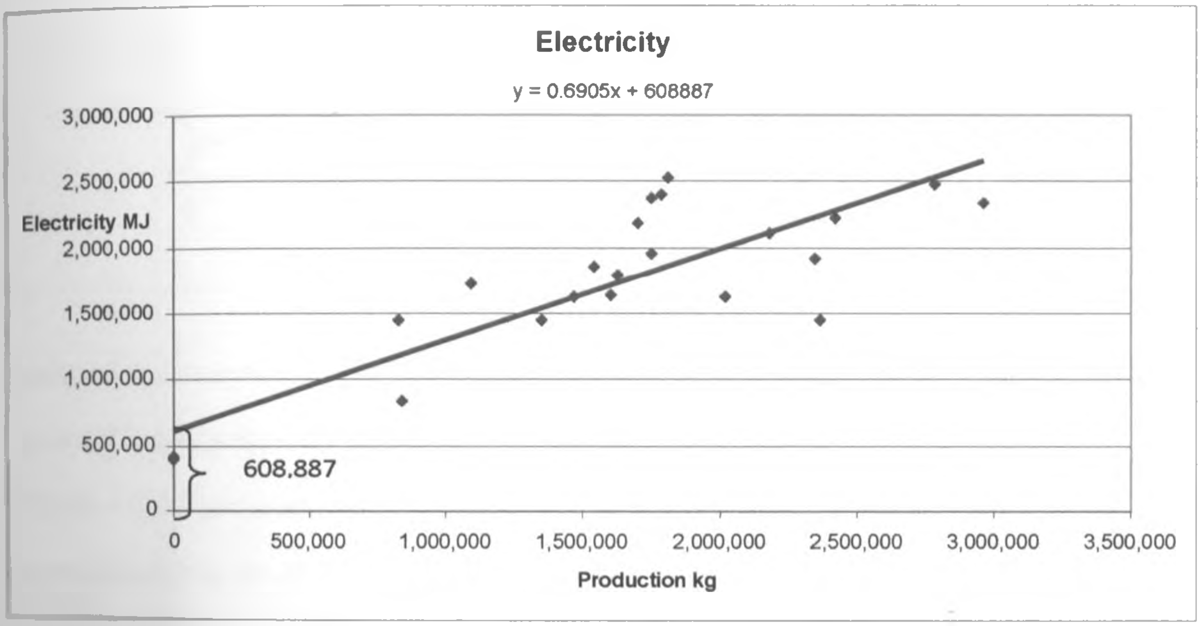


Figure 4.2 Relationship between electricity energy and production from 2009 to 2010

The plot in Figure 4.2 shows a relationship of electricity use as

Electricity MJ = 0.7 x production kg + 608,887 MJ……………………………..(4.1)

The relationship shows that an average 0.7MJ is used for every kg of tobacco processed. 608,887 MJ of electricity used per month is not related to production which is 37% of monthly average use for years 2009 and 2010. This can be attributed to service equipment outside the manufacturing plant not used for production like overhead gantry cranes and water pumping station. However as discussed later in this report an observation was made for equipment in the manufacturing plant running when there was no production during line breakdowns, operation changes. This has been recognized as inefficient in energy use.

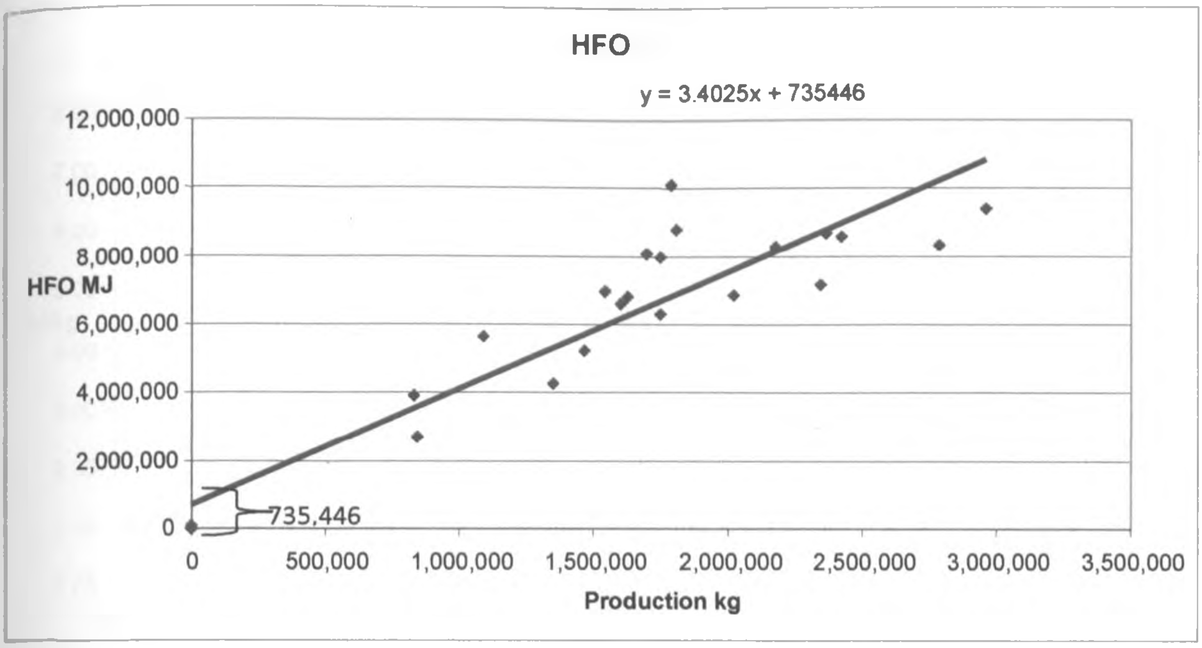


Figure 4.3 Relationship between HFO and production from 2009 to 2010

Figure 4.3 shows a relationship of electricity use as

HFO MJ = 3.4 x production kg + 735,446 MJ.....................................(4.2)

The relationship shows that an average 3.4MJ is used for every kg of tobacco processed. 735,446 MJ of fuel used is not related to production. This is high at 12% of recorded monthly average of years 2009 and 2010. This can be attributed to idle running of boilers during initial pressure rising before production and plant breakdowns. It was observed that during the annual plant shutdown the boilers are run for testing purposes

In both cases on electricity and HFO use, a significant variation is observed in the energy intensity due to the seasonal nature of production between the months. Figure 4.4 shows energy intensities for HFO, electricity and total energy in MJ/kg of tobacco processed between January 2009 and December 2010.

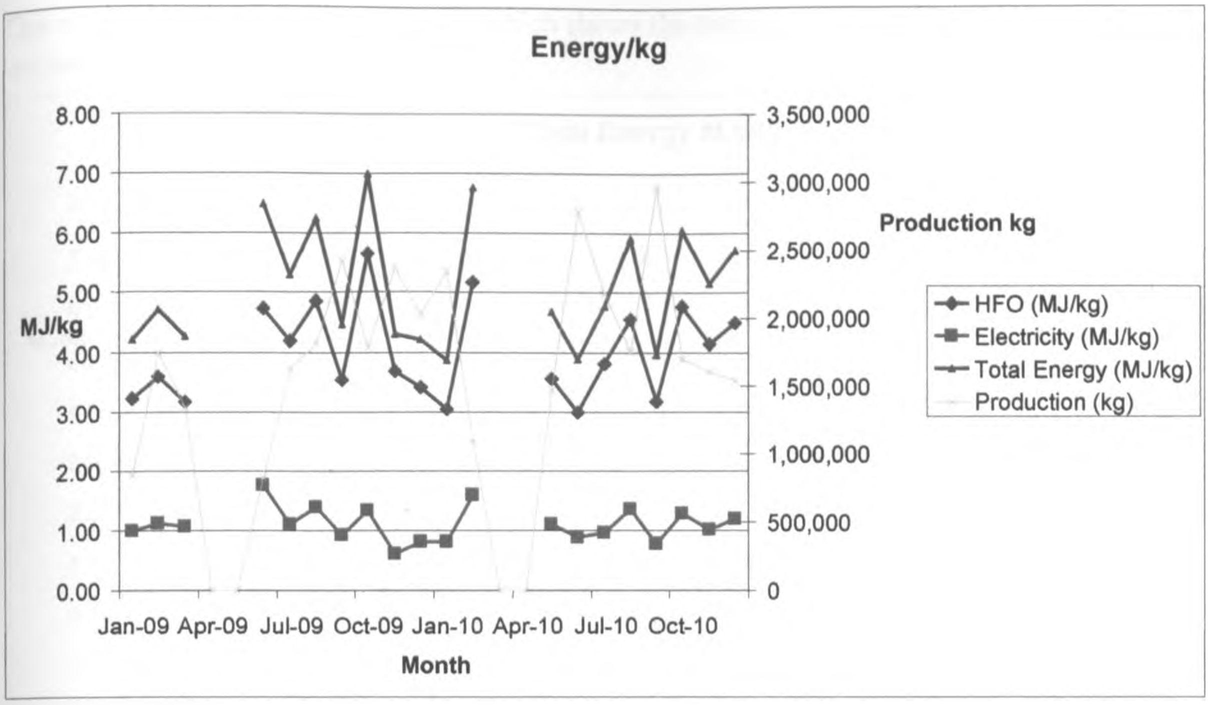


Figure 4.4 Monthly energy intensity trends from 2009 to 2010

There are quite some variations in energy intensities across the production seasons which are dependent on the respective production. Electicity has however shown a steady use. As stated ealier in the relationship of eletricity and production, 37% of eletricity energy use is not related to production and effects of production are minimal in comaprisison to HFO where only 12% of energy use is not influenced by production. The HFO use profile shows an influence by production. The energy intensities are low where production peaks. This shows that as production increases the HFO energy intesities reduce. A similar profile is shown on the total energy as HFO forms a large part of total energy.

This is further illustrated in Figure 4.5 which shows the total energy intensity reduce with increase in production.

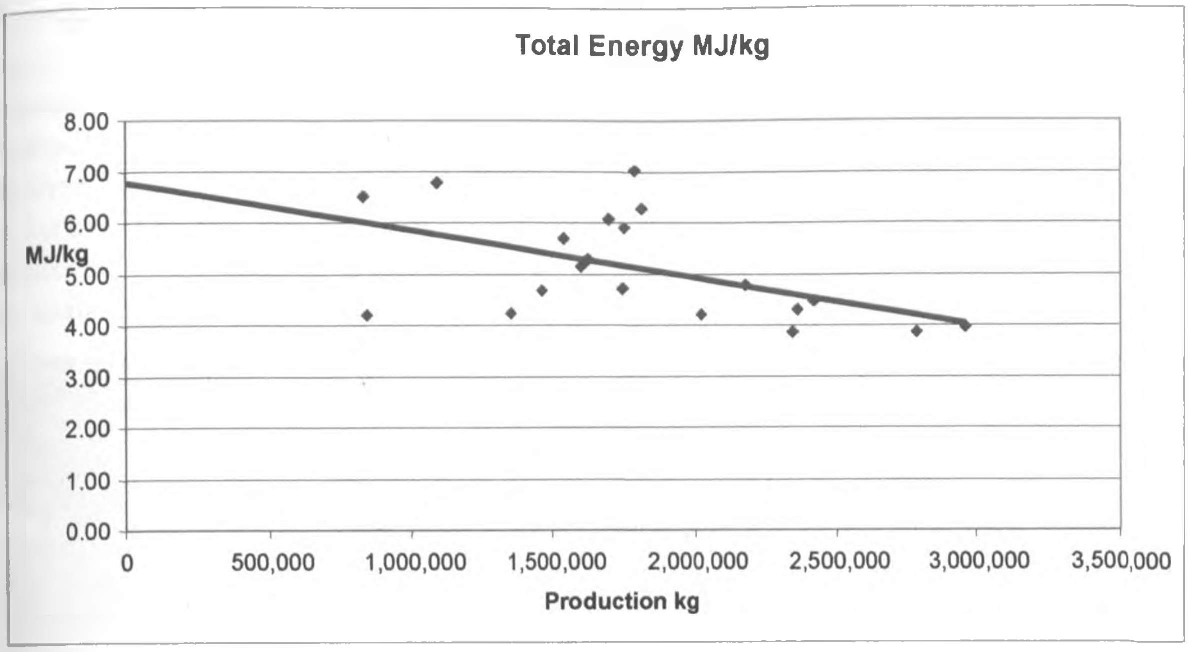


Figure 4.5 Relationship of total energy intensity with production volume

4.4 Boilers and steam distribution system

4.4.1 Boilers

The GLT has installed three boilers. Table 4.2 shows the details of the three boilers in make, rated capacity and rated output pressure.

Table 4.2 Boiler plant details

Boiler no.		Boiler 1	Boiler 2	Boiler 3
Boiler make		Danks of Netherton	Danks of Netherton	Danks of Netherton
Type		Fire tube	Fire tube	Fire tube
Burner make		Harmworthy	Harmworthy	Harmworthy
Rated pressure	bar	9	9	9
Rated capacity	lb/h	8500	8500	15000

As shown in Table 4.2 all the three boilers are HFO fired, fire tube boilers. Normally on full plant production, boiler 3 and either boiler 1 or 2 are run with one boiler on hot stand by. The boilers rated pressure is 9 bar, however in normal operations the boilers supply steam at 8.5 bar with end use equipment pressure range of 5 to 7 bar through pressure reducing valves. Boiler 3 has been fitted with a new burner (installed in 2010) that incorporates an automatic flue gas analyzer with automatic air/fuel control. Boiler 1 shown in Photograph 4.1 has a relatively modern burner, (installed in 2006) however it has a faulty air/fuel control. Air/fuel control is manually set and stays fixed on one position. It was also observed that the mobile flue gas analyzer to assist in this setting is old and frequently breaks down. Few results were achieved using this analyzer during the study. Boiler 2 is rarely run as it has an old burner that often breaks down. The burner has been planned for replacement. For purposes of this report there is no analysis done on this boiler as it was not running most of time during the study period.

Photograph 4.1 Boiler 1

Combustion efficiency and evaporation ratio for boiler 3

Boiler details

Bolier Number		3	
Make		Danks Metric	
Burner		Harmworthy	
Fuel		HFO	
Max continous rating	lb/h	15000	
Max continous rating	kg/h	6819	
Max steam pressure	bar	9	
Normal steam pressure	bar	8.5	
Max steam temperature	°C	175.4	
Normal steam temperature	°C	172.9	
Max fuel consumption	l/h	280.6	

Fuel analysis

Carbon	%	84	estimate [9]
Hydrogen	%	12	estimate [9]
Oxygen	%	0.9	estimate [9]
Sulphur	%	1.9	[20]
Ash	%	0.02	[20]
Moisture	%	0.1	[20]
LHV	kJ/kg	41100	[20]
HHV	kJ/kg	43648	[apendix 1]

Input/output analysis

Final steam pressure	bar	8.5
Final steam temperature	°C	172.9
Feed water temperature	°C	75.4
Air temperature	°C	26.8
Fuel temperature	°C	60
Flue gas temperature	°C	254

Flue gas analysis

Oxygen	%	4.3

Analysis of combustion inputs

Carbon		C	+	O2	=	CO2
		12	+	32	=	44
kg per kg of fuel	=	0.84	+	2.24	=	3.08
Hydrogen		2H	+	O2	=	2H2O
		4	+	32	=	36
kg per kg of fuel	=	0.12	+	0.96	=	1.08

Sulphur	S +	O2 =	SO2
	32 +	32 =	64
kg per kg of fuel =	0.019 +	0.02 =	0.04

Total oxygen

O2 in a kg of fuel

C= 2.24
H= 0.96
S= 0.019
O= -0.01

kg per kg of fuel = 2.24+0.96+0.02-0.01
= 3.21 kg

Air required

% of O2 in air required = 23.3%
kg of air required = 3.21 x 100/23.3
= 13.77 kg
% Excess air = %O2/21-O2% x 100
= 4.3/(21-4.3)x100
= 25.7%

% Excess air = actual air - theoretical air/theoretical air
Actual air kg/kg of fuel = (%excess air x theoretical air) + theoretical air
= (25.7% x 13.77)+ 13.77
Actual air kg/kg of fuel = 17.32 kg

Mass of dry flue gas

= Mass of (CO2 + SO2 + N2 + O2) in flue gas + N2 in air supplied

CO2 0.84 x 44/12 = 3.08
SO2 0.0185 x 64/32 = 0.04
O2 4.3 x 23/100 = 0.99
N2 17.32 x 77/100 = 13.3

Mass of dry flue gas/kg of fuel = 3.08+0.04+0.99+13.3
= 17.4 kg

Heat loss in dry flue gas = mg x Cp x (Tf-Ta)/1kg x HHV x 100
Cp flue gas = 0.23 kcal/k 0.96 kJ/kg/K
Heat loss in flue gas = 17.44 x 0.96278 x (254-26.8)/43648 x 100

Heat loss in flue gas = 8.7%

Heat loss due to combustion of hydrogen
Mass of water formed 1.08 kg/kg of fuel

= mg x Cp x (Tf-Ta)+ m x hfg/1kg x HHV x 100
Cp steam = 0.45 kcal/kg/K = 1.88 kJ/kg/K
hf 26.8 °C= 113
hg 254 °C= 2798.7
= hfg =2799-113 = 2686
= 1.08 x 1.8837 x (254-26.8) + 1.08 x 2686/43648 x 100
= 7.7%

Heat loss due to moisture in fuel
Mass of water formed 0.001 kg/kg of fuel

= mg x Cp x (Tf-Ta)+ m x hfg/1kg x HHV x 100
Cp steam = 0.45 kcal/kg/K = 1.88 kJ/kg/K
hf 26.8 °C= 113
hg 254 °C= 2798.7
= hfg =2799-113 = 2686
= 0.001 x 1.8837 x (254-26.8) + 0.001 x 2686/43648 x 100
= 0.01%

Heat losses through other losses 1%

Boiler efficiency
= 100%- (8.8% + 7.7%+0.01% + 1%)
= 82.5%

Evaporation ratio
Enthalpy of steam = 660 kcal/kg = 2763 kJ/kg
Heat = Boiler efficiency x HHV of fuel/kg of fuel
= 0.825 x 43648
= 36031 kJ/kg
kg of steam per kg of fuel
= 36031/2763
= 13.04
Evaporation ratio =
= 13.04 kg of steam per kg of fuel

Using a similar approach boiler 1 had the following results

Flue gas temperature 203°C

Oxygen in flue gas 13.7%

Excess air 187%

Heat loss in dry flue gas 13.8%

Heat loss due to combustion of hydrogen 7.5%

Heat loss due to moisture in fuel 0.01%

Other heat losses 1%

Boiler efficiency 77.7%

Evaporation ratio 12.27 kg of steam/kg of fuel

Boiler efficiency

Table 4.3 shows a summary of heat losses, boiler efficiency and evaporation ratio for boilers 1 and 3

Table 4.3 Boiler efficiency and evaporation ratio

Boiler Efficiency	**Boiler 1**	**Boiler 3**
Heat loss in dry flue gas	13.8%	8.7%
Heat loss due to combustion of hydrogen	7.5%	7.7%
Heat loss due to moisture in fuel	0.01%	0.01%
Heat losses through radiation and other losses	1.0%	1.0%
Total losses	22.3%	17.5%
Boiler efficiency	77.7%	82.5%
Evaporation ratio kg of steam/kg of fuel	12.27	13.04

ECO 1

The boiler efficiency for the two running boilers 1 and 3 is low at 77.7% and at 82.5% respectively. The following observations in the boiler plant were made. Boiler 3 was replaced in June 2010 with a new burner that incorporates an automatic fuel/air ratio control. This explains the higher efficiency realized in boiler 3 compared to boiler 1.

Stack temperatures are high at 203°C and 254 °C for boilers 1 and 3 respectively which is an indication of poor heat transfer in boiler tubes. This is an indicator of mineral deposits on the external of tubes and soot deposits on internal

Boiler 1 has a very high percentage of excess air at 187% and moderate for boiler 3 at 25.7%. This again is a result of the improper air/fuel ratio control in boiler 1 and poor setting of the automatic air/fuel control in boiler 3. With proper tuning and calibration of air/fuel ratio this can be brought down to optimum excess air levels of 12 to 15% recommended by boiler manufacturers [8, 9]

As a result of the poor boiler efficiency the evaporation ratio is low at 12.3 and 13 kg of steam/kg of HFO fired for boilers 1 and 3 respectively.

ECM 1

From the observations in ECO 1 it is recommended that proper cleaning of boiler tubes and proper regulation of air/fuel ratio to reduce excess air be done to improve the evaporation ratio. Table 4.4 illustrates savings that can be realized with reduced excess air to 12%. An improved evaporation ratio of 13.42 and 13.16 kg of steam/kg of fuel will be realized for boiler 1 and 3 respectively.

With an estimate investment of Ksh 150, 000 on expert service to carry out fine settings of the automatic air/fuel controller for boiler 3 and Ksh 350,000 for boiler 1 to purchase and set a new air/fuel ratio controller monthly savings of up to Ksh 224,648 can be realized with a simple payback period of less than 3 months

Table 4.4 HFO savings from improved boiler efficiency

Item			**Boiler 1**	**Boiler 3**	**Total**
A	Current evaporation ratio kg of steam/kg of fuel	From Workings	12.27	13.04	
B	Evaporation ratio kg of steam/kg of fuel at excess air of 12% [8,9]		13.42	13.16	
C	Current monthly HFO consumption l/month [3]		51,542.33	90,957.05	
D	Density of HFO kg/l [20]	0.927			
E	Current HFO consumption kg/month	=C x 0.927	47,779.74	84,317.19	
F	Proposed optimum fuel consumption l/month	=(A x E)/B	43,690.98	83,560.04	
G	Savings kg/Month	=E-F	4,088.76	757.15	
H	Savings l/month	=G/0.927	4,410.75	816.78	5,227.52
I	HFO cost Ksh/l (average of 2010) [3]	42.97			
J	Savings Ksh/month	=H x 42.97	189,547.47	35,100.14	224,647.60
L	Investment		350,000.00	150,000.00	500,000.00
M	Simple payback months	=L/J	1.85	4.27	2.23

Boiler surface heat losses

Boiler surface temperatures were observed to be very hot. From temperature measurements, boiler 1 was observed to have average temperatures of 72°C, 65°C and 211 °C for front and back surfaces, body and manhole cover respectively and boiler 3 was observed to have average temperatures at 75°C, 65°C and 206 °C for front and back surfaces, body and manhole cover respectively.

Heat losses through boiler surfaces

Boiler 3 back manhole covers

		Radius			Area
1 main manhole	Area 1	0.33	then	$\pi R^2 =$	0.33 m^2
4 inspection doors	Area 2	0.12	then	$\pi R^2 =$	0.14 m^2
	TOTAL				0.47 m^2

Temperature T1 (Current) 206 °C = 479.15 K

Temperature T2 (Ex Lagged) 37 °C = 310.15 K

Heat transfer coefficient for steel h= 15 [9]

Heat transfer Q = h x A x (T2-T1) = 15 X 0.47 X (479.15-310.15)

= 1,184.6 W

Operational time per day = 24h = 86400 s

Power Q = 1,184.6 X 86400/1000

= 102,352 kJ

HHV HFO 43648 kJ/kg

Ideal HFO waste/day = 102,352/43648 = 2.34 kg

HFO density = 0.927 kg/l

Ideal HFO litres waste/day = 2.34/0.927 = 2.53 l/day

Boiler 1 efficiency 0.83

Actual HFO litres waste = 2.53/0.83 = 3.06 l/day

Using the same approach, the following results in Table 4.5 were evaluated from the rest of boiler surfaces.

Table 4.5 HFO loss from heat loses through boiler surfaces

Surface	Area m^2	Surface temperature °C	Heat loss kW	HFO loss l/day
Boiler 1 back manhole covers	0.48	211	1.2	3.43
Boiler 1 front/back	6.95	72	3.6	10.02
Boiler 1 body	27.00	65	11.3	31.18
Boiler 3 back manhole covers	0.47	206	1.2	3.06
Boiler 3 front/back	6.93	75	3.9	10.21
Boiler 3 body	31.40	65	13.2	34.11
TOTAL	73.22		34.6	92.02

ECO 2

The observations made on high boiler surface temperatures of 72 to 211°C for boiler 1 and 75 to 206°C for boiler 3 shows a lot of energy wastage through surface radiation. This shows a failure in boiler lagging in the boiler surfaces and no lagging on areas around the furnace manhole and other inspection covers.

ECM 2

It is recommended that the proper boiler lagging be carried out for the boiler surface temperature to be lowered. Table 4.6 shows effects of heat loss through surface radiation amounting to a monthly equivalent of 1,840 litres of HFO per month and a cost of Ksh 79,090. This can be saved with an estimated investment of Ksh 800,000 and a simple payback time of 10 months.

Table 4.6 HFO savings from boiler surface heat losses

Item	**Description**	**Formulae**	**Boiler 1**	**Boiler 3**	**Total**
A	Actual HFO lost l/day	From table 4.5	44.63	47.39	92.02
B	Operation days per month	5 days x 4 weeks	20.00	20.00	
C	Actual HFO lost l/month	=A x B	892.63	947.79	1,840
D	HFO cost Ksh/l [4]		42.97	42.97	
E	HFO cost Ksh/month	=C x D	38359.82	40730.51	79,090.33
F	Investment Ksh		300,000.00	500,000.00	800,000.00
G	Simple payback months	=F/E	7.82	12.28	10.12

Boiler water quality

The GLT boiler plants normally use water directly from the local water company.

The GLT also operates a borehole normally for use in the fire hydrant and hose reel systems. However it was observed that during prolonged water shortages the borehole water was occasionally directly used as make up water for the boilers in the absence of any water purification systems like a reverse osmosis (RO) plant.

In general the water from the local water company is acceptable for use. However there still exists some level of hardness in the feed water at an average of TDS 212ppm.Table 4.7 shows results of water TDS analysis that was carried out for three months at the boiler plant

Table 4.7 Boiler and water TDS

	TDS ppm		
	9/8/2010	3/9/2010	29/10/2010
Make up water			
Feed water	74.9	203	221
Condensate	24.7	20.8	1683
Boiler 1	3290	4010	6880
Boiler 2	927	1927	1948
Boiler 3	4680	8940	3480
Target boiler maximum	3000	3000	3000

The GLT processing season starts in May/June and boiler TDS were observed on the higher side but closer to target of manufacturers recommended maximum of 3000ppm.

It was also observed as the process season progresses higher boiler TDS results due to occasional usage of borehole water (author observed this in the month of September for four days during a prolonged water shortage)

It was also observed that boiler 3 was drained of contaminated (bore hole) water in the month of September which explains the lower TDS in October of 3480ppm down from 8940ppm in September

Also observed from the results is a high level of condensate contamination in October resulting in a TDS of 1683ppm.

Boiler 2 was observed to have low TDS through out as it was rarely run.

Blow down system

The boilers were fitted with intermittent blow down systems only. There was no manual or automatic continuous blow down systems installed.

Intermittent blow down was normally carried out once every eight hour shift when TDS is within recommended limits and two times every eight hour shift when TDS is higher than recommended maximum levels of 3000ppm

Table 4.8 shows the effects of blow down on energy consumption in comparison to a scenario where water is purified before use at the boiler plant.

Table 4.8 Blow down

	Boiler 3			**Boiler 1**		
Treated water in RO plant	FW TDS	4.24				
(Estimated 98% solids removed)		5455.08 kg/h			3284.41275 kg/h	
		FW TDS x %MU /Max B TDS		=	FW TDS x %MU /Max B TDS	
		4.24 x 20/3000		=	4.24 x 20/3000	
		0.03 %		=	0.03 %	
		5455 08 x 0.03/100		=	5455 08 x 0.03/100	
Ideal blow down Rate	=BD1	1.54 kg/h		=BD1	0.93 kg/h	
3/9/2010	**FW TDS**	**203**				
	Bolier 3			Boiler 1		
Estimate boiler steam flow rate		5455 08 kg/h			3284 41 kg/h	
Blowdown	=	FW TDS x %MU /Max B TDS		=	FW TDS x %MU /Max B TDS	
	=	203 x 20/3000		=	203 x 20/3000	
	=	1.35 %		=	1.35 %	
	=	5455 08 x 1.35/100		=	5455.08 x 1.35/100	
	= BD2	73.83 kg/h		= BD2	44.45 kg/h	
Loss due to excess blowdown	**=HL 1**	**72.28 kg/h**		**=HL 1**	**43.52 kg/h**	
29/10/2010	**FW TDS**	**221**				
	Bolier 3			Boiler 1		
Estimate boiler steam flow rate		5455.08 kg/h			3284.41275 kg/h	
Blowdown	=	FW TDS x %MU /Max B TDS		=	FW TDS x %MU /Max B TDS	
	=	221 x 20/3000		=	221 x 20/3000	
	=	1.47 %		=	1.47 %	
	=	5455.08 x 1.47/100		=	5455.08 x 1.47/100	
	= BD2	80.37 kg/h		= BD2	48.39 kg/h	
Loss due to excess blowdown	**=HL 2**	**78.83 kg/h**		**=HL 2**	**47.46 kg/h**	
Average loss due to blowdown	**(HL1+HL2)/2**	**75.56 kg/h**		**(HL1+HL2)/2**	**45.49 kg/h**	
	172.9	hfbd	731.86		hfbd	731.86
	26.8	hfmu	113.1		hfmu	113.1
	(hfbd-hfmu)	=	618.76			618.76
Heat loss due to blowdown		(BD2-BD1) x (hfbd-hfmu) / ηb			(BD2-BD1) x (hfbd-hfmu) / ηb	
Boiler efficiency		0 83			0.78	
		192.75 x (731.86-113.1) / 0.83			116.05 x (731.86-113.1) / 0.78	
		56634.41609 kJ/h			36238.89 kJ/h	
Actual heat loss due to blow down		46751.34 kJ/h			28148.20 kJ/h	
HHV fuel =		43648				
Fuel savings kg/h	=	46751.34/43648			28148.2/43648	
Fuel savings	=	1.07 kg/h			0.64 kg/h	
Fuel density		0.927 kg/l			0.927 kg/l	
Fuel savings	=1 07/0.927=	1.16 l/h		=0 64/0.927=	0.70 l/h	

ECO 3

The boilers are operating at high TDS of average 4726ppm for boiler 1 and 5700ppm for boiler 3. Feed water TDS was also observed high at average of 212ppm (average of September and October measurements). This results to energy wastage through excessive boiler blow down that also wastes boiler treatment chemicals.

Currently with feed water TDS of 212ppm required blow down to maintain boiler at 3000ppm is 1.41% .This results to excess blow down equivalent to 46kg/h for boiler 1 and 76kg/h for boiler 3 in comparison to usage of treated boiler make up water.

The use of borehole water as direct feed water need to be stopped and appropriate water treatment processes be installed.

ECM 3

The GLT is recommended to install a water treatment plant. With a reverse osmosis treatment plant, boiler make up water TDS can be lowered by 98% to 4ppm [21] .This would require only blow down of 0.03% to maintain boilers at TDS of 3000ppm.

Table 4.9 shows the effects of installing a water treatment plant on energy use. With installation of a water treatment plant a total monthly savings of 889 litres of HFO and a cost of ksh 38,184 can be realized with an investment of Ksh 862,200 and payback of less than 2 years.

Table 4.9 HFO savings due to improved blow down

Item	**Description**	**Formulae**	**Boiler 1**	**Boiler 3**	**Total**
A	Fuel savings l/h	From Table 4.8	0.70	1.16	
B	Average run h/month	=24hours x 20days	480	480	
C	Fuel savings l/month	=A X B	333.92	554.61	888.53
D	Fuel cost Ksh/l [4]		42.97	42.97	
E	Fuel savings Ksh/month	=C x D	14349.94	23833.80	38,183.74
F	Investment				862,200.00
G	Simple payback months	=F/E			22.58

4.4.2 Steam distribution and condensate recovery system

Figure 4.10 shows the layout of the boiler plant, steam consuming equipment, condensate pump and respective distribution pipe work in the GLT site. Steam generated at the boilers is supplied to the two process halls through a main steam header to the various steam consuming equipments. Condensate is piped to a condensate pump located between the two process halls and pumped back to the boiler plants.

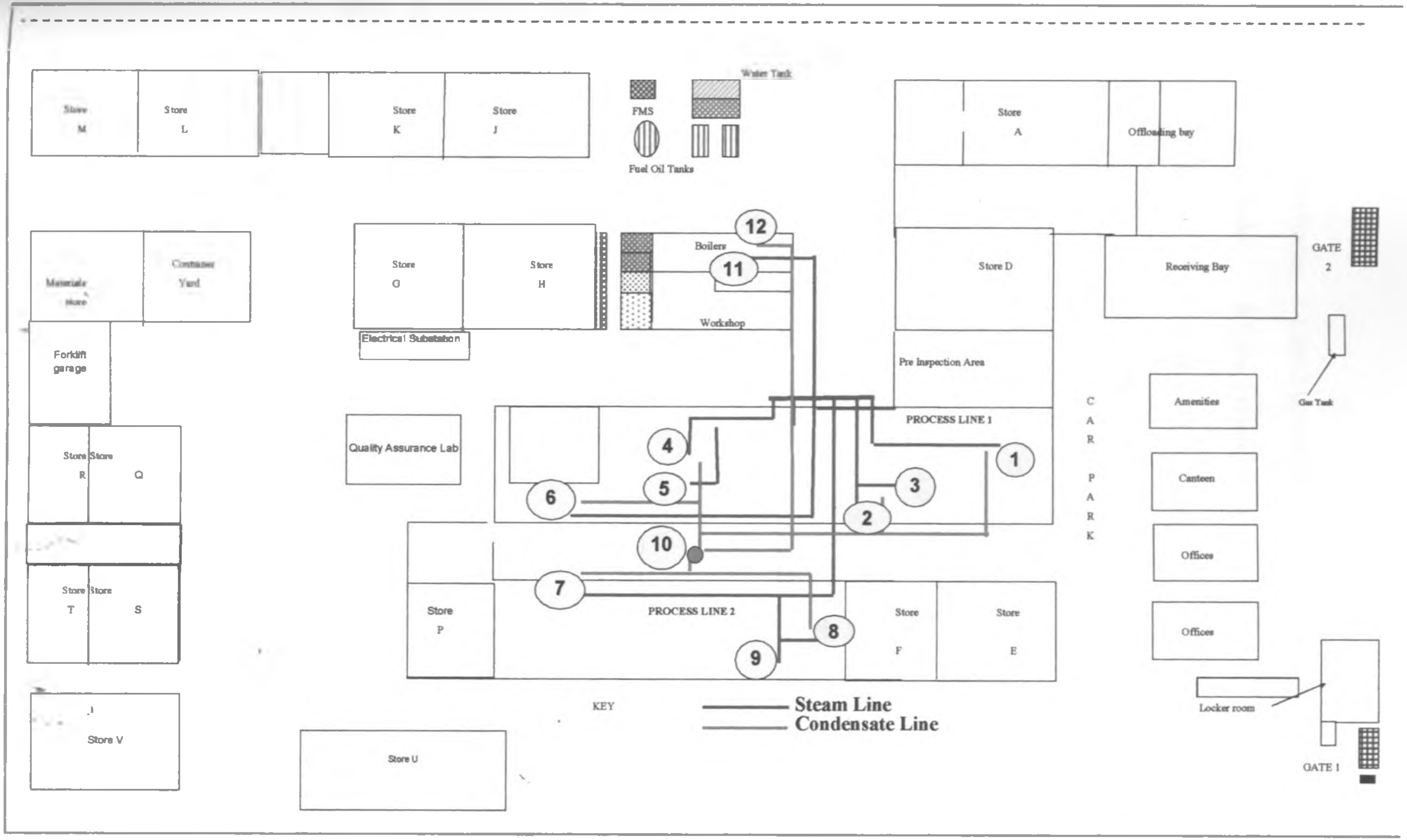


Figure 4.6 Steam distribution and condensate recovery system

Equipment key

1 Secondary conditioning cylinder

2 Primary conditioning cylinder

3 Tips conditioning cylinder

4 Stems drier

5 Fines drier

6 Line 1 lamina drier

7 Line 2 lamina drier

8 Line 2 conditioning cylinder

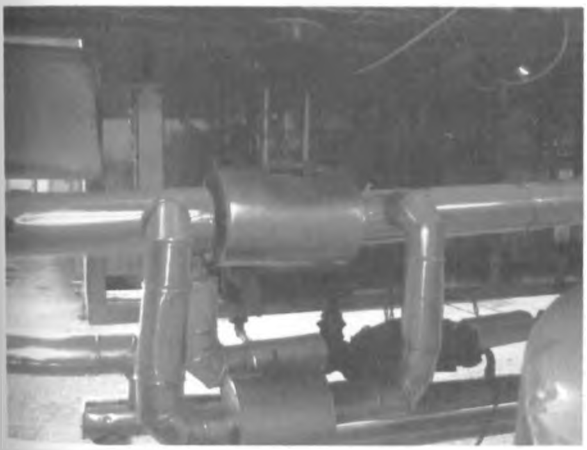
9 Line 2 conditioning box

10 Condensate pump

11 Boilers

12 Boiler feed water tank

It was observed that the distribution network is well laid out and largely lagged to the end user appliances. Supply into end user equipment is through pressure reducing valves. It was observed that while there has been good attempt to insulate steam line and steam line accessories in some areas (flanges, valves, all traps, strainers etc) there are still a lot of accessories that have hot surfaces exposed. Photograph 4.2 shows a well lagged steam line and valve while the Photograph 4.3 shows poorly lagged valves with exposed hot surfaces. Photograph 4.4 shows un-lagged steam lines grouped into a trap which is a poor practice.



Photograph 4.2 Well lagged pipes, valves and steam line accessories

Photograph 4.3 Poorly lagged valves

Photograph 4.4 Poor lagging line 2 cylinders (group trapping a poor practice)

Several steam leaks were also observed through leaking joints and valves. Photograph 4.5 shows a steam safety valve at the stems drier continuously leaking steam, due to a poor valve seat.

Photograph 4.5 A leaking safety valve

Steam is supplied into the line from main steam header through five lines to

- Three conditioning cylinders in line 1
- Two conditioning cylinders and the lamina drier in line 2
- Lamina drier in Line 1
- Stems drier in line 1
- Fines drier in line 1

4.4.3 Tobacco conditioning cylinders

Steam is used in the conditioning cylinder through three application systems. The steam is supplied through a pressure reducing system to 5 bar from boiler pressure of 8.5 bar. The product at entry moisture content of 15% average and ambient average temperature of 25°C leaves the cylinder at moisture content of 19% to 22% and temperature of 45°C to 60°C. Typical product through put is on average 5500 to 6000 kg/h. The steam is applied in the conditioning cylinder through the following processes

Direct application to product

In this system steam is directly injected into a rotating conditioning cylinder drum and applied into the product through steam nozzles. Air is circulated in the cylinder drum that enables mixing and absorption by product. A lot of flash steam was observed coming out of the product entry and exit ports of the conditioning cylinders. It was estimated from Table 4.12 that on average 51% of steam applied directly to the product is not absorbed in the product and hence flashed off. It was also observed none of this steam is recovered as condensate.

Supply into a steam air radiator

In this system steam is supplied into steam to air heat exchangers (radiators). An air fan blows air and circulates the heated air into the cylinder. The air is re-circulated and some exhausted once the air is too moist depending on product exit moisture conditions. It was observed that heat is lost when the heated air is exhausted. It was observed that nearly 100% condensate from the radiators is recovered through steam traps and pumped back to the boiler feed water station.

Atomizing agent for water jets

Steam is applied through a water nozzle to atomize water into a mist. The water mist and steam mixture is applied directly to the product through nozzles. The steam supplied this way is not recovered back as condensate.

4.4.4 Tobacco driers

Lamina drier

In the driers steam pressure is reduced to 5 bar from the boiler pressure of 8.5 bar through pressure reducing valves. Tobacco is dried on a perforated steel apron drier using heated air circulation. The air is circulated by several axial fans blowing air through steam to air heat radiators. At the end of the drying process steam and atomized water are applied direct to the product to correct moisture content to the packing specification. The product enters the drier at average moisture content of 17% and average temperature of 35°C and exits at average moisture content of 12.5% and average temperature of 40°C.

Steam is applied in the drier in three methods.

In the first method steam is supplied to steam to air radiators. Axial fans inside the drier circulate air through the steam to air radiators into the product through a perforated apron. Moist heated air is normally exhausted. The lamina drier has ten radiators in five drying zones. Air temperatures range from 60 to 80°C in this system and nearly 100% condensate is recovered through steam traps. Photograph 4.6 shows an axial fan directly above a steam to air radiator for heated air circulation.

Photograph 4.6 Radiators and axial fans in drier

Steam applied directly to product

In the second method, steam is applied directly to the product at the end of the drying process through steam nozzles to correct product moisture content to packing specification. In this system, axial air fans circulate the air and steam mixture through the perforated apron drier into the product. Again as in conditioning cylinders, approximately 51% of this steam is not absorbed in the product and is exhausted as flash steam. Photograph 4.7 shows a steam pipe with steam nozzles for steam jet supply and an axial air fan above to circulate the air.

Photograph 4.7 Axial fan and steam pipe with nozzles for moisture-correction

Fire hydrant

In the third method, steam is supplied into the drier as a fire hydrant in the unfortunate event of product fire in the dryer. In this process, steam is purged in the drier to put out the fire. It was observed that this has never happened and never been used in the GLT plant.

Stem drier

Steam is applied in the stems drier as in the drying process of the lamina drier. Heated air through radiators is circulated by axial fans through a perforated bed apron drier and is exhausted out once moist. Nearly100% condensate is recovered back to boilers feed water through steam traps. In this drier steam is reduced to 7 bar from boiler pressure of 8.5 bar. Typical air temperatures are around 100 to125 °C

Fines drier

Fines are dried in a cylindrical drier. Air is heated in a steam to air radiator and circulated in the cylinder similar to the conditioning cylinder discussed earlier in this report. Moist air is exhausted. Typical air temperatures are at 40 to 60°C

4.4.5 Condensate recovery system

It was observed that the GLT has a good condensate recovery system that comprises of orifice steam traps and two Ogden condensate recovery pumps. It was observed that all the steam traps are installed with lagging. However the lagging material is not as efficient as normal lagging. Surface temperatures for traps lagging was observed at average of 44°C in comparison to 37°C for normal lagging installed in the GLT steam distribution lines. Photograph 4.8 shows a steam trap number 41 with a strainer. Also shown is trap lagging supplied with the trap.

Photograph 4.8 Orifice steam trap

Two Ogden pumps shown in photograph 4.9 pump condensate back to the boiler feed water tank. However it was observed that there is insufficient lagging at the pump station. Also observed was high pressure flash off steam from the pumps.

Photograph 4.9 Ogden pumps for pumping condensate. Note poor lagging

The condensate recovery network was observed as not well lagged with large potions of pipe work left bare. A lot of the condensate pipe system was observed to run inside water drainage channels that have resulted in damaged lagging materials and reduces heat due to cooling effects of water. Photograph 4.10 shows a poorly lagged condensate drain lines running in water drain channels

Photograph 4.10 Un-lagged condensate pipes in underground drain channel

Table 4.10 shows the effects of un-lagged steam distribution and condensate return systems due to hot surface radiation.

Table 4.10 Losses in steam distribution and condensate recovery system

Steam distribution system					
Total unlagged area	Dia (inch)	Diam (m)	Circ (m)	L (m)	Area (m²)
Area 1	6	0.15	0.48	6.4008	3.06
Area 2	4	0.10	0.32	39	12.44
Area 3	2.5	0.06	0.20	11	2.19
Area 4	1.5	0.04	0.12	108.2	12.94
Total area (A1+A2+A3+A4)					30.64 m²
Temperature T1 (Unlagged) =	155 °C =		428.15 K		
Temperature T2 (Ex Lagged) =	37 °C =		310.15 K		
Heat transfer coefficient for steel h=	15 [9]				
Heat transfer Q =	hA(T2-T1)	=	15 X 0.47 X (428.15-310.15) =		54,237.47 W
Operational time per day =	24h	=	86400 s		
Power Q =	54,237.5 X 86400/1000 =			4,686,117 kJ	
HHV HFO			43648 kJ/kg		
Ideal HFO waste/day =	4,686,117.35/43648 =		107.36 kg		
HFO density =			0.927 kg/l		
Ideal HFO litres waste/day =	107.36/0.927 =		115.82 l/day		
Boiler efficiency	(average boiler 1 and 3)		0.80		
Actual HFO litres waste =	**115.82/0.8 =**		**144.57 l/day**		
Condensate return system					
Total unlagged area	Dia (inch)	Diam (m)	Circ (m)	L (m)	Area (m²)
Area 1	4	0.1016	0.319024	23.4	7.47
Area 2	10	0.254	0.79756	4	3.19
Area 3	1.5	0.0381	0.119634	22	2.63
Area 4	1	0.0254	0.079756	3	0.24
Total area (A1+A2+A3+A4)					13.53 m²
Temperature T1 (Unlagged) =	80 °C =		353.15 K		
Temperature T2 (Ex Lagged) =	30 °C =		303.15 K		
Heat transfer coefficient for steel h=	15 [9]				
Heat transfer Q =	hA(T2-T1)	=	15 X 0.47 X (353.15-303.15) =		10,144.96 W
Operational time per day =	24h	=	86400 s		
Power Q =	10,144.96 X 86400/1000 =			876,525 kJ	
HHV HFO			43648 kJ/kg		
Ideal HFO waste/day =	876,524.82/43648 =		20.08 kg		
HFO density =			0.927 kg/l		
Ideal HFO litres waste/day =	20.08/0.927 =		21.66 l/day		
Boiler efficiency	(average boiler 1 and 3)		0.80		
Actual HFO litres waste =	**21.66/0.8 =**		**27.04 l/day**		

ECO 4

The steam distribution has largely been lagged. Also observed was an effort to lag steam line accessories. Also observation was that all steam traps were supplied with lagging which is good practice. Average temperatures on lagged surfaces at 37°C were observed. However there were several areas observed as bare. From observations and measurements of the steam distribution system a total of 30.64 m² of bare pipe was observed with surface temperatures of 155°C. These results in a total loss of energy equal to 145 litres of HFO per day. Similarly the condensate system was observed to have total bare area of 13.5m² at temperatures of 80°C equal to a loss of 27.5 litres of HFO per day.

ECM 4

Table 4.11 shows effects of heat losses due to un-lagged hot surfaces in the steam distribution and condensate recovery systems on energy usage and savings. It is recommended that all steam distribution piping and accessories are all lagged to reduce surface heat loss. The condensate lagging should be replaced as most of it is currently damaged. The condensate piping should also be removed from water drain channels as this will result to continued damage to lagging materials. An estimate investment of Ksh 700,000 to bring back the surface temperatures to existing surface temperatures of lagged portions of 37°C will have a simple payback period of 5 months.

Table 4.11 HFO savings due to lagging distribution lines

Item	Description	Formulae	Steam	Condensate	Total
A	Actual HFO lost l/day	From Table 4.10	144.57	27.04	
B	Operation days per month	5 days x 4 weeks	20.00	20.00	
C	Actual HFO lost l/month	=A x B	2891.34	540.82	3,432.16
D	HFO cost Ksh/l [3]		42.97	42.97	
E	HFO cost Ksh/month	=C x D	124252.59	23241.09	147,493.68
D	Investment Ksh		500,000.00	200,000.00	700,000.00
F	Simple payback months		4.0	8.6	4.7

4.4.6 Flash steam from conditioning units

It was observed that a lot of flash steam is generated from process systems where direct application of steam to product is done in the conditioning units of the plant and from the condensate pumping station. Photograph 4.11 shows high pressure flash steam from the condensate pump station. This can be an indication of a trap failure. Photograph 4.12 shows flash steam from the exhaust stacks of two lamina driers in process line 1 and 2.

Photograph 4.11 High pressure flash steam from condensate pumps

Photograph 4.12 Flash steam and hot vapor from drier exhaust

ECO 5

The steam usage in the GLT plant is mostly inefficient as a lot of steam is applied directly to product that results to a lot of flash steam losses. This was observed in the conditioning cylinders and the conditioning zones of the driers. The radiators however were better in steam utilization as steam was consumed and converted to condensate. All the condensate from radiators was recovered. Flash steam and hot vapor from all the conditioning processes can be utilized for air or product pre-heating in the conditioning and drying processes. The boiler plants consume make up water at average rates of 1822 l/h. This was assumed to equal the steam applied directly to product in conditioning processes and moisture correction in the driers as this was largely not recovered. Table 4.12 shows estimate flash off steam when steam is directly applied to product. Shown in the table is that 892 kg per hour of steam is absorbed directly in the product with the rest lost through flash off. Also shown is that 930 kg/h of steam is lost to flash steam which is 51% of steam applied directly to product at nearly 100°C.

Table 4.12 Flash off steam from direct application of steam to product

			Line 1equipment			Line 2 equipment		
Item	Description	Formulae	Primary conditioning	Secondary conditioning	Line 1 drier moisture correction	Steam box	Line 2 conditioning cylinder	Line 2 drier moisture correction
A	Product entry moisture %		16%	18%	11%	16%	16%	12%
B	Product exit moisture %		20%	22%	13%	20%	20%	15%
C	Feed throughput kg/h		6000	6000	6000	2000	2000	2000
D	Product yield % of feed throughput kg/h	Actual product into equipment	100%	80%	65%	100%	100%	80%
E	Gross throughput into equipment kg/h	=C x D	6000	4800	3900	2000	2000	1600
F	Actual moisture in product feed kg/h	=A x E	960	864	429	320	320	192
G	Dry basis throughput into equipment kg/h	=E-F	5040	3936	3471	1680	1680	1408
H	Gross throughput of exit product kg/h	=G/(1-B)	6300	5046	3990	2100	2100	1656
I	Net moisture gain from equipment kg/h	=H-E	300	246	90	100	100	56
J	Steam absorbed in product	=Sum of all moisture gains (I)	892					
K	Steam consumed in direct product application kg/h	Steam supplied - condensate return kg/h=equals make up water kg/h (assumption)	1822					
L	Flash off kg/h	=K - J	930					
M	Flash off % of steam consumed	=L/K	51%					

ECM 5

Table 4.13 shows effects on energy recovery in flash steam. From Table 4.12, 930kg of steam is flashed off. The energy in the flash off steam can be recovered and used to preheat product before entry into cylinders and air before it is heated in steam radiators. The efficiency of heat recovery systems is approximately 60% [8]. The recovery of 60% of this energy will realize a fuel saving of 18,665 litres of HFO per month. An estimated investment of Ksh 4 million will have a simple payback period of 5 months

Table 4.13 Effects of steam flash off on energy consumption

Item	**Description**	**Formulae**	**Values**	**Units**
A	Flash off	From Table 4.12	930	kg/h
B	Flash off steam temperature		100	˚C
C	Operation time per day		24	hrs
D	flash steam per day	=A x C	22,308.93	kg/day
E	Estimate energy at	= hfg at 100˚C [19]	2256.9	kJ/kg
F	Energy in flash steam	=D x E	50,349,014.64	kJ/day
G	Estimate heat recovery transfer efficiency 60% = [8]	F x 60%	30,209,408.78	kJ/day
H	HHV for fuel	Appendix 1	43648	kJ/kg
I	kg of fuel recovery on flash steam	=G/H	692.1	kg/day
J	Operation time per month	5 days x 4 weeks	20	days
K	HFO recovery in flash steam	=I x J	13,842.17	kg/month
L	Boiler efficiency (average of two boilers) =		0.80	
M	Actual HFO recovery	=K/L	17,302.72	kg/month
N	HFO density [20]		0.927	kg/l
O	HFO litres recovered	=M/N	18,665.28	l/month
P	Cost of HFO [3]	Average for 2010	42.97	Ksh/l
Q	Total monthly cost recovered	O x P	802,121.82	Ksh/month
R	Investment		4,000,000.00	Ksh
S	Simple payback period	=R/Q	5.0	months

4.5 Electricity system

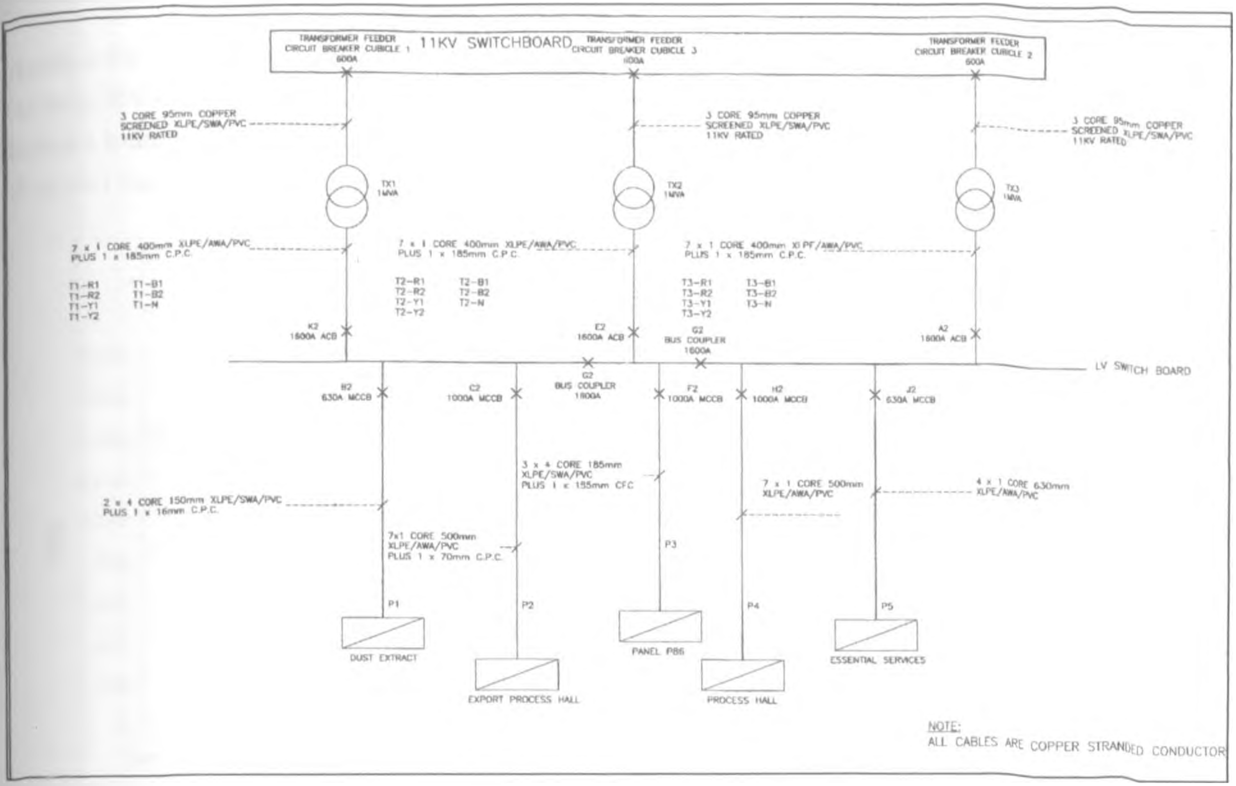


Figure 4.7 Electricity supply and distribution system schematic diagram

Figure 4.7 shows a schematic diagram of the electricity distribution system in the GLT plant. Electricity is mainly supplied to the GLT plant by the Kenya Power and Lighting Company. Details of supply are as voltage of 11kV, 3 phases and neutral with capacity of 1500kVA. The incoming supply is then stepped down through three 1000kVA 11kV/415V transformers that then supply into the low voltage (LV) distribution boards. Two standby generator sets each of 800kVA supply the LV distribution board on the 415V bus-bar side through a manual change over switch. The LV board distributes electricity to five process motor control centers (MCC) and one electrical services distribution board (for office appliances, site lighting and factory support services of boiler plant and water pumping station). A 375kVA generator set also supplies the electrical services distribution board directly through an automatic change over switch gear in the event an external power outage occurs.

4.5.1 Electricity demand and power factor

The average installed demand in the GLT plant is 1206kVA. However it was observed that from January 2009 to December 2010 demand has shown peak levels of 1620kVA in 2009 and 1420kVA in 2010 in some months [4]. Demand is billed as the highest continuous peak for 30 minutes for every billing month [11]. Figure 4.8 shows the demand trend in kVA for the period January 2009 to December 2010. The year 2010 was observed to show a more controlled demand trend than previous year 2009 where demand had an erratic pattern. Low demand was observed during process annual shutdown periods normally between March and June

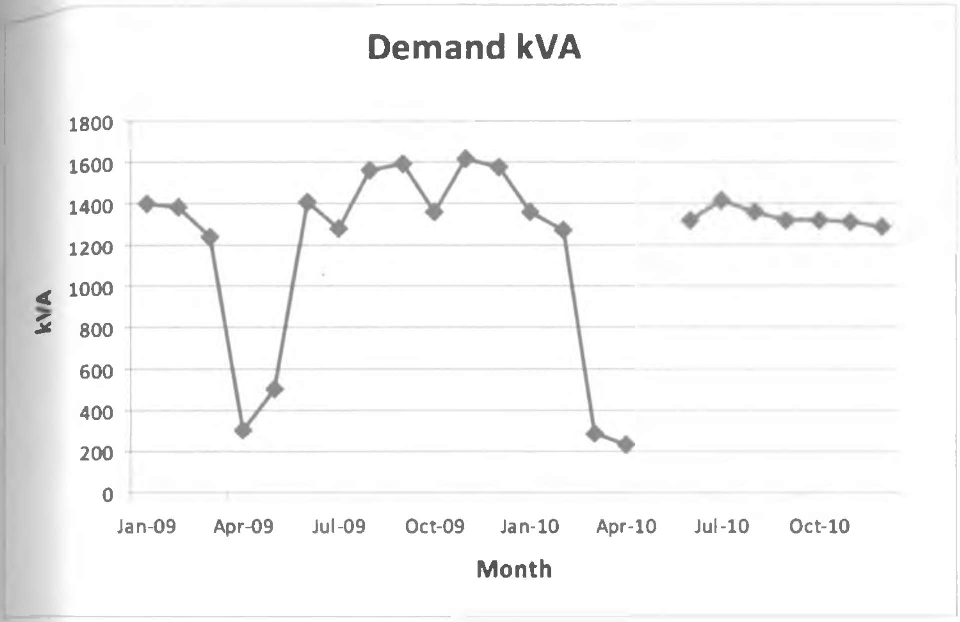


Figure 4.8 Electricity demand kVA trends

All the power factor correction capacitor banks in the GLT are installed at the main LV distribution board and at the five motor control centres. The annual average PF stands at 0.9 which can be improved. Figure 4.20 shows PF values for the period January 2009 to December 2010. A similar trend to the demand plot in Figure 4.9 is seen with an erratic PF pattern in 2009 and a more controlled but falling trend in 2010. There are several months where low power factor was observed that resulted in several surcharges billed against the GLT Plant. From Figure 4.19 PF lows of 0.8 in August 2009 have been observed and a continued falling trend from October 2010 to the end of year.

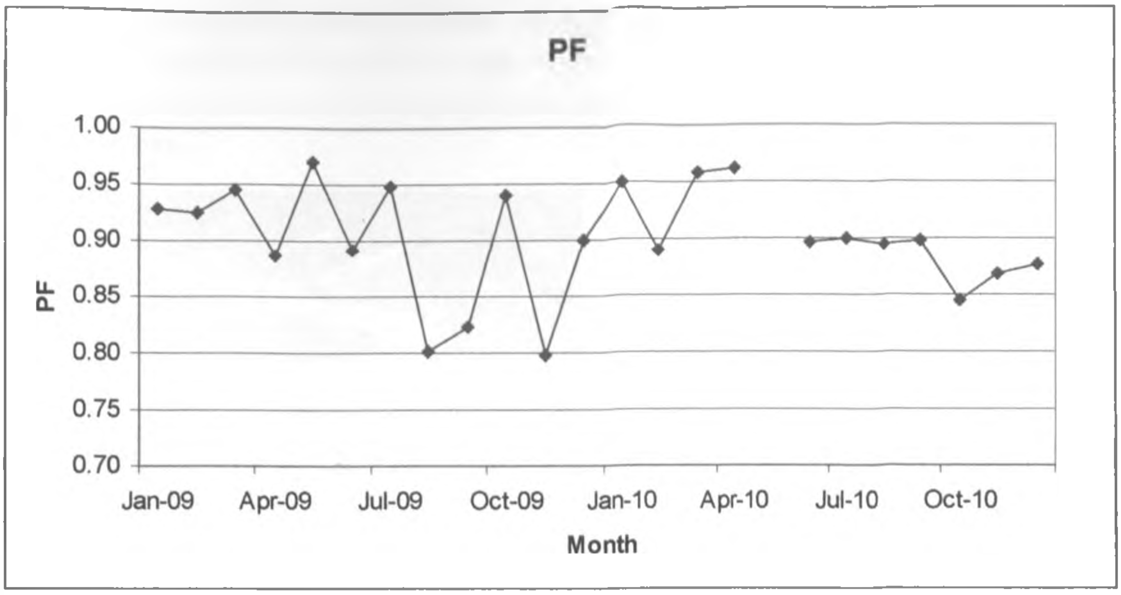


Figure 4.9 PF trends

ECO 6

Observations from demand and PF trends show there is poor load control and PF correction capacity. Better load control to reduce demand needs to be applied as observed on failures in three soft starters in the high rated fan motors in the dust plant that were observed not replaced. Instead an older cheaper star to delta switching was being used which consumes more load during start up.

ECM 6

It is recommended that PF correction be installed to improve average PF to as close to unity as possible. It is also recommended to use soft start on all high power rated motors. For the year 2009 and 2010 PF surcharges stood at Ksh 1,702,834 and 654,948 respectively. This is an average of Ksh 1,179,391 for the years 2009 to 2010. An investment of Ksh 1,167,000 for a PF correction bank will have a simple payback time of one year.

4.6 Factory lighting

Factory lighting in the two process lines mainly consists of 40W twin fluorescent lights all fitted with electromagnetic ballast

Factory lighting is supplied in two ways as general high level lighting of the factory installed at heights of 6m to 8m above floor level and lighting for product visual inspection installed at 2m to 3m above floor level. The factory has also installed translucent skylights in the roof of the process halls for lighting during the day. Photograph 4.13 shows low level product visual inspection lights and Photograph 4.14 shows roof translucent sky lights installed in the roof of the building. Also shown in Photograph 4.14 are general high level lights which are switched off during the day.

Photograph 4.13 Lights for visual inspection of product

Photograph 4.14 Roof sky light showing ceiling lights off during the day

The total power fittings is 2 by 270 twin fluorescent tube fittings for general high level lighting and 2 by134 twin fluorescent fittings for visual product inspection lighting. All the fluorescent tube fittings are installed with electromagnetic ballast control gear. Most lights were observed to be grouped into common switching gear that allows for large potions of factory to be lit even if other areas are not operational.

Illumination

Table 4.14 shows the measured illuminance levels in lux in various parts of the manufacturing plant. The illuminance was observed to be in the range of 170 to 600 lux and upto 2200 lux where there is a skylight. Higher illuminance required for product inspection areas was in the range of 400 to 1200 lux. The byproducts area however had a lower illuminance at 70 lux.

Table 4.14 GLT plant illuminance

Section	**Illuminance**
Line 1	
	LUX
Line 1 lay-down	300 to 520
Blending tables	400 to 680
Picking tables	400 to 600
Between cylinders	250 to 480
Line 1 sample inspection table	600 to 700
Threshing line	250 to 500
Final sieving	300 to 450
By-products	70 to 100
Dryer	600 to 880
Packing area	300 to 600
Under direct skylights	900 to 2200
Line 2	
Line 2 general area	300 to 400
Line 2 blending table	400 to 460
Picking tables	500 to 560
Sample inspection tables	1000 to 1200

Factory illuminance levels was observed to be good and mostly meet general recommended standards for manufacturing requirements of 300-500-750 [9]. The byproducts area had lower illuminacce at 70 lux and it is recommended to improve to recommended standard.

The use of natural light through skylights is a good initiative and saves energy use. The use of fluorescent lights in the factory is also good as these are energy efficient compared to other lights. However the use of electromagnetic ballast results in energy waste as discussed in ECO 7

Table 4.15 shows effect on energy use as a result of usage of electromagnetic ballast control gear in the lights in comparison to a more energy efficient electronic control gear

Table 4.15 Lighting control gear

	Formulae	Process line 1	Process line 2	Packing Hall	TOTAL
General lights	A	350	100	90	540
Product inspection lights	B	160	108		268
Total tubes	C=A+B	510	208	90	808
Power/tube W	D	40	40	40	
Power loss due to magnetic ballast	E	35%	35%	35%	
Total power/(tube + ballast loss) W	F=D X (1+E)	54	54	54	
Power loss to magnetic ballast/tube W	G=F-D	14	14	14	
Electronic ballast savings					
Ceiling Lighting					
Power lost due to for magnetic ballast	= 540 tubes x 14 W	7560	W		
electronic ballast power saving 20%	20% X 7560/1000	1.51	kW		
Operation time (night only)		12	h		
Power saved due to electronic ballast	1.51 kW X 12 h	18.14	kWh/day		
Power savings	18.14 X 30 days	544.32	kWh/month		
Inspection lighting					
Power lost due to for magnetic ballast	= 268 tubes x 14 W	3752	W		
Electronic ballast power saving 20%	=20% X 3752/1000	0.75	kW		
Operation time day and night		24	h		
Power per day	=0.75 kW X 24 h	18.01	kWh/day		
Savings	=18.01 X 30 days	540.29	kWh/month		
Total savings (ceiling and inspection lights)	=544.32 + 540.29	1084.61	kWh/month		

ECO 7

All the fluorescent lights in the factory are controlled by electromagnetic ballast control gear that consumes additional power above actual input to tube to the range of 35% [9]. This amounts to an additional 14W extra for every 40W tube. The electromagnetic ballast control gear continues consuming power even when the tube is faulty or flickering resulting in energy waste. A more energy efficient control gear should be fitted to conserve energy.

ECM 7

Table 4.16 shows the effects of replacing electromagnetic ballast with electronic control gear. Replacing the electromagnetic ballast with electronic ballast will save 20% of the energy currently wasted by electromagnetic ballast.

Replacing all electromagnetic ballast with electronic ballast will amount to a saving of 1084.61kWh per month equivalent to Ksh 13,485 per month. With an investment of Ksh 600 per electronic ballast replacement the simple payback period is 1.5 years

Table 4.16 Electricity savings due to installing electronic ballast

Item	**Description**	**Formulae**	**Total**
A	Proposed power saving kWh/month	From Table 4.15	1,084.61
B	Power cost Ksh/kWh	Average of 2010 [4]	12.43
C	Cost Ksh/month	=A x B	13,484.70
D	Investment Ksh	=Ksh600 x 404 fittings	242,400.00
E	Simple payback period months	=D/C	17.98

4.7 Compressed air plant and distribution

4.7.1 Compressors

Compressed air is supplied by two screw compressors whose details in make, capacity and free air delivery are provided in Table 4.17

Compressed air is used in pneumatic cylinders for automatic damper operation, pneumatic strapping machines, solenoid valve pneumatic actuators (for steam, water and hydraulic systems), instruments and plant equipment deep cleaning

Table 4.17 Compressed air plant details

Compressor No		1	2
Manufacturer		Atlas Copco	Atlas Copco
Model		GA30+FF	GA30
Type		Screw	Screw
Free air delivery	l/s	96	96
Discharge pressure	bar	7	7
Motor rating	kW	30	30
Actual power (from measurements)	kW	27.12	26.39
Actual specific power	kW/l/s	0.28	0.27

Compressor 1 has an inbuilt air drier system whilst compressor 2 delivers air through an external refrigerated air drier. Both compressors deliver into two air receivers at source and one in the factory plant before distribution to end user functions and equipment. Photograph 4.15 shows compressor 1 with a cooling fan used to cool the unit as the room temperature was high.

Photograph 4.15 Compressor 1 with inbuilt air dryer NB: external fan cooling the unit.

Both compressors were observed to have their intake air ports within the compressor rooms. Inlet air was observed to be at average of 37°C and 32°C for compressor 1 and 2 respectively at a time when outside ambient temperature was 25°C.

It was observed that hot exhaust air for compressor 1 flows into the compressor room at 57°C. The exhaust system for compressor 2 was observed to mostly flow outside the compressor room through the door, however some back flow into the compressor room was observed due to the partly flow obstructed by the door edge. Exhaust air temperatures at 50° was observed for compressor 2.

During normal production only one compressor was observed to run at a time with the other on standby duty. During deep cleaning over the weekends when compressed air is used for cleaning equipment, the two compressors were run together due to a higher demand of compressed air for plant equipment deep cleaning.

The compressors are located at two different locations housed in separate compressor rooms, with compressor 1 nearest to the factory (in between the production lines) while compressor 2 located further away at 40m from the production line 1 and 82m from production line 2.

It was observed that the compressors were set to unload at 7.0 bar and load at 6.4 bar. All end user equipment was set at 5 bar air pressure.

Table 4.18 shows the measurements of compressed air intake and outlet temperatures and actual power consumed calculated from measured current and voltage.

Table 4.18 Compressor inlet air temperature and actual power consumption

Compressor No.		1	2
Temperatures			
Average ambient °C	25		
Air inlet °C		37	32
Air outlet °C			80
Air exhaust		57	50
Current A	R	51.6	49.5
Current A	B	47.4	49.6
Current A	Y	51.7	47.5
Voltage V		416	416
Actual power kW		27.12	26.39
Rated power kW		30	30

Table 4.19 shows actual compressor power consumption from measurements of current and voltage. For purpose of this working a PF of 0.9 was assumed.

Table 4.19 Calculation of actual power consumed by compressors

Compressor 1								
crt3	x	Voltage	x	Current	x	PF		
1.44215	x	416	x	51.6	x	0.9	=	27.86
1.44215	x	416	x	47.4	x	0.9	=	25.59
1.44215	x	416	x	51.7	x	0.9	=	27.91
Actual power							=	**27.12** kW
Compressor 2								
crt3	x	Voltage	x	Current	x	PF		
1.44215	x	416	x	49.5	x	0.9	=	26.73
1.44215	x	416	x	49.6	x	0.9	=	26.78
1.44215	x	416	x	47.5	x	0.9	=	25.65
Actual power							=	**26.39** kW

Table 4.20 shows effects of compressor air intakes in the hotter compressor room environment on energy consumption.

Table 4.20 Compressor power consumption

Compressor 1	
Initial compressor Power (W1) =	27.12 kW
Ideal compressor Power (W2) =	
W2=W1 X {1+ 0.00341(T2-T1)}	
W2=W1 X {1+0.00341(25-37)} =	26.01 kW
Power savings = 'W2-W1 =27.12-26.01 =	1.11 kW
Power savings % =1.11/27.12 =	4.1%
Compressor 2	
Initial compressor Power (W1) =	26.39 kW
Ideal compressor Power (W2) =	
W2=W1 X {1+ 0.00341(T2-T1)}	
W2=W1 X {1+0.00341(25-32)}	25.76 kW
W2	
Power savings = 'W2-W1 =26.39-25.76 =	0.63 kW
Power savings % =0.63/26.39 =	2.4%

ECO 8

Both the compressor rooms are poorly ventilated and hot exhaust from the compressor radiators was observed to purge in the compressor rooms at 57°C for compressor 1 and 50°C for compressor 2. As a result the compressor air inlet temperature is high measured at 37°C for compressor 1 and 32°C for compressor 2. This reduces the efficiency of the compressors and more energy is consumed. Compressor no 2 room was also observed to be further away from factory end user equipment than compressor 1 in between the two production lines. Compressor 2 delivers air at higher friction losses than compressor 1 which is wasteful.

ECM 8

To reduce energy consumption, it is recommended that hot exhaust air be properly ducted out to reduce air temperature in the compressor room and as a result inlet air temperature to the compressors. Inlet air to the compressors should also be installed from the coolest point of the compressor environment. Table 4.21 shows effects of drawing inlet air into the compressor at ambient temperature. If inlet air intake is installed to cooler sources other than compressor room at average ambient temperature of 25°C, the compressor power requirement for the same duty will reduce to 26 and 25.8 kW for compressors 1 and 2 respectively. This is a power saving of 4.1% and 2.4% for compressors 1 and 2 respectively and will result in a total monthly saving of Ksh 6,056. An estimate investment of Ksh 20,000 to install air intake from cooler sources will result in a simple payback period of less than 4 months. It is also recommended that compressor 2 be located at the same location as compressor 1 to reduce distribution losses due to friction.

Table 4.21 Electricity savings due to relocation of compressor air intake

Item	**Description**	**Formulae**	**Compressor 1**	**Compressor 2**	**Total**
A	Power savings kW	From Table 4.20	1.11	0.63	
B	Cleaning hours per week (both units running) h		10	10	
C	Average running hours per week (one unit at a time) h	=(5 days x 24hrs)/2	60	60	
D	Total hours per week h	=B + C	70	70	
E	Power savings per week kWh	=A x D	77.69	44.09	121.[illegible]
F	Cost of power Ksh/kWh	(2010 average) [3]	12.43	12.43	12.[illegible]
G	Cost savings per week Ksh	=E x F	965.92	548.12	1,514.0[illegible]
H	Cost savings per month Ksh/month	=G x 4 weeks	3,863.67	2,192.49	6,056.1[illegible]
I	Investment Ksh		10,000.00	10,000.00	20,000.[illegible]
J	Simple payback months	=I/H	2.59	4.56	3.[illegible]

4.7.2 Air leakages

It was observed that most equipment use compressed air at 5 bar pressure. However the compressor pressure was normally maintained at 6.4 to 7 bar due to system distribution losses and presence of leaks. Most leakages were observed to occur at pipe joints and fittings, leaking valves and poorly fitted air hoses. An air decay test (time from unloading to loading when there is no production or air usage) was carried out and resulted in an average of 42.9 seconds compared to an average of 54.9 seconds loading time.

It was also observed that the compressors are not fitted with auto shut off systems when there is no production during pant stoppages and weekends. Compressor shut off was manually done by operators. Photograph 4.16 shows a poorly fitted air hose that can allow air leakages through loose fitting.

Photograph 4.16 Poorly fitted air hose

Table 4.22 shows the quantity of air leakage from measurements of loading and unloading time

Table 4.22 Calculation of air leakage

Air Leakages

Estimate leakage % = {(T x 100)/(T + t)}
where
T =ON load time in min
t =OFF load time in min

T = 54.85 s = 0.91 min
t = 42.85 s = 0.71 min

Leakage % = {(0.91 x 100)/(0.91+ 0.71)} = 56.14

ECO 9

From measurements on time to load and unload when there is no production and air use there are air leakages in the compressed air system to the level of 56.14% of compressor capacity calculated as shown in table 4.22. This is high in comparison to expected leakage of 5% for a well maintained system [8, 9]. This shows an air loss of 51.4% of compressor capacity going to waste compared to a well maintained system. A compressed air loss of 51.4% of compressed air capacity leakage amounts to a monthly loss of 7,881 kWh and cost of Ksh 97,983.

ECM 9

Table 4.23 shows effects on energy use if compressed air leakages are reduced to less than 5% expected for well maintained systems. All air leakages in the joints, valves and fittings should be eliminated. This will involve identification of the leakage areas and installing effective line fittings. An estimated investment of Ksh 500,000 to seal all pipe joints, fittings and valves will result in a simple payback period of less than 6 months.

Table 4.23 Electricity savings due to reduced air leakages

Item	**Description**	**Formulae**	**Value**	**Unit**
A	Air Leakages % of compressor capacity	From Table 4.22	56.14	%
B	Expected leakage for a well system [13]		5	%
C	Reduced air leakages % of compressor capacity	=A - B	51.14	%
D	Compressor capacity		96	l/s
E	Actual leakage reduction	=C/100 x D	49.10	l/s
F	Actual specific power		0.28	kW/l/s
G	Power loss	=E x F	13.7	kW
H	Run hrs per month = =	=24 hours x 6 days x 4 weeks	576	h/month
I	Monthly power loss	=G x H	7881.04	kWh/month
J	Power cost	Average 2010 [4]	12.43	Ksh/kWh
K	Monthly power loss	=I x J	97,983.36	Ksh
L	Estimate cost of reducing leakages		500,000.0	Ksh
M	Pay back time	=L/K	5.10	months

A lot of energy is wasted through air leaks that keep the compressors running when no production is going on. It is also recommended that a compressor shutoff system be installed when air is not required.

4.7.3 Plant cleaning

During normal production compressed air was used for blowing off dust and tobacco waste from confined areas of the plant equipment. Over the weekend the GLT carries a machine deep cleaning where compressed air was used for blowing off dust and tobacco waste off equipment. During this time both compressors were normally on line. The requirement of compressed air during plant deep cleaning was observed to be high. It was observed that both compressor units run continuously loaded at delivery pressures of 4.6 to 5.1 bar and 4.8 to 5.4 bar for compressor 1 and 2 respectively. This shows the capacity for air requirements during cleaning is higher than generation capacity for the two compressors. Observations made showed the system of blowing dust with compressed air was highly abused where air was used in some instances instead of brooms/brushes for cleaning. A ¼ inch hose at 7bar releases 101 CFM of air [14]. Table 4.24 shows effects of cleaning with compressed air at 5 bar on energy usage compared to lowered pressure of 2 bar using pressure regulated blow guns

Table 4.24 Compressed air usage for cleaning at 2 bar versus 5 bar

CLEANING AIR			
	min	max	
Compressor 1 (pressure range bar)	4.6	5.1	
Compresor 2 (pressure range bar)	4.8	5.4	
Average cleaning pressure bar	5.0		
pressure at 2 bar = 29.0 psi			
pressure at 5 bar = 72.5 psi			
	CFM		
CFM at pressure 70 psi on 1/4 inch orifice	74.4	[12]	
CFM at pressure 100 psi on 1/4 inch orifice	100.9	[12]	
Estimate CFM at 2 bar (29 psi)	=100.9-((100.9-74.4)/(100-70)*(100-29))=		38 CFM
Estimate CFM at 5 bar (72.5 psi)	=100.9-((100.9-74.4)/(100-70)*(100-72.5))=		77 CFM
If pressure regulated guns are fitted			
Air flow savings per orifice = 77-38 CFM =	38	CFM	
1 CFM =	0.47	l/s	
Flow per orifice = 38 x 0.47 =	18.06	l/s	
Total no of cleaning nozzles =	11		
Total flow saved =18.06 x 11	198.66	l/s	
Average specific power =	0.28	kW/l/s	
Power savings = 198.66 x 0.28	55.36	kW	
Normal cleaning duration per week (h) =	5	(1 h per day x 5 days)	
Weekend deep cleaning duration (h)	10		
Total cleaning duration per week (h)	15	(15 + 10)	
Total cleaning duration per month (h)	60	(15 x 4)	
Power saved per month = 55.36kW X 60h=	3322	kWh	

ECO 10

The method of using compressed air for cleaning is wasteful. It was observed that plant cleaning was being carried out at compressor delivery pressure. During the weekend cleaning, it was observed that all the 11 compressor cleaning outlets were in use. The consumption was observed to be so high during weekend cleaning that both compressors 1 and 2 ran continuously loaded at average delivery pressures of 5 bar. This shows the usage was higher than capacity of set delivery pressure of 7 bar. Pressure at 2 bar [14] is sufficient to carry out the cleaning task. This can be achieved by use of pressure regulated blow guns

ECM 10

It is then recommended that pressure regulated blow guns be installed in each of the cleaning outlet nozzles. Installation of pressure regulating air blow guns will also reduce energy wastage. Table 4.25 shows the effects of cleaning equipment at compressor delivery pressure on energy consumption. Cleaning with the ¼ inch hoses at actual cleaning pressure of 5 bars delivers air at 75CFM. With pressure regulated blow guns at 2 bar, this can be reduced to 38CFM with the same cleaning quality achieved. This will save 37CFM of air (17.44 l/s). The average specific power for both compressors is 0.28 kW per every l/s delivery. This would result in a monthly saving of 3,322 kWh and a cost of Ksh 41,299. An investment in blowguns estimated at Ksh 25,000 a piece will give a payback period of less than 7 months.

Table 4.25 Electricity savings due to installation of pressure regulated blow guns

Item	**Description**	**Formulae**	**Value**
A	Total power KWh per month	From Table 4.24	3321.81
B	Power cost	Average for 2010 [4]	12.43
C	Cost per month Ksh	=A x B	41,299.33
D	Estimate cost of blow gun Ksh		25,000.00
E	Investment cost 11 blow guns Ksh	=D x 11	275,000.00
F	Simple payback period months	=E/C	6.66

Alternatively other ways of cleaning should be used that include use of brooms, industrial vacuum cleaners and electric air blowers

4.8 Factory drives (electric motors)

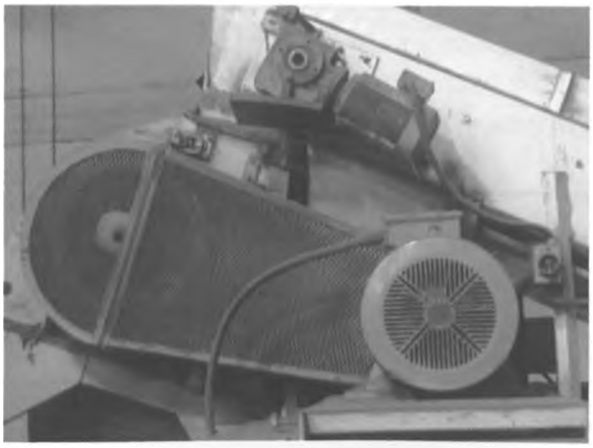
The factory drives are mainly used to run

- Operational process equipment with power rating ranges as
    - Tipping and bursting (rating of 1.5kW)

  - Conditioning cylinders (rating of 4 to 7.5kW)
  - Threshers and classifiers (rating of 18 to 30kW)
  - Sieving shakers (rating of 5.5kW)
  - Driers (rating of 0.75 to 11kW)
  - Packing press (rating of 0.75 to 3kW)
- Product conveyance
  - Open band conveyors (rating of 0.75 to 3kW)
  - Pneumatic conveyors (rating of 18 to 75kW)
- Dust extraction fans (rating of 37 to 75kW)

All the factory drives are electric induction motors with a wide range of rated capacity from 0.75kW to 75kW. Most drives are directly coupled to reduction gearboxes (geared drives) except for few instances of transmission through chain or pulley systems. Small drives are normally powered on 'direct on line' switching with higher rated motors of 22kW and above switched through soft start switching gear to reduce demand on start up. It was however observed that three motors in the dust plant with 55kW each had a star to delta switching gear following failure of the soft start switches. However plans were in place to replace them with the soft start switches.

Photograph 4.17 shows a direct shaft mounted geared motor drive for the open band conveyor and a pulley drive motor transmission for the second stage thresher motor



Photograph 4.17 Direct and pulley transmission drives

4.8.1 Electrical motor loading

The GLT plant production line was set as a line process where motors were sequenced to start after another from last equipment of production line to first motor at the product feeding end. This was observed as a good practice to assist in total load control during line start up and maintain a low power demand.

It was also observed that there were several instances of no load running of motors especially during breakdowns downstream of the line, cleaning time and product operation changes. On average such breakdowns are of the range of 5.5% (Average for year 2010 at the GLT plant). The GLT Plant has installed several variable frequency drives to control operational capacity by varying motor speeds. However it was also observed that a lot of manual process controls especially in the big motors in the dust extraction plant where pneumatically controlled dampers operated on fully open or fully closed.

It was observed that motors are generally not well matched to loads as the GLT plant normally replace motors based on estimated loads and availability in stock to suit mechanical specification on the delivery end of the geared drive (final gearbox speed and shaft sizes) and to overcome overload conditions that are often caused by wear and failure in mechanical systems. Also observed was that OEM design motors with large safety factors at maximum capacity which in most times is rarely utilized due to lower demand and bottleneck effects of different line equipment with mismatched capacities. Capacity utilization was also limited by product quality where a lower throughput was at times used to ensure product conformance to quality specification. The GLT rated at 8,000kg/h normally runs at average of 5,500 to 6,000kg/h [2]. As a result there are several motors that are oversized for the required duty that results in energy wastage through overdrawn currents and lowers power factor. This results in unnecessary energy wastage when the plant is running under low load conditions. It is then recommended that proper sizing of motors be carried out to match line requirements. It is also recommended that motor load sensors be installed to shut off motors in the event that there is no production for prolonged periods.

4.8.2 Motor rewinding

It was observed that there were several instances where motor coils have had to be rewired after failure, including all the high rated motors at the dust plant. It was also observed the GLT plant had no procedures for testing rewired motors for efficiency. Such motors are generally put back online. Motor rewiring generally reduces motor efficiency especially if not done properly. It is recommended that all rewired motors be tested to determine their efficiency before use.

4.8.3 Energy efficient motors

All motors observed were not energy efficient and are of older designs. Energy efficient motors generally operate at 3 to 4% higher efficiency than standard motors [9]. They feature longer core to increase active material, thicker wires to reduce current resistance, thinner laminations, smaller air gap between rotor and stator, superior bearings and a smaller cooling fan to reduce mechanical loads. It is recommended that all future motor replacements be with energy efficient motors.

4.9 Air fans

The GLT has several fans used for performing several duties as heated air flow through heat exchangers (steam radiators), product air classifiers and the dust plant (dust extraction and pneumatic product transportation system). In the heated air flows, these were largely centrifugal fans driven by 4kW motors for conditioning cylinders and axial fans driven by 5.5kW motors for the product driers. The fans circulate air through steam to air radiators into the product. The systems are mostly closed system with air re-circulation. Spent air was exhausted into the atmosphere and an equivalent amount of make up air allowed in the system depending on product conditions. The fans air delivery and quantity of heat transferred in the radiators determined the heat levels in the conditioning cylinders and driers. All the fans were run on fixed speed and process heat variation achieved by varying quantity of steam into the radiators through manual or electro-pneumatic control valves. Observations showed in some instances, colder makeup air through manual dampers is used to remove moist air which lowered temperatures in the driers and cylinders. It was observed during all such instances the fans run at maximum speed.

In the product classifiers, there were fourteen centrifugal fans. They were made of mostly radial with only two backward curved vane impellers driven through pulley transmission system. Power rating varied between 18 to 30 kW. The fans were used for product classification (separation of tobacco leaves from tobacco stem by way of air winnowing) where medium pressure with higher flow is required. Eight out of the fourteen fans in the first stage classifiers were controlled by variable frequency drives and the rest in the second, third and fourth stage classification through manual dampers. The first stage fans were installed in parallel (four classifiers with two fans each in parallel) whilst the second to fourth stage had a single fan each. Photograph 4.18 shows a first stage classification fan.

Photograph 4.18 First stage classification fan

In the dust plant were the largest fans in the GLT plant and were driven by the highest rated motors. All the fans had backward curved blade impellers

The fans were used for dust extraction and pneumatic product conveyance with dust extracted from all these systems being collected in the dust plant through cyclones and bag filters. Figure 4.10 shows a schematic layout diagram of the dust plant system comprising of a cyclone, fan and bag filter unit. In this system air with tobacco dust and sand particles extracted from the line passes through the cyclone where large particles are removed from the air through centrifugation. The air then passes through the fan before passing through the bag filters where the smaller and finer dust is removed by trapping in the filter bags. Clean air exist the filter and discharged to the atmosphere. The filter bags are cleaned by a reverse air fan which periodically purges counter flow air opposite of normal air flow to remove particles clogged in the filter bags.

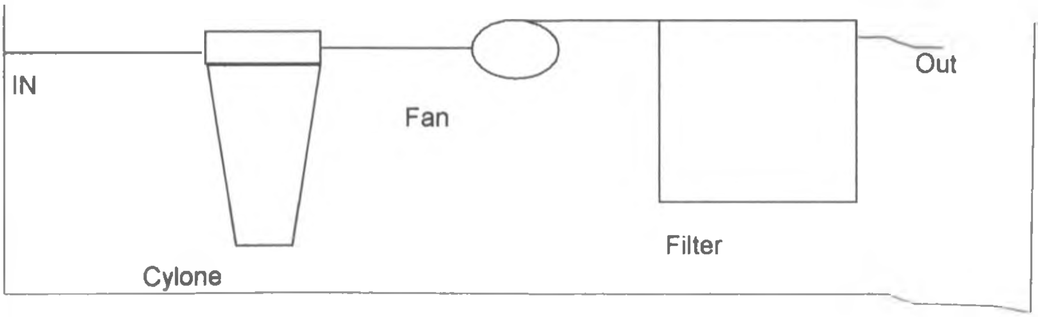


Figure 4.10 Dust plant fan, filter and cyclone schematic diagram

It was observed that the dust plant system had the fan upstream of the filters where the air still had a lot of particles of dust and sand. This causes premature wear on fan blades. The wear causes inefficiency in the fan system due to pressure loss to leakages and worn blades. It is recommended that the fans are fitted on the clean air side (discharge of filter) for a longer efficient fan life that will reduce energy waste. It was also observed that the bag filters contribute to high pressure drops due to blocked dust bags. The reverse air filter bag cleaning system in the dust plants was observed not working efficiently. Manual cleaning of the filter elements had to be done at least once a shift due to clogging of filters and higher pressure drop. It is recommended that are more efficient self cleaning system of the dust bags be installed to reduce energy wastage when filter elements are clogged.

Motor power rates ranged from 37 kW to 75 kW. All these fans were normally controlled through a soft start switching gear and in some instances star to delta switch. It was the start to delta switching a temporary solution after some soft start switches failed and will be replaced.

Flow control for all the fans was by way of fully closed/open pneumatic controlled dampers. The system of manual damper control was observed as wasteful in energy consumption as motors continue running at maximum speed even when lower demand is required. VFD control for all fans will improve on power consumption subject to economic analysis. It is recommended that VFD control of the fans be installed and will reduce energy use.

CHAPTER FIVE

DISCUSSIONS

In this chapter the results of the study are discussed highlighting specific observation and findings in relation to energy use.

5.1 Historical trends

The past trend of electricity use on average is 369,448kWh for 2009 and 419,121kWh for 2010. There is however a decline in electricity intensities from 1.11MJ/kg in 2009 to 1.10 MJ/kg in 2010.

For HFO 118,936 litres was used in 2009 compared to 130,438 litres in 2010. The HFO intensities however declined from 4.0MJ/kg in 2009 to 3.96 MJ/kg in 2010. The energy intensities improve with higher production evident from the total production of 16.8 million kgs in 2009 compared to 19.4 million kgs in 2010. This was shown in the total energy intensities relationship in Figure 4.5. This was attributed to observations that energy is sued to support operations not directly related to production that include compressor power for cleaning, lighting outside the factory for electricity system. For the steam system, energy losses are expected to be equal irrespective of the production throughput through the plant and initial steam rising in the boiler plant at start of the production season and every week is same irrespective of production throughput. The effects of such constant energy use and losses allow constant baseline energy consumption where higher production results to lower energy intensities.

Figure 4.2 and 4.3 show power usage irrespective to production of 608,887 MJ of electricity (37% of total electricity usage) and 733,687 MJ of HFO (12% of total HFO usage) during the two year review period which suggests opportunities for energy savings.

5.2 Boiler and steam system

The study has shown a lot of effort in good practice on energy usage. The installation of an automatic air/fuel control in boiler 3 is recognized as good practice. The lagging of some steam distribution lines including some line accessories (valves, separators, strainers and traps) is also good practice. There was good condensate trapping system with traps supplied with lagging.

However observation has shown several areas of energy wastage as expressed in high flue gas temperatures over 203°C and 254°C for boiler1 and 3 respectively. This is high and requires to be brought down to maximum of 200°C. There is high excess air in use at the boilers in excess of 187% for boiler 1 and 26% for boiler 3. This needs to be reduced to maximum of 15% and possibly 12% for a good standard to reduce heat losses through hot flue gas.

The boiler TDS was observed high at average of 4726ppm for boiler 1 and 5700ppm for boiler 3. This needs to be reduced to manufacturers recommended levels of 3000ppm. As a result of this, energy is lost through excessive blow down rates.

Poor lagging in some sections of the boilers and the steam distribution lines was observed. Hot un-lagged surfaces with temperatures in excess of 211°C at the boilers and 155°C at the steam lines were observed. This need to be reduced to current existing standard of 37°C for lagged surfaces. The trap lagging was observed not as effective as normal lagging materials with surface temperatures at 44°C. Energy is lost through surface radiation and convection.

A lot of flash steam was observed in the conditioning and drying units. The condensate pumps were also observed to flash off steam. This flash steam can be recovered and residual energy reused to conserve energy.

Table 5.1 shows the various ECM's suggested to reduce HFO usage for each identified ECO. The table also shows the quantity of recoverable energy, estimated investments to carry out the tasks and payback period.

Table 5.1 Summary of ECOs and ECM showing HFO savings and investment benefits

Item	Energy Conservation Opportunity (ECO)	Energy Conservation Measure (ECM)	Energy Savings per Month (HFO l)	Cost savings per month (Ksh)	Estimate investment (Ksh)	Payback (months)
1	Low boiler efficiency and evaporation ratio. Boiler efficiency boiler 1 and 3 at 78 & 83% respectively and evaprotaion ratio at 12.3 and 13 respectively.	Correct set up of automatic air/fuel control in boiler 3. Installation of air/fuel controller in boiler 1.	5,228	224,648	500,000	2.23
2	Heat losses due to surface radiation of boiler plants	Installa laging on front and back of boilers. Replace lagging on body of boilers	1,840	79,090	800,000	10.12
3	High TDS in boiler and feed water resulting to excessive blow down	Install a water treatment plant (RO Plant)	889	38,184	862,200	22.58
4	Heat losses due to surface radiation due bare hot surfaces in the staem distribution and condensate recovery system	Install pipe lagging of all bare hot surfaces	3,432	147,494	700,000	4.75
5	A lot of flash steam from conditioning cylinders and product driers and condensate puming station	re- use flash steam for product and air preheating into the cylinders and driers	18,665	802,122	4,000,000	4.99
	TOTAL		30,054	1,291,537	6,862,200	5.31

5.3 Electricity system

The study has shown poor electricity load control. The study revealed high demand and PF fluctuations. This was observed more in the year 2009 with some better control in 2010 however not to recommended good standards of near unity. Low PF of 0.8 was observed in some months.

There is need to have better load control and high power factor close to unity. The use of variable speed drives in some production plants observed in the classification fans and thresher drives is a good practice. However the switching mode of big motors in the dust plant on star to delta due to failure of installed soft starters was observed not to be efficient. The study shows there are no energy efficient motors installed in the plant. However it was recognized that future motor installations are planned to be energy efficient. Rewired motors were being put on line without checking motor efficiency. There is then no way of knowing the performance of such motors and this can lead to poor load control.

The lighting in the factory was observed to be sufficient at an average of 300lux to 700lux. The use of fluorescent tubes in the factory was also observed to be energy efficient. However the use of electromagnetic ballast as control gear was observed not energy efficient in comparison to electronic ballast control gear.

5.4 Compressed air system

The study shows poor control in energy usage in the compressed air system. The compressed air ventilation was observed not efficient as some hot exhaust air from compressors found its way into the rooms. The air intakes to the compressors were not suitably located and resulted to lower compressor efficiency due to high air intake temperature of 32 to 37°C. Air intake should be located at the coolest point of the room.

The loading and unloading set point of compressors was observed a good practice in usage control. However this benefit was not being realized due to existence of air leakages. Compressed air leakages were estimated at 56%. This should be reduced to recommended standard of a maximum 5%.

The study showed a lot of compressed air abuse in use. A lot of air was used to clean the factory equipment at compressor delivery pressure of 5bar. The recommended cleaning pressure is 2 bar and energy saving potential exists.

Table 5.2 shows the various ECM's suggested that can reduce electricity use for each ECO identified. The table also shows the quantity of electric energy and cost benefits against estimate investment.

Table 5.2 Summary of ECOs and ECM showing electricity savings and investment benefits

Item	**Energy Conservation Opportunity (ECO)**	**Energy Conservation Measure (ECM)**	**Energy savings per month (kWh)**	**Cost savings per onth (Ksh)**	**Investment (Ksh)**	**Payback time (Months)**
6	PF and Demand Improvements resulting to PF surchages	Install additional PF capacitor banks		1,179,391	1,167,000	0.99
7	Electromagnetic ballast in use consumes un-productive energy	Replacing with electronic ballast will save 20% energy wasted	1,085	13,485	242,400	17.98
8	All Ccompressors draw in inlet air from hot compressor environment lowering efficiency	Transfer air intake to a cooler location outside the compressor environment	487	6,056	20,000	3.30
9	Air Leakages high at 56% of compressor capacity	Reduce leakages to max 5%	7,881	97,983	500,000	5.10
10	Plant cleaning using compressed air at 5 bar is wasteful and consumes unproductive energy.	Install pressure regulated blow guns to reduce nozzle pressure to 2 bar	3,322	41,299	275,000	6.66
	TOTAL		12,775	1,338,215	2,204,400	1.65

CHAPTER SIX

CONCLUSIONS AND RECOMENDATIONS

In this chapter conclusions of the study observations and results are made. Highlights of observations in energy use are presented and proposed ECM is shown. Further recommendations are also made to recover residual energy conservation opportunities observed.

6.1 Conclusions

The following conclusions can be drawn from this study

The main sources of energy is HFO at HHV of 43.65 MJ/kg and electricity supplied at 11kV stepped down to 415V

The average HFO energy use is at average of 4MJ/kg per month. This was shown to decrease with increased production. 12% of HFO energy is not related to production and shows potential to conserve energy.

The boilers generated steam at average efficiency of 80% (77% and 83% for boiler 1 and 3 respectively). This was observed to be low and can be improved. Boiler 3 was observed to have a modern and more efficient burner in comparison to boiler 1.The main energy losses were observed to be high levels of excess air at 187% for boiler 1 and 26% for boiler 3, high flue gas temperatures at 203°C for boiler 1 and 254°C for boiler 3, high boiler surface temperature at excess levels of 211°C and high boiler blow down rates of 44 to 48kg/h for boiler 1 and 74 to 80kg/h for boiler 3.

HFO was used to generate steam at the boiler plant for the conditioning and drying processes of tobacco.

The steam distribution system was observed to have well lagged portions with surface temperatures at 37°C. However several sections of bare pipes and valves were also observed at surface temperatures of 155°C

Steam was used mainly to preheat air for tobacco conditioning and drying processes and in the direct application to tobacco for the conditioning and moisture correction of the drying processes. The steam for air preheating was recovered as condensate through a good steam trapping system. The direct application of steam to the product was observed wasteful. 51% of such steam was observed to flash off and not recovered as condensate.

Several ECM's to conserve energy have been recommended in this study. These include the following

1. Improve air/fuel ratio in the boiler burners to reduce excess air
2. Cleaning of the boiler tubes to reduce flue gas temperature
3. Lagging of the boiler surfaces to reduce heat loss
4. Install a water treatment process to reduce boiler TDS and blow down rates
5. Lagging of steam line and steam line accessories to reduce heat loss
6. Flash steam heat recovery process

The ECM's recommended will result in energy reduction equivalent to 30,054 litres of HFO as shown in Table 5.1. This represents an annual saving of 270,485 litres of HFO (for a nine months process year) which is a 17% reduction using the 2010 total usage of 1,565,257 litres of HFO as baseline.

Electricity energy use is at average of 1.1MJ/kg per month. This was shown to decrease with increased production. 37% of electrical energy is not related to production and shows potential to conserve energy. It was observed that several operations not directly related to production go on (office appliances and electricity for essential services) which may explain this.

The electricity load control was observed to be erratic with high fluctuations. Demand on average is 1205kVA with lows of 233kVA during plant shutdowns and highs of 1620kVA. PF was observed equally erratic with several surcharges done on the GLT. This shows poor load control in powering appliances.

Electricity in the production plant is used for powering motor drives and lighting.

Electrical motors observed were all of induction type and not energy efficient. Several motors had been rewired that could contribute to low efficiency and PF. Some motors were observed to use older design switching gear of star to delta that result in higher demand at start up.

The compressed air system was observed to have high air intake temperatures of 32°C to 37°C, high air leakages at 56% and compressed air abuse through factory cleaning. This resulted in higher energy usage than expected standards.

The factory lighting was found sufficient at an average of 500lux with energy efficient lights of the fluorescent type. However the electromagnetic ballast control gear was observed to consume higher energy than recommended practice.

Several ECM's have been recommended in the electrical system that include the following

1. Additional PF correction banks
2. Change the electromagnetic ballast for fluorescent lamps to electronic ballast
3. Relocate the compressor air intake to cooler areas of compressor rooms
4. Reduce air leakages in joints and accessories to maximum 5%
5. Reduce compressed air cleaning pressure to maximum of 2 bar

The ECM's recommended will result in electrical energy reduction equivalent to 12,775 kWh shown in Table 5.2. This represents an annual saving of 114,971 kWh (for nine months of processing season) which is a 2.3% reduction using the 2010 total usage of 5,029,544 kWh as baseline.

6.2 Recommendations

The GLT production process is observed to generate a lot of tobacco waste in form of dust and rejected products at 5% of total crop. For the year 2010 alone a total of 970 tons of tobacco waste was generated from the annual input volume of 19,359 tons.

It is recommended that the GLT install furnaces that can generate heat from combustion of biomass (tobacco waste) or biogas generated from the tobacco waste that can save energy in HFO usage.

The GLT can consider installation of economizers to recover waste heat in boiler flue gas. This can be used to preheat boiler input air or boilers feed water and reduce HFO usage.

It is recommended to install load control systems for the production line and compressors. This will stop line motors when production is not going on and avoid idle plant running. This will save electricity energy usage especially during break downs and other waiting stoppages during operation changes and cleaning.

It is recommended that all future motor purchases be of energy efficient type. Current installations can also be replaced subject for economic benefit analysis.

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APPENDICES

Appendix 1 Calculation of HHV from LHV

LHV=HHV-(0.2121xH + 0.02442xH2O + 0.0008xO [21]

Where LHV and HHV are in MJ/kg, and H, H2O and O are in %.

LHV = 41.1 MJ/kg [19]

H=12%

O=0.9%

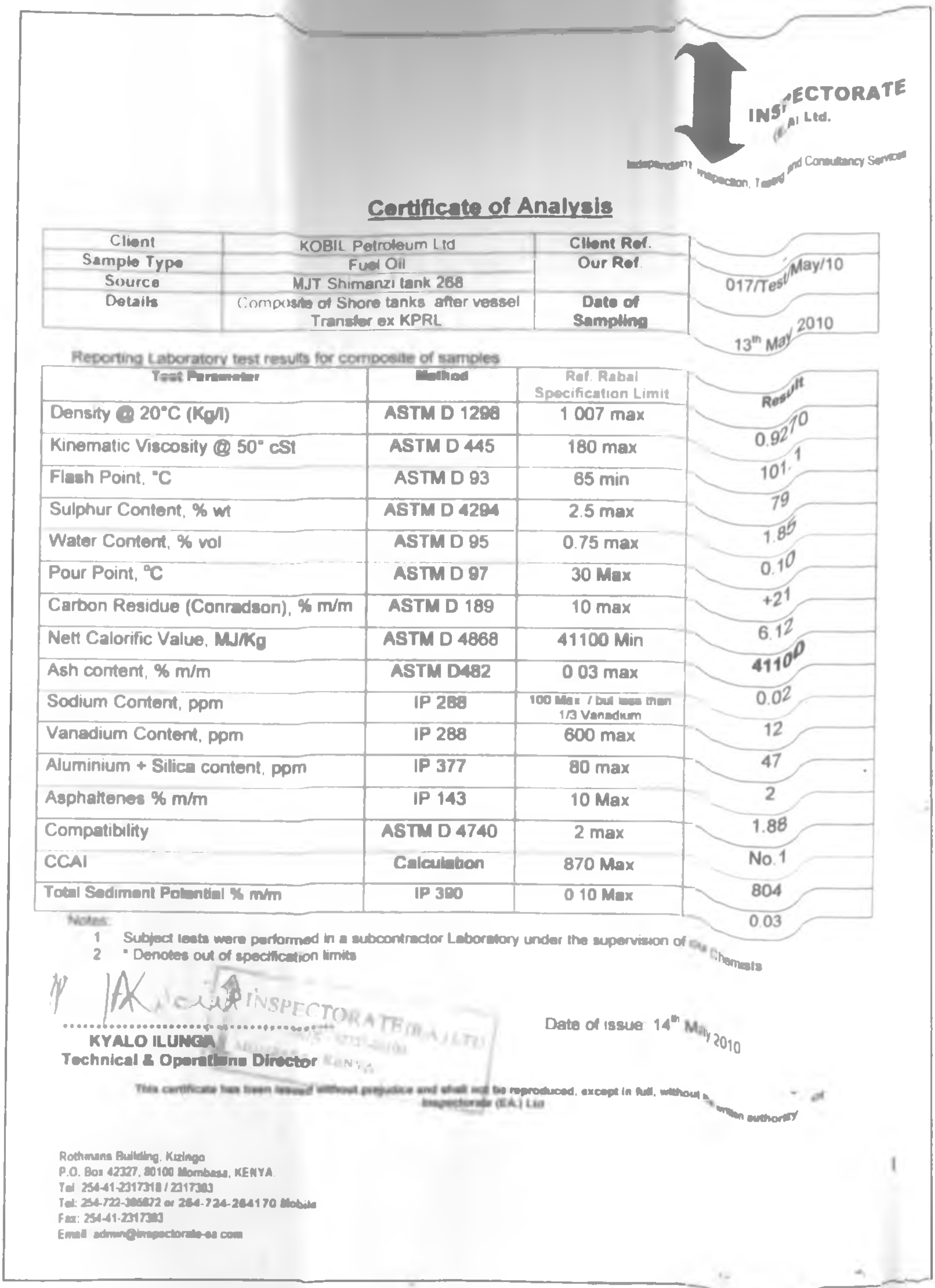
Moisture (H2O) =0.1% [19]

HHV =LHV + (0.2121xH + 0.02442xH2O + 0.0008xO)

HHV =41.1 + (0.2121 x 12 + 0.02442 x 0.1 + 0.0008 x 0.9)

HHV =43.648 MJ/kg

Appendix 2 Test certificate of HFO



INSPECTORATE
(E.A) Ltd.
Independent Inspection, Testing and Consultancy Services

Certificate of Analysis

Client	KOBIL Petroleum Ltd	**Client Ref.**	
Sample Type	Fuel Oil	**Our Ref.**	017/Test/May/10
Source	MJT Shimanzi tank 268		
Details	Composite of Shore tanks after vessel Transfer ex KPRL	**Date of Sampling**	13th May 2010

Reporting Laboratory test results for composite of samples

Test Parameter	Method	Ref. Rabai Specification Limit	Result
Density @ 20°C (Kg/l)	ASTM D 1298	1 007 max	0.9270
Kinematic Viscosity @ 50° cSt	ASTM D 445	180 max	101. 1
Flash Point, °C	ASTM D 93	65 min	79
Sulphur Content, % wt	ASTM D 4294	2.5 max	1.85
Water Content, % vol	ASTM D 95	0.75 max	0.10
Pour Point, °C	ASTM D 97	30 Max	+21
Carbon Residue (Conradson), % m/m	ASTM D 189	10 max	6.12
Nett Calorific Value, MJ/Kg	ASTM D 4868	41100 Min	**41100**
Ash content, % m/m	ASTM D482	0 03 max	0.02
Sodium Content, ppm	IP 288	100 Max / but less than 1/3 Vanadium	12
Vanadium Content, ppm	IP 288	600 max	47
Aluminium + Silica content, ppm	IP 377	80 max	2
Asphaltenes % m/m	IP 143	10 Max	1.88
Compatibility	ASTM D 4740	2 max	No. 1
CCAI	Calculation	870 Max	804
Total Sediment Potential % m/m	IP 390	0 10 Max	0.03

Notes:
1 Subject tests were performed in a subcontractor Laboratory under the supervision of our Chemists
2 * Denotes out of specification limits

INSPECTORATE (E.A.) LTD
KENYA

Date of issue 14th May 2010

KYALO ILUNGA
Technical & Operations Director

This certificate has been issued without prejudice and shall not be reproduced, except in full, without the written authority of Inspectorate (EA.) Ltd

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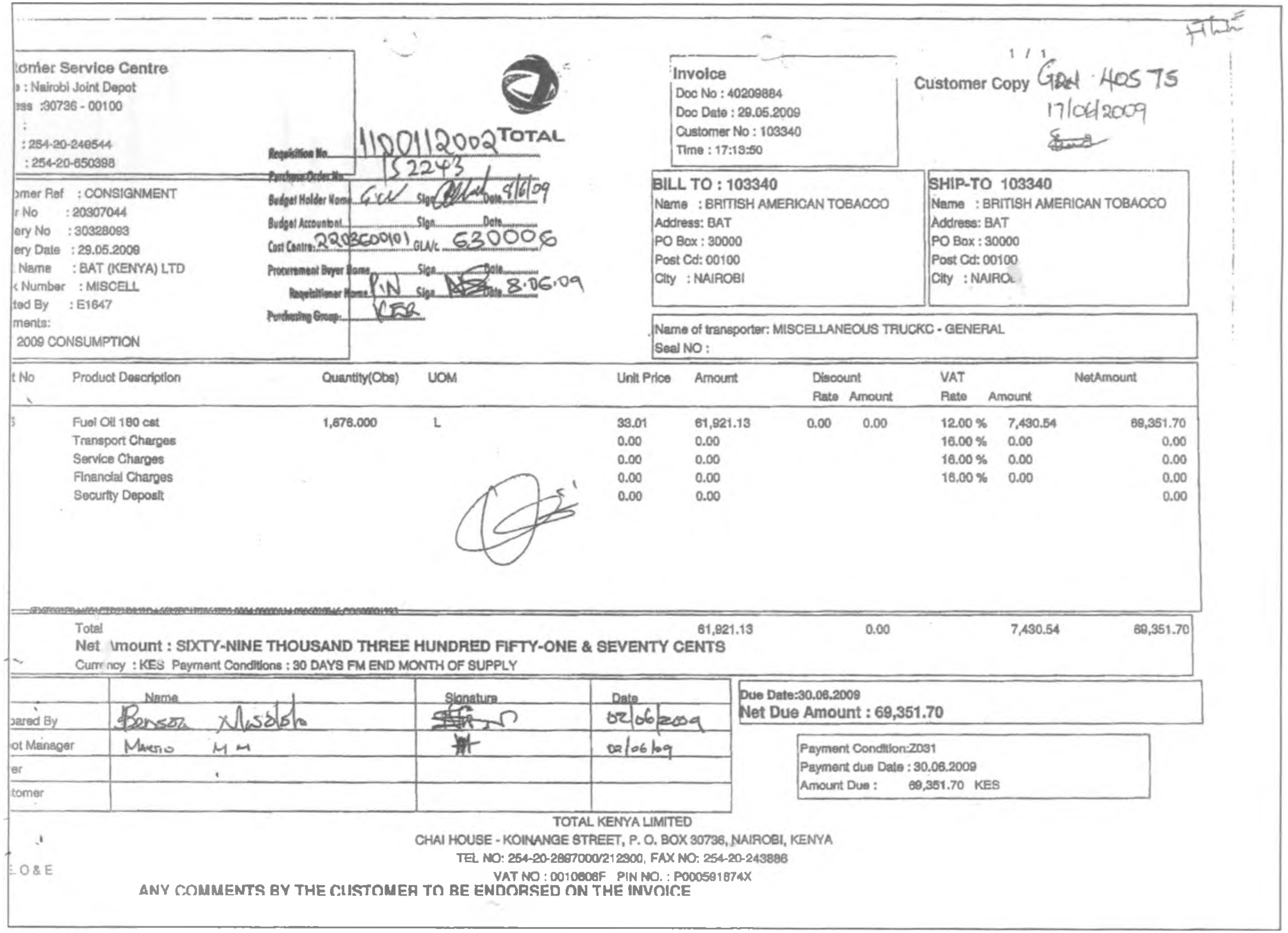
Tel 254-41-2317318 / 2317383
Tel: 254-722-386872 or 264-724-264170 Mobile
Fax: 254-41-2317383
Email admin@inspectorate-ea.com

Appendix 3 Copy of HFO invoice



tomer Service Centre
: Nairobi Joint Depot
ss :30736 - 00100
:
: 254-20-249544
: 254-20-650398

TOTAL

Requisition No. 1100112002
Purchase Order No. 152243
Budget Holder Name G.W Sign Date 9/6/09
Budget Accountant Sign Date
Cost Centre: 2203600101 GL/A/c 630006
Procurement Buyer Name Sign Date
Requisitioner Name P.N Sign Date 8.06.09
Purchasing Group KER

Invoice
Doc No : 40209884
Doc Date : 29.05.2009
Customer No : 103340
Time : 17:13:50

1 / 1
Customer Copy GRN 40575
17/06/2009

omer Ref : CONSIGNMENT
r No : 20307044
ery No : 30328093
ery Date : 29.05.2009
Name : BAT (KENYA) LTD
Number : MISCELL
ted By : E1647
ments:
2009 CONSUMPTION

BILL TO : 103340
Name : BRITISH AMERICAN TOBACCO
Address: BAT
PO Box : 30000
Post Cd: 00100
City : NAIROBI

SHIP-TO 103340
Name : BRITISH AMERICAN TOBACCO
Address: BAT
PO Box : 30000
Post Cd: 00100
City : NAIRO

Name of transporter: MISCELLANEOUS TRUCKC - GENERAL
Seal NO :

t No	Product Description	Quantity(Obs)	UOM	Unit Price	Amount	Discount Rate	Discount Amount	VAT Rate	VAT Amount	NetAmount
	Fuel Oil 180 cst	1,876.000	L	33.01	61,921.13	0.00	0.00	12.00 %	7,430.54	69,351.70
	Transport Charges			0.00	0.00			16.00 %	0.00	0.00
	Service Charges			0.00	0.00			16.00 %	0.00	0.00
	Financial Charges			0.00	0.00			16.00 %	0.00	0.00
	Security Deposit			0.00	0.00					0.00
	Total				61,921.13		0.00		7,430.54	69,351.70

Net mount : SIXTY-NINE THOUSAND THREE HUNDRED FIFTY-ONE & SEVENTY CENTS
Curr ncy : KES Payment Conditions : 30 DAYS FM END MONTH OF SUPPLY

	Name	Signature	Date
ared By	Benson Msololo		02/06/2009
ot Manager	Mureno M M		02/06/09
er			
tomer			

Due Date:30.06.2009
Net Due Amount : 69,351.70

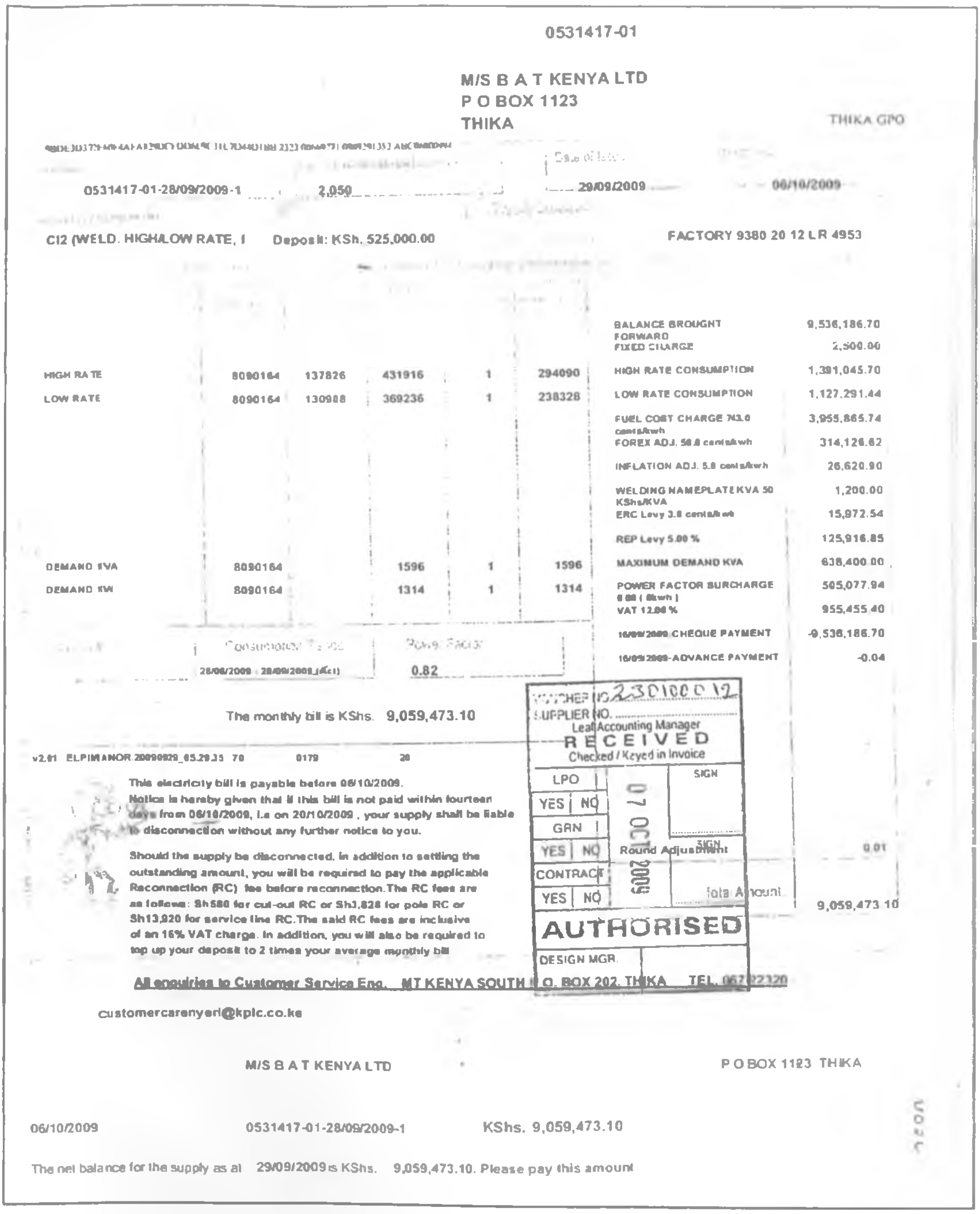
Payment Condition:Z031
Payment due Date : 30.06.2009
Amount Due : 69,351.70 KES

TOTAL KENYA LIMITED
CHAI HOUSE - KOINANGE STREET, P. O. BOX 30736, NAIROBI, KENYA
TEL NO: 254-20-2897000/212300, FAX NO: 254-20-243886
VAT NO : 0010606F PIN NO. : P000591674X

. O & E

ANY COMMENTS BY THE CUSTOMER TO BE ENDORSED ON THE INVOICE

Appendix 4 Copy of electricity bill



0531417-01

M/S B A T KENYA LTD
P O BOX 1123
THIKA

THIKA GPO

0531417-01-28/09/2009-1 2,050 29/09/2009 06/10/2009

CI2 (WELD. HIGH/LOW RATE, 1 Deposit: KSh. 525,000.00

FACTORY 9380 20 12 LR 4953

HIGH RATE	8090164	137826	431916	1	294090
LOW RATE	8090164	130908	369236	1	238328
DEMAND kVA	8090164		1596	1	1596
DEMAND kW	8090164		1314	1	1314

Consumption Period	Power Factor
28/08/2009 - 28/09/2009 (Act)	0.82

BALANCE BROUGHT FORWARD	9,536,186.70
FIXED CHARGE	2,500.00
HIGH RATE CONSUMPTION	1,391,045.70
LOW RATE CONSUMPTION	1,127,291.44
FUEL COST CHARGE 743.0 cents/kwh	3,955,865.74
FOREX ADJ. 59.0 cents/kwh	314,126.62
INFLATION ADJ. 5.0 cents/kwh	26,620.90
WELDING NAMEPLATE KVA 50 KShs/KVA	1,200.00
ERC Levy 3.0 cents/kwh	15,972.54
REP Levy 5.00 %	125,916.85
MAXIMUM DEMAND KVA	638,400.00
POWER FACTOR SURCHARGE [illegible]	505,077.94
VAT 12.00 %	955,455.40
16/09/2009 CHEQUE PAYMENT	-9,536,186.70
16/09/2009-ADVANCE PAYMENT	-0.04
Round Adjustment	0.01
Total Amount	9,059,473.10

The monthly bill is KShs. 9,059,473.10

v2.01 ELPIMANOR.20090929_05.29.35 70 0179 20

This electricity bill is payable before 06/10/2009.
Notice is hereby given that if this bill is not paid within fourteen days from 06/10/2009, i.e on 20/10/2009 , your supply shall be liable to disconnection without any further notice to you.

Should the supply be disconnected, in addition to settling the outstanding amount, you will be required to pay the applicable Reconnection (RC) fee before reconnection.The RC fees are as follows: Sh580 for cut-out RC or Sh1,828 for pole RC or Sh13,920 for service line RC.The said RC fees are inclusive of an 16% VAT charge. In addition, you will also be required to top up your deposit to 2 times your average monthly bill

VOUCHER NO. 2301000012
SUPPLIER NO.
Leaf Accounting Manager
RECEIVED
Checked / Keyed in Invoice

LPO	07 OCT 2009	SIGN
YES | NO		
GRN		SIGN
YES | NO		
CONTRACT		
YES | NO		

AUTHORISED
DESIGN MGR.

All enquiries to Customer Service Eng. MT KENYA SOUTH P.O. BOX 202, THIKA TEL. 06722320

customercarenyeri@kplc.co.ke

M/S B A T KENYA LTD P O BOX 1123 THIKA

06/10/2009 0531417-01-28/09/2009-1 KShs. 9,059,473.10

The net balance for the supply as at 29/09/2009 is KShs. 9,059,473.10. Please pay this amount