SEAM ***Project***

Guidance Manual

Cleaner Production for Food
Water and Energy Conservation

Ministry of State for Environmental Affairs
Egyptian Environmental Affairs Agency
Technical Cooperation Office for the Environment

***En*tec UK Ltd**
UK Department for International Development

Guidance Manual
Cleaner Production for Food
Water and Energy Conservation

SEAM Project
Implemented by:

Egyptian Environmental Affairs Agency
Technical Cooperation Office for the Environment
and
Entec UK Limited

Guidance Manual prepared by Chemonics Egypt on behalf of the SEAM Project

With Contributions from:

Egyptian Environmental Affairs Agency
Technical Cooperation Office for the Environment

***En*tec UK Ltd**

July 1999

SEAM Project
Implemented by:

Egyptian Environmental Affairs Agency
Technical Cooperation for the Environment
and
***En*tec UK Ltd**

TABLE OF CONTENTS

The SEAM Project - An Introduction

Support for Environmental Assessment and Management (SEAM), is a multi-disciplinary environmental project being funded by Britain Department for International Development (DFID). This Project is being implemented by the Egyptian Environmental Affairs Agency (EEAA) through the Technical Cooperation Office for the Environment (TCOE) and Entec, a UK based engineering and environmental consultancy.

The SEAM Project is made up of 5 components, focusing on environmental management issues. These include Industrial Pollution Prevention/Cleaner Production, Environmental Impact Assessment, Solid Waste Management, Environmental Action Plans and development of an Environmental Database.

The main goal of the Industrial Pollution Prevention/Cleaner Production component is to show that significant financial savings and environmental improvements can be made by relatively low-cost and straightforward interventions. These consist of pollution prevention through good housekeeping, waste minimisation, process modification and technology changes. This approach has two benefits - valuable materials are recovered rather than wasted and factories are moved towards legislative compliance. This work is being undertaken in support of the National Industrial Pollution Prevention Programme (NIPPP) and has focused on three sectors: textiles, food and oil & soap.

Industrial auditing was used as a systematic approach to identify pollution prevention measures. Industrial auditing of 32 factories led to identification of more than 200 low cost/no cost pollution prevention measures. Measures that had relevance across the sector, innovative contents and a high multiplier potential were then developed as demonstration projects. The idea of these demonstration projects was to show how the pollution prevention approach can lead to financial benefits while gaining improved environmental performance.

Thirteen demonstration projects have been implemented in 21 sites as follows:

Textile Sector

- Eco-friendly Processing for Securing International Eco-label.
- Water and Energy Conservation.
- Combined Processing: Desize, Scour and Bleach.
- Bleach Clean-Up using Enzymes.
- Sulphide Reduction in Sulphur Dyeing.

Food Sector

- Installation of Milk Tank Level Controls and Valves.
- Water Conservation in Food Factories.
- Energy Conservation in Food Factories.
- Reducing Waste by Improved Quality Control.
- Recovery and Use of Whey as Animal Feed.

Oil and Soap Sector

- Waste Minimisation in an Edible Oil Factory.
- Oil and Fat Recovery.
- Improving Raw Water Quality to Reduce In-Plant Losses.

Outputs from these projects include industry workshops and seminars, demonstration projects with supporting Guidance Notes and Manuals (to enable other factories to implement similar projects themselves), case studies incorporating cost-benefit analyses to demonstrate project feasibility, detailed Sector Reports and Guidelines describing how to carry out industrial audits.

Factories Participating in the Water and Energy Conservation Demonstration Project

This demonstration project was implemented in two different food processing factories, as follows:

1. Edfina for Preserved Food, Alexandria (Edfina):

Edfina co. for preserved food is one of the largest companies in Egypt in the area of preserved and frozen food production. It is a public sector company and is under control of the holding company for food industries. The main products of the company for the years 1995/1996 and 1996/1997 are shown in the following table. The production is seasonal and the plant operates 3 shifts/day, 8h/shift.

Edfina Company Production in 1995/1996 and 1996/1997

Product	Quantity in tons	
	1995/1996	1996/1997
Juices	5,477	4,033
Beverages	552	451
Jam	5,473	3,839
Tomato paste	1,121	519
Canned vegetables	192	231
Canned beans	692	1,428
Frozen vegetables	1,718	812
Agar-agar	48	97
Others	4,448	161
Tin cans (LE)	344,472	-

The Edfina co. production facility at Ras El-Souda contains the following production lines:

1. Juice production lines
2. Tomato paste production line
3. Canned vegetable
4. Canned beans
5. Frozen vegetables
6. Agar-Agar
7. Tin can manufacturing

Project Objectives: The project objectives are to study, suggest and implement no cost/low cost energy and water conservation measures and assess the result of implementation through monitoring and cost/benefit analysis.

2. Kaha for Preserved Food, Kaha (Kaha):

Kaha company for preserved food is one of the biggest companies in the field of preserved food in Egypt. The company is located in Kaha Town, Qalubiya Governorate, 30 km north of Cairo on the Cairo/Alexandria agricultural road. It belonged to the public sector since it started in 1976 until 1998. Under the recent privatisation policy, it was sold to a new owner.

The products include jams, juices, tomato paste and frozen and canned vegetables. The factory is working seasonally according to market requirements. The following table shows the quantities produced during the period from 1/7/1996 to 30/6/1997.

Kaha Company Production in 1996/1997

Product	Quantity in tons
Juices	1,997
Jam	1,358
Tomato paste	840
Canned vegetables	69
Canned beans	3,150
Frozen vegetables	253
Pickles	109

Kaha co. contains the following production lines

1. Juice production lines
2. Jam production line
3. Tomato past production line
3. Canned vegetables
4. Canned beans
5. Frozen vegetables line
6. Frozen vegetables line
7. Metal cans forming and printing line

Project Objectives: Study, suggest and implement no cost/low cost energy conservation measures and assess the result of implementation through monitoring and cost/benefit analysis.

Egyptian Environmental Affairs Agency (EEAA)
Technical Cooperation Office for the Environment (TCOE)
30 Misr Helwan Agricultural Road
5th floor, Maadi, Cairo, Egypt
Tel.: 20 2 525 6452 Fax: 20 2 525 6457
email: EEAA2@idsc.gov.eg

Entec UK Ltd
30 Misr Helwan Agricultural Road
4th floor, Maadi, Cairo, Egypt
Tel.: 20 2 525 6452 Fax: 20 2 349 9795
email: entecegy@eis.com.eg

Part A

1. General Overview
   - 1.1 Importance of Water Conservation
   - 1.2 Water Use in Egypt
   - 1.3 Importance of Energy Conservation
   - 1.4 Energy Use in Egypt
2. Introduction to this Guidance Manual

1. General Overview

1.1 Importance of Water Conservation

In order to cope with an increasing population and at the same time realising social and economic growth, the present government is undertaking revolutionary developments in different directions. New industrial projects around Cairo and in Upper Egypt, as well as the planned reclamation of desert for agricultural use will all increase the national demand for water.

Encouraging exports in order to improve the economic balance is a real challenge especially under the GATT (General Agreement on Tariffs and Trade) economic system, where the Egyptian goods have to be competitive both in price and quality. Energy and water are important components contributing to the production cost.

All the above mentioned factors depend on the availability of water. Water conservation projects therefore environmental protection since depletion of natural resources is considered an environmental hazard.

There are many benefits for water conservation:

- Decrease production cost by reducing water consumption
- Decrease cost of wastewater collection system
- Decrease cost of wastewater treatment

1.2 Water Use in Egypt

The main source of water in Egypt is the Nile River, it supplies Egypt with about 97% of water needs. According to the 1959 Nile Agreement, Egypts stable share has been 55.5 billion cubic meters per year. The annual extraction of water from ground water reservoirs in the Nile valley and Delta in the western desert and in the eastern desert and Sinai is in the order of 4.7 billion cubic meters. The total amount of water expected for use in the different sectors was 60.2 billion cubic meters in 1996. From this amount 83.2% was used for irrigation, 9.8% was used by industry, 5.5 was used in the domestic and commercial sector and the remaining 1.5% for other purposes.

The current water use and projections to year 2000 show a rapid increase in demand. Water conservation is therefore an important issue.

1.3 Importance of Energy Conservation

First of all, the **Production Company** will benefit from saving energy. Electricity and fuel bills constitute a sizeable part of the production cost. Saving energy will therefore reduce the production cost. This is especially true if we take into consideration the continued increase in the price of primary energy (see table 1). The net result is improving the competitiveness of the products.

The **locality** where the factory is situated, will benefit since reducing the amount of fuel burnt will reduce emissions of the greenhouse and polluting gases. See table 2 for the progress of CO_2 emissions associated with burning fossil fuels in Egypt in the years 1990/1991 to 1996/1997. CO_2 emissions increased from around 75 million tons in 1990/1991 to 85 million tons in 1996/1997. Figure (1) shows sectoral distribution of CO_2 emissions in 1996/1997. Industry and electricity generation sectors are responsible for around 58% of the total emissions.

Sulphur oxide emissions, coming from sulphur present as organosulphur compounds in petroleum fractions, also pollutes the environment. The most polluting fraction is fuel oil followed by gas oil or diesel fuel, see Figure (2).

The **country** will benefit since reducing energy (fuel + electricity) consumption in several factories will make available more energy for new projects and also may hopefully delay 20 years. This will also limit CO_2 and SO_2 emissions in the Egyptian environment.

The **globe** will benefit from the improved environment due to less burning of fossil fuels.

Table 1. Price Development for Primary Energy (LE/ton)

Year Fuel	1985	1987	1998
LPG	52	52	200
Gas Oil (solar)	36	60	450
Fuel Oil (mazot)	7.5	28	182

	Aug. 90	May 91	Aug. 98
Natural Gas Price piaster/m^3	4.67	7.5	14.1

Table 2. Progress of CO_2 Emissions Associated with Petroleum Products and Natural Gas Consumption 1990/1991 to 1996/1997

Year	Total Fuel Consumption (million tons)	CO_2 Emissions (million tons)
1990/1991	27	75
1991/1992	27	75
1992/1993	27	74
1993/1994	27	73
1994/1995	28	77
1995/1996	30	83
1996/1997	31	85

1.4 Energy Use in Egypt

Table (3) shows the annual demand, production and proven reserves of crude oil in Egypt (in million ton) for the fiscal year 1997/1998 and projected figures for the year 2016/2017.

Table 3. Production, Demand and Reserves of Crude Oil in Egypt (in million tons)

Crude Oil	1997/1998	2016/2017
Annual Demand	23.9	61.6
Annual Production	40.1	20.7
Reserves	404.8	116.8

This shows that although Egypt is exporting crude oil at present, soon it will be importing most of its oil demand before the year 2016 because of the declining reserves and the increasing demand.

The situation, however, is better in the case of natural gas, where the reserves are increasing and Egypt may be able to export 700 to 1000 MSCFD in the year 2000/2001.

Industry consumes 50% of the total final energy consumption and 43% of electricity consumption as shown in figures 3 and 4 and tables 4 and 5. Any savings in this sector will have a pronounced effect on the energy situation.

2. Introduction to this Guidance Manual

This manual will help engineers, technicians and related personnel to know more about water and energy savings to become more efficient users, consequently, reduce operating costs and mitigate economic losses.

Questions should be raised concerning water and energy conservation, such as Why we do it and How?

All these questions and many others help to define the procedures which should be followed to achieve the required goals.

Part B

Water and Energy Conservation - A Step by Step Guide

Step 1:	**Management Commitment**
Step 2:	**Establish a Factory Water and Energy Conservation Team**
Step 3:	**Conduct a Water Audit**
Step 4:	**Identify Water Savings Opportunities**
Step 5:	**Evaluate Expected Water Savings**
Step 6:	**Conduct an Energy Audit**
Step 7:	**Identify Energy Saving Opportunities**
Step 8:	**Evaluate Savings expected from Implementations**
Step 9:	**Prepare a Monitoring Plan for Assessment**
Step 10:	**Implementing Water Savings Opportunities**
Step 11:	Implementing Energy Savings Opportunities
Step 12:	Implement the Monitoring and Maintenance Plan for follow-up

Water and Energy Conservation - A Step by Step Guide

Step 1 - Management Commitment

1.1 Ensure Top Management Support

The first step in an energy conservation program is to convince the top management with the benefits that can be achieved by applying such a program. Being convinced, the top management will not only give you the green light to act, but will also support you, help you overcome unforeseen problems, and secure - even partially - the required funding.

Convincing the top management is not always an easy task. Some managers - especially in the public sector are concerned only about the productivity. They do not pay great attention to other elements such as fuel, electricity or water consumption. Their main concern is just keeping the production line operating.

Management may be encouraged when it realises that the bills of fuel, electricity and water are much more than double or triple of what must be paid. Collect data about energy and water consumption and costs in the company and in competitive and international companies. Compare the figures.

Show the management the extent to which the bill could be cut down if utilities consumption is reduced. Clarify to them the benefits - minimising water and energy use reduces the production cost, makes additional water and energy available for increased production without purchasing additional supplies and enhances the company public image.

1.2 Set Goals to be achieved

Once you have ensured top management support, you should set goals to be achieved, establish priorities to be followed. A primary goal may be just good house-keeping for the company production lines. This action may cause a reduction in water or energy consumption by 10-20% without significant budget to be paid. The payback period may not exceed a year.

Arrange the priorities according to their importance. Start with the section/production line/equipment that seems to be more wasting water/energy. This makes the savings more pronounced.

1.3 Get Employees Participation

After establishing the goals, get the employees participation. This can be done through the distribution of a letter to all employees from the head of the company. This letter should clarify the company strategy for energy conservation, identify the conservation manager, show full support and invite feedback.

Another means for getting employee participant is to establish education program to enhance their awareness towards water and energy conservation. The program may include the company conservation plan, the responsibility of each individual to achieve the conservation goals, ask for ideas from all levels, and offer incentives for distinguished ideas. Chose a Champion or Conservation Manager to be responsible for energy saving activities.

1.4 What should the Conservation Manager do?

The Conservation Manager should do the following:

- Review the effectiveness of existing conservation programs for possible improvements (if any).
- Evaluate institutional and regulatory constraints.

- Establish a budget and procure funding.
- Seek outside funding if necessary.
- Establish a schedule for water and energy audits.
- Establish criteria for implementing water and energy conservation measures.
- Prepare a conservation action plan.
- Implement water and energy - conserving measures.
- Establish a system for employees to notify the proper parties about leaking steam traps, valves, connections, etc..
- Evaluate the program through monitoring plan and make modifications to meet goals and priorities.

Step 2 - Establish a Factory Water and Energy Conservation Team

A factory team should be formed with senior members ideally coming from each of the main departments in the factory. A team co-ordinator should also be nominated to co-ordinate the different responsibilities and tasks.

At Edfina and Kaha factories, the factory team is composed of the following persons:

- Area Manager.
- Factory Manager.
- Projects and Engineering General Manager.
- Manager of Projects Department.
- Manager of Engineering Department.
- Manager of Workshop.
- Two Engineers from Projects and Engineering Departments.

The factory team is responsible of identifying conservation options, supervising monitoring (pre and post implementation), issuing agreements on bills of quantities and follow up on the implementation of the identified conservation measures.

Step 3 Conduct a Water Audit

A water audit is required to check for water losses, mismanagement of water, spills, leakages for the purpose of minimising water consumption. It will assess the amount of water used for different purposes, as well as water leaking from pipes equipment, pipe connections. Water quality is also monitored to investigate possibilities for water re-use or recycling.

3.1 How to Conduct a Water Audit?

The different water uses must be surveyed for each production line or each plant within the factory according to the level of the monitoring system.

- ***Process water*** which is part of the process, can be used for dilution or reaction or any other processing step. Many of the food factories use water in barometric leg condensers to create vacuum. These types of condensers require large amounts of water.

- ***Cooling water*** represents a major contribution to the total water consumption of industrial establishments. The following operating conditions should be checked:

  - The cooling cycle (closed/open)

  - Leaks in pipes and related pumps

  - Performance of cooling tower and related equipment (fan, pumps, collecting sumps).

- ***Water for steam generation***. Industrial establishments require large amounts of steam for heating, sterilisation or electric power production. Leaks in steam lines as well as production of steam over the required amount due to lack of measuring and control devices, will result in higher consumption of both energy and water.
- ***Floor and equipment wash water***. The amount of water used for this activity depends on the type of industry. Food industry uses large amounts of water for hygienic reasons.

3.2 Activities involved in a Water Audit?

A water audit involves the following activities:

- Preparation of the process flow diagrams for the different production lines process flow diagrams provide information about the type and amount of water consumed. Some insight on effluent water quality could be gained. Water conservation opportunities can be identified in a preliminary manner.
- Preparation of checklists. A checklist should be prepared for data collection before the actual site visit. All information regarding the water audit should be included, such as:

  - Total annual monthly water consumption for the whole factory.
  - Monthly water consumption for each plant.
  - Raw material consumption and annual production rate for various products.
  - Number and capacity of boilers.
  - Number and capacity of cooling towers.
  - The presence of barometric leg condensers.
  - Factory sewer lines.
  - Segregation/integration of different types of water.
  - Washing/rinsing procedure.
  - Maintenance of pipes and fittings.
  - Wastewater quality.
  - Quality of consumed water (well water, softened water, de-ionised water, drinking water).

Step 4: - Identify Water Savings Opportunities

The factory is surveyed for each type of water use. The main sources for water losses in Edfina factory were found to be:

- Open cycle cooling water for barometric leg condenser for tomato paste production.
- Open cycle cooling water for sterilisation of juice bottles
- Excessive amounts of water used for floor washing due to lack of shut-off valves
- Surcharging of sumps of existing cooling tower
- Leaks from pipes and sterilise troughs.

The criteria for choosing the measures to be implemented are the payback time and cost savings.

The identified water saving opportunities in Edfina Factory are:

I. **Installation of Hose Nozzles:** Seven nozzles were purchased for Plant A. It is expected that water savings of 3000 m^3/y can be achieved.

II. **Rehabilitation of the water collection system at the Dowe Pack line:** The collecting tank used in conjunction with the cooling tower of the Dowe-Pack line is underdesigned, and the pump is out-of-order. A larger tank has been purchased as well as a new pump. Cost savings of about LE 15600 are expected.

III. **Cooling tower for juice bottles sterilise:** The sterilise for juice bottles is using open cycle cooling water. A 60 m^3/h cooling tower has been installed. Cost savings of LE 200,000 are expected when the plant is operated at full capacity.

Step 5: - Evaluate Expected Water Savings

Water savings can be evaluated through the following steps:

- Water flow rate is measured using flowmeters.
- Measurements are taken at the same time over a period of 1 month and several times a day.
- Maximum, minimum and daily average for water consumption is calculated.
- The amount of water saved by implementing the measure can be estimated and therefore the cost of water saved.
- Cost savings can be estimated based on maximum production as well as current production.
- Cost of measure is estimated and cost-benefit calculated.

Table (6) summarises the cost-benefits for the identified water-saving options for Edfina factory.

Table 6. List of Water Conservation Projects in Edfina Factory

Project Code	**Project Name**	**Payback Time**	**Cost (LE)**	**Cost Saving (LE/y)**
WE1	Rehabilitation of the Cooling System for the Tomato Paste Production line	28 days	20000	264,000
WE2	Hose Nozzles	1 month	2500	30,000
WE3	Washing and Cooling of Tomato Paste Cans	3.5 month	1500	5,200
WE4	Rehabilitation of the Water Collection System at the Dowe-Pack Line, Plant B	4.5 month	6000	16,000
WE5	Cooling Tower for Juice Bottles Sterilise	5 month	75000	200,000
TOTAL			**105,500**	**515,200**

Step 6 - Conduct an Energy Audit

An energy audit is the way of collecting and presenting information on the utilisation of energy in its different forms (electricity and thermal) and from the different types of fuels in a given period of time for a specific site be it a hospital, a hotel, a manufacturing firm or a production unit.

The first step in energy conservation projects is to perform an energy audit. An energy audit helps understand more about the way energy is used in the plant and helps identify areas where waste can occur and where scope for improvement may be possible and effective.

6.1 Review Consumption Records

A production plant may contain more than one production line. Each production line usually includes several production stages. The following procedure can be applied on the whole plant as well as on each production line.

- Prepare a process flowsheet for the plant/production line illustrating the various production stages and the major energy consuming equipment such as boilers, fired heaters, air compressors, ... etc.
- Use the company reports to collect the required data for a specific period of time. The period may be the last twelve months, or the last few years. The data may include the following:
  - amount of consumed raw materials.
  - amount of produced goods.
  - amount of consumption.
  - amount of fuels consumption (e.g. fuel oil, gas oil, natural gas, etc.).
- Convert the consumption figures of electricity and fuels into common energy units such as Giga Joule (GJ) or Ton Oil Equivalent (toe).
- Use the conversion factors presented in the appendices to perform this step.
- Tabulate the values of energy consumption.
- Get the overall energy consumption of the plant by summing up these values.
- Divide the obtained figure by the amount of produced goods to obtain the specific energy consumption (energy consumption per unit product). The units of specific energy consumption may be toe/t product or GI/T product or any other energy units/unit product. In some case the specific energy consumption is related to the raw material rather than the product. In this case, the overall energy consumption is divided by the amount of consumed raw material.
- Evaluate the efficiency of energy utilisation in your company by comparing the value of specific energy consumption in your company with the designed value or other local or international norms.
- Evaluate the energy consumption for each production stage, and even the major energy consuming equipment.

This analysis will help to identify areas where energy is not properly used.

For the present case studies whether at Edfina Co. or at Kaha Co., electricity is used for lighting and to run the motors and equipment at the different production sections. No individual section meters are installed. Only overall company consumption is measured also there is one type of fuel being used for steam production at the boiler house, mazot in case of Edfina Co. and solar oil in Kaha Co.. No meters are installed on the boiler fuel feed lines.

The consumption is counted from daily fuel tank filling. No steam meters are available whether at the boiler house or at the individual factory sections that consume steam. Therefore evaluation of individual section steam consumption was not available from measurements. However, there was a water meter on the water line feeding the softeners. Daily readings of this meter shows the daily amount of water converted to steam.

6.2 Prepare a Checklist for Energy Conservation

The checklist should be prepared in such a way as to collect information such as:

- Electricity consumption
- Fuel consumption
- Steam production
- Raw material and product annual amounts
- Data on major energy consuming equipment: Boilers, furnaces, generators, air compressors.

6.3 Check Steam Leakage from Traps, Valves and Joints

The first concern should be that there is no heat lost through direct steam leakage from faulty steam traps, valves and joints. This kind of waste is easy to detect and should not be allowed to continue. For example, if steam at a pressure of 100 psi (6.9 bar) is leaking from an 0.8 mm diameter hole, the steam lost will cause up to 1500 litres of oil to be wastefully burned a year (ref. 1) costing LE 600. See Appendix 1 for steam leak rates through holes. Minimising steam leakages can be done through:

(i) Maintenance of Existing Steam Traps, Valves and Fittings

One of the most common causes of steam traps blowing steam is dirt. Dirt and scale are to be found in all steam pipes. Fragments of welding material are also quite common. As the steam traps should be connected to the lowest part of the system, sooner or later this foreign matter will find its way to the trap. Once the dirt accumulates on the valve seat preventing the valve from shutting down tight, the trap will leak steam. Unless the valve seat is quickly cleared of the obstruction, it is more than likely that continued leakage of steam will occur until the valve seat and valve have to changed or simply the trap is replaced by a new one. On the average a leaking trap would loose around 27 kg/h steam (ref. 2) $\approx$ 2.06 kg/h gas oil costing around LE 7,500/year.

Regular checking for steam traps operation is, therefore, extremely important. One or two operators should be assigned this job for all around the factory steam traps inspection. The whistling voice of the steam trap should be heard or periodic discharge of condensate as an indication of good operation should be noticed.

(ii) Installation of Steam Traps

It is extremely important that steam distribution system always be properly drained. When steam has given up its latent heat in the heating or process equipment, condensate will have collected. If water is allowed to accumulate it will very soon cover the heated surfaces and prevent steam from getting near the surface. So it is important to arrange for condensate to be discharged from the steam space. Steam traps are the key to optimum and condensate system operation. They automatically regulate the discharge of condensate and trap the steam in the process equipment. Moreover, some types allow to remove air and other noncondensable gases. If steam traps are not installed and the drain pipe is left open to the atmosphere, huge steam losses would occur causing fuel to be unnecessarily burned.

A quick guide for the payback period for installing a steam trap, to an open pipe and would be to know that a 1/2 inch leaking pipe looses ≈ 383 kg/h of steam at an average pressure of 7 bars gauge (ref. 3).

Based on the calorific value of gas oil (solar) and an average boiler efficiency of 80%, each kg gas oil produces 13.13 kg of steam. The price of gas oil is 0.45 LE/kg, therefore, the cost of wasted energy amounts to 13.126 LE/h = 100807 LE/y (a year = 320 working days). On the other hand if the price of a steam trap is 300 LE, the payback period is only one day.

6.4 Verify the Insulation of Hot Surfaces

(i) Insulation of Steam Pipes and Pipe Fittings

Heat can be lost due to radiation from bare steam pipes. One simple example will serve to emphasise the need for lagging. A 30 meter length uncovered 6 inch diameter pipe carrying steam at a pressure of 100 psi (6.9 bar) can waste 3,000 litres of oil a year (ref. 1) costing LE 14,000. See Appendix 2 for heat losses from bare and insulated steam pipes. The optimum thickness for insulation can be calculated as given in Appendix 2.

When lagging steam pipes it is a common practice to terminate the lagging 3 to 4 inches from the pipes flanges, leaving the flanges uncovered. Generally this is done to make it easy to get to the flanges, but is a source of considerable heat loss.

If on a 6 inch steam pipe there are five uncovered flanges we shall be wasting 3,000 litres of gas oil a year (ref. 1) costing LE 1,400.

(ii) Insulation of Tanks, Reactors, etc.

While on the subject of heat losses due to radiation from uncovered surfaces, we should also remember that this applies also to uncovered ends of drying cylinders, uncovered steam chests and similar surfaces. Every square meter of unlagged steam-heated surface means at a pressure of 100 psi (6.9 bar) an hourly loss of 5 kg steam. This means wasting about 3 tons of solar yearly, costing LE 1,350.

6.5 Check the need for installation of temperature control equipment

In the process work it is essential to avoid unnecessary heat losses. In a factory in the west of England (ref. 1) 5 open process liquor tanks were found to be operating at a temperature of 82°C when it was known that a temperature of 65°C was adequate for the particular process. The unnecessary overheating was causing a wasteful use of about 52,300 litres of fuel oil a year at a cost of over LE 6,000, a waste which could be prevented by an initial outlay of about LE 1,500 on temperature control equipment.

Temperature control equipment usually consist of a temperature sensor/controller combination that measures the temperature of the process fluid, compares it to a set point and sends a signal (an order) to a pneumatically or electrically operated control valve on the heating medium line (e.g. steam) to open or close, thus providing steam when it is only necessary.

6.6 Check the possibility of using Condensate as Boiler Feed Water

The condensed steam (condensate) still has much useful heat in it. It is a hot, soft water and without doubt is the ideal boiler feed. The most sensible thing to do is to return the condensate to the boiler feed water tank.

If cold water is fed to the boiler at a temperature of 10°C, it contains a small amount of sensible heat, but if the boiler is fed with water at 70°C the amount of heat that has to be added to the boiler to raise the water temperature to the boiling point would be less. The resulting saving is about 9% for 100% condensate return see Figure (1) in Appendix 3.

As a matter of fact for every 6°C rise in the temperature of the feed water approximately 1% less fuel will be used in the boiler (ref. 4).

6.7 Improving Boiler Thermal Efficiency

Minimum costs are achieved by running boilers at high thermal efficiency. The boiler efficiency is calculated from the basic equation:

Boiler thermal efficiency (%) = 100 % - (flue gas loss percentage + radiation loss percentage + blowdown loss percentage).

Savings or losses due to change in efficiency are simply calculated as follows:

$$\textbf{Change in fuel cost} = \text{original cost} \times \frac{\text{new efficiency - original efficiency}}{\text{new efficiency}}$$

Taking for example the original fuel cost of LE 500,000 per year, if the efficiency is raised from 70% to 80% the saving would be:

$$\textbf{Fuel saving} = \text{LE } 500{,}000 \times \frac{80 - 70}{80} = \text{LE } 62{,}500$$

Improving thermal efficiency can be achieved by performing the following actions:

(i) Adjustment of Air to Fuel Ratio

To achieve a high thermal efficiency, thereby minimising fuel costs, the amount of combustion air required should be limited to that necessary to ensure complete combustion of fuel at all times including a margin of excess air to suit the particular combination of burner and boiler. The boiler and burner supplier should be consulted to find out the best settings.

To check that the air to fuel ratio is correct the usual method is to analyse the composition and measure the temperature of the flue gases. Modern gas analysers do this and instantaneously calculate the boiler combustion efficiency.

Typical conditions for efficient oil fired shell boilers are 10-20% excess air resulting in 13-14% CO_2.

Figures 1-5 (Appendix 3) illustrate the % reduction in flue gas losses (and thereby the % improvement in boiler efficiency) as a result of decreasing the % excess combustion air for different kinds of fuel.

Referring to Figure (1) (Appendix 3) if for example the flue gas temperature was 300°C reducing the % excess combustion air from 90 to 15% will result in decreasing the flue gas losses by 7% (from 25% to 18%). The boiler thermal efficiency will increase by the same value (say from 70 to 77%). For a LE 500,000 annual fuel cost the amount of savings would be calculated as:

Savings = LE 500,000 x (77 - 70)/77 = LE 45,454

(ii) Reducing the Temperature of Flue Gases

Boiler tubes may become fouled after a long period of operation leading to the increase of flue gas temperature and hence the stack losses. Cleaning costs will be quickly repaid by the resulting fuel saving. The boiler manufactures advice should be sought on the frequency of cleaning.

For example at 15% excess air (Figure 1 Appendix 3) if the flue gas temperature is decreased from 300°C to 200°C the flue gas losses will be reduced from 18% to 14%, thus increasing the boiler thermal efficiency by 4% (say from 75 to 79%). The saving will be

Fuel saving = 500,000 (79 - 75)/79 = LE 25,316

(iii) Keeping Blow-down as low as possible

Boiler blow-down is necessary to remove sludge from precipitated salts, to prevent scale formation on the tubes and tube plates on the water side and to avoid priming and carry-over into steam mains.

To avoid unnecessary loss of heat, blow-down should be kept as low as possibly compatible with dissolved solids TDS should not exceed 2000-3500 ppm (s). The loss of heat due to blow-down is shown in Figure 6 Appendix 3. It is worth mentioning that if all the factory condensate is able to be returned to the boiler feed tank, blow-down can be drastically reduced.

6.8 Verify the efficiency of Electrical Energy Utilisation

Electrical energy is expensive and undoubtedly will become more costly in future thus it behoves every utility customer to use electric energy as efficiently as possible, whether the customer be a university campus, a building complex, or an industrial plant. This can be achieved by:

(i) Improving Power Factor (PF)

The installation of power-factor correcting capacitor permits the consumer to reduce this electricity bill by maintaining reactive energy consumption below a value contractually agreed with the power-supply authority. Reactive energy is billed according to the tan criterion (i.e. the PF, indicated by the following formula):

Tan (f) = KVAR/kWh

The consumer must balance the cost of reactive energy against that of purchasing, installing and maintaining the power factor improvement capacitor and control switch gear, automatic control equipment (where stepped levels of compensation are required) together with the additional kWh consumed by the dielectric losses of the capacitors, etc.

It may be found that it is more economic to provide partial compensation only, and that paying for some of reactive energy consumed is less expensive than providing 100% compensation.

The question of the power-factor correction is always a matter of optimisation, except in very simple cases.

(ii) Reducing Harmonics

In power systems, the harmonics mainly result from a controlled rectifier to obtain DC voltage for DC motors. In other words, electrical and electronic equipment that draws nonsinusoidal current can cause disturbances that are harmonically related to the AC mains frequency (i.e. 50 HZ. mains supply 100 HZ, etc.).

Harmonics have negative effects on the performance of electrical instruments, machines and transformers. It can be reduced using harmonic filters, and active power line conditions.

Step 7 - Identify Energy Saving Opportunities

Having prepared the energy check list and collected data on monthly (and yearly) sectoral or overall energy consumption, the energy manager and his team should walk through the factory and report any type of noticeable energy inefficiency.

The report should include the following for each of the factory sectors.

1. The number, size, type and specifications of leaking valves that need to be replaced.
2. The number, size, type and specifications of leaking steam traps that need to be replaced.
3. The number, size, type and specifications of steam traps to be installed on open end steam pipes that are left leaking.
4. Surface temperature, diameter and length of bare steam pipes.
5. Area and surface temperature of bare heated vessels, reactors and holding tanks that need to be insulation.
6. Any steam leaking equipment e.g. uncovered hot water baths.
7. The way hot condensate is being handled, is it drained or recycled to the boiler feed water tanks.
8. The presence of adequate measuring instruments showing fuel and water consumption in the boiler house and on steam feeding lines.
9. The rate of boiler blowdown.
10. Check that flue gas analysis has been performed recently, and calculate boiler efficiency.
11. Examine electricity feeding system, has any power factor correction been implemented? Has harmonics been analysed?

The report will identify clearly what are obvious causes of energy inefficiency that has to be taken care of.

7.1 Identified Energy Saving Opportunities in Edfina Factory?

(i) Insulation of Bare Steam Pipes

Almost all the factory steam lines needed insulation. A total length of 1,475 meter were identified to be insulated. The steam pipe diameters ranged between 8″ in the boiler house down to 2″ in the factory distribution lines.

(ii) Replacement of Leaking Steam Traps

The number and types of leaking steam traps was identified by the factory team. These were 35 steam traps (thermodynamic type) ranging in size between o.s. to one inch.

(iii) Replacement of Leaking Valves

A number of 98 high pressure (16 bar) leaking steam valves were identified by the factory team. They ranged in size from 0.5 inch to 4 inches diameter.

(iv) Installation of Pressure Regulators on Juice and Tomato Sterilisers

It was noticed that steam leaks are excessive from the top of the sterilisers used in juice bottles and tomato jars sterilisers. A total number of 4 pressure reducing valves were proposed to be installed on the steam line entering these sterilisers. Consequently, steam pressure was reduced from 8 to 2 bar gauge and therefore reducing the live steam mass discharged per unit time, i.e. reducing steam consumption in sterilisers.

(v) Condensate Recovery

Condensate recovery from two of the three tomato evaporators is being practised by the factory. Supplying the third and the mostly used evaporator and the tomato paste pre-cooker by condensate recovery systems was identified as one of the options for reducing energy and water consumption.

(vi) Air/Fuel Ratio Adjustment for Boilers

This is a no-cost alternative based on regular flue gas analyses. Reducing the air to fuel ratio resulted in a reduction of about 3% of total fuel consumption.

7.2 Identified Energy Saving Opportunities in Kaha Factory?

(i) Insulation of Bare Steam Pipes

The factory steam lines needed insulation were identified. Total length of 485 metres were identified to be insulated.

(ii) Replacement of Leaking Steam Traps

24 leaking steam traps was identified by the factory team.

(iii) Replacement of Leaking Valves

74 high pressure leaking steam valves were identified by the factory team they ranged in size between 0.75 to 6 inches.

(iv) Installation of Temperature Controller of the Juice Sterilisers with Simultaneous Monitoring of the Steam Flow Rate

This measure was chosen to study the effect of temperature control on reducing the steam amount discharged from the open steam pipe submerged in the sterilise. The reduced steam flow would then be realised in other similar sterilisers by reducing the pressure on the live steam line.

(v) Installation of Pressure Regulators on Juice and Tomato Sterilisers

It was noticed that steam leaks are excessive from the top of the sterilisers used in juice bottles and tomato jars sterilisers. A total number of 4 pressure reducing valves were proposed to be erected on the steam line entering these sterilisers. Thus reducing steam pressure from 8 to 2 bar gauge and therefore reducing the live steam mass discharged per unit time. Thus reducing steam consumption in sterilisers.

(vi) Condensate Recovery

Initially, there was no condensate recovery in Kaha factory. Two opportunities for condensate recovery were implemented. The most suitable jacketed equipment for condensate return are the tomato precookers and the evaporators used for tomato juice concentration to tomato paste. It has been calculated that around 2.75 tons condensate are produced for each ton of tomato paste produced.

(vii) Air/Fuel Ratio Adjustment for Boilers

This is a no-cost alternative based on regular flue gas analysis, reducing the air to fuel ratio around 3% of total fuel consumption was reduced.

Step 8 - Evaluate Savings expected from Implementations

One of the most common reasons for evaluating potential savings is to justify expenditure on purchasing the required equipment. In order to evaluate the savings expected due to implementation of the identified energy saving opportunities the prices of fuel used in the factory, as well as the price of water and electric power should be available. Also the cost of steam per unit mass should be calculated. To calculate the exact cost of steam the following information is needed.

1. The type of fuel, its calorific value per unit mass (or volume) see Appendix 4.
2. Annual consumption of fuel used for raising steam and its cost.
3. Annual water consumption for steam raising and its cost.
4. Amount of boiler blow down.
5. Annual spare parts and maintenance expenses for the boiler house and its pumps.
6. Annual electricity consumption for running pumps associated with boiler house.
7. Annual water softening chemicals consumption and their cost.
8. Properties of the steam produced.

The total annual cost of the items from 2 to 7 divided by the amount of steam produced (item No. 3 minus item No. 4) will give the cost of steam per unit mass. The cost of fuel represents more than 85% of the total cost of steam (items 2-7). Moreover, items like maintenance, water softening chemicals and cost of pumping would not be much affected by the reduction of steam consumption. Therefore, the cost of fuel saved is usually sufficient to evaluate savings resulting from implementing energy conservation measures.

8.1 Calculation of Fuel Savings

The implementation of energy saving opportunities will cause annual saving of thermal units (e.g. kJ). If the annual savings in thermal units is divided by the calorific value of fuel used times the boiler efficiency, the result will be the mass of fuel saved per year. Knowing the price of fuel then the expected money saving can be calculated.

Example: Suppose a bare 6 pipe carrying steam, having a pipe surface temperature of 200°C is to be insulated with a Rockwool blanket of 50 mm thickness, the amount of losses will reduce from 1800 to 120 W/m (see Appendix 2). Savings = 1800 - 120 = 1680 W/m.

Annual energy savings $= \frac{1680\,J}{m.s}\left(3600\frac{s}{h}\right)x\left(\frac{24h}{D}\right)x\left(\frac{300D}{year}\right)x\left(\frac{MJ}{10^6\,J}\right)$

= 43545.6 MJ/year

If gas oil having a gross calorific value of 45,500 MJ/ton and costing LE 450/ton is used as a fuel and the boiler efficiency is 80%, then:

Amount of fuel saved = 43545.6 ÷ 45500 x 0.8 = 1.196 ton/year

Costing = 1.96 x 450 = 538 LE/year

If the bare pipe length is 10 meters then savings due to insulation will be equal to 11.9 ton gas oil/y costing 5380 LE/y.

8.2 Calculation of Steam Savings

Additional saving other than the cost of fuel would be the amount of water saved due to reduction is steam consumption if steam is produced at say 7.5 bar gauge, then the heat required to raise one kg of steam is 2772 kJ (Appendix 5). Then kgs of steam raised as a result of burning 1 kg gas oil is (45500 x 0.8) ÷ 2772). 13.57 kg .i.e. each kg of gas oil is equivalent to 13.13 kg steam if the boiler efficiency is 80%. Therefore each kg of gas oil saved will cause saving of 13.13 kg steam or water.

Depending on boiler efficiency and the fuel used the kgs steam produced per kg fuel can be similarly calculated.

If however the amount of steam saved can be estimated (e.g. steam leaking from orifices and steam traps), then the equivalent fuel saved can be calculated vice versa.

8.3 Evaluation of Savings due to Implementing Energy Saving Measures in Edfina Co.

The fuel used in Edfina Co. is mazot (fuel oil) with a calorific valve of 42,500 MJ/t and the boiler efficiency is 80%.

One ton fuel oil = 42500 x 0.8 ÷ 2772 = 12.27 ton steam

The cost of one ton fuel oil = LE 18

The estimated savings due to implementation of 6 identified measures are summarised in table 7.

Table 7. Summary of Estimated Savings due to implementation of Identified Energy Saving Options in Edfina Co.

Project Code	Project Name	Steam Savings (t/y)		Fuel Savings (t/y)		Cost Saving (LE/y)	
		Actual	Max.	Actual	Max.	Actual	Max.
EE2	Installation of Steam Traps	1,362	4,536	111	370	20,202	67,340
EE3	Pressure Regulators	3,600	12,000	293	978.8	53,326	178,142
EE4	Gaskets for Sterilisers	300	1,000	24.5	81.5	4,459	14,833
EE5	Replacement of Leaking Valves	1,058.4	3,528	86.22	287.9	15,692	52,307
EE6	Insulation of Steam Pipes	5,394	5,394	440	440	80,080	80,080
EE7	Condensate Return System	323	6,469	26.3	52.6	5,109	10,218
TOTAL		**11,972.4**	**27,317**	**975.72**	**2,228.2**	**17,7581**	**405,442**

***Total Actual Fuel Consumptio*n** = 2419 t/y

% Saving = $\frac{975.75}{2419}$ x 100 = 40.3%

8.4 Evaluation of Savings Due to Implementing Energy Saving Measures in Kaha Co.

The fuel used in Kaha co. is solar (Gas Oil) with a calorific value of 45,500 MJ/t and the boiler efficiency is 80%.

One ton solar = 45500 x 0.8 ÷ 2772 = 13.13 ton steam.

The cost of one ton solar = 450 LE

The estimated savings due to implementation of the 7 identified measures are summarised in table 8.

Table 8. Summary of Estimated Savings due to implementation of Identified Energy Saving Options in Kaha Co.

Project Code	Project Name	Steam Savings t/y		Fuel Savings t/y		Cost Saving LE/y	
		Actual	Max.	Actual	Max.	Actual	Max.
EK2	Installation of Steam Traps	933	3,110	71.1	237	31,995	3.8
EK3	Controllers & Regulators	4,500	15,000	342.7	1,142.4	15,421.5	18.14
EK4	Gaskets for Sterilisers	394	1,313	30	100	13,500	1.6
EK5	Replacement of Leaking Valves	799	2,664	60.867	202.89	27,390	3.2
EK6	Insulation of Steam Pipes	2,129	2,129	162	162	72,990	8.6
EK7	Condensate Return System	177	591	13.5	45	6,075	0.7
TOTAL		**8,932**	**24,807**	**680.167**	**1,889.29**	**167,372**	**36.04**

Total Actual Fuel Consumption = 1889.5 t/y

% Saving $= \frac{680.167}{1889.5} \times 100 = 36\%$

Step 9 - Prepare a Monitoring Plan for Assessment

While implementing the measures, fuel consumption and water consumption should be monitored in order to assess the benefits resulting from implementing each measure individually. Monitoring plans for water and energy consumption were prepared. A monitoring plan for water is Edfina Co. and monitoring plans for Energy in both Edfina and Kaha factories were prepared. Details are given below:

9.1 Monitoring Plan for Water Conservation

Plant (A) will be specifically considered.

A decrease in water consumption is expected to occur when all projects are implemented. Furthermore, a decrease will also be noticed at the tomato paste line and the bottled juice line.

Water flow meters should be placed at the inlet to these units, and readings done for 2 weeks before implementation and 2 weeks after implementation.

Table 9. Monitoring of Water Consumption

Date (every day for 2 weeks)	Time (every hr)	Location (1)	Location (2)	Location (3)

Where: Location (1) is the inlet pipe to plant (A)
Location (2) is the inlet pipe to tomato line
Location (3) is the inlet pipe to juice sterilise

(i) Monitoring of Water Quality

(a) At the Tomato Washing Tank

Water samples are taken from the final collecting tank before recycling.

Table 10. Monitoring of Water Quality in Washing Tank

Date of Sampling	No. of Samples	Type of Samples	Measured Parameters
Before implementation	1	grab	pH, BOD, COD, TSS, TDS, TS
After implementation	2	grab	pH, BOD, COD, TSS, TDS, TS

(b) At the evaporator

Table 11. Monitoring of Cooling Water Temperature

Date	Location	Measured Parameter
	Inlet cooling water to evaporator	Temp.
	Outlet cooling water from evaporator	Temp.

9.2 Monitoring Plan for Energy Conservation

The proposed monitoring plan is summarised in Tables 12 and 13. The aim of this is to demonstrate how energy consumption has changed as a result of implementing this project. The monitoring plan comprises; boilers monitoring plan and steam consumption monitoring plan as described in what follows.

Table 12. Boilers Monitoring Plan

Activity	Kaha		Edfina		Sampling Type Frequency
	Original	Modified	Original	Modified	
Boiler efficiency Measurement	Suite 1 Four Boilers	Suit 1 Four Boilers	Already done by Edfina	Two boilers	Flue gas analysis once
Combustion efficiency of fired heaters	Suite 1	Suit 1	-	-	Flue gas analysis once
Boiler feed water consumption	Metering	Metering	Metering	Metering	Daily for one month before modification and then daily as routine for modified process
Boiler fuel consumption	Metering	Metering	Metering	Metering	Daily for one month then daily as routine for modified process

Suite 1 CO_2, O_2, NO_2, SO_2, CO, flue gas temperature and boiler efficiency.

*Table 13. Steam Consumption Monitoring Plan**

Location	Kaha		Edfina		Frequency
	Original	Modified	Original	Modified	
Juice line	√	√	√	√	Once for the original and once the modified process
Jam line	√	√	√	√	
Tomato paste	√	√	√	√	
Frozen vegetables	√	√	√	√	
Cooked beans	√	√	√	√	

A proforma of this data is given in table 11 and 12.

(i) Monitoring for Boilers Combustion Efficiencies

Kaha factory has 4 boilers 3 of capacities 12 t/h each and the fourth. Edfina factory, on the other hand, has two boilers each with a capacity of 12 t/h the boilers efficiencies will be evaluated through measurements of flue gas analysis and the temperature of the exhaust gas. The boilers at Edfina company have recently been evaluated for their efficiencies. One more evaluation will be needed after modification. The boilers at Kaha factory need to be assessed for their efficiencies before and after modifications, if any, are done total number of samples 4x2 + 2 = 10 samples.

(ii) Monitoring of Fired Heaters Combustion Efficiencies

Kaha factory uses (gas oil and LPG) as fuels for the heaters in the cans factory.

The efficiencies of these heaters need to be evaluated before and after modification. Total number of samples needed is 5.

(iii) Monitoring of Boiler Feed Water Consumption in Conjunction with Fuel Consumption

This will require erection of water and fuel lines for each boiler in order to be able to measure steam generation and corresponding fuel consumption. Readings are to be taken daily for one month before modifications and afterwards daily as routine measurements.

(iv) Monitoring of Steam Consumption

Steam consumption is neither measured for each equipment, nor for each production line. The proposed plan will help quantify steam consumption at each stage within the production line and for the production line as a whole. One line only will be allowed to operate on the monitoring day. Boilers will start up as in a usual operating day. An observer at the boiler house will record the water flow meter readings every 15 minutes for the full monitoring period. It will take some time t_l before steam reaches the required temperature and pressure in the boilers and in the whole steam network. If we intend to quantify steam consumption in, say, the juice line, then another observer at the juice section will record then zero time (time of boilers start up).

Pressure builds up with time until it becomes constant (i.e. steady state) . At t_l The start up of juice heating occurs at t_2 while, the start up of pasteurisation is at t_3 and finally the start up of sterilisation is at t_4.

The difference in water flowmeter readings between any two successive events divided by the time elapsed between these events will give the steam consumption rates of the operations prevailing in this time span, where:

- $(Q_1-Q_0)/(t_1-t_0)$ = the rate of boiler water consumption (=kgs of steam consumed/hr) in start up process.
- $(Q_2-Q_1)/(t_2-t_l)$ = steady state steam loss from bare tubes and leaks, r_1.
- $(Q_3-Q_2)/(t_3-t_2)$ = rate of steam loss by bare tubes, r_1 + rate of steam consumption by juice heating, r_2.
- $(Q_4-Q_3)/(t_4-t_3) = r_1 + r_2$ + rate of steam consumption by the pasteuriser, r_3.
- $(Q_5-Q_4)/(t_5-t_4) = r_1 + r_2 + r_3$ + rate of steam consumption by sterilise, r_4 or the total rate of steam consumption by the juice line + losses.
- t_l = time at pressure stabilisation
- t_2= time at start of juice heating
- t_3 = time at start of pasteurisation
- t_4 = time at start of sterilisation

In this manner, a detailed energy audit for each line can be established. This process should be undertaken once before and once after modifications are implemented in order to quantify accurately the savings due to project implementation and be able to perform cost/benefit analysis. The same monitoring plan can be repeated at least annually to check that the benefits gained are not lost.

Table 14. Proforma for Monitoring Steam Consumption

(Observer at fire house)

Basic Information					
Date:					
Investigated production line:					
No. of boilers operating:					
Boiler No. 1 (Ton/h)		**Boiler No. 2 (Ton/h)**		**Boiler No. 3 (Ton/h)**	
Press	**(Bar)**	**Press**	**(Bar)**	**Press**	**(Bar)**
Time h min	**Meter Reading** m^3	**Time** h min	**Meter Reading**	**Time** h min	**Meter Reading** m^3

Table 15. Proforma for Monitoring Steam Consumption

(Observer at Production Line)

Basic Information			
Date:			
Investigated production line:			
input feed rate:			
Boiler start up time Press stabilisation time			
Equipment Name	**Start up** **h min**	**Shut down** **h min**	**Comments***

Comments on process conditions, mass rate, temp, press, leaks .... etc.

(v) Monitoring of the Power Factor

The proposed monitoring regime is summarised in the table 11. The aim of these is to check the supplied power quality which is characterised by (power factor, supply harmonics, supply frequency, voltage dipe, voltage sage, ... etc.).

Table 16. Monitoring Regime for Power Factor

Basic Information		
Site: (factory main switch board)		
Date:		
Transformer No.:		
Measured Parameter	**Value**	**Frequency of Readings**
Volt		Once every 12hr for a period for one day
Amper		Once every 12hr for a period for one day
Watt		Once every 12hr for a period for one day
Voltamper		Once every 12hr for a period for one day
Voltamper reactive		Once every 12hr for a period for one day
Power factor true		Once every 12hr for a period for one day
Frequency		Once every 12hr for a period for one day
Voltage crest factor		Once every 12hr for a period for one day
Current crest factor		Once every 12hr for a period for one day
Displacement power factor		Once every 12hr for a period for one day
Voltage harmonic distortion		Once every 12hr for a period for one day
Demand		Once every 12hr for a period for one day
Energy rate		Once every 12hr for a period for one day
Project demand		Once every 12hr for a period for one day
Daily energy		Once every 12hr for a period for one day
Monthly energy		Once every 12hr for a period for one day

Step 10 - Implementing Water Savings Opportunities

10.1 Set the Criteria for Selecting Measures for Implementation

The criteria for selecting the measures for implementation were

- Payback time (see section C.1)
- Cost savings

However, another constraint was introduced which is the budget allocated for the project. Monitoring equipment necessary for measuring actual water savings are also included.

10.2 Select Measures for Implementation

Based on the abovementioned criteria the following measures were chosen for implementation.

- Installation of Hose nozzles (shut-off valves)
- Rehabilitation of the Dowe Pack collection system
- Cooling tower for juice sterilise

10.3 Implement Measures

The following steps were found to be important:

- Get the factory approval on the implemented measures
- Get the factory approval on items purchased
- Identify the factory contribution
- Get factory approval on implementation plan
- Make sure the implemented measures are operating correctly

Step 11 - Implementing Energy Savings Opportunities

11.1 Set the Criteria for Selecting Measures for Implementation

Rank your identified energy saving opportunities according to the calculated payback period with opportunities with the least payback on the top of list. Select your measures so as to fall within the allocated budget for the energy conservation.

11.2 Implement Measures

Design an implementation plan that should be agreed upon from the factory officials so as to design their production plan accordingly.

(i) Implementation of Energy Saving Measures at Edfina Co.

All six identified saving measures were decided to be implemented. Official agreement from the factory management on the selected measures, the bill of quantities and the implementation plan was then obtained. The necessary equipment was purchased and the factory team took the responsibility of their installation according to the agreed upon implementation plan.

(ii) Implementation of Energy Saving Measures at Kaha Co.

All seven identified energy saving measures were chosen for implementation. Official agreement from the factory management on the selected measures, the bill of quantities and the implementation plan was then obtained. The necessary equipment was purchased and the factory team took the responsibility of their installation according to the agreed upon implementation plan.

Step 12 - Implement the Monitoring and Maintenance Plan for follow-up

In order not to loose the benefits achieved, routine measurements of energy and water consumption should be regularly monitored. These measurements has to be correlated with the production type and capacity in order to detect any non efficiency and update your energy audit on regular time basis. A maintenance plan must be developed to ensure that the performance of the installed equipment does not drop.

Part C

1. Cost/Benefit Analysis

1.1 Evaluate Actual Water Savings

1.2 Evaluate Actual Energy Savings due to Implementation of each Measure

2. Cost and Benefits at Edfina Factory

2.1 What were the Costs?

2.2 What were the Benefits?

3. Cost and Benefits at Kaha Factory

3.1 What were the Costs?

3.2 What were the Benefits?

1. Cost/Benefit Analysis

Having identified opportunities for energy and water conservation, calculated expected savings due to implementation of the identified opportunities, price quotations for the necessary equipment need to be obtained. This can then be used to calculate the simple payback period for each measure. The payback period is defined as:

$$\textbf{\textit{Payback in years}} = \frac{\text{Cost of implementation}}{\text{Net Annual Savings}}$$

Opportunities with payback periods of up to two years are considered to have high priority. Installation of hose nozzles, rehabilitation of Dowe Pack collection system and installation of a cooling tower for the juice steriliser all had an estimated payback period of less than 6 months, as indicated in table (6). Insulation of bare steam pipes, installation of steam traps and changing faulty valves and steam traps have payback periods of less than two years. Tables (7) and (8) represent summary of cost-benefit for the identified energy saving options for Edfina and Kaha companies.

1.1 Evaluate Actual Water Savings

The difference between the water readings of the water flowmeters before and after implementation indicates the actual water savings.

1.2 Evaluate Actual Energy Savings due to Implementation of each Measure

Having monitored fuel and water consumption before and after implementation of each measure, the real savings in terms of money can be calculated to make sure that the estimated savings were not far away from reality.

2. Cost and Benefits at Edfina Factory

2.1 What were the Costs?

The SEAM Project provided a total budget of LE 232,465 for purchasing the required insulation and other energy saving and monitoring equipment.

The company contribution was LE 60,000. The breakdown of factory contribution by measure was as follows:

Action	Capital Investment (LE)
Installation of 24 Steam Traps	2,900
Installation of 74 High Pressure Valves	8,000
Assistance in Installation of Rockwool	2,000
Installation of Cooling Tower and Water tanks	14,000
Installation of Pressure Regulators	4,000
Installation of temperature control system	2,000
Monitoring	6,100
Total Savings	**39,000**

2.2 What were the Benefits?

2.2.1 Cost Benefits

- Fuel oil consumption was reduced by 40% corresponding to a fuel bill reduction of LE 178,451.

- Water consumption was reduced because of the efficient use of steam, recycling condensate water and recycling of cooling water for one of the sterilisers.
- Less production cost.

2.2.2 Environmental Benefits

- Less emissions of polluting and green house gases because of reduced burning of fuel oil
- Reduced load on sewer system because of lower water consumption.

Tables (9) and (10) summarise the reduced consumption of both fuel and water as a result of implementation of the different energy and water conservation measures.

3. Costs and Benefits at Kaha Factory

3.1 What were the Costs?

The SEAM Project provided a total budget of LE 232,465 for purchasing the required insulation and other energy saving and monitoring equipment.

The company contribution was LE 60,000. The breakdown of factory contribution by measure was as follows:

Action	Capital Investment (LE)
Installation of 24 Steam Traps	2,900
Installation of 74 High Pressure Valves	8,000
Assistance in Installation of Rockwool	2,000
Installation of Cooling Tower and Water tanks	14,000
Installation of Pressure Regulators	4,000
Installation of temperature control system	2,000
Monitoring	6,100
Loss of Production	33,000

3.2 What were the Benefits?

3.2.1 Cost Benefits

Fuel oil consumption was reduced by 34 accordingly the fuel bill reduced by LE 319,675.

Water consumption was reduced because of the efficient use of steam, recycling condensate water and recycling of cooling water for one of the sterilisers.

Less production cost.

3.2.2 Environmental Benefits

- Less emissions of polluting and green house gases because of reduced burning of fuel oil.
- Reduced load on sewer system because of lower water consumption.

Table (11) summarises the reduced consumption of both fuel and water as a result of implementation of the different energy and water conservation measures.

Total Actual Fuel Consumption = 1889.5 t/y

$$\textit{\textbf{\% Saving}} = \frac{680.167}{1889.5} \times 100 = 36\%$$

Table (9) Summary of Identified Water Saving Options and Cost/Benefit Analysis for Edfina Factory

Project Opportunity (Name)	Water Saved m^3/y		Cost Saving t/y		Cost LE	Payback Time Actual Production (month)	Payback Time Maximum Production (month)
	Actual	Max.	Actual	Max.			
1. Hose Nozzles	9,000	30,000	9,000	30,000	4,900	6.5	2
2. Rehabilitation of the Dowe Pack Collection System	24,000	96,000	24,000	96,000	8,453	4.2	1
3. Cooling Tower for Juice Steriliser	86,400	288,000	86,400	288,000	84,812	11.8	3.5

Table (10) Summary of Identified Energy Savings Options and Cost Benefit Analysis in Edfina Factory

Project Opportunity (Name)	Steam Saved m^3/y		Fuel Saved t/y			Cost Saving LE/y		Cost LE	Payback Time Actual Production	
	Actual	Max.	Actual	% Saving (*)	Max.	Actual	Max.		Actual	Max.
Installation of steam traps	1,362	4,536	111	4.6	370	20,202	67,340	13,976	8	2.5
Installation of pressure regulators	3,600	12,000	293.5	12.1	978.3	53,417	178,050	43,560	10	3
Replacement of leaking valves	1,054.4	3,528	86.22	3.6	287.4	15,692	52,307	46,990	36	11
Insulation of steam pipes	5,394	5,394	440	18.21	440	80,080	80,080	124,212	19	19
Installation of condensate return system	3,867**	7,735**	28.53	1.2	57	9,060	18,120	33,182	44	22
TOTAL			**959.25**	**40**	**2133**	**178,451**	**395,897**			

! Estimated

* Based on actual fuel oil consumption of 2419 t/y (from plant data see Progress Reports 1 & 2).

** Water saved

Table (11) Summary of Identified Energy Savings Options and Cost Benefit Analysis in Kaha Factory

Project Opportunity (Name)	Steam Saved t/y		Solar Saved t/y			Cost Saving LE/y		Cost LE	Payback (month)	
	Actual= (Max.*0.3)	Max.	Actual	% Saving [a]	Max.	Actual	Max.		Actual	Max.
Installation of steam traps	933	3,110	71.1	3.8	237	31,995	106,650	14,477	5.5	2
Installation of temperature controllers and regulators	3,600	12,000	342.7	14.5	914	154,215	411,300	45,170	3.5	1.5
Replacement of leaking valves	799	2,664	60.9	3.2	202.89	27,400	91,300	38,860	17	5
Insulation of steam pipes	2,123	2,123	162	8.6	162	72,990	72,900	61,946	10	10
Installation of condensate return system	10,670[b]	21,340[b]	73.5	4	147	33,075	66,000	39,812	15	7
TOTAL			**710.2**	**34**	**1,662.9**	**319,675**	**748,150**	**200,265**	**10**	**5**

[a] Based on actual solar consumption of 1889,5 t/y.
[b] Water saved

Part D

Do and Donts For Efficient Energy Utilisation

Do and Donts For Efficient Water Utilisation

References

Do s and Don ts For Efficient Energy Utilisation

Do ..

For better steam utilisation:

☺ Repair leaking steam traps and steam valves immediately.
☺ Repair damaged steam pipes insulation.
☺ Install steam traps at open steam pipe ends.
☺ Isolate unused steam lines.
☺ Check periodically the operation of steam traps.
☺ Insulate bare steam pipes.
☺ Install temperature control devices to reduce unnecessary steam usage.
☺ Install pressure regulators (or reducers) to lower open steam consumption.

Do ..

For improved boiler performance:

☺ Use less excess air.
☺ Lower the temperature of flue gases.
☺ Reduce boiler blow down to minimum.
☺ Perform periodic flue gas analysis.
☺ Make periodic maintenance to clean scales formed on tube surfaces.
☺ Monitor fuel and water consumption used for steam raising.
☺ Return hot condensate wherever possible.

Do not ..

☹ Leave steam valves and traps leaking.
☹ Leave hot steam pipes and hot surfaces uninsulated or with damaged insulation.
☹ Allow excess air to be more than 5%.
☹ Allow flue gas temperature to rise above 300°C.
☹ Allow steam leaks of any type.

Do and Donts For Efficient Water Utilisation

Do.....

Repair leaking pipes and valves.

☺ Make sure that sumps are not surcharged.
☺ Make sure that hoses are provided with nozzles.
☺ Make sure that the wash water is recirculated with the correct number of cycles before discharging.
☺ Check the performance of the cooling towers.
☺ Use spare pumps to allow for pump repair.

Do not ..

☹ Do not increase the number of wash water recirculation to the extent that would pollute the raw material or product.
☹ Do not use open cycle water for cooling.

References

1. Fuel efficiency booklet 3, Dept of Energy, Thames House, South Millbank, London SW1 P 4QJ.

2. Danckind, W.E. Steam Management in Petroleum Refinery. CEP PP 51-53 Feb. (1997).

3. Dyer, D., Maples, G. and Maxwell, T. Steam Efficiency Improvement, Boiler Efficiency Institute, Auburn, Alabama.

4. Boiler Blowdown, Fuel Efficiency Series, Energy Efficiency Office, Thames House, South Millbank London SW1 P 4QJ.

Appendices

1. **Steam Leak Rates through Holes**
2. **Heat Losses from Bare and Insulated Steam Pipes**
3. **Fuel Savings from Condensate Return**
4. **Calorific Values of Energy Sources**
5. **Steam Table**

Appendix 1

Steam Leak Rates through Holes

Table 1: Steam Leak Rate Through Holes (Note: Units are Ibm/ hr)

Orifice Diameter (inches)	Steam Pressure (PSIG)												
	2	5	10	15	25	50	75	100	125	150	200	250	300
1/32	0.31	0.49	0.70	0.85	1.14	1.86	2.58	3.3	4.02	4.74	6.17	7.61	4.05
1/16	1.25	1.97	2.8	3.4	4.6	7.4	10.3	13.2	16.1	18.9	24.7	30.4	36.2
3/32	2.81	4.44	6.3	7.7	10.3	16.7	15.4	29.7	36.2	42.6	55.6	68.5	81.5
1/8	4.5	7.9	11.2	13.7	18.3	29.8	41.3	52.8	64.3	75.8	99.0	122.0	145.0
5/32	7.8	12.3	17.4	21.3	28.5	46.5	64.5	82.5	100.0	118.0	154.0	190.0	226.0
3/16	11.2	17.7	25.1	30.7	41.1	67.0	93.0	119.0	145.0	170.0	222.0	274.0	326.0
7/32	15.3	24.2	34.2	41.9	55.9	91.2	126.0	162.0	197.0	232.0	303.0	373.0	443.0
1/4	20.0	31.6	44.6	54.7	73.1	119.0	165.0	211.0	257.0	303.0	395.0	487.0	579.0
9/32	25.2	39.9	56.5	69.2	92.5	151.0	209.0	267.0	325.0	384.0	500.0	617.0	733.0
5/16	31.2	49.3	69.7	85.4	114.0	186.0	258.0	330.0	402.0	474.0	617.0	761.0	905.0
11/32	37.7	59.6	84.4	103.0	138.0	225.0	312.0	399.0	486.0	573.0	747.0	921.0	1095.0
3/8	44.9	71.0	100.0	123.0	164.0	268.0	371.0	475.0	578.0	682.0	889.0	1096.0	1303.0
13/32	52.7	83.3	118.0	144.0	193.0	314.0	436.0	557.0	679.0	800.0	1043.0	1286.0	1529.0
7/16	61.1	96.6	137.0	167.0	224.0	365.0	506.0	647.0	787.0	928.0	1210.0	1492.0	1774.0
15/32	70.2	111.0	157.0	192.0	257.0	419.0	580.0	742.0	904.0	1065.0	1389.0	1713.0	2037.0
1/2	79.8	126.0	179.0	219.0	292.0	476.0	660.0	844.0	1028.0	1212.0	1580.0	1949.0	2317.0

Appendix 2

Heat Losses from Bare and Insulated Steam Pipes

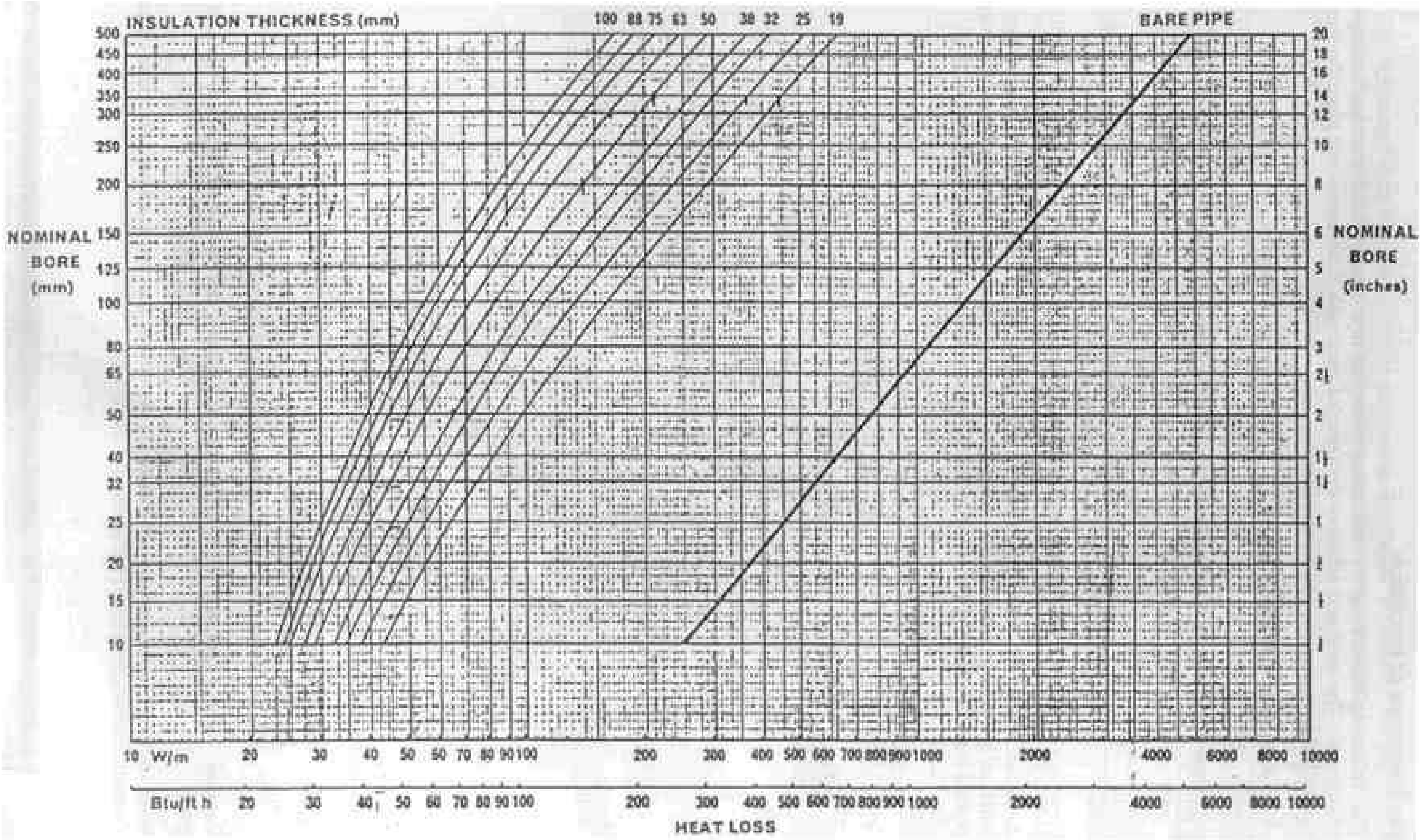


Fig. 1 Heat Loss for Pipes with Surface Temperature of 200 degrees centigrade with Varying Insultation Thickness

Economic Thickness of Insulation

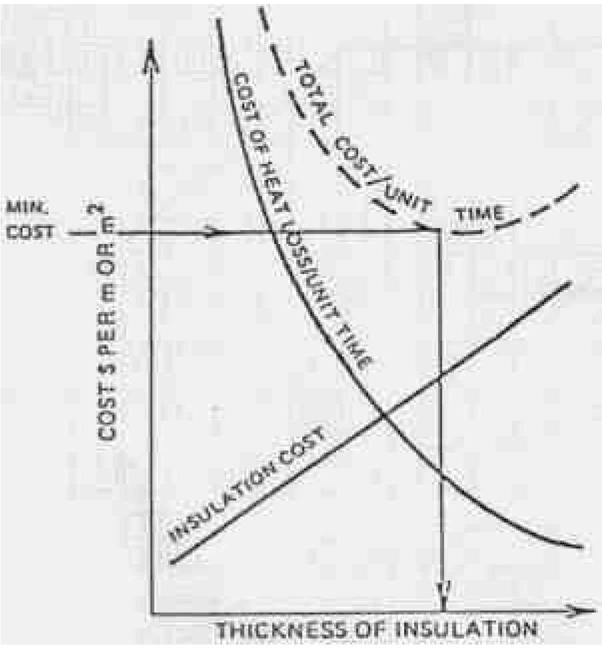
The following method can be used to determine the most economical thickness of a single layer of material. The most cost effective thickness of insulation is the one which gives the least total cost of lost heat plus the cost of insulation.

Annual cost of heat losses = $\frac{k \times A \times K \times h \times p}{100\ t}$ dollars

where:

k = Thermal conductivity of insulant, W/m.K
A = Area of insulation, square meters
K = Temperature drop across insulation, °C
h = Hours of operation per year
p = Cost of power, cents per kWh
t = Thickness of insulation, mm

A set of values for different thickness of insulation is calculated, and a corresponding set of costs of providing insulation is estimated. From these values the following set of curves is plotted from which the value of the most economical thickness of insulation can be read.



Method of estimating economic thickness of insulation:

1. Plot cost of insulation
2. Plot cost and heat loss
3. Plot total cost and derive economic thickness from point of minimum cost

Because cost of heat loss change with price of energy, use up-to-date suppliers data to draw graph.

When different combinations of insulation materials are contemplated the costs of various alternative arrangements are tabulated and compared.

The following data can be used for evaluating insulation proposals. For high temperature applications consider the use of recent developments such as ceramic fibre.

Product	Normal Temperature) Use Limit (°C)	Thermal Conductivity milliwatts (m.k)			Density (kg/m^3)	Heat Storage
		250°C	540°C	820°C		
Ceramic fibre felts and blankets	1250 - 1400	98 - 75	175 - 115	330 - 183	5 - 13	very, very low
Ceramic fibre boards	1150 - 1350	69	102	150	19 - 22	very low
Diatomaceous Silica Block	1100	90	111	-	40	Low
Calcium silicate block	900	75	-	-	21	very low
Diatomaceous silica powder	900 - 1000	75	100	126	27	very low
Hi-temp mineral wool block	800 - 1050	68	98	-	22 - 29	very low
Low Temp mineral wool block	560	81 - 65	-	-	6 - 16	very, very low
Fibreglass board	500	81	-	-	5	very, very low

Appendix 3

Fuel Savings from Condensate Return

Fig(1) Fuel Saved by Condensate Return

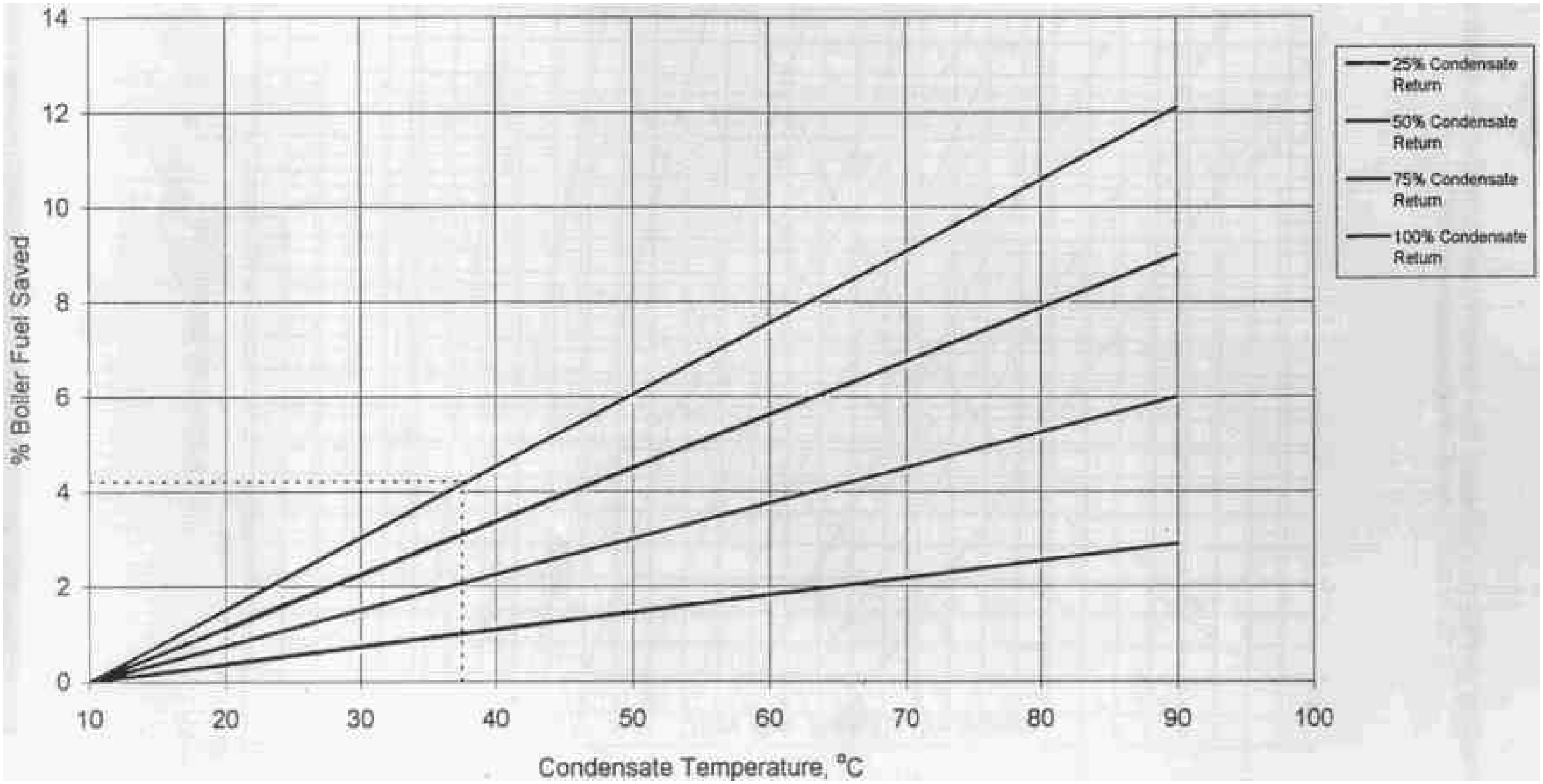


Figure 2: Flue Gas Losses –Gas Oil based on Gross Calorific Value and an Ambient Temperature of 20°C

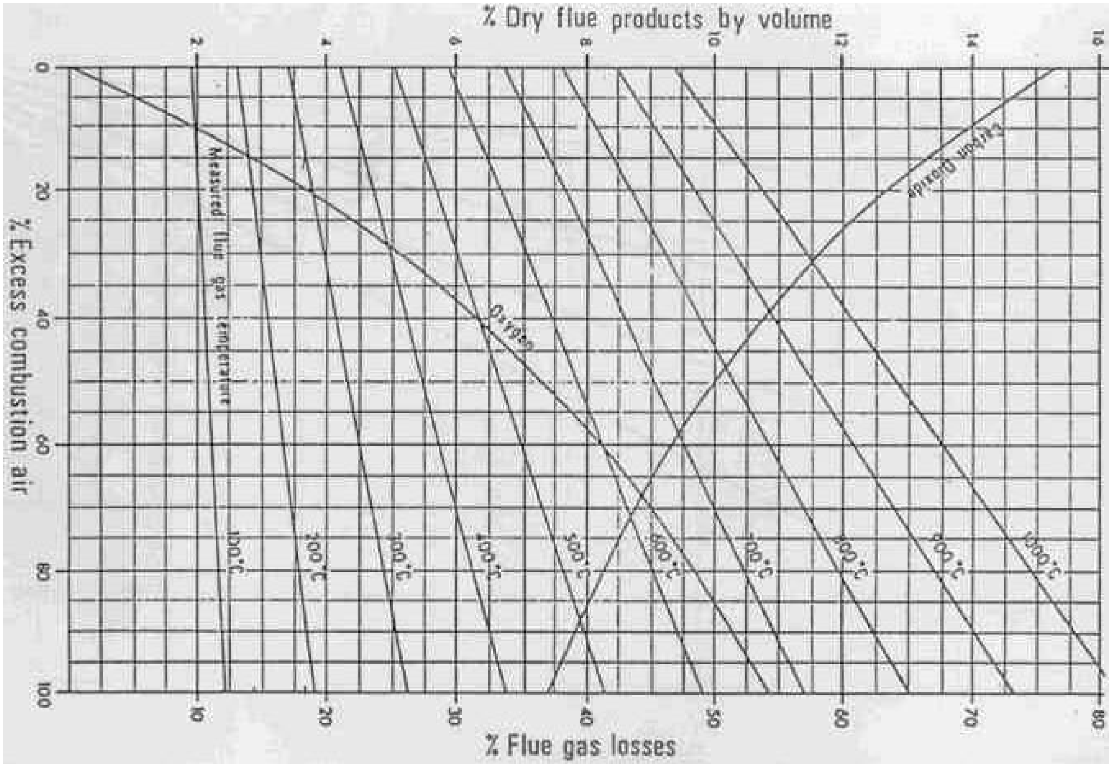


Figure 3: Flue Gas Losses –Medium and Light Fuel Oils based on Gross Calorific Value and an Ambient Temperature of 20°C

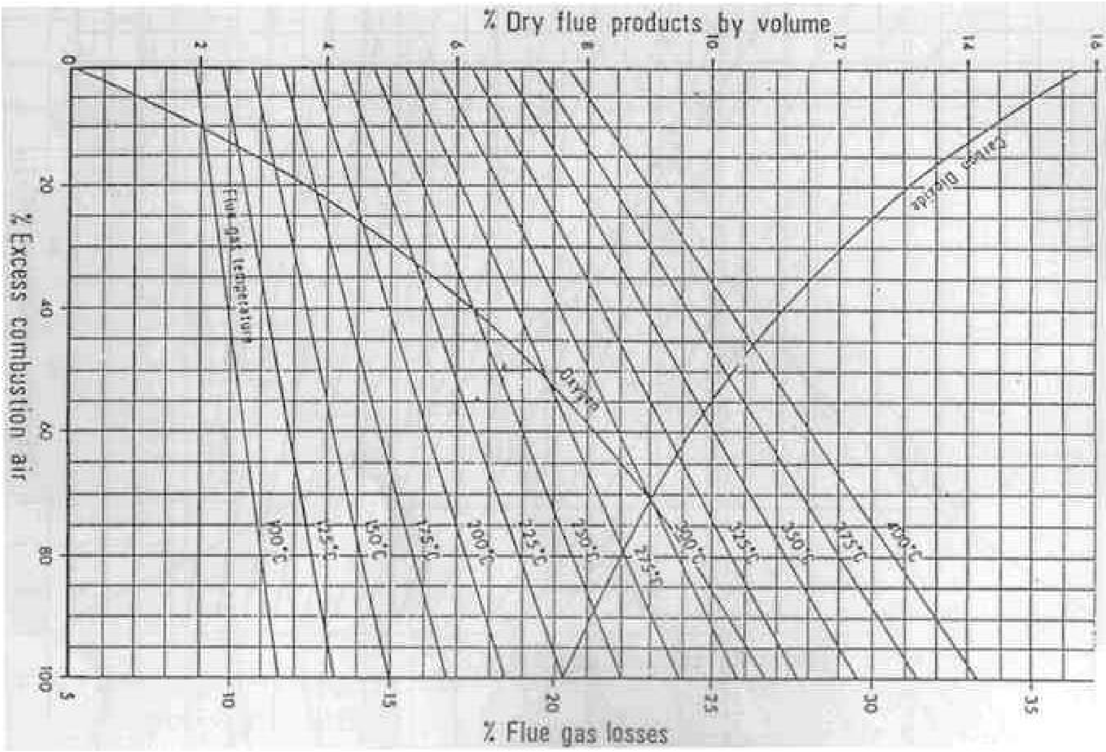


Figure 4: Flue Gas Losses –Heavy Fuel Oils based on Gross Calorific Value and an Ambient Temperature of 20°C

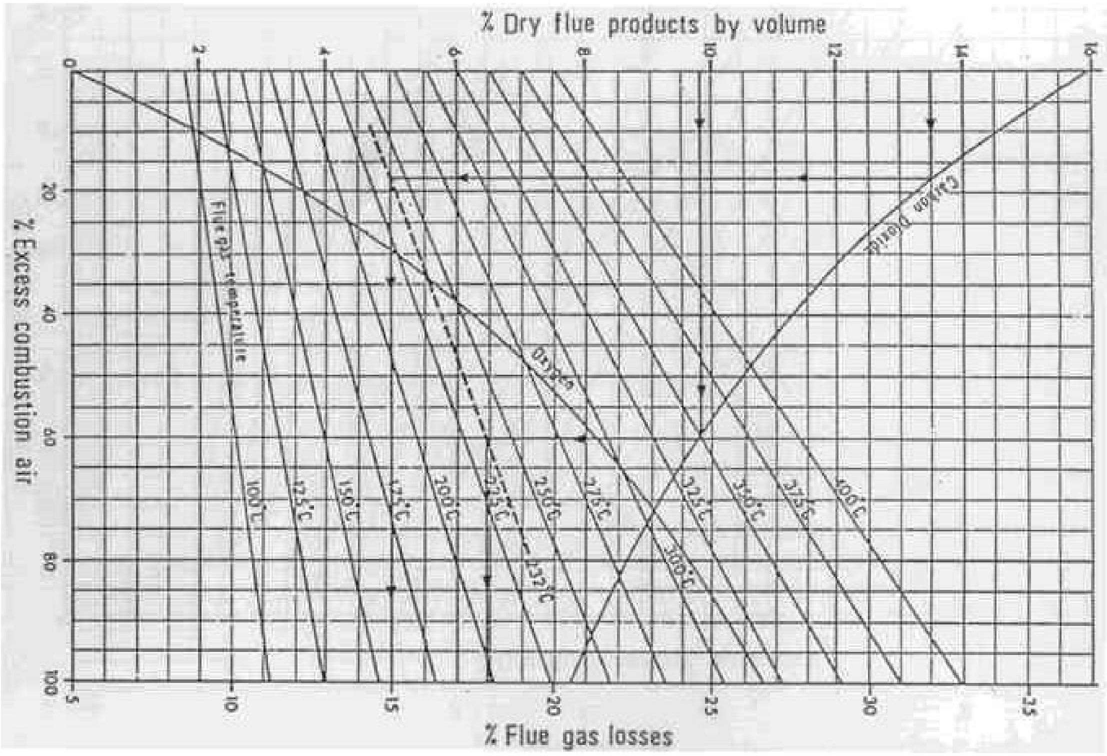


Figure 5: Flue Gas Losses –Natural Gas Effect of Higher Flue Gas Temperature

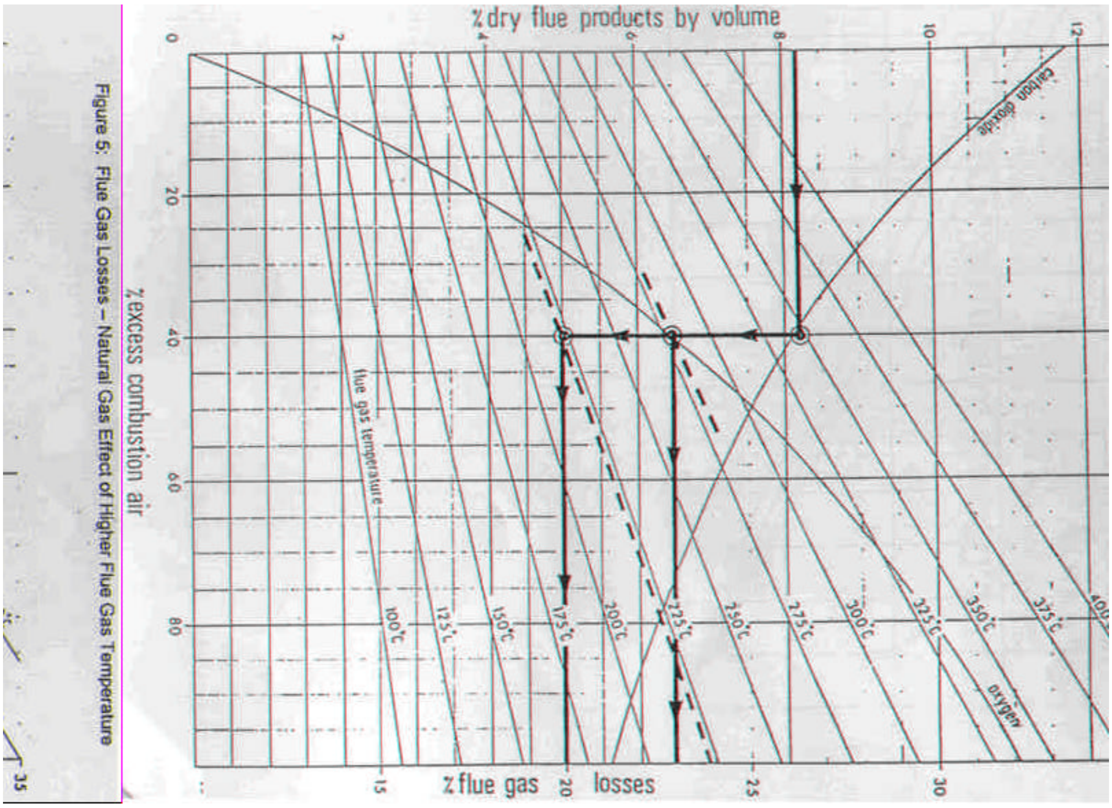
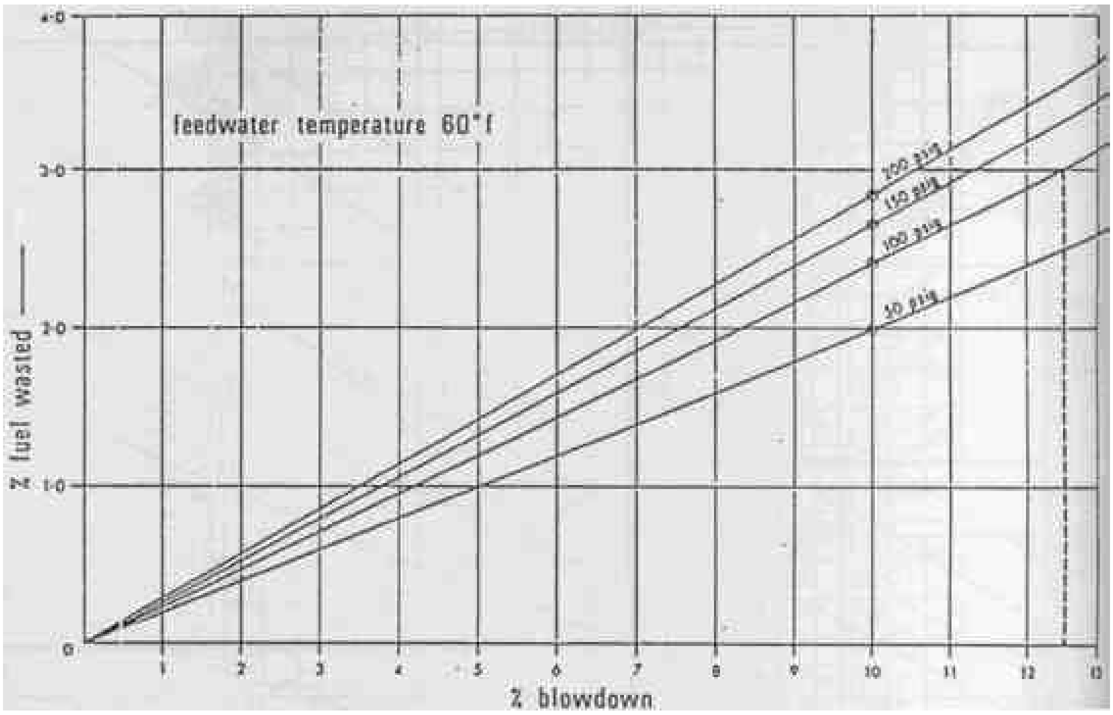


Figure 6: Percentage of Fuel wasted in Blowdown



Appendix 4

Calorific Values of Energy Sources

Conversion Tables: SI (International) Prefixes

10^{18}	exa E	10^{3}	Kilo k	10^{6}	micro u
10^{15}	peta P	10	deca da	10^{9}	nano n
10^{12}	tera T	10^{-1}	deci d	10^{12}	pico p
10^{9}	giga G	10^{-2}	centi c	10^{15}	fanto f
10^{6}	mega M	10^{-3}	milli m	10^{-18}	atto a

Calorific Values of Energy Sources

		Nominal Value (MJ)				
		Per tonne	**Per m^3**	**Per litre**	**Per kg**	**Per kWh**
Coal	Black	28,000			28	
	Briquettes	22,550			22.55	
	Brown	13,000			13	
Electricity						3.6
Gas	Natural		38.9			
	LP (propane)	50,000	93.3	25.4	50.0	
	LP (butane)	49,500	124.0	28.7	49.5	
Oil	Distillate	45,700		37.8	45.7	
	Diesel	45,500		38.2	45.5	
	Fuel Oil	42,500				

Appendix 5

Steam Table

Steam Table (SI Units)

Pressure (bar)	Temperature (°C)	Specific Enthalpy Water (kg/kg)	Specific Enthalpy Evaporation (kj/kg)	Specific Enthalpy Steam (kj/kg)	Specific Volume Steam (m^3/kg)
absolute					
0.03	69.10	289.23	2336.1	2652.3	5.229
0.50	81.33	340.49	2305.4	2655.9	3.240
0.75	91.78	348.39	2278.6	2663.0	2.217
0.95	98.20	411.43	2261.8	2673.2	1.777
gauge					
0	100.00	419.04	2257.0	2676.0	1.673
0.10	102.66	430.2	2250.2	2680.4	1.533
0.20	105.10	440.8	2243.4	2684.2	1.414
0.30	107.39	450.4	2237.2	2687.6	1.312
0.40	109.55	459.7	2231.3	2691.0	1.225
0.50	111.61	468.3	2225.6	2693.9	1.149
0.60	113.56	476.4	2220.4	2696.8	1.083
0.70	115.40	484.1	2215.4	2699.5	1.024
0.80	117.14	491.6	2210.5	2702.1	0.971
0.90	118.80	498.9	2205.6	2704.5	0.923
1.00	120.42	505.6	2201.1	2706.7	0.881
1.10	121.96	512.2	2197.0	2709.2	0.841
1.20	123.46	518.7	2192.8	2711.5	0.806
1.30	124.90	524.6	2188.7	2713.3	0.773
1.40	126.28	530.5	2184.8	2715.3	0.743
1.50	127.62	536.1	2181.0	2717.1	0.714
1.60	128.89	541.6	2177.3	2718.9	0.689
1.70	130.13	547.1	2173.7	2720.8	0.665
1.80	131.37	552.3	2170.1	2722.4	0.643
1.90	132.54	557.3	2166.7	2724.0	0.622
2.00	133.69	562.2	2163.3	2725.5	0.603
2.20	135.88	571.7	2156.9	2728.6	0.568
2.40	138.01	580.7	2150.7	2731.4	0.536
2.60	140.00	589.2	2144.7	2733.9	0.509
2.80	141.92	597.4	2139.0	2736.4	0.483
3.00	143.75	605.3	2133.4	2738.7	0.461
3.20	145.46	612.9	2128.1	2741.0	0.440
3.40	147.20	620.0	2122.9	2742.9	0.422
3.60	148.84	627.1	2117.8	2744.9	0.405
3.80	150.44	634.0	2112.9	2746.9	0.389
4.00	151.96	640.7	2108.1	2748.8	0.374
4.50	155.55	656.3	2096.7	2753.0	0.342
5.00	158.92	670.9	2086.0	2756.9	0.315
5.50	162.08	684.6	2075.7	2760.3	0.292
6.00	165.04	697.5	2066.0	2763.5	0.272
6.50	167.83	709.7	2056.8	2766.5	0.255
7.00	170.50	721.4	2047.7	2769.1	0.240
7.50	173.02	732.5	2039.2	2771.7	0.227
8.00	175.43	743.1	2030.9	2774.0	0.215
8.50	177.75	753.3	2022.9	2776.2	0.204
9.00	179.97	763.0	2015.1	2778.1	0.194
9.50	182.10	772.5	2007.5	2780.0	0.185
10.00	184.13	781.6	2000.1	2781.7	0.177
10.50	186.05	790.1	1993.0	2783.3	0.171
11.00	188.02	798.8	1986.0	2784.8	0.163
11.50	189.82	807.1	1979.1	2786.3	0.157
12.00	191.68	815.1	1972.5	2787.6	0.151
12.50	193.43	822.9	1965.4	2788.8	0.148