OPTIMIZATION OF ENERGY REQUIREMENTS IN COCOA BEANS PROCESSING PLANT IN NIGERIA: ILE-OLUJI COCOA PRODUCTS COMPANY AS A CASE STUDY

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CERTIFICATION

This is to certify that this project work was embarked upon and carried out by AIKHOJE IKHUOKHIO GODSON in the Department of Mechanical Engineering for the award of Master of Engineering (M.ENG) Degree in Mechanical Engineering of the Federal University of Technology Akure.

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DEDICATION

To God be the Glory.

This work is dedicated to God who was and

is in charge of my life.

Also to my Late Father Major Z.U. Aikhoje

and

My late brother Gilbert Aikhoje

who left this sinful world within an

interval of two years.

Father Almighty take control.

ACKNOWLEDGEMENT

The contribution of my supervisor, Dr. C.O. Adegoke cannot be over emphasized. He effectively, patiently and in a human manner guided me in this work. His timely advice, assistance and co-operation were unquantifiable. Words alone cannot express my gratitude to him. My prayer is that God will continue to reward him abundantly.

I will not fail to acknowledge the kind gesture of my past and present Head of Department, Prof. A.A. Aderoba and Dr. O.P. Fapetu whose contribution towards achieving my goals cannot be quantified.

Also I acknowledge the contribution of Engineer O.O.M. Balogun my former boss for giving me the opportunity and time during lectures as well as open doors for information towards the completion of my project work. Also Mr. A.O. Oni, my assistant for holding forth in my absence.

This acknowledgement cannot be complete without remembering the immense contribution of my immediate family after the loss of my father, late Major Z.U. Aikhoje. They were my inspirators, my Mum - Mrs D.I. Aikhoje, my brothers - Godwin and George as well as my sister Charity.

I cannot forget the role my beloved "Nkem" played in all. She would always ensure that my assignments were done on time and wake me up at odd hours for my project work.

Above all, I thank God for giving me strength and inspiration to do the work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOMENCLATURE

A	-	Radiating Surface Area (m^2)
C_v	-	Specific heat capacity at constant value - (J/kgK)
E	-	Mean wave Energy per unit area of water (W/m^2)
g	-	Acceleration due to gravity (m/s^2)
GCV	-	Gross Calorific Value (kJ/kg)
h	-	Specific enthalpy (kJ/kg)
NCV	-	Net Calorific Value (kJ/kg)
P	-	Power (J)
q	-	Specific heat energy (kJ/kg)
Q	-	Heat energy (kJ)
rms	-	Root mean square
t	-	Temperature (°C)
T	-	Temperature (K)
U	-	Internal Energy
w	-	work done per unit mass (kJ/kg)
W	-	Work done (kJ)
z	-	Height above a datum position (m)
ρ	-	Density (kg/m^3)
η	-	Cycle efficiency

ABBREVIATION

D.C's	-	District of Colombia
E.U	-	European Union
GDP	-	Gross Domestic Product
ICPCL	-	Ile-Oluji Cocoa Product Company Limited
LPFO	-	Low Pour Fuel Oil
MTBF	-	Mean Time Before Finishing
MTOE	-	Million Ton of Oil Equivalent
N.E.P.A	-	National Electric Power Authority
OEM	-	On Equipment Manufactures Recommendation
OSMO	-	Osmotic Pressure Power
OTEC	-	Ocean Thermal Energy Conversion
SFEE	-	Steady Flow Energy Equation
TWh	-	Tera Watt Hour
UDI	-	Utility Data Institute

ABSTRACT

In this study, energy savings in a cocoa processing factory was found to be dependent on various factors which include monitoring and auditing of total energy usage and steam consumed.

As a result, tests were carried out on the load centers such as the boiler, power generating house, process zone and offices where equipment for processing beans as well as air conditioners are put to use on a daily basis.

Complete analysis of the results obtained from raw data over five years reveals that L.P.F.O is preferred to A.G.O at a boiler combustion efficiency of 74.49%. Savings amounting to ₦112,334.50 per annum could also be realizable. On steam distribution, the company would loose as much as 325W/m if its steam supply lines are insulated with 15mm thick materials as against the present 25mm thick. 50W/m of energy would be conserved using an insulating material of 50mm thickness.

A proposal of using 40 sodium lamps in place of 586 fluorescent tubes would increase illuminance in the factory by 22% with a realisable cash savings of ₦308,9971.80 per annum.

CHAPTER ONE

1.0 INTRODUCTION

With the increasing cost and demand for fuel today, no progressive business can afford wastage of energy. A proper energy monitoring, auditing, conservation and targeting system can yield substantial savings in both time and money.

Most practicing engineers and industrialists consider energy management in abstraction which ideally to them cannot be realised in small and medium scale manufacturing industries thus production processes are carried out without much consideration on ways to harness available internal energy resources. Today in Nigeria, companies employ management consultants who are not more knowledgeable than practicing engineers for such energy management thus cost of implementation is still on the high side.

1.1 Aim of the Project

Most of the demand of energy arises from domestic, commercial, industrial and transport uses. Virtually all the processes involved in supplying this energy have one thing in common: they are quite inefficient in their conversion of primary energy to an end use. The basic reason for this inefficiency, and what can be done about it form the content of this study.

The techniques used in the management of energy have much in common with those required for the management of any other resources in an establishment. These are: resources, such as materials and manpower;

l concept of monitoring performance, the setting of targets which l to the control of costs and the motivation of staff associated y usage.

t industries use energy in one or two major ways:

e direct manufacture of a product, e.g. in the roasting of cocoa s/cocoa nibs, powering electric motors as well as energy to rs for steam generation.

e activities which support manufacturing process, e.g. energy l to maintain a factory's environment for the benefit of employees as space heating or cooling of offices, warehouses, hot water ices and lightings.

an over simplification to imagine that the concept of money an energy study is just a question of establishing areas of es and taking appropriate corrective actions, though it does form nt starting point in the description of the activity of energy The fuel and energy cost of a company is related to the tariffs ublished by N.E.P.A.

rancis (1958) put it, there is often a choice of tariff structure, for ith electricity and it is a matter of negotiation with relevant uring installation as to which is the most advantageous structure he tariff structure will not of itself necessarily alter the total n of energy but may support a different pattern of usage to s.

rding to Eastop and Croft (1990), companies employ tariff or obtain advice from relevant authorities during plant upgrading he complicated nature of tariffs in some countries. For most he selection that would give the lowest average prices is oon the load pattern which the consumer imposes on his oply system through the year.

duction can also be achieved by reviewing assessed capacity rticular for premises which have undergone a reduction in anges in electrical utilization. Tariffs should be reviewed at als particularly when NEPA introduces changes to their tariff

Data Uses

om energy studies in an industry can provide useful information ys which include:

f fuel to use.

tance, the ever increasing cost of fuel in Nigeria can impede wth of industries and send unstable ones to oblivion. Energy s enables energy managers to identify areas where higher c value fuels would be useful as against lighter fuels.

on of statistical data to compare the energy efficiencies of one elative to another in the same market setting.

nvestment decisions as energy analysis provides investors and cturers knowledge of the certainty of the future hence the lity of management of an organization to make decisions which ead to an optimal behaviour of the organisation.

d. Research guidance as proper energy record of a plant gives a researcher an insight to the energy state of a plant which in effect gives him a lee way to his research work.

1.3 Objectives

i. To quantify fuel energy cost per metric tonne of cocoa products (butter and Cake)

ii. To determine how effective Ile-oluji cocoa products company utilises her energy.

iii. To establish an optimum energy requirement for cocoa industries in the country.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Energy Management Process

Broadly speaking, there are three major ways to manage energy use. The first is by reduction of demand, either through self-denial or through enforcement, regulatory action, or economic measures. The second approach is to use an alternative method, process or piece of equipment to achieve the desired end result with greater efficiency. Implementation of these types of change hinges largely on the availability of technology and economic justification. The third method is to substitute one fuel or energy source for another. The current enlightenment trend in the country on the use of natural gas as substitute for diesel and heavy fuel oil by the Nigeria National Petroleum Corporation and the Nigerian Gas Company is a step towards achieving the third method. This may or may not lead to net energy savings, but can shift the requirement from one fuel to another, saving thereby scarce resources.

2.2 Alternative Power Sources

2.2.1 *New Electric Capacity Turning To Natural Gas*

In Europe, electric utilities and independent power producers are selecting natural gas as the fuel of choice for new power plants in the 12 countries comprising the European Community (EC), according to a new report released by the Utility Data Institute as highlighted by Snow (1992).

Utilities and non-utility power producers are planning a combined total of 86,000MW of new generating capacity over the next ten years, of which

39% will be fueled by gas, 23% by coal, 13% by nuclear and 13% by hydroelectric. Of this planned capacity, only 40% is actually under construction. Tables 2.1 and 2.2 show respectively the distribution of installed and projected generating units and capacity by fuel in the European Union.

Utility Data Institute's (UDI) 1992 edition of directory of power plants in the European Community is a substantial update of the European Community power plant data base and includes about 30% more units records than the 1990 edition. "The power plant business in the EU is both dynamic and unsettled at the present time", said Christopher Bergesen, UDI Vice President.

TABLE 2.1: Distribution of Installed generating units and Capacity by Fuel in the European Union.

Fuel/type	Number of units	Capacity(MW)	% of capacity
Coal	852	163,110	33.6
Natural Gas	446	30,580	6.3
Oil	1,302	89,383	18.4
Nuclear	131	108,925	22.4
Hydraulic	3,433	77,763	16.0
Other gas	60	2,889	0.6
Unknown	138	10,580	2.2
Others	177	2,660	0.6
	6,539	485,896	

Source: (Snow, 1992)

TABLE 2.2: Distribution of Projected generating Units and Capacity by Fuel in the European Community.

Fuel/type	Number of units	Capacity (MW)	% of capacity
Coal	55	19,705	22.8
Natural Gas	24	33,425	38.7
Oil	19	3,559	4.1
Nuclear	8	10,945	12.7
Hydraulic	137	11,204	13.0
Other gas	23	1,204	1.4
Unknown	9	1,103	1.4
Others	105	5,292	6.1
	596	86,437	

Source: (Snow, 1992)

Other alternative energy sources include: solar energy; osmo power, ocean thermal energy conversion; tidal power; wind energy and wave power.

2.2.2 *Solar Energy*

Solar energy, which has been considered as a pollution - free and a renewable form of energy especially for cooking is considered a better alternative to the conventional sources of energy. The 1974 report of Bruce Research Institute Senegal to UNEP shows that solar cooking with smokeless wood stoves as a back-up was far the least expensive alternative compared to butane gas or charcoal.

2.2.3 *Osmo - Power*

According to Jellinek (1974), Osmo power is as a result of the chemical potential difference between fresh and sea water. As fresh water rivers are discharged into estuaries, this potential energy is dissipated by direct mixing without producing useful work. The energy of this mixing process can be utilized if the mixing is allowed to proceed via a semi permeable membrane.

Osmosis occurs between solutions separated from solvent by means of such a membrane thus allowing diffusion to occur between the solutions. If this diffusion is restricted, Osmotic pressures are built up across the membrane.

This high Osmotic pressure can thus be made to do work. One method of doing this is to let the liquid rise to a high level and then allowed to discharge through a turbine.

2.2.4 *Ocean Thermal Energy Conversion (OTEC)*

The OTEC or "power from the sea" concept utilises the temperature gradient which exists between the ocean floor and the surface in tropical region. The surface waters heated by solar irradiation, are directed over the heat - transfer surfaces of the evaporator of a Rankine cycle engine while the cold water returning from polar region and settling on the ocean bed is used to cool the condenser (Robert, 1983).

The cost of such a system is dominated by the large heat - exchanger area involved. The design, construction and maintenance of the long deep pipes necessary is also a major problem in OTEC.

2.2.5 *Tidal Power*

This is the energy stored in tides, currents and the thermal gradients of the ocean. The tides and tidal currents have a power estimated at 3 x 10^{12}W (Shaw, 1974). The tidal motions of the ocean are the results of the interaction of the gravitational forces of the sun-moon-earth system, which change as the earth rotates about it's axis, and the centrifugal force due to the rotation of the earth - moon doublet. Although the estimated global tidal power available is about 3 x 10^{12}W, practical sites on world coastline for tidal power extraction installation might obtain only about 64,000MW.

2.2.6 *Wind Energy*

The wind energy occurs as a result of atmospheric changes and thus operates on the original fuel of the sun.

The kinetic power available per unit area of capture in a wind stream is calculated from.

$$E = \frac{\rho C^3}{2} \quad (W/m^2) \quad \text{------------} \quad 2.1$$

Where ρ is the density of the wind (kg/m^3) and c is the average wind speed (m/s). Wind energy is usually harnessed using the aerogenerator or the wind mill as discussed by Holland (1978).

2.2.7 *Wave Power*

Solar energy generates atmospheric winds and the winds and tides cause waves. As estimated by Holland (1978), wave fronts contain kinetic energy at the rate of 100kWh/m and that the energy stored in global ocean waves is in the order of 2.7TW.

For a wave of a root mean square height about the mean plane of H_{rms}, density of water, ρ(kg/m³) and acceleration due to gravity g (m/s²), the mean wave energy per unit area of water is calculated from.

$$E' = \rho g H^2_{rms} \text{ -------- } 2.2$$

and the power per unit depth of a wave crest, assuming a sinusoidal form is

$$P = \frac{\rho g^2 H_{rms} T}{4\pi} \text{ ------ } 2.3$$

where T is the periodic time of the circular orbit.

2.3 Load Factor Improvement

The selection of the cheapest tariff is one method of reducing electricity cost, a change of tariff on its own is unlikely to produce large benefits if the load factor is poor.

$$\text{Load factor} = \frac{\text{annual consumption in kWh}}{\text{Max demand (kW) x hours in years}} \quad \text{........ } 2.4$$

Because maximum demand tariffs comprise a demand and an energy - related component, an improvement in the load factor will lead to the demand charge being distributed over a greater number of units and hence lead to a lower average price.

As Eastop and Croft (1990) put it, an increase in total electricity consumption will also increase the load factor. The maximum demand can often be reduced by energy recovery schemes or careful sizing of equipment such as heating element or the use of modern methods of lighting and heating.

2.3.1 *Load Factor Improvement Technique*

A technique for improving the overall load factor is demand management, a system which will reduce electricity consumption if the metered demand looks likely to exceed some present limit. The actual value of the maximum demand is taken from a meter which aggregates energy (kWh) over a 30 minutes period. Systems normally employ microprocessor-based units to predict the half life demand and compare this with a reference level. If the forecast demand exceeds the reference level then the management system will either sound a warning alarm or take action by disconnecting the supply from non-essential usage and later reconnecting when the total demand has reduced. The equipment which is considered non - essential will vary with the type of company or establishment, e.g space and water heaters or air conditioners.

2.4 Power Factor Correction

Power factor is the ratio

$$\frac{\text{Useful power (kW)}}{\text{apparent power (kVA)}}$$

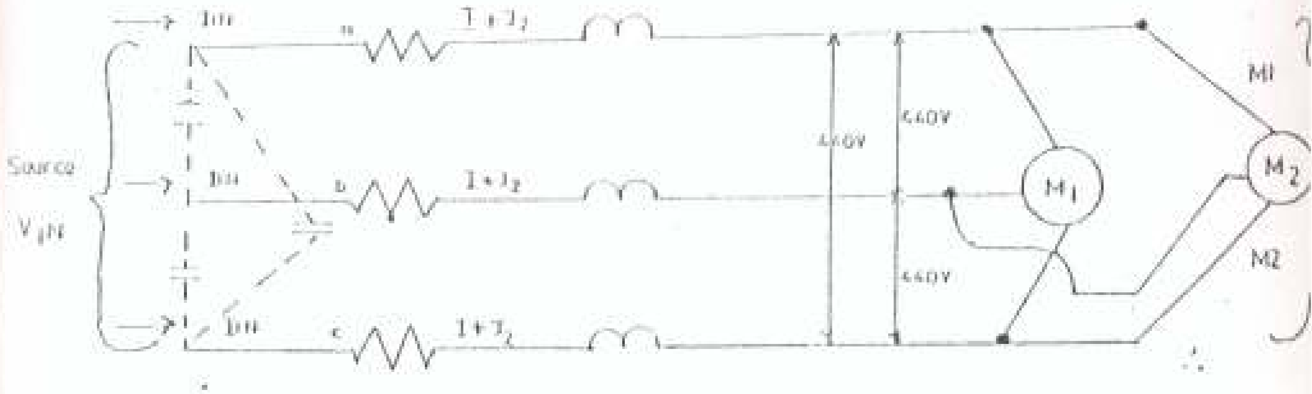
Certain types of electrical equipment such as resistance heaters and incandescent lamps take only useful power and so the power factor of a system using only these devices would be unity. Other types of equipment such as electric induction motors, transformers and other inductive devices alter the phase between the voltage and the current causing the apparent power to be greater than the useful power.

A customer will be billed for apparent power because it is his responsibility to make best use of the energy on his premises. If a factory has a low power factor then NEPA will have to install a large supply capacity than is really needed, for which the factory will have to pay via the demand and availability tariffs. The power factor can be improved by installing banks of capacitors (to correct the phase angle) either at the supply point or an individual piece of equipment, (Francis, 1958).

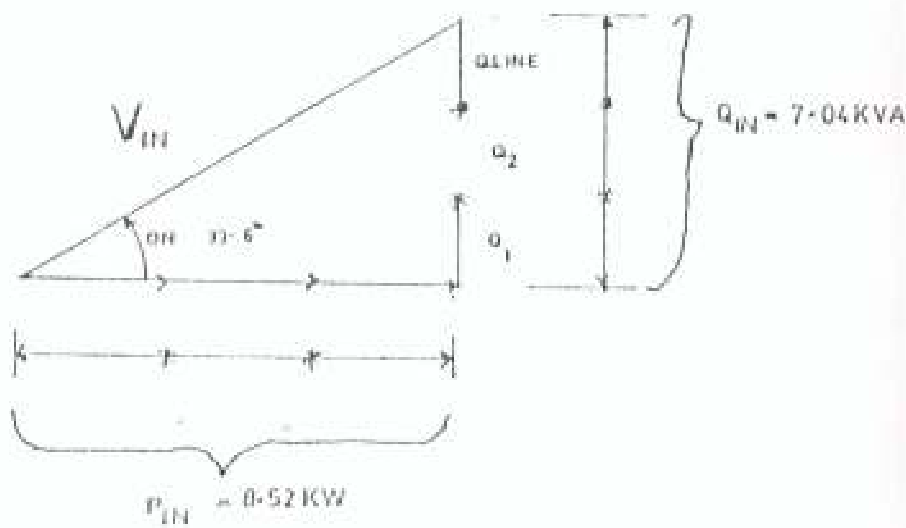
2.4.1 *Power Factor Correction Technique*

As an illustration, two induction motor loads are connected in parallel at the end of a three - phase line with balance impedance. The voltage at the input terminals of the motors is a balanced 440V (Figure 2.1). It is expected to find the input voltage V_{IN}. Input current I_{IN} and the input power factor with a sketch of the power triangle for the system.

In order to correct the power factor, consideration is given to the correction of a three - phase delta connected capacitor bank (shown by dotted lines in Fig. 2.1). It is expected to find also the capacitance per phase of the delta necessary to bring the input power factor to a 0.9 lagging, compare the value of input current before and after power factor correction assuming V_{IN} is constant at the value found above.



Figured 2.1 Induction Motor Loads Connected In Parallel.



Figured 2.2: Phasor Diagram for Figure 2.1.

From Figure 2.1,

$$P_T = P_1 + P_2 \quad \text{--------} \quad (2.5)$$

$$= 5 + 3 = 8kW$$

$$Q_T = Q_1 + Q_2 \quad \text{--------} \quad (2.6)$$

$$= 4 + 2 = 6kVAR$$

$$S = P_1 + jQ_1 \quad \text{--------} \quad (2.7)$$

$$= 8 + j6 \text{ kVAR}$$

$$|S| = \sqrt{P_T^2 + Q_T^2} \text{ -------- } (2.8)$$

$$|S| = \sqrt{8^2+6^2} = 10kVA$$

$$|S| = \sqrt{3}\,|V_L|\,|I_{IN}| = 10kVA \text{ ---}(2.9)$$

$$|I_{IN}| = \frac{10kVA}{\sqrt{3}(440)} = 13.13A$$

$$P_{line} = 3|I_{IN}|^2 R \text{ ------ } (2.10)$$

$$= 3(13.13)^2(1) = 518W = 0.518kW$$

$$Q_{line} = 3|I_{IN}|^2 x2 \text{ ----- } (2.11)$$

$$= 3(13.13)^2(2) = 1036\,VAR = 1.036kVAR$$

$$P_{IN} = P_{line} + P_T = 0.518 + 8 = 8.518kW$$

$$Q_{IN} = Q_{line} + Q_T = 1.036 + 6 = 7.036kW$$

$$S_{IN} = 8.518kW + j7.036kVA$$

$$(S_{IN}) = \sqrt{(8.518)^2 + (7.036)^2}$$

$$= 11.05kVA$$

$$V_{IN} = \frac{11.05kVA}{\sqrt{3}(13.13)} = 486V$$

The phasor diagram is shown in Fig. 2.2.

$$Q_{IN} = \tan^{-1} \frac{Q_{IN}}{P_{IN}} \text{ ----- } 2.12$$

$= 39.6°$

$Pf_{IN} = \cos 39.6° = 0.771$ lagging.

To correct the power factor to 0.9 lagging, the new Q_{in} must be such that $Q_{in} = \text{Cos}^{-1}\ 0.9 = 25.8°$. This is a reduction from 39.6° to 25.8°, This is accomplished by adding negative (capacitive) VARs. Real power does not change during this process if one assumes that the capacitor is lossless as in Figure 2.3.

$Q_{IN} = P_{IN} \tan \Theta_{IN} = 8.52 \tan 25.8° = 4.12$KVAR

$Q_{added} = Q_{IN}$ (with capacitance)- Q_{IN} (without capacitance)

$Q_{added} = 4.12 - 7.04 = -2.92$ KVAR (Negative sign indicates Capacitor)

$$Q_{added}/\text{Phase} = \frac{Q_{added}}{3} = \frac{2.92}{3} = 0.973 \text{ KVAR}$$

$$Q_{added}/\text{Phase} = \frac{/V_{IN}/^2}{X_c}$$

$$X_c = \frac{/V_{IN}/^2}{Q_{added}/\text{phase}} = \frac{(486)^2}{973} = 243\ \Omega$$

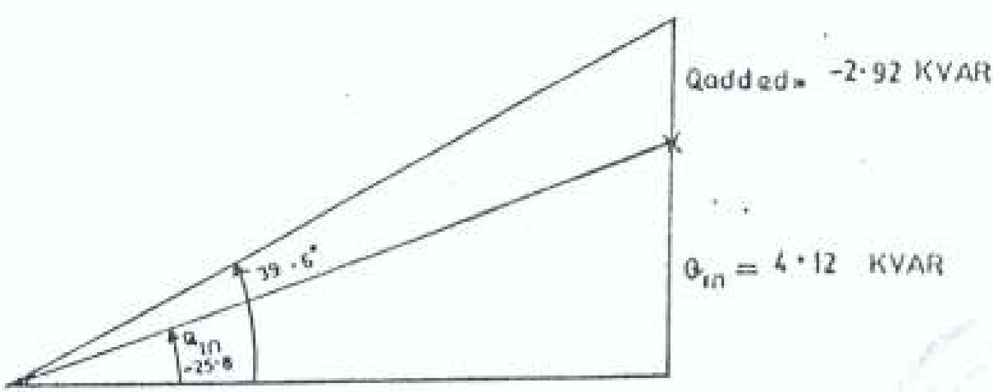


Fig 2.3: Corrected Phasor Diagram.

$$C = \frac{1}{2\pi f x_c} \quad \ldots\ldots\ 2.13$$

$$= \frac{1}{2\pi(60)(243)}$$

$$= 10.9\mu f$$

Magnitude of the input current with the capacitor added is

$$|I_{IN}| = \frac{P_{IN}}{\sqrt{3}V_{IN} \times pf}$$

$$= \frac{8518}{\sqrt{3}(488)(0.9)}$$

$$= 11.25A$$

The reduction in current is

$\Delta T \quad = \quad 13.13 - 11.25 \ = \ 1.88A$

In large power situations with high load (current), wiring costs can be reduced with proper maintenance of a power factor of 0.85 or greater. (Leander and Morgan, 1987).

2.5 Energy Recovery

A typical system producing useful heat and work from an energy input rejects energy in the form of waste gas/or liquid, and transfers heat to the atmosphere due to mechanical friction, electrical losses, and heat transfer from surfaces. To minimise the energy input for a given useful output of work and heat, the plant must be carefully designed to reduce the energy wastage to a minimum. Energy recovery is one of the ways of minimizing the thermal losses and various energy recovery methods would be discussed.

Considerable savings have been made in industries by producing insulating materials for steam, hot water as well as chilled water distribution and circulatory pipe networks.

Many industrial processes involve the heating of liquid in open tanks and considerable savings in heat loss can be made by using oxidation/reduction (KDF redox media) in removing chlorine from municipal water suppliers, protecting reversed osmosis system, controlling scale formation as well as bacteria and algae growth in cooling tower water.

2.5.1 *Process Water Treatment*

When water temperature changes, minerals precipitate in the form of a hard brittle scale that collect in pipings and on heat transfer surfaces. This insulating scale build-up reduces efficiency of equipment, increases fuel requirement, maintenance time and cost.

KDF (Redox) process media are high purity copper - zinc formations. They reduce contaminants in water using oxidation/reduction method. Water is the most frequently used media to transport thermal energy for some useful purposes (Al-Kharusy, 1996).

2.5.2 *Luminaire Energy Recovery*

There are several ways in which the energy used for lighting may be reduced with a consequent reduction of annual running cost. The first and perhaps most obvious way is to check that each lamp is switched on only when required. Simple timers can be used and photocell switches connected in areas where day light level provide adequate lighting for parts of the period of use in the building.

The most frequently used heat - recovery luminaire draws air from the room across the tubes or lamps and delivers it to a plenum above the ceiling from where it can be passed to mix with the inlet air to the room. Less frequently, water is used as the coolant fluid. (Eastop and Croft, 1990).

It can be seen that for the normal use luminaire, the way the luminaire is enclosed and ventilated is important in order to maintain optimum light output and when it is designed for heat recovery then the heat transfer from the tube must be too high otherwise the tube surface temperature could fall below the optimum value.

2.5.3 *Advanced Heat Recovery System*

A growing number of organisations that consumes large amount of energy are cutting cost by installing their own combine heat and power (CHP) systems Peter (1993) reported that heat recovery system is flexible to allow for reduced amount of heat recovery depending, of course, on the loading and varying demands. When full waste heat recovery is not needed, an automatic electrically controlled system within the heat exchanger gradually reduces the recovery of exhaust heat by allowing the exhaust flue temperature to rise.

Whenever lower level of heat recovery is required, an automatic system within the flametec module increasingly directs coolant to a bank of external cooling radiator to dump the excess heat to atmosphere.

The heat exchange system reduces the exhaust gas temperature to below 120°C during full exhaust heat recovery. According to Peter (1993), Normal Love, Flametecs Managing Director noted that it is not anticipated that clearing of the exhaust heat exchanger will ever be needed. The design is based on many years of experience in the manufacture of diesel engine exhaust gas heat exchanger for flametec flame protection system covering a wide range of sizes and types of engine.

2.6 Solar Heating Applications in Industrial Process

Charles (1984), emphasized that energy conservation is the best first step in the thermal design of buildings. His view was that the procedure for determining the optimum amount of energy conservation is no different for a passive or active solar building than for any other building. He further said that the life-cycle cost analysis of insulation may take into account any number of credits or changes, such as maintenance, tax saving and salvage value.

Kenneth (1988), defined industrial process heat as thermal energy used directly in the preparation and/or treatment of materials and goods produced by manufacturing concerns. He further assessed surveys of the relative quality of heat energy required at various temperatures in the industrial sector showing that a significant fraction of industrial process heat is used at temperature within the operating range of current solar thermal collector technology that 60% of total industrial process heat demand occurs below 150°C and over 40% of total manufacturing energy consumption in 1978 was used for heat required in the processing of manufactured goods.

2.7 Proactive Maintenance - A Cost Reduction Strategy in Industries

James, (1992) worked extensively on machines predictable service life and came up with strategies of machines maintenance to achieve useful operating lives many times that attainable just a few years ago. He said that the 1980s bore the popular practice of predictive maintenance and condition monitoring to combat rising maintenance costs and that in the 1990s predictive maintenance was implemented with greater confidence and precision. These early warnings have proven effective at reducing the magnitude of failure and most of unscheduled downtime, however no real progress has been made in reducing frequency.

Proactive maintenance stresses the monitoring of conditions, not failure itself. Abnormal or unhealthy conditions are the precursors to failure. The implementation of proactive maintenance has the potential to extend a machine's life (MTBF) by more than ten times. It is the maintenance strategy that extends machine life by monitoring and correcting failures root causes.

The monitoring and control of contamination in lubricating fluids is a proactive maintenance activity since lubricating-oil contamination is a cause of wear and failure, exceedingly clean fluids proactively lead to exceedingly reliable and long -lived machines.

The tactic of targeting clean fluids, installing capable filtration/separators, and frequent contaminant monitoring makes sense in diesel and gas - turbine engine maintenance. Finley (1990), stated that periodic checks on the levels of various contaminants are essential to ensure adequate (contamination) control. The four principal contaminants to be monitored in order of importance, are: solid particles, water, acids and low - boiling hydrocarbons.

Contamination control is not a matter of doing or not doing in a generic sense. What really matters is how clean the fluids are and how rigorously this cleanliness is maintained. The quality of contamination control as a plant maintenance activity can be categorized in a number of ways.

i. **Passive Contamination Control.**

Fluids and filters are changed infrequently. No schedule is observed, no accountability of parts changed. Fluid cleanliness targets are not defined and fluid cleanliness levels are not measured.

ii. **Reactive Contamination Control.**

Filters and fluids are changed according to available manpower, budgets, and the frequency of machine problems. There is no regimented schedule.

iii. **Active Contamination Control.**

Filters and fluid are changed according to a structured preventive maintenance schedule. Filter type and change intervals are based on equipment manufacturers recommendations (OEM). Target cleanliness levels are based also on equipment manufacturers recommendations.

Implementation of proactive contamination control requires lots of effort. Typically required are: change of maintenance habit; change of filtration methods; and most importantly, a change of maintenance philosophy and attitude.

2.8 Maintenance Technology in Factories

The field of maintenance technology is going through a revolution of change. Gone are the days when a machine had a predictable service life, after which it was replaced, continuing the cycle. Today, machinery and equipment can achieve useful operating live many times over what it used to be a few years ago.

Any or combination of the following methods of maintenance are being applied to the different plants and machineries in our production system taking into consideration:

i. Complexity

ii. Age

iii. Quantity

iv. Mode/condition of operation

v. Reliability

vi. Manufacturers specification

vii. Reliability factor (MTBF).

2.8.1 *Preventive Maintenance*

Preventive maintenance is applied for single pieces of equipment such as Beans cleaner, Micronizer, Roaster. Boiler etc. This involves inspection, lubrication adjustment, cleaning, checks (visual and audio).

2.8.2 *Predictive Maintenance*

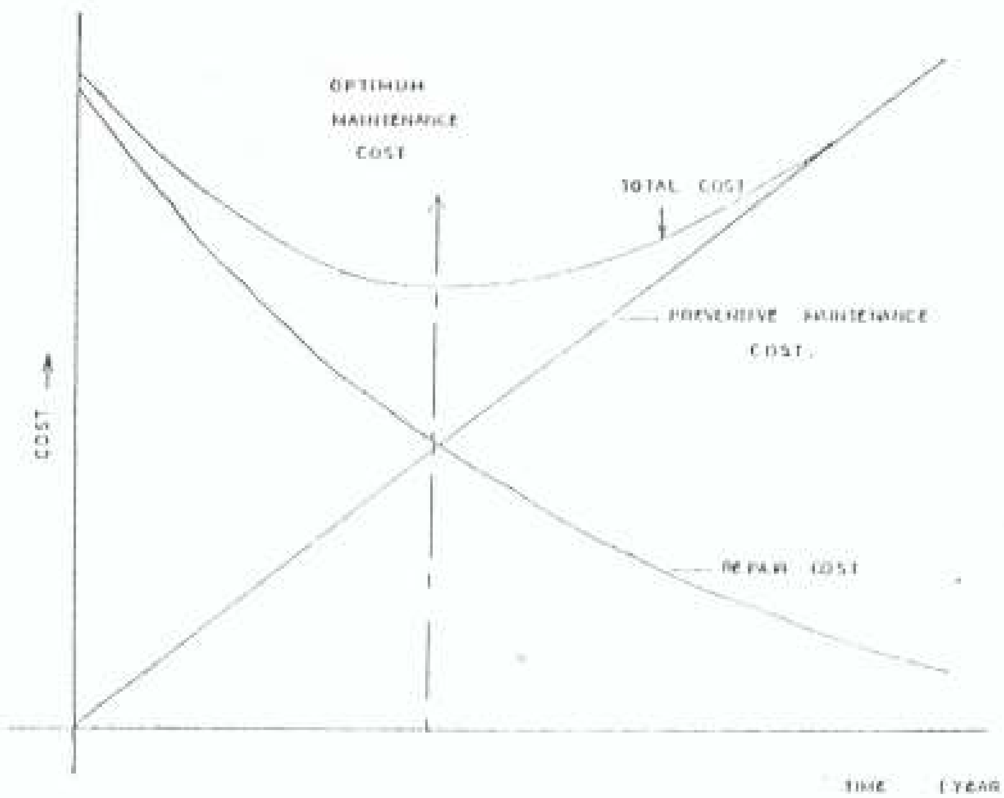
This involves condition monitoring with trend analysis to combat raising maintenance cost and these early warning have proven effective at checking the magnitude of failure and amount of unscheduled downtime.

2.8.3 *Shutdown Maintenance*

This would involve overhauling, replacement installation, multiple preventive maintenance.

i. General shutdown (planned, unplanned)

ii. Emergency shutdown (emanating from failure).



[illegible]

2.8.4 *Economic Life of Machines*

The useful service life of a machine before it becomes unprofitable for its original purpose due to technological obsolescence, wear or a change in the firm enterprise.

All new machines are supplied with maintenance schedules. For most factory machines; preventive maintenance and overhaul schedules are specified in terms of hours of work. Figure 2.4 shows an optimum maintenance interval whereby the total cost of maintenance and repairs is minimum.

2.9 Electrical Energy Consumption

In his lecture, titled Electric Energy Management in the Factory, Esan (1998), was of the view that government plans of deregulation of electricity industry in Nigeria will amount to skyrocketing cost in generation of electric energy which would invariably increase energy pricing.

According to Esan, the world's commercial energy consumption for 1995 was 8,000million tons of oil equivalent (M.T.O.E) of which only 28 percent went to developing countries.

In 2020, the projection for world commercial demand would be over 11,500 M.T.O.E with developing countries consumption increasing to 50 percent. Global electricity production in 1995 was estimated to be around 13,000 Tera watt hour (TWh), with only 25% in developing countries. In 2010 global electricity production is estimated at 18,700 TWh with 6,600 TWh (35%) in developing countries. By the year 2030, 50% of the world's electricity production is expected to be from developing countries as indicated in Table 2.3.

TABLE 2.3: Estimated World Energy Production

S/N	Region	1990	2000	2010	2030
	(TWh)				
1	OECD & Others	9,020	11,150	12,000	14,200
2	D.C'S	2,680	4,000	6,600	14,200
	World	11,700	15,650	18,700	28,400

TWh: Tera Watt hour
OECD: Oceanic region
D.C's: District of Colombia

Source: (Esan, 1998)

2.9.1 *Energy Demand and Consumption in Nigeria*

The total electricity generated in 1990 was about 14,000TWh with industries consuming about 25.7 percentage (Esan, 1998). Table 2.4 shows the percentage share of commercial energy consumption in Nigeria for 1989, 1990 and 1992.

The electrical energy consumption levels for various years are given in Table 2.5. Shortage of petroleum products and frequent electric power failure in recent times are due to operational problem such as, obsolete equipment, inadequate distribution of facilities and high operational cost.

TABLE 2.4: Energy Consumed In Nigeria To Arrive At GDP For The Years 1989, 1990 and 1992

		1989	1990	1992
1.	DP at 1984 factor cost (₦b)	NA	90.34	98.07
2.	GNP at current factor cost (₦b)	49.63	257.88	440.26
3.	Population (million)	73.80 Projected	98.0 projected	88.6 (1991 census)
4.	% shares			
i	Petroleum[2]	79.4	79.4	49.6
ii	Natural gas[2]	0.30	29.8	28.3
iii	Coal[2]	1.30	0.2	0.1
iv	Electricity[2]	19.0	23.3	22.0
5.	Fuel Wood[1]	69.4	50.0	50.0

1. Estimated from total primary energy consumption

2. Estimated from total commercial energy consumption

Source: (Esan, 1998)

Table 2.5: Electrical Energy Consumption

Year	Electric Energy (kWh)
1987	7374.7
1989	8556.3
1992	8699.0
1995	9435.9

Source: (Esan, 1998)

The electric energy requirement for various years are given in Table 2.6. The additional generating capacity indicated in Table 2.6 is presently very prohibitive. Even the running cost of stand-by generators has increased due to increase in cost of fuel.

A way out is energy savings, an alternative form of energy supply. It is cheaper to supply energy by releasing portion lost due to inefficiency from the existing supply capacity than it is to add new capacity.

TABLE 2.6: Electric Energy Requirement

Year	Electric energy (kWh)
1986	14482.6
1989	12813.1
1992	14833.8
1994	15531.0
1995	14482.0

Source: (Esan, 1998)

Table 2.7 gives a typical fuel consumption profile by sectors in Nigeria. It must be pointed out that despite this rapid growth rate, on a per capital basis, Nigeria still has a low electricity consumpttion per capital at 70kWh per capital (1987). From international comparative stand point, the per capital electricity consumption in Nigeria is less than 1% of that of any of the industrialised countries. The low level of electricity consumption per capital is due to the fact that more than 80% of the population resides in the rural areas where they have no access to electricity.

TABLE 2.7: Fuel Consumption Profile In Nigeria

Year	Household kWh/capital	Industry kWh/capital	Transport kWh/capital	Others kWh/capital	Total kWh/capital
1970	0.204	0.257	0.830	0.040	1.350
1972	0.261	0.394	1.229	0.080	1.960
1974	0.388	0.547	1.699	0.100	2.680
1976	0.495	0.806	2.507	0.210	3.980
1978	0.770	0.870	4.413	0.210	6.260
1980	0.965	1.870	5.312	0.330	8.540
1982	2.114	3.860	4.771	0.750	11.500
1984	2.372	2.530	5.091	0.660	10.650
1986	2.523	3.150	4.652	0.510	10.840
1988	2.703	4.410	4.991	0.590	12.090

Source: (Esan, 1998)

2.10 Fundamental Concept of Thermodynamics

All materials have the tendency to degrade by dispersion, decay or oxidation to a condition in harmony with the environmental datum. The equilibrium process which causes ordered energy to "diffuse over larger volumes" is governed by the capacity to do work. Application review of fundamental law is considered in this section.

2.10.1 *First Law of Thermodynamics*

Contemporary science has gained deep insight into the concept of energy by establishing the relationship between the two characteristics of matter, energy and mass. In various thermodynamic processes, involving changes in the state of working fluids, energy either enters or leaves the system in the form of heat, Q, and work, W, as a result, the internal energy, U, of the system changes. Then, according to the law of conservation and conversion of energy, we may write.

$$\oint w \propto \oint Q \quad \text{..........................} 2.14$$

or $$Q - W = \Delta U \quad \text{......................} 2.15$$

When expressed in such a form, the law of conservation of energy in a thermodynamic process is referred to as the first law of thermodynamics. (Neduzhy, 1965).

Any work performed on a closed system is converted to thermal energy and a substance's internal energy is a function of temperature only (Rogers and Mayhew, 1958).

$$U = mC_vT \quad \text{......................} 2.16$$

$$\Delta u = C_v\Delta T \quad \text{......................} 2.17$$

Δu = Change in internal energy of a system, J/kg

ΔT = Temperature difference, K

m = Mass flow rate, kg/s,

C_v = Specific heat capacity at constant volume J/kgK.

or $Q - W = U_{final} - U_{initial}$ which is regarded as the non flow energy equation.

For steady flow equation.

$$Q - W = (H_2 - H_1) + 1/2\,(C_2^2 - C_1^2) + g(Z_2 - Z_1) \quad \text{..........} 2.18$$

and for a unit mass of working fluid .

$$q - w = (h_2 - h_1) + 1/2\,(C_2^2 - C_1^2) + g(Z_2 - Z_1) \quad \text{..........} 2.19$$

where h_2 - Final enthalpy (kJ/kg)

h_1 - Initial enthalpy (kJ/kg)

C_2	-	Final velocity (m/s)
C_1	-	Initial velocity (m/s)
Z_2	-	Location above datum (final) (m)
Z_1	-	location above datum (initial) (m)

2.10.2 *Application Of SFEE To Boilers And Condensers*

(Neglecting potential energy term)

Heat added or extracted at constant temperature

$Q - W = m\,(h_2 - h_1) + 1/2\,(C_2^2 - C_1^2)$ 2.20

$C_2 = C_1, W = 0$ 2.21

and so $Q = m\,(h_2 - h_1)$ 2.22

This implies that the flow rate is constant hence $C_2^2 - C_1^2 = 0$ and there is no work done across the boundaries thus $W = 0$ for boilers the fluid enters as liquid and leaves as Vapour while in condenser the reverse is the case.

2.10.3 *Application In Turbine Or Compressor*

Assume $Q = 0$ (isentropic, $PV^{\gamma} = k$, $\Delta S = 0$)

Assume $C_2 = C_1$

Then $W = m\,(h_2 - h_1)$ 2.23

2.10.4 *Application In Throttle Valve*

$Q = 0, W = 0, C_2 = C_1 = h_2 = h_1.$

There is no enthalpy change, during the flow.

2.10.5 *Availability, Exergy and Anergy*

The availability of energy, or exergy is a measure of the maximum useful work that can be performed by a system interacting with an environment which is at a constant pressure P_o and a temperature T_o (O' Callagham, 1981).

Availability or exergy fulfills a function of correctly rating the quality of desirable energy requirement in an energy conversion process. The maximum efficiency with which heat withdrawal from reservoir may be converted into work is the Carnot efficiency, Thus the availability, x, of a reservoir T providing a rate of heat transfer Q in surrounding at To is given by

$$X = \left(\frac{T - T_o}{T}\right) Q \quad \ldots. \; 2.24$$

Heat exergy.

Thus the efficiency of a Carnot cycle operating between two reservoirs at T_1 and T_2 may also be expressed in terms of exergy as

$$\eta_C = \left(\frac{X_1 - X_2}{X_1}\right) \quad \ldots. \; 2.25$$

if "exergy"is that part of energy capable of doing work, "Anergy", Y, is the remaining energy because "heat Anergy"

$$\eta = \frac{T_o}{T_1} Q \quad \ldots. \; 2.26$$

2.10.6 *Application of the Laws of Thermodynamics*

Non - flow system:

$$W_g = \int_{V_1}^{V_2} pdv \text{ --------- } 2.27$$

The net useful work performed is reduced according to the work required to displace the surrounding environment at a constant pressure P_o.

i.e.

$$W_N = W_g - P_0(V_1 - V_0) \text{ -------- } 2.28$$

and from 1st law of thermodynamics

$$Q = \Delta u + W \text{ ---------------- } 2.29$$

for isothermal heat transfer

$$Q = T_0(S_1 - S_0) \text{ ----------- } 2.30$$

where S represent the entropy of the system. Substituting equation 2.30 into 2.29 and the result into eqn 2.28.

$$W_N = T_0(S_1 - S_0) - (U_1 - U_0) - P_0(V_0 - V_1) \text{ --------- } 2.31$$

which represents the net useful work obtainable from the thermodynamic substance undergoing a reversible process between state points 1 and 0.

i.e Net useful work = (heat transferred to the environment - change in internal energy - displacement work)

$$W_N = Q - U - Wd \text{ --------- } 2.32$$

for real or irreversible process

$$W_N \leq T_0(S_1 - S_0) - (U_1 - U_0) - P_0(V_1 - V_0) \text{ -------- } 2.33$$

The non flow availability function,A is defined

as $A = U + P_0v - T_0s$

$\therefore W_N = A_1 - A_0$ for a reversible process

$W_N \leq A_1 - A_0$ for an irreversible process and for steady flow process.

$$exergy\ X = (B_1 - B_0) + m(c^2/2 + gz) \quad ....2.34$$

$$where\ B = (U + Pv - T_0s) = (H - T_0s)$$

$$X = (H_1 - T_0S_1) - (H_0 - T_0S_0) + mc^2$$

2.11 Second Law of Thermodynamics

The second law is an expression of the fact that some heat must always be rejected during the cycle, and therefore that the cycle efficiency is always less than unity. Kelvin Plank statement of the second law of thermodynamic states that "it is impossible to construct a system which will operate in a cycle, extract heat from a reservoir, and do an equivalent amount of work on the surrounding. Clausius statement on the other hand states that: it is impossible to construct a system which will operate in a cycle and transfer heat from cooler to a hotter body without work being done on the system by the surroundings.(Royers and Mayhew, 1958).

The first law says that the net work can never be greater than the heat supplied, while the second law goes further and states that it must always be less.

2.11.1 *Application Of Second Law Analysis Of Energy Flow*

Consider a set of industrial process operating in a steady - state situation which requires energy to be supplied as follows.

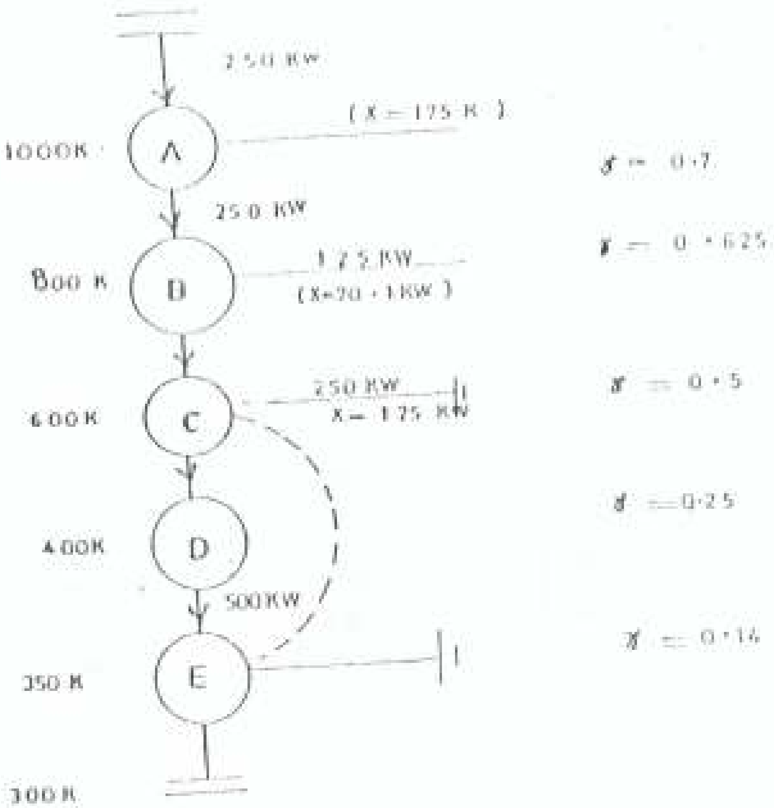
A	1000kW	at	1000K
B	1500kW	at	800K
C	2500kW	at	600K
D	2000kW	at	400K
E	4000kW	at	350K.

The figures above are for space heating in an outside environment at 300K. Assume that insulation levels are double and that 50% waste heat is recorded. This reduces each process energy demand to 25% of its initial value, resulting in the schedule shown below and illustrated in figure 2.4 with a net energy demand of 2750kW

Processes	A	250kW	at	1000K
	B	375kW	at	300K
	C	625kW	at	600K
	D	500kW	at	400K
	E	1000kW	at	350K in an environment at 300K.

The second law analysis gives the grade of energy required at each process in terms of exergy. The exergetic potential and throughout exergies are provided in figure 2.5. It is noted that while 1000kW of energy is needed, this represents only 430kW of exergy.

Assuming that all the energy is available at 1000kW. (γ = 0.7) then the introduction of exergy converter (such as gas fired heat Pump) operating between 1000K and 300K, and having and overall exergetic conversion efficiency of 50% can reduce the amount of primary energy supplied to the 350K temperature level to 153kW.



Source of ENERGY ············> Energy Input

Ambient Tempertura ············> Cascade line

Environment - - -> - - - By pass routs.

Fig 2.5: A CASCADED ENERGY FLOW SYSTEM.

Okwose (1998) highlighted some other studies carried out on energy analysis of production plants. According to Okwose, Gaggioli compared the energy efficiency for a number of processes and unit operations based on the first and second laws of thermodynamics as indicated in Table 2.8.

TABLE 2.8: Comparism Of First And Second Law Efficiencies (%)

Unit operation (or process)	First law	Second Law
Residential water	60	9
Domestic Water heater	40	2-5
High pressure steam boiler	90	50
Tobacco dryer	40	4
Coal classification	55	46
Petroleum refining	90	10
Steam heated boiler	100	40
Blast furnace	76	46

Source: (Okwose, 1998)

He observed that the second law efficiencies were much lower than the calculated using the simple enthalpy balance (first law). Thus according to him it is due mainly to the irreversibilites of the process which have destroyed some of the available energy of the input materials, so that the products have a lower capacity to effect changes than the feed streams.

CHAPTER THREE

3.0 METHOD OF PRODUCTION AND USES OF ENERGY AT ILE - OLUJI COCOA PRODUCTS INDUSTRY LIMITED

3.1 Introduction

The corporate objective of Ile-Oluji Cocoa Products Company Limited is to make profit on the invested capital. Within this context, the actual trade is processing of cocoa beans into cocoa products viz:

a. Prime cocoa butter

b. Cocoa cake

c. Cocoa powder

d. Cocoa liquor

In commercial cocoa processing, there are two major technologies in use and these are based on mode of cocoa roasting adopted. The first technology is whole beans roasting which in any case is becoming obsolete and the second is the cocoa nibs (fragmented cotyledon) roasting, which is the favourite of processors because of its advantages.

Whatever technology that is adopted by a processor, the following are the major operations in cocoa processing (Fig 3.1):

- Cleaning and sorting of the cocoa beans
- Winnowing
- Roasting
- Grinding (milling)
- Pressing
- Butter cleaning
- Products packing.

Production unit is being faced with a lot of challenges in annexing all the operating units economically to achieve the set goal.

Among the challenges that readily come to mind are:

- Production of wholesome products
- Plant capacity management
- Optimal utilization of resources
- Efficient operation of plants and machinery
- Effective and efficient process control.

The aim of this research work is to identify areas of energy losses and find ways of minimising these losses if not totally eradicating them.

3.2 Plant Description

3.2.1 *Cleaning*

The first processing operation is cleaning of the beans to remove all foreign materials such as stones and grits, metal pieces, fibre from the sacks as well as unwholesome mouldy and immature beans. The cleaning machine is equipped with magnetic separators, different sizes of sieves meshes, brushes and air lifts for separating good beans from impurities. Apart from immature grains, all the foreign materials are rejected. Immature beans and clusters are usually blended with other winnowing products and processed for the production of cocoa butter.

3.2.2 *Shelling And Winnowing*

A typical cocoa bean contain about 87.1, 12.0 and 0.9 percent respectively of cotyledon or nib, shell and germ. (Makanjuola, 1996).

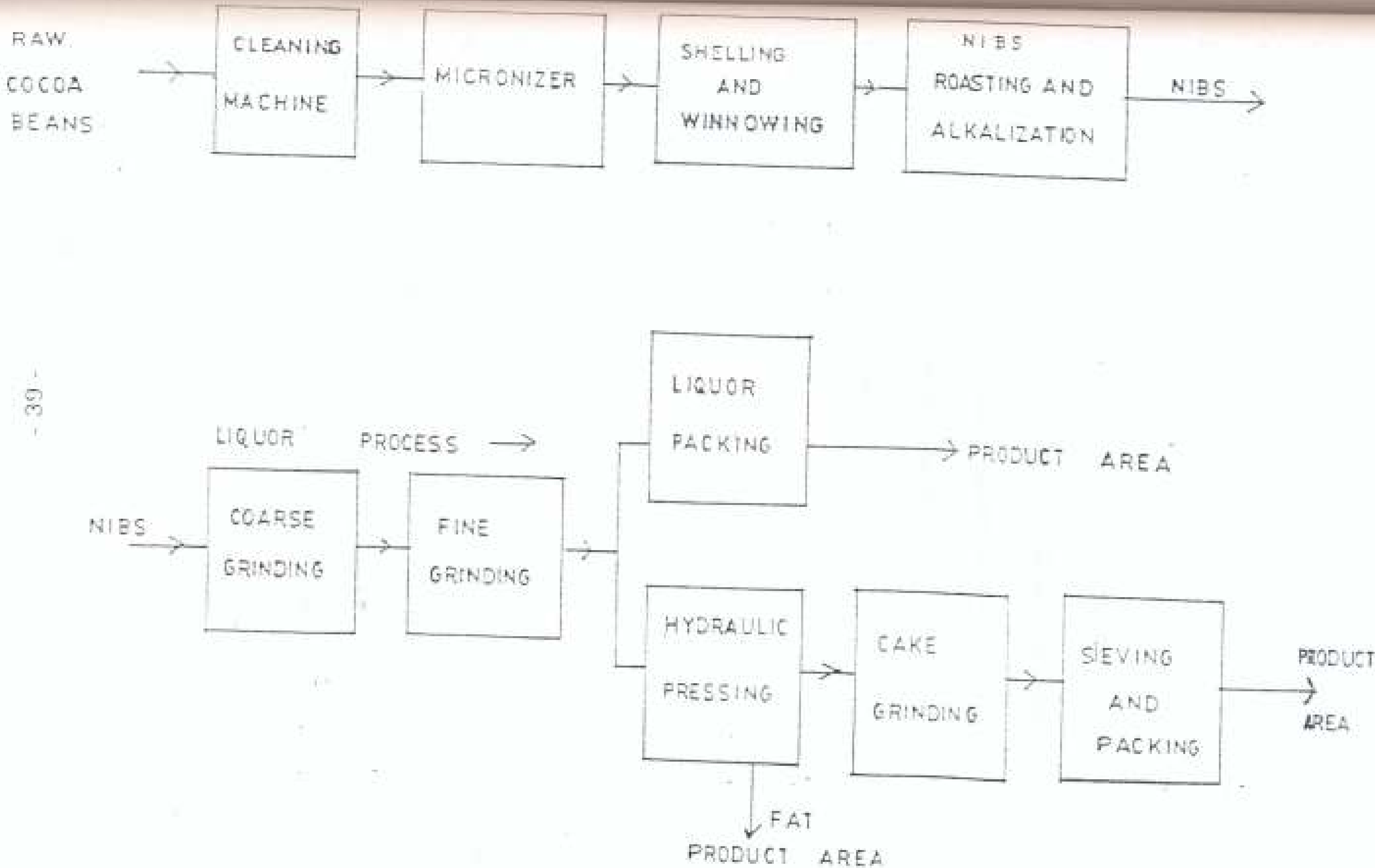


Figure 3.1: COCOA PROCESSING CHART.

Shelling and winnowing are aimed at separating all the cotyledon from the shell and germ. Most mechanical devices give maximum nib yields of about 82 to 83 percent.

Shelling is achieved by passing micronized beans through impact crushers. The crushed cotyledon then falls under gravity onto vibratory sieves of various mesh sizes ranging from 5mm (the largest) to 1.0mm (smallest) for effective sieving and complete removal of shell via dust shells at the other end of the machine. Winnowers are equipped with cyclones and air filters to remove the fine dust from the air coming out of winnowers. (Hermman, 1976a).

3.2.3 *Roasting*

Roasting is particularly an important process in the production of chocolate or cocoa but it is less important if the beans are to be processed solely for production of cocoa butter. It is pertinent to note that Ile-Oluji Cocoa Company uses the most recently developed method of heat treating cocoa beans, the Nibs, Alkalizing, Roasting and Sterilizing (NARS) processes. It involves the subjection of nibs to a very high temperature via a heat exchanging medium for 30 minutes, no direct heat is involved and finally, a fine water spray is applied to the hot nib, which includes moist air capable of destroying all microorganisms, including heat resistant spores.

3.2.4 *Nib Grinding*

This is achieved via a two stage particle size reduction arrangement. The first state known as the Beater Blade Mills reduces particle size to 10%

of the milled liquor. This section houses most of the piping network for steam and hot water distribution as it utilizes hot water especially when put out of operation to keep the mill content in pasty form. Hammer mills are employed here to create impact at 90° to the direction of flow of nibs. Sieves of 0.25mm mesh size are used during the light cropping season while that of 0.5mm are used for main cropping season to achieve a residue of 10% maximum in the cocoa liquor.

Next is the agitated ball mill which further reduces the particle size to 1% for maximum butter extraction.

3.2.5 *Fat Removal*

The fat in the liquor is removed by hydraulic pressing in pot press. Most modern pot presses are of the horizontal type with up to 22 pots. Ile-Oluji Cocoa Product Company was installed with horizontal presses with 12 pots each of 150kg capacity. Maximum butter is extracted from the liquor more readily when the liquor is hot. To achieve this, steam is introduced through inlet pores to the pots which keeps the press temperature at a 100°C before and during operation (Hermman, 1976b).

3.2.6 *Cocoa Cake Grinding*

The cake from hydraulic or pot presses are expelled and ground into cocoa powder. The cake lumps are first passed through hammer mills and then finally ground to fine powder. Since the cake still contains some cocoa butter, there is a tendency for the fat to melt as grinding progresses and there is a need to use cooling air during grinding to prevent the melting of cocoa butter. The cooling is done with the aid of an all air-conditioning system with low relative humidity. The cocoa cake is transported via a double screw conveyor into the grinder chamber with the use of a vibro feeder which regulates the flow. To achieve the pulverization, are a segmented stator assembly with bars arranged at 0.5mm equidistance and a rotor assembly which hits the cake against a grinding jaw in the stator. Particle size of 9% maximum is acceptable for powder. The transfer pipes are cooled and at the end of the pipes, an air stream then returns into circulation (Hermman, 1976c).

Plants that generate steam, hot water or hot fluids usually depend on heat transfer from the gases produced by the combustion of fuel. The potential for high thermal efficiency depends on the design of the plants and the insulation of appropriate firing equipment. Ideally, the plant should include sufficient heat transfer surface area to extract the maximum possible amount of heat from the combustion products. The actual thermal efficiency of a particular plant depends on how it is operated and maintained. The maximum efficiency can be achieved only under a reasonably steady load when attention can be given to efficient firing and combustion control.

3.3 Fuel and Combustion

The categories of fuel used in industries in Nigeria range from kerosine, gas oil (diesel), natural gas, high fuel oil and heavy fuel oil. Industrial coal is not left out. Their specific gravity range from 0.79 for kerosine to 0.97 for heavy fuel oil. The lighter fraction known as gasoline and benzene are not commonly used industrially. Gasoline is used mainly as a fuel for cars and benzene for cooking. The major factor in the cost of useful heat is the fuel cost. The initial capital cost is usually less as an annual charge for capital and interest, then the labour, maintenance and sundries such as chemicals and spares needed to run a plant (Dryden, 1975).

TABLE 3.1 Physical Properties Of Some Fuels

Fuel	C%	H%	S%	Others%	GCV MJ/kg	Viscosity at 16°C (kgs/m)
Kerosine	86.2	13.6	0.2	-	46.4	0.002
Diesel	86.2	12.8	1.0	-	45.5	0.004
LPFO	82.9	11.4	4.5	1.2	42.5	7.275

Source: (Eastop and Croft, 1990)

Of more significance are the physical properties of the oil which affect their storage, pumping, firing and burning. The most important single property of oil is the viscosity since this is directly related to the pumping power required and also affects the oil's ability to be atomized (i.e broken into small droplets) an essential prerequisite for combustion.

The viscosity of an oil decreases rapidly as the temperature is increased and hence the residual fuel oils must be stored at above 20°C and heated to about 100°C before delivery to the burner (its viscosity will be reduced by a factor of about six in the process) (Eastop and Croft, 1990).

Industrial boilers for heating plant burn light and heavy fuel oil and many use low or medium pressure air atomizer. The turn down ratio is about 2:1 but can be extended by using oil spill ports. The highest temperature in combustion is obtained when a fuel is burned with an excess supply of air and when combustion is complete. When excess air is supplied it must be heated thus taking useful energy from the process. On the other hand, if insufficient air is supplied leading to incomplete combustion, the efficiency is even less and pollution may be caused.

In oil firing, especially of industrial boilers, it is essential to match combustion equipment properly to the plant to be fixed. The characteristic of an oil flame are affected mainly by the composition of the fuel and the rate at which fuel and air are mixed and subsequently burned in the combustion zone. Good mixing of fuel and air is assisted by fine atomization of the oil.

A general equation can be written for combustion problems which makes calculation of air-fuel ratio and product analysis easier. For cases when the fuel is a solid or a liquid hydrocarbon the equation is as follows.

$$1kg\ fuel + A\ [(\frac{0.233}{32})O_2 + \frac{0.767}{28}N_2]$$

$$\longrightarrow B\ [aCO_2 + bO_2 + (1-a-b)N_2] + cH_2O \quad \text{---- } 3.1$$

The air fuel ratio by mass is given the symbol A and hence the volume of oxygen supplied per kg of fuel is (A x 0.233/32)kmol, and similarly for Nitrogen. The symbol B represents the kmol dry fuel gas per kg of fuel; the symbols a, b represent the volumetric fractions of carbon dioxide and oxygen in the dry flue gas, the symbol c represents the kmol of steam per kg of fuel.

3.4 Energy Efficacy in Utilities

The overall efficiency of a steam system, η, may be defined as:

$$\eta = \frac{\text{mass of fluid heated} \times \text{increase in specific enthalpy of fuel}}{\text{mass of fuel burnt} \times \text{specific calorific value of fuel.}} \times 100$$

The thermal efficiencies usually are quoted in terms of the gross overall efficiency or the gross calorific value (G.C.V) of the fuel. The gross or upper calorific value of a fuel includes the latent heat of combustion of the water vapour in the combustion products. The quantity of water in the combustion product depends on the percentage of hydrogen in the fuel as well as its moisture content. The net lower or available caloric value (N.C.V) excludes the latent heat contribution and is therefore a more accurate measure of the heat made available when fuel is burned in a plant. It is also a better basis for comparing efficiencies obtained from fuels having different hydrogen and moisture contents.

3.4.1 *Boilers*

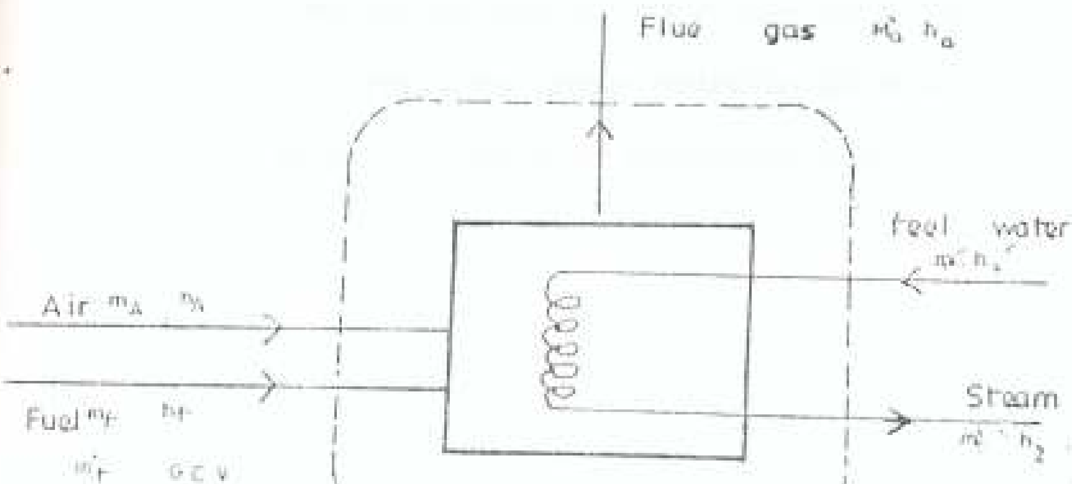
Boilers are essentially heat exchangers in which the thermal energy released by the combustion process is transformed from the products of combustion to the coolant fluid (e.g water or water/steam). The increase in enthalpy of the transfer fluid represents the useful output. An energy balance applied to the system within the doted line shown in (Figure 3.2) gives the following equation.

$$m_f h_f + m_A h_A + m_f GCV = m(h_2 - h_1) + m_G h_G + Q_L \text{ ---------- } 3.2$$

GCV is used in equation 3.2 which implies that the water vapour in the product is condensed out. This is unlikely to happen unless a condensing boiler is used and therefore the NCV is frequently used. Boiler efficiency can then be defined as.

$$\eta_B = \frac{m(h_2 - h_1)}{m_f GCV} \quad \text{or} \quad \frac{m(h_2 - h_1)}{m_f NCV} \text{ ----------------- } 3.3$$

The first term in equation 3.2 is the enthalpy of the fuel and is usually negligible compared with the other terms in the equation. The term Q_r is the radiation loss; heat is lost from the casing by both convection and radiation but the latter term is in general use. The casing loss is usually less than 1% for shell and water tube boiler, but can be as high as 10% if the boiler is not adequately insulated or if the insulation is allowed to deteriorate.



Substituting for m $(h_2 - h_1)$ from equation 3.2 in the expression for boiler efficiency

$$\eta_B = \frac{m_f(GCV) + m_A h_A - m_G h_G - Q_r}{m_f(GCV)}$$

$$\therefore \eta_B = 1 - \frac{(m_G h_G - m_A h_A)}{m_f(GCV)} - \frac{Q_r}{m_f(GCV)} \text{ ---------- } 3.4$$

The enthalpy of the flue gas should be considered in two parts, the enthalpy of the dry flue gas, and the enthalpy of the super heated water vapour. The flue gas loss will then reflect the thermal energy necessary to provide the enthalpy of evaporation for the water vapor formed during combination i.e flue gas loss is given by Eastop and Croft, (1990) as:

$$\{m_f + m_A - (18d + V)m_f\}t_G\Sigma(m_iC_{pi}/m) - m_AC_{PA}t_A +$$

$$(18d + v)m_f(h_{wv} - h_f) \quad \text{---------} \; 3.5$$

Where d is the number of kmol of water vapour in flue gas per unit mass of fuel.

V is the mass of water vapour in unit mass of fuel supplied.

h_{wv} is the specific enthalpy of the super heated water vapour at the partial pressure of the water vapour and the flue gas temperature t_G, h_f is the specific enthalpy of water at the temperature of the air - fuel mixture at combustion, t_A .

Blow down loss = xm (hr_2 - hw) 3.6

Where x is the fraction of the steam flow which is lost as blow down, and hw is always equal to h_1.

A more detailed expression for equation (3.4) would thus incorporate these additional terms from equation (3.5) and (3.6) thus boiler efficiency is given by

$$\eta_B \quad = \quad \frac{\text{Energy Input - losses}}{\text{Energy Input}}$$

or

$$\eta = 1 - \frac{Losses}{Energy\ Input} \quad \ldots\ldots \quad (3.7)$$

from equation 3.7

$$\eta_B = 1 - (FGL - BDL - CL)/\text{Energy input} \quad \text{-------- (3.8)}$$

where

FGL = flue gas loss

BDL = Blow down loss

CL = Casing loss

From equation (3.8), it is obvious that for the efficiency of a unit to be improved, the losses in that unit must be monitored. Very often, no attempt is made to put a monetary value on steam. It is being treated as an overhead, spread over the various processes. The result of a costing exercise can be illuminating, perhaps uncovering areas of potential saving that had been overlooked during a heat and mass balance survey. Heat losses are temperature dependent and not load dependent. The true cost of steam includes all the expenses incurred in its generation and distribution as well as taking account of the thermal efficiency of the boiler and its mode of operation, that is load factor. The contributions to the total cost of steam include:

a. The cost of fuel delivered to the site and the cost associated with storage and handling

b. The cost of raw water and the costs associated with water treatment.

c. The cost associated with condensate water system

d. Capital interest and depreciation charges.

e. Insurance, inspection, clearing and descaling charges

f. Cost of spare parts and materials for maintenance

g. Labour and supervision wages.

Steam supply to ICPCL's process line is generated by two oil fired boilers burning diesel or heavy fuel oil.

3.4.2 *Heat Losses In Boilers*

3.4.2.1 *Flue Gas Losses*

The loss of heat with the flue or dry chimney gasses is the largest of all heat losses involved: from 4 to 8 percent for large boiler units, and from 10 to 20 percent for small - capacity boilers. This heat loss is due to the fact that the products of fuel combustion leave the boiler unit at a high temperature, 115 to 150°C in high capacity boiler unit and even higher in smaller boilers (Neduzhy, 1965).

Equation (3.5) can be used for the calculation of flue gas losses.

3.4.2.2 *Blow Down Loss*

Blow down can be as high as 10% or more of the steam flow rate which represents a loss of about 3% of the fuel energy input. This loss can be reduced by recovering part of the thermal energy of the blow down water by using it to heat the feed water.

3.4.2.3 *Heat Loss Due To Incomplete Combustion Of Carbon*

The products of combustion may contain gaseous combination of combustible components such as CO, H_2 or CH_4. Their after - burning beyond the boiler furnace is practically impossible since the temperature of gasses and the concentrations of the combustible components and oxygen are too low. The heat that might be produced by the after burning of these components, constitute what is known as heat loss by incomplete combustion.

The heat loss through incomplete combustion is given by

$Q = V_{dg}[126.4CO + 108H_2 + 358.2CH_4 + 591.2C_nH_m]$ kJ/kg

(Neduzhy, 1965) ---------------- 3.11

Where

V_{dg} is the specific volume of dry flue gases, m^3/kg and CO, H_2, CH_4, C_nH_m are the volume concentration of the products of incomplete combustion in dry flue gases, %.

3.4.2.4 *Radiative Heat Loss*

The heat loss to the surrounding through radiation remain virtually unchanged from the rated value, unless the boiler insulation is defective, in which case, the relative heat loss increases. At a boiler load, D differing from the rated load, D_{rated}, the relative loss q_{rated} can be found from the formular.

$$q = q_{rated}\frac{D_{rated}}{D} \quad \text{------} \quad 3.12$$

Where

D = actual capacitty of the boiler unit

D_{rated} = rated capacity of the boiler unit

q_{rated} = loss of heat by radiation at rated capacity of the boiler.

For high capacity boiler unit q is very small (from 0.2 to 0.3 percent) but many reach 3 to 4 percent in smaller boiler units. Its magnitude is estimated from special reference graphs and tables.

3.5 Water Treatment

Water is the most frequently used thermal energy transfer fluid. A proper water treatment programme can yield substantial savings in both energy and money. When water temperature changes, minerals precipitate in the form of a hard, brittle scale that collects in piping and on heat transfer surface. This insulating scale build-up reduces efficiency of equipment, increases fuel requirements, and increases maintenance time and cost.

The impurities in water are in the form of dissolved gases and solids in solution or suspension. The nature and concentration of the impurities depend on the source of the water. Scale formation on heat transfer surface is due to the thermal decomposition of calcium and magnesium salts and the subsequent deposition of products such as calcium carbonate, hydroxide and silicate.

Scale may also be produced by the deposition of corrosive products, algae, silt and sludge. These scales may be dense or porous and firmly attached to the heat transfer surfaces or they may be loose and easily removed from the system. The additional thermal resistance created by the presence of such scale on a heat transfer surface will decrease the heat transfer rate. This may lead to increased energy consumption in the form of fuel in heating system and increased pumping costs in the case of cooling systems. More importantly, it may result in metal hot spots and tube failure. Figure 3.3 shows a typical boiler water treatment system.

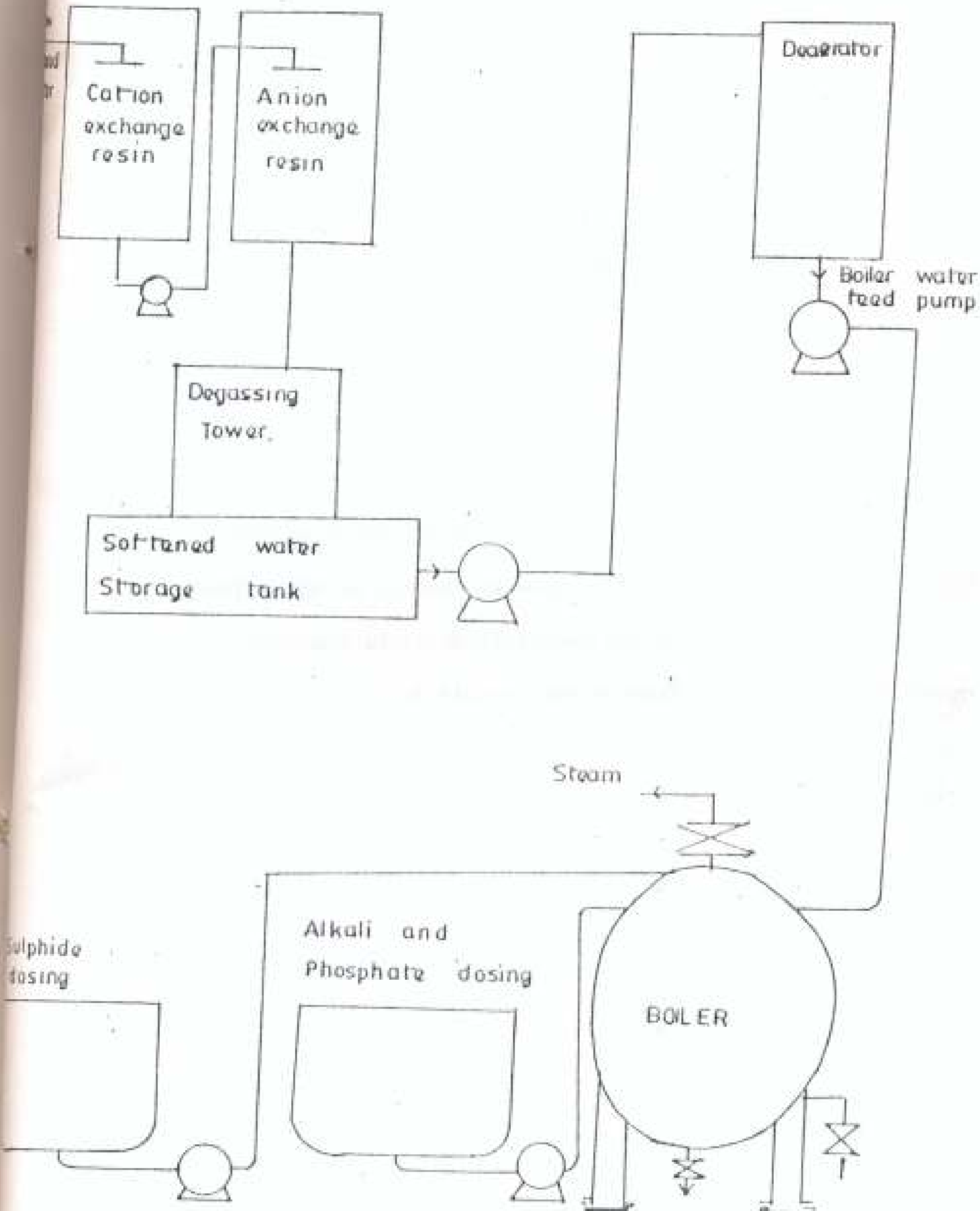
Corrosion of heat transfer surfaces in water systems is caused by dissolved oxygen and pH lower than 7.0. The low pH can be due to dissolved carbonates originating from the decomposition of bicarbonates. Corrosion products either alone or in combination with scale, can decrease the cross sectional area available to the flow of water. This can lead to decrease in heat transfer capacity, an increase in pumping costs to overcome the additional pressure drops or shut down to clear or replace tubes. From Table 3.2, it can be seen that more energy is required to overcome commensurate scale build-up areas during heating.

Unscheduled shut-down due to plant failure caused by corrosion can have serious implication on production programme and on labour relations if space heating is affected.

TABLE 3.2 Energy cost due to hard scale build - up

Scale Thickness	Energy required to overcome thickness
1.6mm(1/16")	Scale requires 15% more energy
3.2mm (1/8")	Scale requires 20% more energy
6.4mm (1/4")	Scale requires 39% more energy
9.5mm (3/8")	Scale requires 55% more energy
12.7mm (1/2")	Scale requires 70% more energy

Source: (Al-Kharusy, 1996)



Figured 3.3: TYPICAL BOILER WATER TREATMENT SYSTEM

3.5.1 *Oxidation Reduction Method*

As good as existing water filtration/purification technologies are, each has limitations. They are short - lived, expensive and difficult to ma.ntain. Also, they are easily fouled by microorganisms or just plainly unable to perform up to anticipated stricter regulations.

New process media of high purity copper-zinc formulations known and marketed as KDF process media using oxidation/reduction (redox) method reduces contaminants in water. The process media improves old technologies by protecting, and in some cases replacing existing filtration/purification technologies. It provides extended life for machines using water as coolant as well as lowers maintenance cost, controls microorganism growth and improves performance (Al - Kharusy, 1996).

According to Al Kharusy, the removal of iron from the dissolved solid in water was made possible by Stum and Lec in 1961. The following chemical equations are ways with which KDF process media reacts with contaminants

i. Chlorine removal

$Cu/Zn + Cl_2 \rightarrow Zn^{++} + 2Cl + Cu$

ii. Hydrogen Sulfide removal

$Cu/Zn + H_2S \rightarrow CuS + H_2 + Zn$

$2H_2 + O_2 \rightarrow 2H_2O$

iii. Heavy metal removal

$Cu/Zn + Pb^{++}(NO_3)^-_2 \rightarrow Zn/Cu/Pb + Zn^{++}(NO_3)^-_2 + Cu$

iv. Iron (II) removal

$Fe(II) + Cu(II) \leftrightarrow Fe(III) + Cu(I)$

(Stumn and Lec 1961)

$Cu(I) + O_2 + H^+ \leftrightarrow Cu(II) + HO_2$

$Fe(II) + HO_2 + H^+ \leftrightarrow Fe(III) + H_2O_2$.

$Fe(II) + H_2O_2 + H^+ \leftrightarrow Fe(III) + OH + H_2O$

-wiess mech.

$Fe(II) + OH + H^+ \leftrightarrow Fe(III) + H_2O$

$Fe(III) + 3OH \leftrightarrow Fe(OH)_{3(s)}$ precipitation

$4Fe(II) + O_2 + 8OH + 2H_2O \leftrightarrow 4Fe(OH)_3(s)$.

Net reaction.

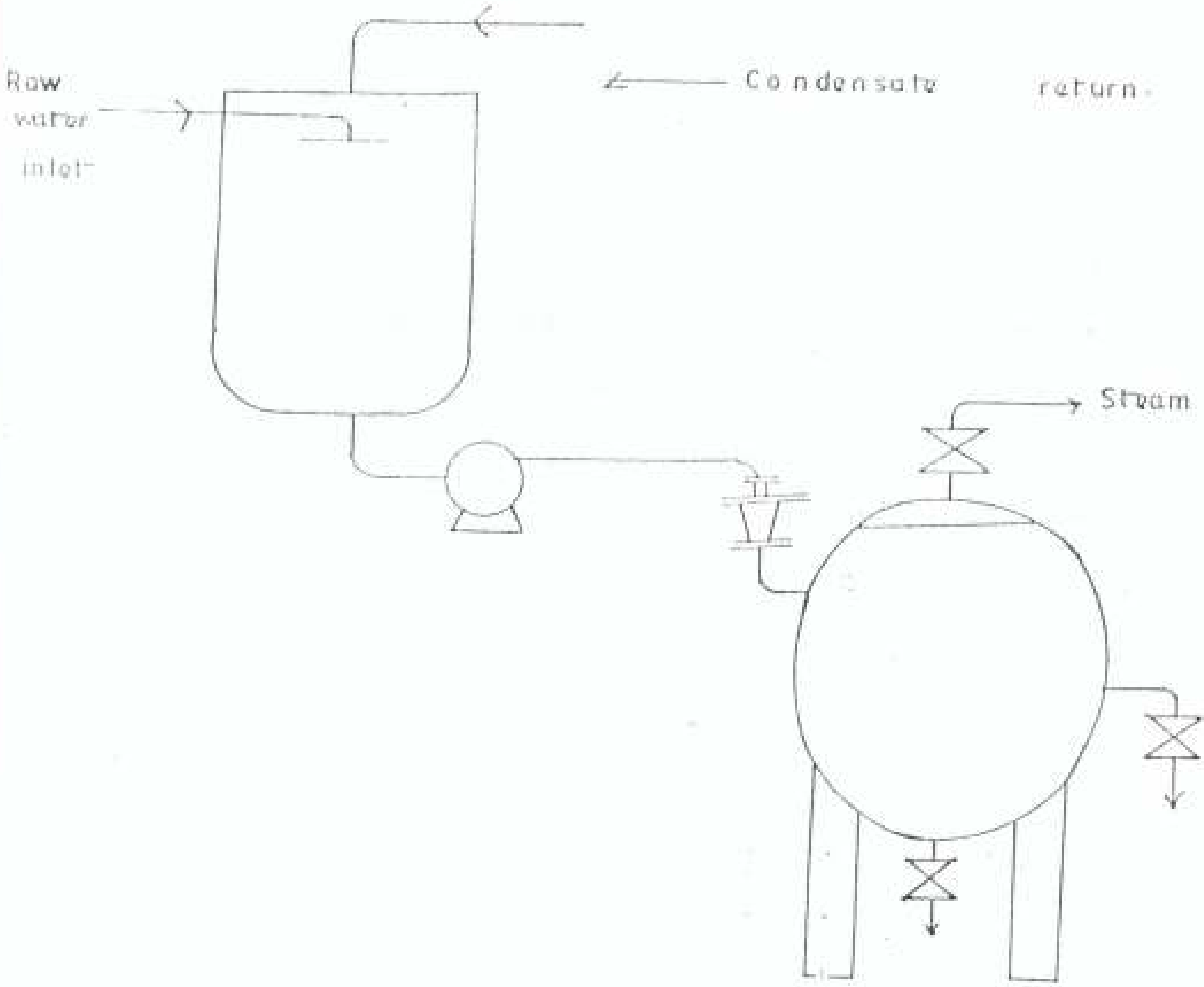


Figure 3.4: CONDENSATE RETURN PROCESSING STEAM BOILER WITH REDOX WATER TREATMENT SYSTEM INCORPORATED

3.6 Energy Saving in Process Zones

The overall efficiency of a steam plant is the product of the individual efficiencies of steam generation, distribution and utilisation processes, hence, it is important to ensure that all three are as high as possible. It is relatively easy to monitor the boiler efficiency with respect to steam production and fuel used during the same period. It can be rather more difficult to monitor the efficiency of distribution and utilization of steam, especially when individual steam meters are not available.

There is ample scope for inefficiencies in the distribution and utilisation of steam: poor or non-existent insulation; steam leaks; fouled heat-transfer surfaces with low heat transfer coefficients. If on a site, the steam or any other heat transfer medium, is treated as an 'on-tap' service and this service is not shown as a separate change to the management of the area, there will be a tendency to regard the services as "free" and little, if any attempt will be made to measure or monitor its utilisation efficiency.

Steam line design should be made to transport steam by the shortest route in the smallest diameter pipe with the least heat loss and pressure drop that circumstance will permit. Steam should be distributed at an appropriate pressure and velocity. Steam should be distributed at as high a pressure as possible and used at as low a pressure as practicable. The operating conditions and steam usage for each process should be monitored and reviewed periodically preferably and if economically feasible, heat should be interchanged from effluent to influence stream but avoiding the use of live steam.

When steam is condensed on a heat transfer surface, the condensate should be removed quickly and efficiently from the stream space to ensure that the maximum proportion of the heat transfer surfaces are in contact with condensing steam. Water logged surfaces reduce the rate of heat transfer. Condensate drained from heat transfer surfaces and pipelines serves as a valuable source of treated water; each 5 degree centigrade increase in boiler feed water temperature is equivalent to about a 1 percent decrease in fuel usage. (Craig, 1981). Thus, necessitating the insulation of return pipelines and connections from plants and process steam usage area to the boiler feed water tank. Much care should be to ensured that it does not become contaminated with process fluids or corrosion products.

Insulating surfaces which reject heat to the atmosphere is one of the most obvious and basic ways of recovering energy. The annual fuel cost is invariably reduced as the thickness of the insulation is increased but the capital cost of the insulation material increases with the thickness, hence the financial saving must be off-set against the capital cost for a typical write - off period. There will normally be an economic thickness of insulation for a particular case.

3.6.1 *Optimization With One Variable*

Consider a system which losses heat equivalent to ₦C_1 per year, according to the equation

$$C_1 = F_1(x) = \frac{a}{x} + b \quad \ldots\ldots\ldots\ldots 3{:}13$$

The system can be insulated, using insulation of thickness x, and the fixed charges, NC_2 for purchasing and installing insulation are given by

$$C_2 = F_2(x) = cx + d \quad \ldots\ldots\ldots\ldots\ldots 3.14$$

Where a, b, c, and d are constants. All other plant costs are independent of thickness of installation and therefore need not be considered. Since differentiating a constant would result in zero.

The total variable cost, C_T, is given by

$$C_T = C_1 + C_2 = \frac{a}{x} + b + cx + d \quad \ldots\ldots\ 3.15$$

The optimum value is found analytically by differentiating eqn 3.15

$$\frac{dC_T}{dx} = -\frac{a}{x^2} + c = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.16$$

∴ the optimum value of x is given by

$$x = (a/c)^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.17$$

Substitution of this value into equation 3.15 yields the optimum value of the total variable cost C_T, that is

$$C_T = (ac)^{\frac{1}{2}} + b + (ac)^{\frac{1}{2}} + d \quad \ldots\ldots\ldots\ 3.18$$

or

$$C_T = 2(ac)^{\frac{1}{2}} + b + d$$

To determine whether the optimum value is a maximum or a minimum equation 3.16 is differentiated a second time

$$\frac{d^2C_T}{dx^2} = \frac{2a}{x^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3.19$$

A positive value of this function indicates that C_T is a minimum and a negative value indicates a maximum. Substitution of equation 3.17 into 3.19 yields

$$\frac{d^2C_T}{dx^2} = \frac{2c^{\frac{3}{2}}}{a^{\frac{1}{2}}} \quad \ldots\ldots \; 3.20$$

(Murphy and Mckay, 1982)

i.e a positive result, therefore a minimum total cost, C_T. If the cost parameter C, does not attain a maximum or minimum value, an impossible result is obtained for the differentiation process, such as zero or infinity, or the square root of a negative number.

Consider a steam jacketed vessel and its associated pipelines. The existing insulation needs replacement and it is necessary to determine the thickness of insulation which will result in the minimum total cost. Table 3.3, shows the fixed costs, based on the purchase and installation of the insulation, and the variable costs of the heat losses, based on insulation thickness, steam cost and heat transfer (kW).

TABLE 3.3: Insulation Thickness And Cost Variation.

Insulation thickness (mm)	20	40	60	80	100
Fixed Cost (₦ 10^4/year)	2.2	3.5	4.8	6.1	7.4
Heat losses (₦ 10^4/year)	10.2	6.5	5.2	4.6	4.2
Total Cost	2.4	10.0	10.0	10.7	11.6

Source: (Murphy and Mckay, 1982)

A graph of the cost may be plotted against insulation thickness as shown in Figure 3.5. The total cost curve representing fixed cost and costs due to heat losses is shown. The point of inflection is at a minimum total cost corresponding to C_T of ₦97,500. The corresponding thickness of insulation is 49mm which represents the most economic thickness of insulation. This is corroborated with the analysis carried out in Ile-Olup Cocoa products industry as indicated in section 4.3.1 whereby the cost of heat loss was found to be smallest using a 50mm thick insulating material compared to two others 15mm and 25mm thick respectively.

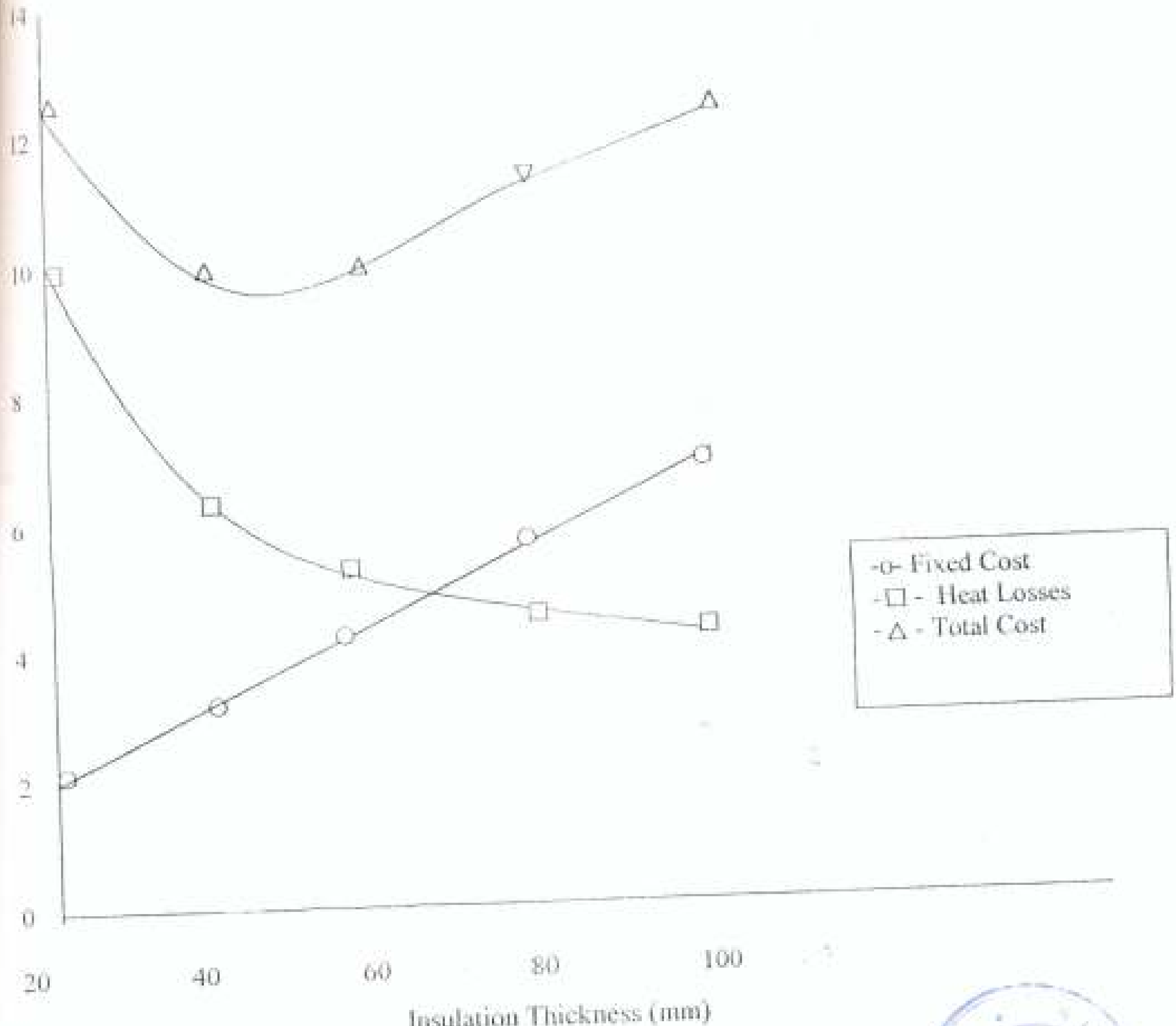


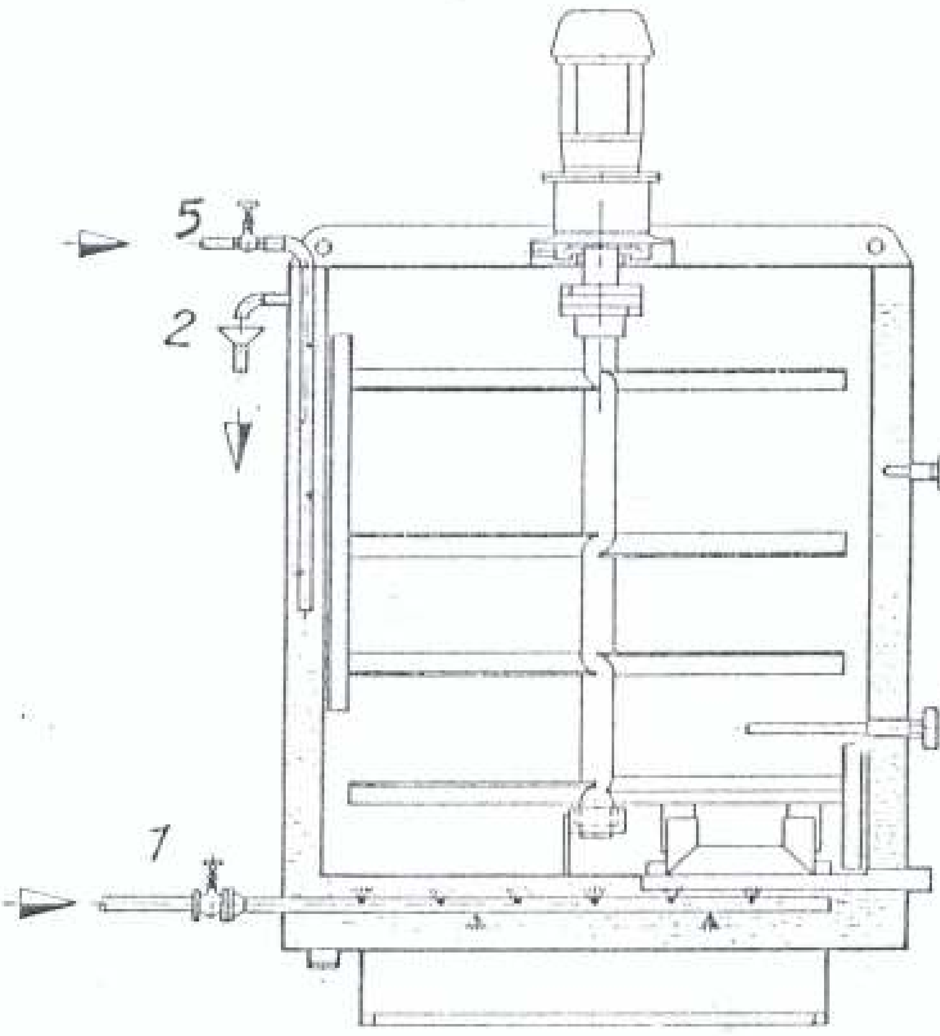
Fig. 3.5 Optimum Economic Thickness of Insulation

3.6.2 *Savings In Steam Utilization Within A Process Zone*

Considerable savings in heat loss can be achieved using Allplas balls for the exposed areas. These are hollow polypropylene balls which float on the liquid surface and can be used up to temperatures of about 120°C which is considerably higher than the process temperature above which the free fatty acid in cocoa liquor cannot be controllable. The balls also act as insulating layer thus reducing considerably the evaporation from the tanks. A double layer is even more effective, for example, water at 30°C with a double layer of balls has been shown to reduce in evaporation rate by 90% (Eastop and Croft, 1990).

Evaporated fumes from tanks must be extracted by fans giving an additional source of heat loss; by reducing the evaporation, the extraction rate can be reduced considerably thus reducing further the energy loss. Ile - Oluji cocoa products company has 13 uninsulated steel tanks used for liquor storage during processing. Five of them are of 20MT capacity, Two of 10MT capacity and six of 7.5MT capacity as shown in Table 3.4. The liquor in nine of the tanks are heated to a temperature of 90°C while the butter in four of the 7.5MT tanks are heated to a temperature of 60°C by steam in tubes immersed in a jacketed compartment as in Figure 3.6; the steam is produced by two alternating boiler with an average efficiency of 76.3%.

Insulating the tank walls with a 10mm thick slab of insulator would yield the company an annual savings as indicated in Table 3.5. Using a double layer of Allplas balls for the liquid exposed surface, the company's annual saving would be as tabulated in Table 3.5. Lastly the simple pay - back period, if the measures above are implemented is also shown in the same table:



1 = Manual STop Valve For Steam

2 = Over-flow for Condensate

3 = Thermometer for Heating Jacket

4 = Thermometer for Liquor

5 = Manual Stop Valve for Cooling Water

Figure 3.6: TYPICAL JACKETED TANK IN ICPCL

TABLE 3.4 Liquor Storage Tank Specification

Number of Units	Capacity	Height	Diameter
5 units	20MT	3.0m	2.12m
2 units	10MT	2.0m	1.60m
6 units	7.5MT	1.8m	1.33m

Ambient temperature = 31°C

Heat transfer coefficient for tank surfaces = $10W/m^2K$

Assume the same for all surfaces.

Heat transfer coefficient, liquid surface to ambient air, $10W/m^2K$

Heat transfer coefficient from liquid to inside wall of the tanks = $500W/m^2K$

Heat loss by evaporation from liquid surface for big tanks $6,500W/m^2$ and

for the small tanks $4,200W/m^2$

Thermal conductivity of insulating material = 0.07 W/mK

Heat loss by evaporation from tanks with Allplas balls $1500W/m^2$

Cost of fuel used in boiler ₦7/ltr

Additional resistance due to Allplas ball = $0.2m^2K/W$

Insulation Cost = ₦1,620/m^2

Cost Allplas balls = ₦5,210/m^2

Operating hours = 5400 hrs per annum.

Table 3.5: Energy Savings Expected Due to Tanks' Insulation.

Tank sizes	7.5 M T liquor tank	7.5 M T butter tank	10.0 M T liquor tank	20.0 M T butter tank
Tank quantity	4	2	2	5
Conductive losses through Tank walls (kW)	8.80	4.33	11.70	23.22
Expected savings from conductive losses (kW)	72.61	71.91	12.10	479.49
Convective and Evaporative losses (kW)	18.84	10.08	12.10	59.05
Saving expected from convective & Evaporative losses (kW)	12.10	6.30	7.84	44.90
Monetary value of savings N from various schems	30,506.56	39,620.03	40,035.54	207921.27

Total expected savings per annum N318,083.40

Pay back period = 2.81 years

Corresponding to 33.7 months.

3.7 Energy Savings in Factory Buildings

In a factory, the energy consumption due to lighting may be as low as 3% of the total energy consumption but considerable cash savings can still be made by making simple changes to the lighting system as in offices, workshops, warehouse and factory floor. Industrial consumption accounts for up to 40 percent of the total in many industrialized countries and significant savings are possible (Weedy, 1979).

In this section, ways will be considered in reducing the annual lighting costs with comparatively small capital cost and with short pay back periods.

Savings are possible due in part to advances in lighting designs and in part to the introduction of control systems and many recovery methods.

3.7.1 *Types Of Lamps And Tubes*

The following types of lighting in common use in the industry under study are considered.

3.7.1.1 *Incandescent Bulbs*

The most common type of lamps, or light bulb is basically referred to as tungsten lamp. Incandescent lamps are more efficient and have a longer life when filled with a halogen gas, various proportions of halogen are used but the type is generally known as tungsten halogen.

3.7.1.2 *Fluorescent Tubes*

In the fluorescent tube, light is produced by the excitation of a gas (originally neon) or a metallic vapour by an electric discharge. With phosphorus coating, a white light is produced. This type of light has much higher efficiency than the incandescent lamp and also has a longer life. Connected usually in two pin fitting on each end of the tube.

Various improvements to the design have been made in recent years to increase the efficiency. Krypton gas is replacing argon gas in the tube; tube diameters have been reduced; tri-phosphorus coatings provide more stability and better colour rendering. High frequency fluorescent tubes have recently been introduced which operate on frequencies as high as 28KHz instead of the normal mains frequency of 50Hz. Such tubes have an electronic ballast which increase the cost over the normal tube but the efficacy is increased by about 10%.

A higher advantage of high frequency tubes is that the stroboscope effect is eliminated.

3.7.1.3 *Others*

Lamps using the principle of discharge through a gas or metallic vapour but not necessarily using the fluorescent concept are also in common use. These are the mercury fluorescent which requires six minutes to reach full illumination and six minutes on re-start, the metal halide lamp producing light by radiation from metallic vapour mixture requiring 12 minutes to reach full illumination with five minutes on restart. Low pressure sodium (SOX) lamps which have a high efficiency but give an almost monochromatic yellow light requires eight minutes with same time for restarting. High pressure sodium (SON) lamps are almost as efficient as SOX. Such types of discharge lamp are not suitable for instant lighting since there is a warming up period before full illumination is obtained.

There are several ways in which the energy used for lighting may be reduced with a consequent reduction of annual running cost. The first and perhaps the most obvious way is to check that each lamp is switched on only when required. Simple timers can be used and photocell switches connected in areas where daylight levels provide adequate lighting for parts of the period of use of the building. The choice of lamp and luminaire for the purpose required are obviously very important. Too much light waste energy but it has been shown by various studies that there is a strong correlation between productivity and lighting level, likewise choosing the right type for a specific purpose can lead to greater energy efficiency. The cost of replacement must be considered as well as the running cost and hence the probable life of a lamp is an important factor. Replacement cost includes the labour cost as well as the cost of the lamp itself and infact the former may be the greater cost element.

The factory floor area of Ile - Oluji cocoa Products Company building is 7,880m^2 and is lit by 586 single fluorescent tubes having a rating of 43.0W and an electrical input of 40W with an efficacy of 64 lm/W and a life expectancy of 8000 hours.

In an attempt to reduce the cost of lightings it was proposed to replace the fluorescent tubes with 40 Sodium lamps of 320W electrical input, efficacy of 143 lm/W and a life expectancy of 12,000 hours. The factory is illuminated for 54,000 hours annually.

Cost of fluorescent tube ₦180.00

Cost of sodium lamps ₦360.00

It is required to determine the viability of the above project and the increase in illuminance if any,

Unit cost of electric energy is ₦4.25/kWh.

Assume that the efficacy is based on the total electrical input then for the present system in use, illuminance

$$\frac{586 \times 64 \times 40}{7880} = 190.4LX$$

For the proposed system, illuminance is

$$\frac{40 \times 143 \times 320}{7880} = 232.3LX$$

Percentage increase in illuminance

$$= \frac{(232.3 - 190.4)}{190.4} \times 100$$

$$= 21.99\%$$

Annual electricity cost with exiting system is

$$\frac{586 \times 40 \times 5400 \times 4.25}{1,000} = ₦537948.00$$

and with the proposed system

$$= \frac{40 \times 320 \times 5400 \times 4.25}{1,000} = ₦293760.00$$

In the existing system, the tubes have a life span of 800 hours and hence should be replaced at a time interval of 8000/5400 = 1.48 years.

For the proposed system, this should be replaced at a time interval of 12000/5400 = 2.22 years.

∴ Annual cost of replacement of tubes will be for existing system.

$$\frac{586 \times 180}{1.48} = ₦71270.27$$

for the proposed system

$$\frac{40 \times 360}{2.22} = ₦6486.49$$

Thus using 40 sodium lamps in place of 586 fluorescent tubes, there will be 22% increase in illuminance and cash savings of ₦308971.18 annually

3.8 Energy Auditing

The technique used in the management of energy have much in common with those required for the management of any resources in a company or establishment. Energy monitoring is the term applied to the regular recording of data relevant to the energy performance of anything from a single piece of plant to an entire site. The electricity consumption of a company will effectively be monitored by the meter installed for billing purposes by NEPA; such company may wish to have a more detailed knowledge of consumption and will install separate meters at a number of locations of major use. This recording of information for analysis of trends in areas of major demand can be carried out. Similar system can be used to meter the detailed consumption of other consumables such as oil and water. other data such as temperature and pressure can be detected by sensors and again recorded (manually or by automatic means).

Monitoring will not of itself lead to energy savings unless the data is analysed and put in context within the company or establishment. Therefore after monitoring, the next step is to analyse the data and carry out an energy audit. A company will pay bills for fuels such as electricity and oil. The objective of energy audit is to determine how well the company uses the energy and ultimately the energy cost contained in the price of the product. Having then established how the energy is being utilized, many industries apply the concept that energy consumption can be decreased by say 5% per year by the practice of good house keeping and more systematic maintenance. Starting with the present annual consumption related to a unit of production (e.g in MJ/ton) or to the unit area of a building (Craig, 1981).

This approach has two advantages, first it affords a comparism of one system with another, the other advantage of expressing energy consumption in terms of unit cost is that changes in output or building size will lead to change on consumption unrelated to efficiency of energy use.

Ile-Oluji Cocoa Product Company produces four major cocoa products; Cocoa butter, Cocoa Cake, cocoa powder as well as cocoa liquor all stored at different stores within the factory. Details of monthly production figures for five years are as shown in Table 3.6. Table 3.7 shows the regression analysis for the year 1996/97 for prediction of product yield.

TABLE 3.6: Product Output For 5 Years

Months	1992/93 MT	1993/94 MT	1994/95 MT	1995/96 MT	1996/97 MT
October	128	152	441	110	749
November	305	121	601	121	981
December	145	190	455	-	1078
January	241	212	377	105	1084
February	251	134	70	156	1177
March	236	212	636	108	633
April	339	268	170	126	640
May	479	471	416	69	612
June	379	441	-	119	661
July	207	149	-	219	697
August	95	133	-	659	720
September	-	199	112	884	814
Total	2,805	2,687	3,278	2,676	9,846

TABLE 3.7 Regression Analysis for the year 1996/97

MONTHS	Production Output X (MT)	Diesel for Roasting Machine Y (LTRS)	XY	X^2
October	749	9,785	7,328,965	561,001
November	981	13,560	13,302,360	962,361
December	1078	15,470	16,676,660	1,162,084
January	1084	18,380	19,923,920	1,175,056
February	1177	16,270	19,149,790	1,385,329
March	633	12,790	8,096,070	400,689
April	640	14,857	9,508,480	409,600
May	612	8,022	4,909,404	374,544
June	661	9,790	6,471,190	436,921
July	697	8,515	5,934,955	485,809
August	720	11,610	8,359,200	518,400
September	814	12,590	10,248,260	662,596
Average	820.5	$\Sigma Y =$ 151,639	$\Sigma XY =$ 129,909,314	$\Sigma X^2 =$ 8,534,390

$$X = \frac{\Sigma x}{N} = \frac{9846}{12} = 820.5$$

$$Y = \frac{\Sigma y}{N} = \frac{151{,}639}{12} = 12636.6$$

$$b = \frac{\Sigma xy - Nxy}{\Sigma x^2 - n(x)^2} = 12.05$$

Regression equation

$$a = y - bx$$

$$a = 2758.9$$

Thus the regression equation of the above is

$y = 2753.9 + 12.05x$ 3.24

3.8.1 *Load Profile*

In industries, it is possible to relate energy usage and energy cost to production figures thus formulating energy indices which are used for checks as well as energy forecast. Such forecasts are based on previous years loading for the period in question updated by factors such as general load increases, major new loads, and weather trends. Both power demand and energy (kWh) forecasts are used, the latter often being the more readily obtained.

Figures 3.7 to 3.11 show the Trend for five years of internally consumed power and consumption from national grid in Ile-Oluji Cocoa Products Company. From these figures further detailed breakdown can be achieved e.g.

Energy index for October 1992/93

= Corresponding total load/product output

$$= \frac{815.7}{128} = 6.37\text{kW/Ton}$$

and for October 1996/97

$$\text{Energy index} = \frac{1200}{749} = 1.60\text{ kW/Ton}$$

When a company produces specific products, a useful parameter to monitor and compare energy consumption is the energy index. The energy index is the figure obtained when the energy use is divided by the production output, and the index may be calculated weekly, monthly or annually.

Although the total energy index is sufficient for monitoring purposes a record of the individual energy indices should be maintained. In the event of an increase or decrease (due to a conservation measure) in the energy index, the particular source can be investigated immediately.

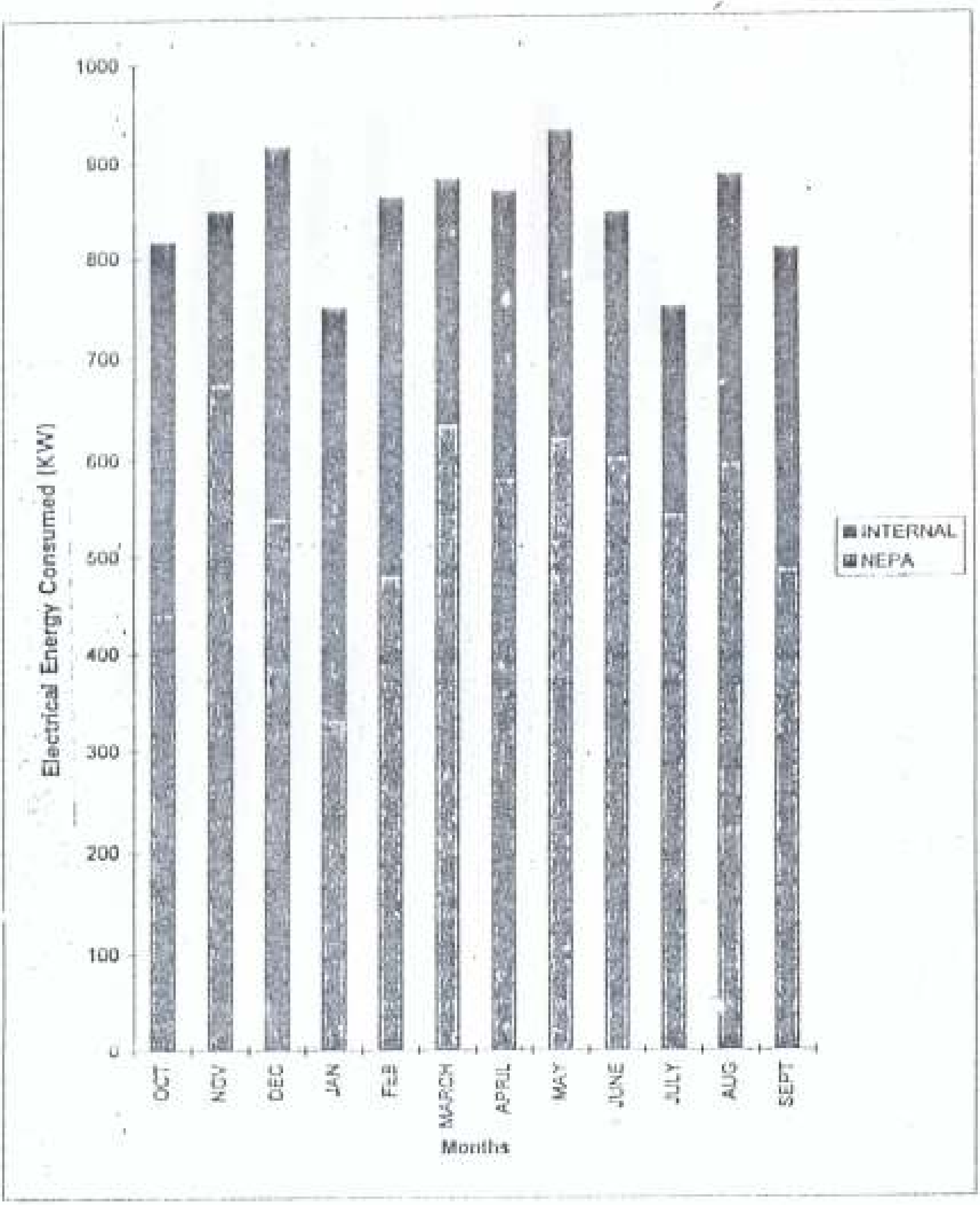


Fig. 3.7: Cummulative Monthly Load Profile (10 KW) Showing Energy Consumption For 1992/93.

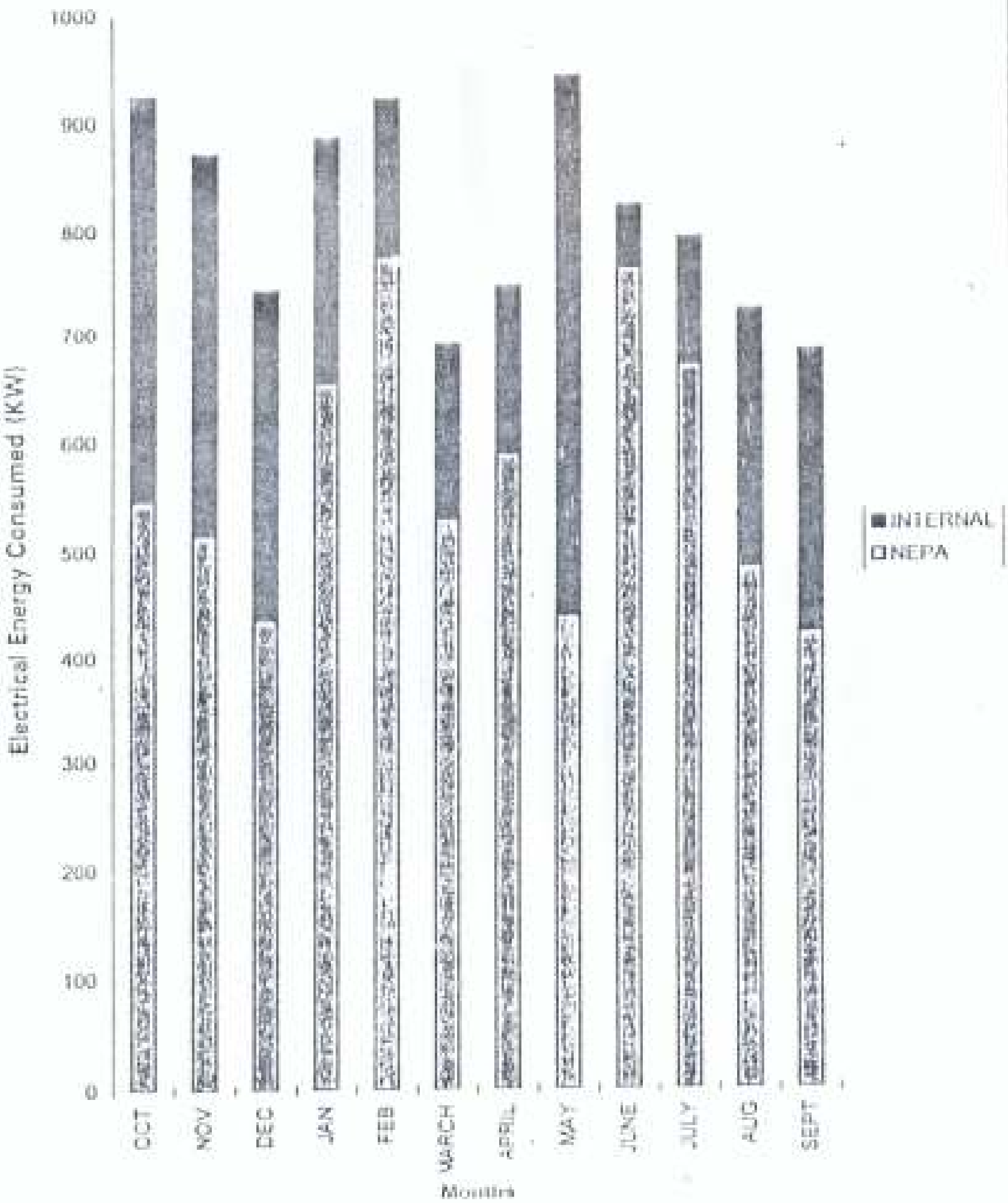


Fig. 3.8: Cummulative Monthly Load Profile (10 KW) Showing Energy Consumption For 1993/94.

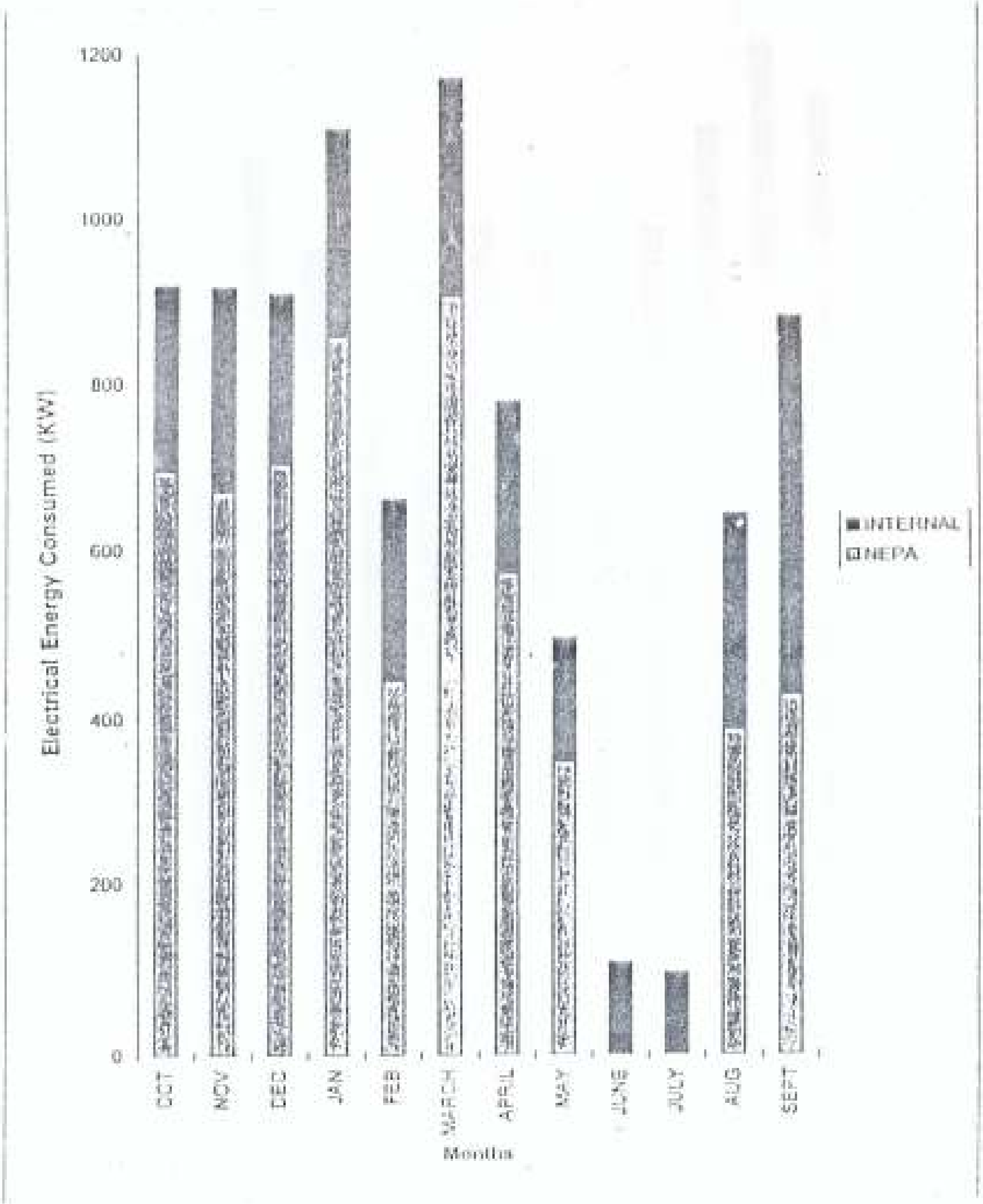


Fig. 3.9: Cummulative Monthly Load Profile (10 KW) Showing Energy Consumption For 1994/95.

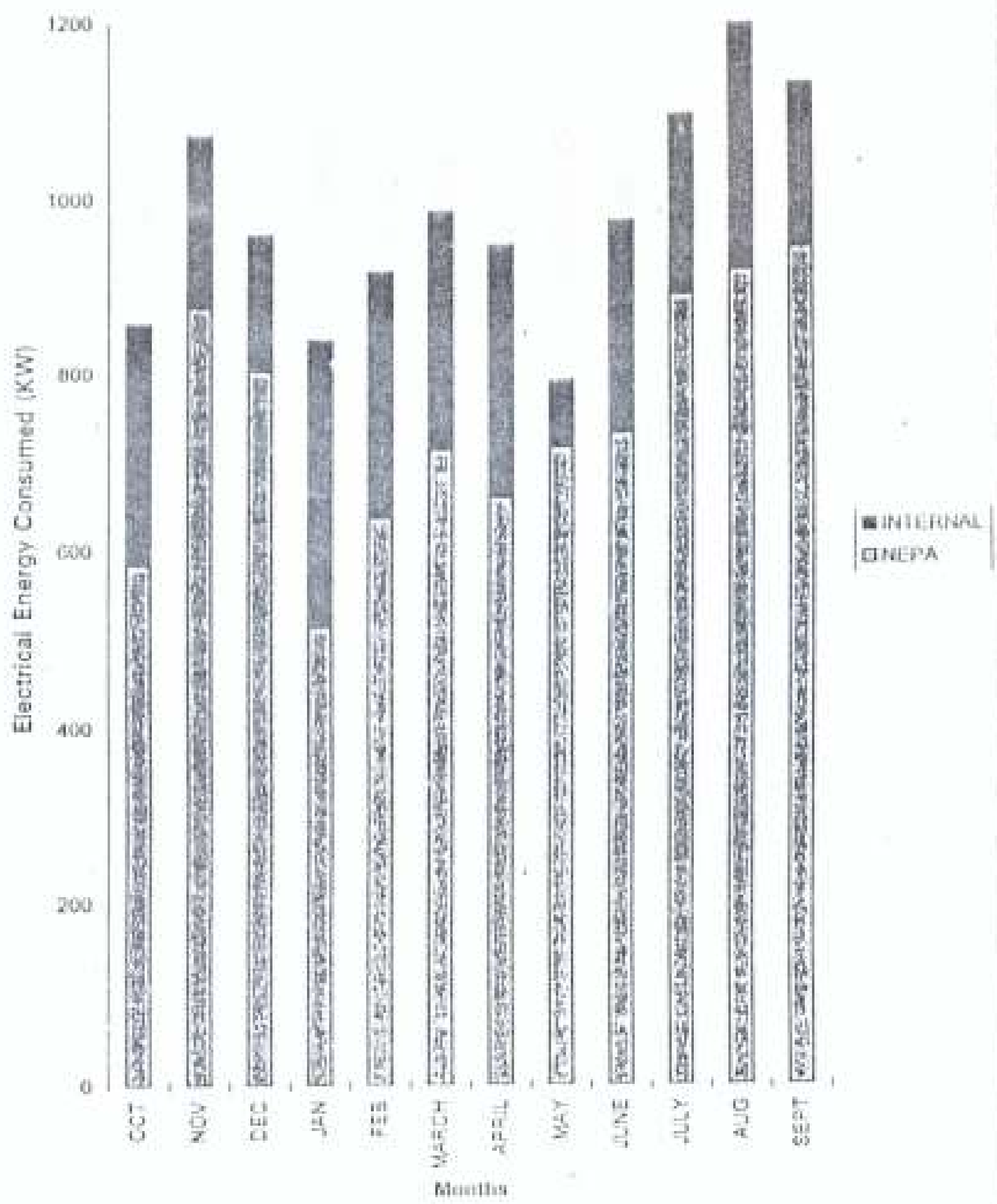


Fig. 3.10: Cummulative Monthly Load Profile (10 KW) Showing Energy Consumption For 1995/96.

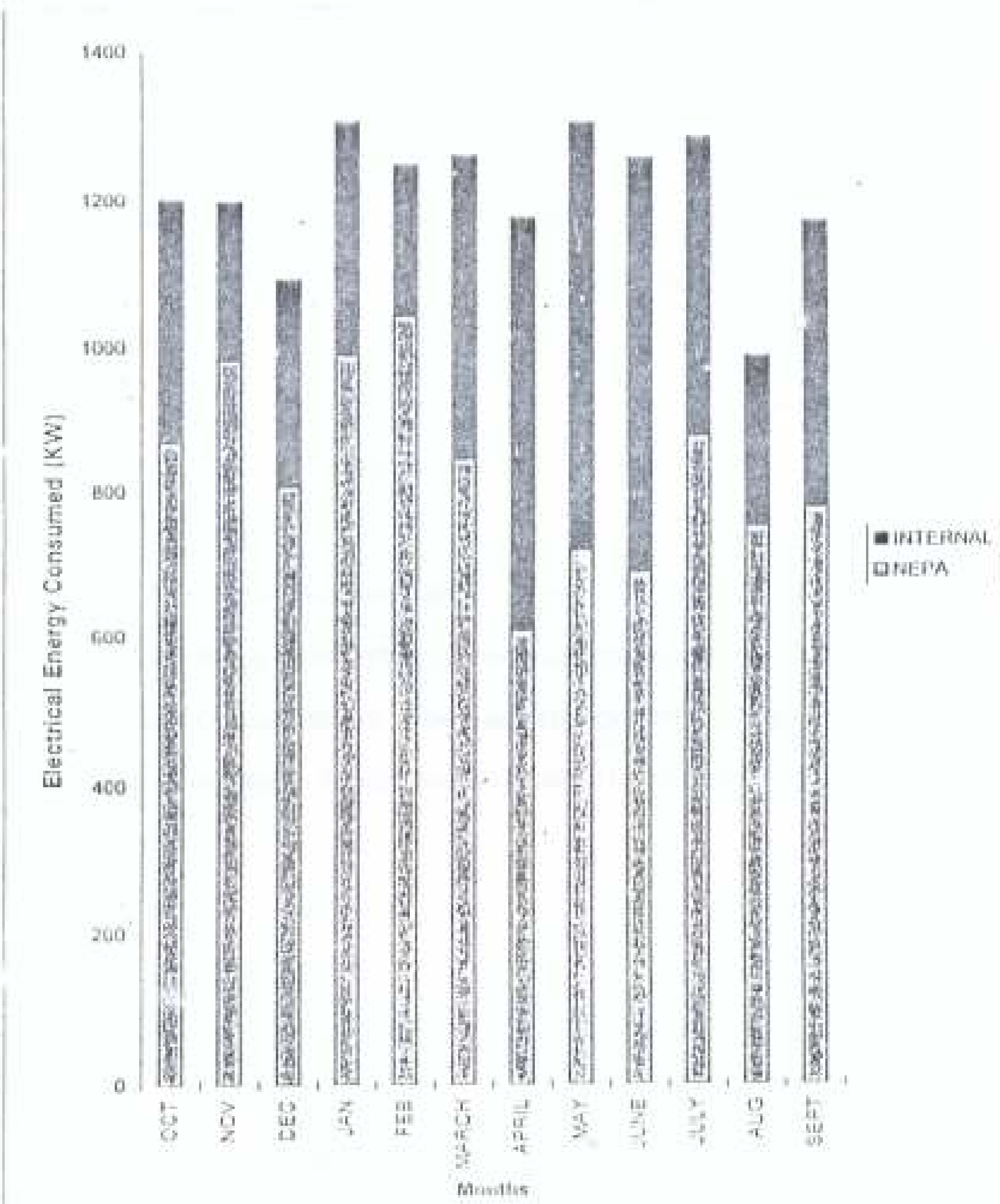


Fig. 3.11: Cummulative Monthly Load Profile (10 KW) Showing Energy Consumption For 1996/97.

It can be observed that the energy consumed for the year 1996/97 was far higher than corresponding years but the energy index for that year is least for the five years compared because there is a corresponding increase in the tonnage of products - produced hence the trend thus exists.

Energy managers would not be pleased if there is an increase in energy consumption but will not necessarily complain if there is a proportionate increase in output as in the above case. The slope of graphs from Figure 3.12 also indicate fuel energy index for Roasted beans in the year 1995/96 and 1996/97 which are 16.08 liters per tonne and 15.40 litre/ton respectively.

From the scatter diagram in Figure 3.12, the points show considerable scatter but there is a distinct trend relating production output and beans roaster fuel consumption. The best straight line relating the points can be obtained using least square analysis and the regression line is given by the equation:

$$Y = 2753.9 + 12.05x \qquad \text{..................} \; 3.21$$

The regression line can be used to compare energy consumptions with actual results and when consumption is unfavorable, measures may be taken to reduce the marginal consumption. The relationship between energy consumption and production output is not linear. Energy index can be used to specify how usage and consumption efficiency of fuels affect the production costs. The identification of energy cost center, in order to breakdown the total consumption, varies between different organizations. Typical specific areas of energy consumptions are offices, factory premises, machine shops and process units.

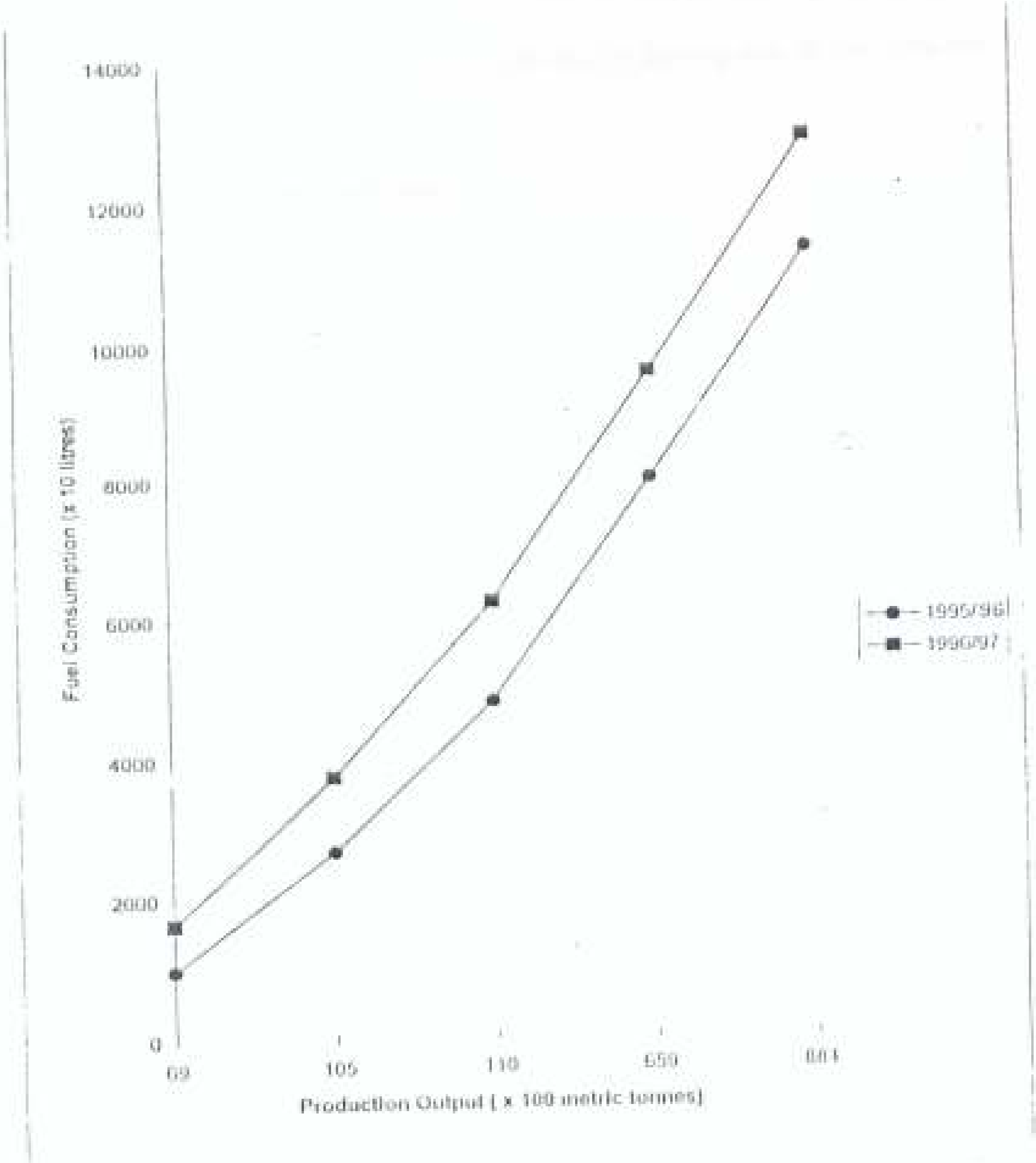


Figure 3.12: Diesel Fuel For Roasting Machine Against Production Output For The Years 1995/96 and 1996/97

The monthly usage of fuel oil and electricity for steam generation in Ile - Oluji Cocoa Product Company is consumed in the following stages.

a. Process use

b. Environment use

c. Unaccounted losses

d. Boiler losses i.e flue gases.

The gas oil consumption by the company is used for.

i. power house

ii. Roaster

iii. Vehicles

The third energy source used by the company which is electricity is utilised as follows:

	Energy Center	Power consumed (kWh)
(i)	Boiler	20.30
(ii)	Power house	1.36
(iii)	Environment	97.80
(iv)	Process zone	1491.72
(v)	Offices	4.40

Total fuel utilised during the year 1996/97 stands at 861,645.46 litres valued at ₦6031518. For an annual production output of 9,846 MT, the cost of producing a MT of beans would be ₦7350.13/MT of beans.

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

There are generally scopes for energy savings in any organizat.on but the energy manager should remember that there is ample opportunity to embark on ill - conceived energy "conservation" projects that can result in maldistribution of energy or greater overall expenditure by the company.

4.1 Discussion of Findings and Observations

Careful considerations were given to proposed projects to determine their cost effectiveness. This was to ensure that money that ought to have been spent on other profitable aspects of the business was not spent on energy conservation project without commensurate profit margin. It is a matter of fact that an energy manager should be familiar with the financial policy of a company and his case should be stated in terms of potential savings discounted over a period of time, against the project cost of energy.

A straight forward pay -back time based on present - day costs can often be misleading and may result in the rejection of a proposal for what is in reality a cost effective project. In trying to find solution to some problems through energy optimisation in Ile-Oluji Cocoa Products Company, various options in cost reduction strategy were analysed within the context of this research work.

These include:-

1. Development of more efficient processes for energy use which takes time and money into consideration.
2. Operating existing process more efficiently which requires the dedicated enthusiasm of all.

All common services should be regularly inspected for leaks, since they are often not attended to for long period due to poor accessibility. Where more than one boiler is in use, it may be possible to shut one down for part of the time. Hot water storage of a boiler will vary with the load on it and is greatly affected by the efficiency of combustion and by the transfer of heat from the waste gases to the water.

The treatment of feed water protects a boiler from the effects of corrosion, reducing the risk of failure by overheating and loss of efficiency which would otherwise result from the build-up of deposits carried to excess, blowdown of the dissolved solids in boiler water which can cause up to 10% of the energy supplied as heat to be lost.

When energy is rejected in the form of pressure, heat, waste gases and other products of unburnt fuel from one process, it may be possible to harness it to reduce the energy needs of the same or some other processes.

4.2 Heat Recovery

Heat recovery systems can be introduced at the design stage of a new plant, but it is more often the case that heat recovery has to be applied to existing plants like Ile-Oluji Cocoa Products Company.

With two boilers of sizes UL-S 2600x10 which emit flue gases as high as 190°C/220°C respectively, a run around coil, shell and tube or cross flow heat exchanger can be used to recover energy from the flue gas for feed water heating from the present 40°C thus reducing the energy requirement for raising the temperature of feed water into steam. From the boiler parameters, the efficiencies of the two boilers were estimated in order to ascertain their cost effectiveness. Also, the reduction in fuel consumptions if feed water temperature was increased to about 90°C and if the boiler were redesigned for a flue gas temperature of 127°C and 177°C respectively were estimated. The results are presented in Tables 4.1 and 4.2 respectively.

The specifications and operating conditions of the boilers are as shown below:

1) BOILER A

Fuel type: Diesel

Composition by mass

86.2%C, 12.8% H, 1.0%S, GCV 45.5MJ/kg

Mass flowrate of fuel	=	200kg/h
Fuel Cost (October 1998)	=	₦9.00/litre
Rate of steam generated	=	2600kg/h
Pressure of Dry saturated air	=	10bar
Feed water temperature	=	40°C

Blow down flash vessel at 1.1 bar and 10% of steam mass flow rate.

Temperature of make up water at blow down = 15°C

Air temperature at entry 32°C.

Average flue gas temperature at boiler exit = 190°C

Flue gas pressure at exit	=	1.03 bar
Heat losses from casing	=	180kW

Boiler is used at full load for 4,800 hours per annum

ii) BOILER B

Fuel type : Heavy fuel oil

Composition by mass: 82.9%C, 11.4%H, 4.5%S, 1.2% other GCV 42.5MJ/kg

Mass flow rate of fuel	=	145kg/h
Fuel cost (October 1998)	=	₦7.00/litre

Steam produced at 10 bars

Flue gas temperature at boiler exit = 220°C

Heat loss from casing = 150kW

All other parameters are similar to that of boiler A above.

A cross flow heat exchanger is used to recover energy from exhaust flue gas which consists of mixed stream of hot exhaust flue gas flowing at 2.5kg/s across a bank of tubes conveying unmixed boiler feed water.

The gas with specific heat capacity of 1.09kJ/kgK enters at 190°C and leaves at 127°C. The overall heat transfer coefficient being 180W/m^{2}K, the calculated heat exchanger area required was 13m^2. The fuel cost savings per annum using an L.P.F.O boiler with efficiency of 74.49% amounted to ₦112334.50. This is in addition to over a million naira that would be realised from the reduction in flue gas temperature as indicated in Tables 4.1 and 4.2. The project has a payback period of less than two years when implemented.

TABLE 4.1: Result Of Analysis On Boilers A and B

	Boiler A	Boiler B
Flue gas losses	13.016%	14.23%
Casing loss	7.120%	8.76%
Blow down loss	1.70%	2.31%
Efficiency	78.16%	74.49%
Savings from feed water Temperature increase from 40°C to 90°C	₦661678.68 Per annum	₦578109.92 per annum

TABLE 4.2: Result With Reduced Flue Gas Temperatures.

From To	190°C 127°C	220°C 177°C
Boiler	A	B
Flue gas losses	10.5%	12.29%
Casing loss	7.06%	8.43%
Blow down loss	2.03%	2.57%
New efficiency	80.41%	76.18%
Annual reduction in fuel cost	₦1225224.00	₦652800.00

4.3 Savings in Cost of Steam Distribution Within a Process Zone

Existing wet steam supply pipings from a fuel oil fired boiler into the process zone of Ile-Oluji Cocoa Product Company utilises pipe network with an outer diameter of 15.2mm and an insulation thickness of 25mm. With insulation thicknesses of 15mm and 50mm, comparison of economic viability and cost savings, if any, in the use of different thickness was estimated using the following data and the result tabulated in Table 4.3.

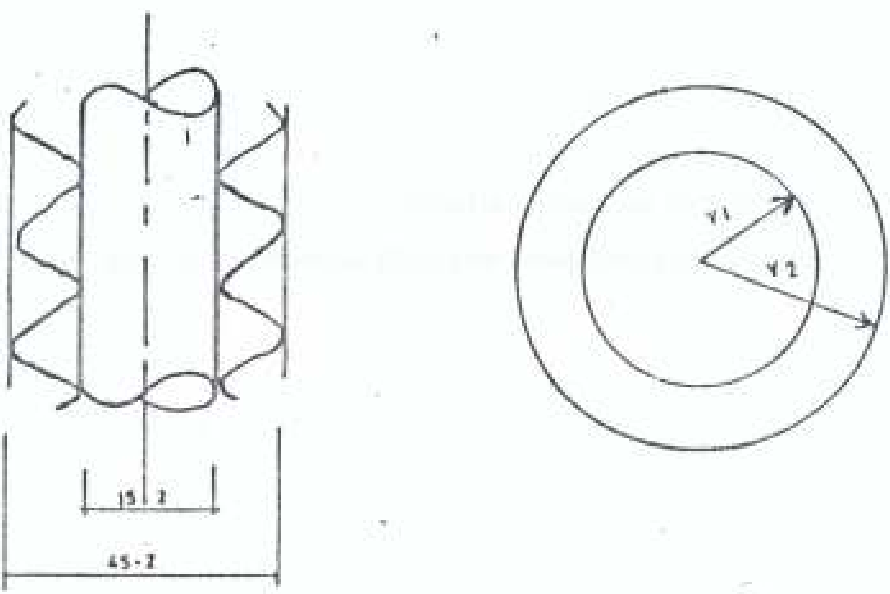


Figure 4.1 PIPING WITH INSULATION THICKNESS OF 15mm.

Steam supply pipe outer diameter 15.2mm

Heat transfer coefficient for outer surface of insulation = 10W/m²K

Thermal conductivity of insulation	=	0.043W/mK
Steam temperature	=	185°C
Temperature of ambient air	=	30°C
Boiler efficiency	=	74.49%

Price of heavy fuel oil = ₦7.00/litre

Duration of operation = 5400h/annum

Cost of insulating material = 50mm at ₦4100=/m

25mm at ₦1800=/m

15mm at ₦1080=/m

The thermal resistance of cylindrical insulation is given by

$$R = \frac{\ln\{r_2/r_1\}}{2\pi Kl} \text{ for unit length .... 4.1}$$

From figure 4.1

where r_2 = pipe + insulating material outer radius lm

r_1 = pipe outer raius m

k = thermal conductivity of insulation in W/mK

l = length of section being considered m.

The thermal resistance R of the fluid film on the outside surface is given by

$$R' = 1/LA \text{.............................. 4.2}$$

and the heat transfer per unit area

$$Q = \frac{\Delta t}{R_t} \text{ .... 4.3}$$

where

$$R_t = R + R'$$

TABLE 4.3: Result Of Analysis Using Different Insulation Thicknesses

Insulation Thickness (mm)	Thermal Resistance of Insulation (mK/W)	Thermal Resistance fluid film (mK/W)	Heat Transfer per unit length W/m	Annual cost of heat loss per meter (₦) 250m	Payback period (months)
0	0	2.10	73.5	17595.9/m 4398975.0	-
15	4.03	0.71	32.5	7631.9/m 1907975.0	1.30
25	5.39	0.49	26.2	6152.0/m 1538007.5	1.88
50	6.98	0.28	21.2	4989.3/m 1247319.0	3.90

From the above analysis, the company would pay about ₦1.9million more for fuel if its steam supply lines are insulated with 15mm thick material or waste a sum of ₦369976.5 for using 15mm insulating materials. Whereas the company would save ₦290688.5 using an insulating material of 50mm thick.

It can be further deduced that the cost of heat loss is smallest using the 50mm thickness of insulation compared to others but the initial material cost is higher than others. The heat loss from the surface can be reduced substantially by covering it with a material that has a low thermal conductivity and a low emissivity.

In general, the temperature of the outer layer of a properly insulated surface is such that the steady-state heat loss is maintained by natural convective heat transfer. The air in the immediate vicinity of the insulation is heated, thereby reducing its density; the warm air rises and is replaced continuously by colder air.

Considerable savings have been made in the cocoa processing sector by providing insulation to cover machines that have extreme temperature difference with its surroundings during operation. Many cocoa industries involve the heating of liquids in partially opened tanks such as mixing tanks for alkalization process or mass and liquor storage tanks during operation.

4.4 Insulation

In particular situations, the actual economic thickness of an insulator depends on the relationship, trade offs between insulation cost and heating cost. Considering the analysis of energy savings in section 4.3, one can evidently ascertain that as the insulation thickness increased from 15mm to 50mm, the thermal resistance for insulation also increased proportionately from 4.024mK/W to 6.975 mK/W with a corresponding decrease in the fluid film resistance from 0.7m^2K/W to 0.3m^2K/W.

Thus there is a high rate of heat loss from the 15mm thick insulation compared to higher thickness. It was also shown that the minimum heat loss was obtained with the 50mm insulation thickness but with a longer pay back period of 3¾ months, basically due to the higher cost of the 50mm insulating material. This implies that the 15mm material has more initial cost advantage but long-term saving is in favour of the 50mm material.

At present ICPCL uses the 25mm thick insulating material with an annual fuel cost of heat loss valued at ₦6738.6 per meter. An additional fuel savings of ₦1273.50/m can be achieved using the 50mm thick insulating material. Hence, with a total length of 238m of insulating steam pipes, fuel saving valued at ₦303093.00 can be achieved. A loss of ₦1,620.90/m could have been incurred using the 15mm insulating material resulting is a gross loss of ₦385774.20 annually.

The insulation of tanks is capital intensive with a very long pay back period of over two years which some industrialists would consider unprofitable to invest over a million Naira on. Though the annual savings is worth the investment, ignorant enterpreneurs would prefer to invest on raw materials at the expense of energy saving ventures.

4.5 Water Treatment

The treatment given to the raw water depends on its composition and the type of boiler system in which the treated water will be used, the higher the boiler pressure, the purer the treated water.

In ICPCL, water technology is far behind technology for today's boiler. The raw water hardness in the company is 60ppm and the boiler water hardness is20ppm. Thus, there exist a high degree of scale formation. Water is pumped directly from the company's borehole into underground tanks of 460,000 litre capacity without chlorination or any other physical treatment. The raw water goes directly into the boiler house. It is then passed through ion softners which are not functional as the resins are spent hence all feed water hardness goes to the boiler.

The water pH is maintained at relatively high value and gamadyne is periodically dozed in but that alone cannot perform the primary function of removal of ions from the water. Thus, the formation of heavy scales. The high hardness load on the boiler is the main cause of scale deposition on the boiler tubes. The deposited scale reduces heat transfer leading to increased time for pressure build-up in the boiler and increases in fuel cost. Scales also lead to overheating of tubes, and it is therefore capable of causing ultimate demage to the boiler installation.

In an attempt to solve the above stated problems, different management had on one occasion or another visited the issue of purification of water but cost had been a major impediment in the realization of these goal. Newly invented oxidation/reduction system in water technology by a research team headed by Dr. Wayne C.Turner, Regents Professor at the

Oklahoma State University (OSU) College of Engineering, Architecture and Technology resolves costly problem from water treatment.

Keltronics design and assembles printed circuit boards for customers which fabricate electronic equipment for telecommunications, aircraft and scientific application. At one time the tin/lead content of effluent water used to rinse off printed circuit boards was costing Keltronic Corp, Oklahoma City Ok ₦327.60 per gallon to dispose off as harzardous waste.

The cost has been eliminated with the installation of a closed loop wash down system using proprietary water treatment technology based on oxidation/reduction (redox) chemistry. The first of the two solutions was by using ion exchange to remove lead and adjust the pH. The second solution offered by Turners team involved the use of redox chemistry. The redox chemistry system offered two disposal options.

1. Discharging the treated effluent into the sanitary sewer system at a standard industrial discharge cost of ₦78.75 per 1,000 gallons.
2. Continually reusing the water in a closed loop rising system that would eliminate not only the sewer discharge fees, but also the constant cost of using incoming city water for the rinse process. The savings were in addition to eliminate the ₦327.60 per gallon cost to treat lead -impregnated waste-waters.

Much as these proposals had been tested and found not only to have a fast pay back period but also having a high profit yield. Ile-Oluji Cocoa Product Company's management still considers cost as a major impediment in treating her water both for process operation as well as for drinking.

4.6 Lightings in Building and Power Factor Correction

Energy expended on lighting in ICPCL is small, significant conservation of energy had been achieved in this area. Most significantly is the type of luminaire used in various sections in the factory. A knowledge of the maximum light output of a typical fluorescent tube enabled us in the distribution and installation of the tubes, thus fluorescent tubes are not used in the butter rooms where the room temperature is below 18°C. Such temperature reduces light output to about 75% of maximum.

In the refinery as well as the tankage areas where tank temperature go up as high as 90°C in which case surrounding air temperature will be commensurately increased above 40°C, fluorescent tube light output will again reduce to 75% of maximum. Replacement rate of tube and bulbs had been haphazard thus incurring undue running cost, labour cost as well as the cost of purchase of the lamps themselves.

Luminaries, tubes and bulbs cleaning at predetermined intervals depends on the cleanliness of the atmosphere in which they are sited. It is most advisable that lamps and tubes should be replaced after a fixed number of hours of lighting based on the probable life expectancy since if this is not done, productivity may suffer when light fails unexpectedly.

A proposed lighting system for ICPCL by replacing 586 pieces of fluorescent fittings with 40 sodium lamps is estimated to have an increased percentage illuminance of 21.99% and a cash savings of ₦3089971.18.

The simplest method of power factor improvement which is the installation of power factor improvement capacitors is in place in ICPCL to provide the required amount to capacitive reactance CVAR. The company seems to be comfortable with a power factor of 0.90.

To maintain comfortable environments, there are many types of air conditioning systems, based on various concepts and using different methods to achieve the heating and cooling. The system and equipment chosen for a particular building thermal load combination can have a significant effect on the energy usage and hence require careful selection.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study is focused on optimisation of energy in a cocoa processing industry. This involved identification of areas of energy losses, proposed ways of minimising the losses in a cocoa industry which will enhance operational system and the finances of running such plants. Findings from the case study can be summarized as follows:

Fuel savings per annum using L.P.F.O as boiler fuel with a combustion efficiency of 74.4% amounts to ₦112334.50 using fuel price of ₦7.00 per litre. This is in addition to over a million naira that would be realised from the reduction in the gas temperature and a pay back period of less than two years.

Optimum energy savings in insulation was realised using a 50mm thick insulating material. Savings valued at ₦303093.00 was realised and a loss of ₦1620.90/m could have been incurred using the 15mm insulating material which would have resulted in a gross loss of ₦385774.20 annually. The insulation of tanks were considered to be capital intensive with long pay back period of over two years which the management considered unprofitable in her current dispensation. Though the annual savings is worth the investment, ignorant enterpre..eurs would prefer to invest on raw material at the expense of energy saving ventures.

There are several ways in which the energy used for lighting may be reduced with a consequent reduction of annual running costs. The choice of lamp and luminaire for the purpose required is obviously very important.

Studies have shown that there is a strong correlation between productivity and lighting level likewise choosing the right type for a specific purpose can lead to greater energy efficiency. Thus using 40 sodium lamps in place of 536 fluorescent tubes, there will be 22% increase in illumination and cash savings of ₦308971.18 annually.

The analysis of power generation has shown that reliable generating sets for internal power consumption reduces overhead cost for power in a locality where the average power availability from the National grid is below 60%. Most of the causes of energy wastage have been identified which can be prevented at low capital cost as highlighted in the study. Ways of curbing losses from the steam generation plant (boiler), pipe distribution network, as well as steam utilisation areas had been advocated for cocoa plants.

It is noteworthy that a collosal amount of money would be saved if the above is put in practice. This is due to the fact that, market structure in the last ten years tended towards perfect competitive markets whereby the cost of finished products are determined by the market forces "Demand and Supply".

5.2 Recommendations

If energy consumption at Ile-Oluji Cocoa Products Company is to be optimised the following recommendations are suggested for further work.

1. Research on fuel savings should be carried out on machines requiring combustible fuel.
2. Further research work should be carried out on different types of insulating materials for steam distribution and chilled water distribution.
3. Research work involving unit by unit material, energy balance as well as a steam and utility balance should be carried out.
4. Simulation of the identified area of losses to establish how the system efficiency will compare with similar industries in terms of energy management.

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APPENDIX 1

Schematic Diagram of a Process Line and Holding Vessels (attached)