GOOD PRACTICE GUIDE 262

Practical tips for energy saving in the rubber processing industry

BEST PRACTICE PROGRAMME

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

GOOD PRACTICE GUIDE 262

PRACTICAL TIPS FOR ENERGY SAVING IN THE RUBBER PROCESSING INDUSTRY

This Guide is No. 262 in the Good Practice Guide series and is intended to help those in the rubber processing industry who wish to make energy savings. The main areas to be included in an energy efficiency strategy are detailed. The main components of energy use in a rubber processing site are then examined and energy saving tips given for each.

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LIST OF RELEVANT GOOD PRACTICE GUIDES

2. GUIDANCE NOTES FOR REDUCING ENERGY CONSUMPTION COSTS OF ELECTRIC MOTOR AND DRIVING SYSTEMS
3. INTRODUCTION TO SMALL-SCALE COMBINED HEAT AND POWER
14. RETROFITTING AC VARIABLE SPEED DRIVES
18. REDUCING ENERGY CONSUMPTION COSTS BY STEAM METERING
30. ENERGY EFFICIENT OPERATION OF INDUSTRIAL BOILER PLANT
31. COMPUTER AIDED MONITORING AND TARGETING FOR INDUSTRY
36. COMMERCIAL REFRIGERATION PLANT: ENERGY EFFICIENT OPERATION AND MAINTENANCE
42. INDUSTRIAL REFRIGERATION PLANT: ENERGY EFFICIENT OPERATION AND MAINTENANCE
43. INTRODUCTION TO LARGE-SCALE COMBINED HEAT AND POWER
47. RUBBER COMPOUNDING IN THE RUBBER PROCESSING INDUSTRY
59. ENERGY EFFICIENT DESIGN AND OPERATION OF REFRIGERATION COMPRESSORS
69. INVESTMENT APPRAISAL FOR INDUSTRIAL ENERGY EFFICIENCY
84. MANAGING AND MOTIVATING STAFF TO SAVE ENERGY
85. ENERGY EFFICIENCY TRAINING AND DEVELOPMENT
86. RUBBER MOULDING AND CURING IN THE RUBBER PROCESSING INDUSTRY
88. ENERGY EFFICIENT USE OF BOILERS USING CHAIN GRATE STOKERS
89. GUIDE TO COMPACT HEAT EXCHANGERS
90. ENERGY EFFICIENCY IN THE PROVISION AND USE OF INDUSTRIAL GASES
91. MONITORING AND TARGETING IN LARGE MANUFACTURING COMPANIES
112. MONITORING AND TARGETING IN LARGE COMPANIES
115. AN ENVIRONMENTAL GUIDE TO SMALL-SCALE COMBINED HEAT AND POWER
116. ENVIRONMENTAL ASPECTS OF LARGE-SCALE COMBINED HEAT AND POWER
125. MONITORING AND TARGETING IN SMALL AND MEDIUM-SIZED COMPANIES
126. COMPRESSING AIR COSTS
141. WASTE HEAT RECOVERY IN THE PROCESS INDUSTRIES
197. ENERGY EFFICIENT HEAT DISTRIBUTION
198. EXPERIENCE IN THE OPERATION OF COMPACT HEAT EXCHANGERS
213. SUCCESSFUL PROJECT MANAGEMENT FOR ENERGY EFFICIENCY
216. ENERGY SAVING IN THE FILTRATION AND DRYING OF COMPRESSED AIR
217. CUTTING ENERGY LOSSES THROUGH EFFECTIVE MAINTENANCE (TOTALLY PRODUCTIVE OPERATIONS)
220. FINANCING LARGE-SCALE CHP FOR INDUSTRY AND COMMERCE
221. IMPROVING BOILER ENERGY EFFICIENCY THROUGH WATER TREATMENT
225. INDUSTRIAL COOLING WATER SYSTEMS
231. INTRODUCING INFORMATION SYSTEMS FOR ENERGY MANAGEMENT
235. MANAGING PEOPLE, MANAGING ENERGY
238. HEAT RECOVERY FROM AIR COMPRESSORS
249. ENERGY SAVINGS IN INDUSTRIAL WATER PUMPING SYSTEMS
251. MAINTAINING THE MOMENTUM: SUSTAINING ENERGY MANAGEMENT
252. BURNERS AND THEIR CONTROLS
256. AN INTRODUCTION TO ABSORPTION COOLING

Copies of these Guides may be obtained from:

Environment and Energy Helpline
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FOREWORD

This Guide is part of a series produced by the Government under the Energy Efficiency Best Practice Programme. The aim of the programme is to advance and spread good practice in energy efficiency by providing independent, authoritative advice and information on good energy efficiency practices. Best Practice is a collaborative programme targeted towards energy users and decision makers in industry, the commercial and public sectors, and building sectors including housing. It comprises four inter-related elements identified by colour-coded strips for easy reference:

— *Energy Consumption Guides:* (blue) energy consumption data to enable users to establish their relative energy efficiency performance;

— *Good Practice Guides:* (red) and *Case Studies:* (mustard) independent information on proven energy-saving measures and techniques and what they are achieving;

— *New Practice projects:* (light green) independent monitoring of new energy efficiency measures which do not yet enjoy a wide market;

— *Future Practice R&D support:* (purple) help to develop tomorrow's energy efficiency good practice measures.

If you would like any further information on this document, or on the Energy Efficiency Best Practice Programme, please contact the Environment and Energy Helpline on 0800 585794. Alternatively, you may contact your local service deliverer – see contact details below.

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CONTENTS

FIGURES

TABLES

1. INTRODUCTION

1.1 About this Guide

The rubber processing industry has the potential to reduce its energy usage by some 15% over the next 8 - 10 years. Reducing energy use will save the industry money, will make it more competitive and help the United Kingdom meet its environmental commitments.

This Practical Tips Guide will help rubber processing companies save money by saving energy. It will encourage you to consider how much energy is costing your company, and to start taking action. The Guide is full of useful tips that will get you started on simple, low-cost energy saving measures that will produce quick results.

Because of the wide range of equipment which may be encountered, the Guide is aimed at reducing energy use in the power components of plant. Sections are therefore aimed at saving in, for example, ‘motors and drives’, rather than in ‘banbury mixers’ or ‘calenders’.

This Guide is part of a portfolio of publications produced under the Government’s Energy Efficiency Best Practice Programme (EEBPP) especially for the sector. Where further reading could bring additional savings, relevant literature is signposted throughout.

1.2 Why Save Energy?

The savings available from reducing energy use are a big incentive to industry. Energy generally represents up to *10% of direct costs* in the rubber processing industry. By introducing best practice, companies can save between 10 and 20% of their overall energy bill. Better control of energy use is achieved by gaining a greater understanding of processes through improved monitoring, management and training. This closer monitoring of overall processes can have additional positive side effects, such as:

- better specification of product;
- fewer rejects.

Reducing energy use does more than just save money. It also helps your company to reduce its effects on the environment by consuming fewer finite resources and reducing the generation of harmful greenhouse gases.

Being able to demonstrate a responsible attitude to the environment is becoming increasingly desirable as environmental legislation grows, and can have a positive effect on your company’s public image and customers.

1.3 How Will this Guide Help My Company?

This Guide contains ideas and techniques (see Fig 1) that can be followed by people with no energy management experience. It also acts as a reference for companies that have already introduced some form of energy management policy and signposts further information for companies ready to take the next steps. The Guide can be used by operatives, fitters, line management, designers, buyers and directors.

Section 2 will help you to assess your current levels of energy use compared with your competitors in the industry.

Section 3 will help you to begin an energy management programme, introduce monitoring and targeting techniques to control all your energy use and processes, and build good energy practice into your everyday business.

Areas for energy savings	**Section**	**Average level of energy use (%)**
Improving your energy management	2	
Comparing your energy use with competitors	2	
Practical measures for good overall energy management	3	
Maintenance matters	3	
Steam and high pressure hot water	4 5	55
Cooling systems	6	1.5
Chilled water	7	1.0
Hydraulics	8	2.0
Compressed air	9	3.5
Ventilation	10	4.0
Insulation	11	–
Motors and drives	12	4.0
Lighting	13	3.0
Heating	14	12.0
Fuel and electricity purchasing tips	15	–
Miscellaneous	–	14.0

Fig 1 How to use this Guide

Together, steam, high pressure hot water (HPHW), cooling systems, chilled water, hydraulics and compressed air are directly responsible for some 60% of the energy bill of a rubber processing company. Reducing the energy costs of these utilities is the main focus of this Guide. There are three main areas of a utility system where energy is a consideration:

- conversion;
- distribution;
- use.

For each utility mentioned above, this Guide contains:

- a Section detailing typical systems, plant and equipment that are commonly in use in the rubber processing industry and how these can affect energy efficiency;
- tips for energy-efficient operation and maintenance;
- guidelines for monitoring and targeting of each utility;
- a list of savings opportunities.

2. ENERGY MANAGEMENT ASSESSMENT

2.1 Benchmarking Your Performance

Understanding the current levels of energy use in your company will give you an idea of how much money you could save through energy efficiency measures.

This Section enables you to compare your energy management with others in the rubber processing industry and leaders in other areas. Benchmarking your performance will highlight the areas that will bring you the biggest savings, and will help you gauge your competitive position within the industry.

2.1.1 *Your Company Assessment*

To obtain a measure of how good the energy management is within your company, a simple questionnaire and energy efficiency chart has been developed. Fill in the details in Fig 2 (overleaf) to get a preliminary assessment for your company. Simply ring the statement that fits most closely the description of your company's procedure, then total the score and see how your rating compares.

Keep a record of your initial answers as this will give you a benchmark against which to gauge your own progress. Being able to demonstrate results will help you to win support from senior management for energy efficiency, and motivate those directly responsible for implementing the changes.

The following free publications describe how to improve your overall energy management. They are available from the Environment and Energy Helpline on 0800 585794.

Good Practice Guide (GPG) 167 *Organisational aspects of energy management*.
General Information Reports (GIR) 12 *Aspects of energy management* and GIR 13 *Reviewing energy management*.
Good Practice Case Study (GPCS) 163 *A co-ordinated approach to energy management*.

2.2 Benchmarks for the Rubber Processing Industry

A survey was carried out in 1997 to review utilities consumption in the rubber processing industry. From the results, the energy consumption of the participants has been calculated and related to production. Charts prepared from these results allow you to use your production rates to make a simple energy comparison.

	Score
Energy policy	
Full action plan as part of environmental strategy	4
Formal policy but no top commitment	3
Unadopted energy policy set by energy manager	2
An unwritten set of guidelines	1
No explicit policy	0
Organising	
Energy management fully integrated, clear responsibility	4
Energy manager responsible to energy committee	3
Energy manager in post but authority unclear	2
Part-time energy manager	1
No energy management	0
Motivation	
Regular formal and informal channels of communication	4
Energy committee and direct contact with major users	3
Contact with users through ad hoc committee	2
Informal contact with engineer and a few users	1
No contact with users	0
Information systems	
Set targets, monitored consumptions and quantified savings	4
M&T reports but savings not quantified	3
M&T reports on supply meter data	2
Cost reporting on utility invoice data	1
No energy accounting	0
Marketing	
Value of energy management marketed by company	4
Programme for staff awareness with regular publicity	3
Some ad hoc staff awareness training	2
Informal contacts to promote energy efficiency	1
No promotion of energy efficiency	0
Investment	
Positive favouring of 'green schemes' in projects	4
Energy projects treated as any other project	3
Short-term investment criteria only	2
Only low cost measures undertaken	1
No investment to increase energy efficiency	0
Total score	

Indications from your ratings

22 – 24 Very Good	Energy management has the highest priority in your company. Keep up the good work, remembering it is easy to become complacent. Action: Use this Guide as a reference aid in maintaining your high standards and maybe pick up a few tips!
19 – 21 Good	Energy management is the concern of the whole company although some managers consider it to be technical rather than part of their responsibility. Action: Review the basic organisational aspects discussed in Section 3 and improve the deficient areas, formalising where possible. Use this Guide as a reference.
13 – 18 Medium	Energy management on an almost casual basis with managers thinking it's the engineers' responsibility (the fuel and electricity budget is probably the managers' responsibility). Action: Section 3 is the main starting point to formalise energy management, integrating it into the company's management structure and producing a positive energy programme.
7 – 12 Fair	Certain staff realise the value of energy management but it is still on too casual a basis with little or no corporate policy. Great potential to save. Action: Use this Guide to assist in setting up a fully integrated energy management system within your company.
0 – 6 Poor	Energy management has a long way to go, so there is great potential to reduce energy consumption, probably by 20% or more. Read on! Action: Use this Guide to assist in setting up a fully integrated energy management system within your company.

Fig 2 Preliminary assessment questionnaire

2.2.1 *The Charts*

Since there is a wide range of production rates within the industry, charts for electricity and fuel use have been prepared for three ranges of production (Figs 3 - 5):

- 0 - 200 kg/hour;
- 200 - 1,200 kg/hour;
- 1,200 - 6,000 kg/hour.

To compare your performance you need:

- annual electricity and fuel consumption;
- annual production tonnage;
- annual production hours.

Then calculate:

1. Electricity/production ratio = $\dfrac{\text{Annual electricity usage in kWh}}{\text{Annual production in kg}}$
2. Fuel/production ratio = $\dfrac{\text{Annual fuel usage in kWh}}{\text{Annual production in kg}}$
3. Production rate = $\dfrac{\text{Annual production in kg}}{\text{Annual production hours}}$

Next choose the chart that applies to your production rate and see how your ratios compare.

The bands on the charts are positioned to take account of the spread of energy usage at different production rates. Users producing similar products lie in all of these bands. High energy usage may indicate that your processes are less efficient than those of some of your competitors. However some products are intrinsically more energy intensive.

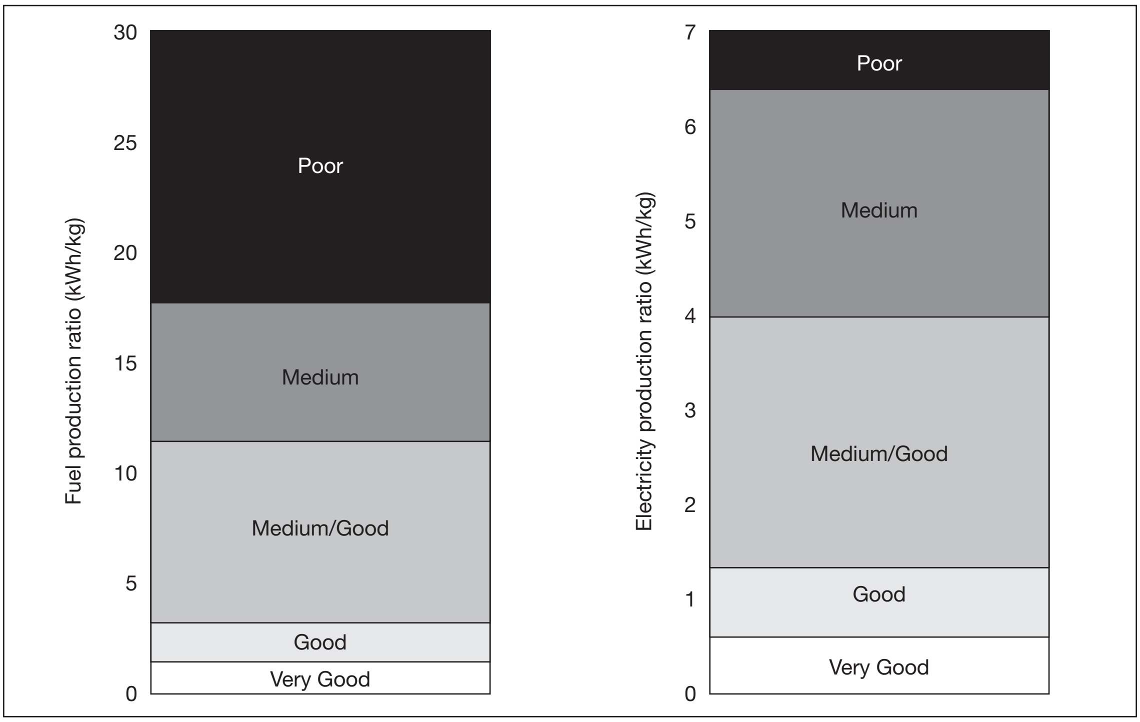

Fig 3 Fuel/production ratio (left) and electricity/production ratio for production rates of 0 - 200 kg/hour

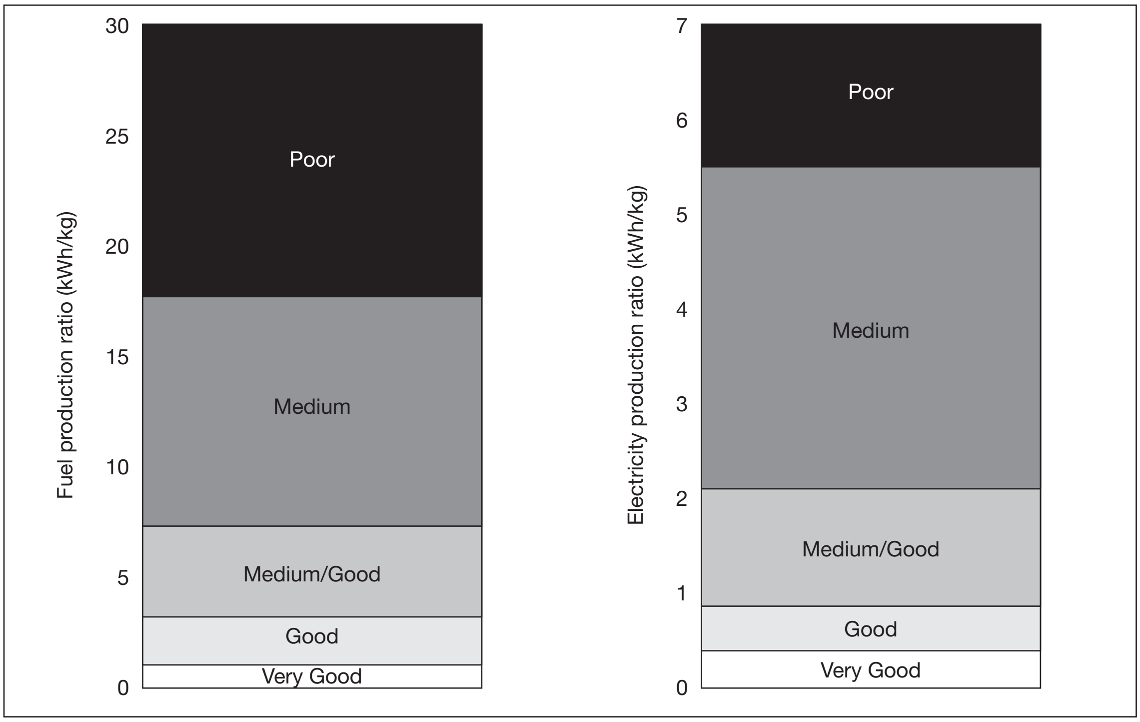

Fig 4 Fuel/production ratio (left) and electricity/production ratio for production rates of 200 - 1,200 kg/hour

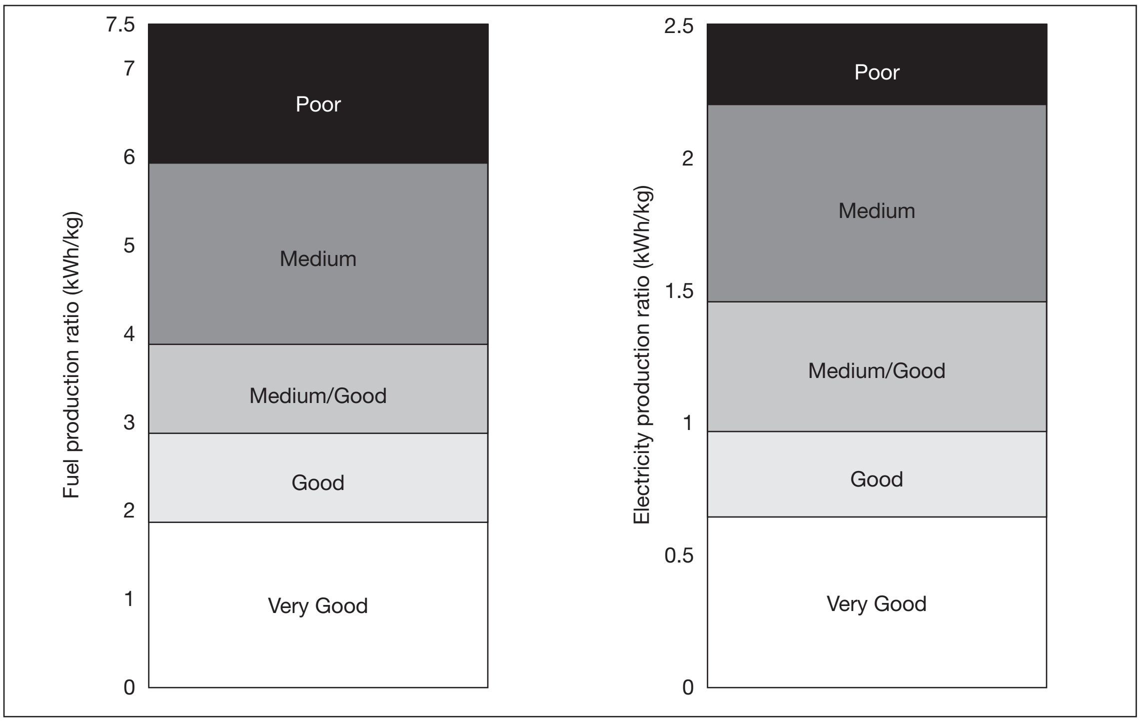

Fig 5 Fuel/production ratio (left) and electricity/production ratio for production rates of 1,200- 6,000 kg/hour

Note: 1 therm = 29.3 kWh.

3. PRACTICAL MEASURES: ENERGY MANAGEMENT

This Section covers the basic organisational aspects of energy management. In Section 2 you established your company performance. This Section will help you start improving your energy management. It covers the importance of measuring energy use, and shows how measuring will lead to reducing energy consumption. It also gives detailed advice on how to capture and measure data, offers suggestions for improved operating practices that will save your company money and at the end of the Section lists further information about incorporating energy management practices formally into your company systems and processes.

3.1 The Importance of Measuring Energy

Unlike cost factors such as labour or raw materials, energy costs often tend to be accepted as overheads, almost a 'fact of industrial life'. However, energy is a controllable cost with the potential for significant cost savings for your company.

You cannot control any resource if you do not measure it. Measuring energy:

- is not difficult or expensive;
- is a vital part of good business management.

You should ask yourself:

- How much energy are we using?
- When are we using it?
- Where are we using it?

The answers to these questions will help you to find out: where and when you are wasting energy and how you can reduce this waste.

Remember: There are probably up to 20% savings to be made. Consider how much extra turnover would be needed to achieve that amount in profit.

If you know how much energy you are using, write it down here as a record.

Current level of energy use is . . . . electricity

. . . . .gas

. . . . other

Date . . . .

In a few months' time, after taking action, these figures should be lower. If you do not know your current level of energy use, consider why not, then go and find out. You can easily establish your overall site energy usage from recent bills. Monthly electricity and gas bills are usually in kWh. Monthly use of oil can be calculated by comparing storage tank levels at the beginning and end of each month with the monthly purchases.

Measuring is a vital step, but it won't save you money unless you use it to find out where you are using and wasting energy, and act on the answers!

3.1.1 *Monitoring and Targeting (M&T)*

Monitoring and Targeting (M&T) is a disciplined approach to energy management that ensures energy resources are used to the maximum economic advantage. M&T programmes give the control that will lead to energy savings. It is generally accepted that energy savings of around 5% are achievable in the year following the introduction of an M&T programme. M&T has two principal functions:

- it allows ongoing control of energy use;
- it allows planned improvements in the efficiency of energy use.

Monitoring specifically allows ongoing control of energy use and measures any improvements or backward steps. Targeting allows setting of achievable improvements in performance.

The same techniques for M&T apply to:

- a company, small or large, as a whole;
- departments;
- individual machines.

3.2 Data Collection and Analysis

3.2.1 *When Are We Using Energy?*

Your energy consumption figures, together with your production data, will give you a history of total site-specific energy use per unit of product (item, kilo or tonne). This specific energy use forms the basis of your monitoring system. If it is plotted on a time chart (see Section 3.2.6) it will show:

- changes in energy use with changes in product mix;
- changes in energy use when particular pieces of equipment are used;
- inconsistencies in energy management;
- decreases in plant efficiency prior to maintenance.

If you plot the data and draw the best straight line through the points, these patterns may emerge more clearly and may present some surprises. If the plotted line does not pass through zero, this means that some of your energy use is not related to production volume, due to a base load of lights, motors, heaters, etc. consuming power even when you are not making product. Although unavoidable to a certain extent, base load can certainly be minimised.

3.2.2 *How Can I Identify the Base Load?*

Examine the records of fuels used and plot consumption each month. The consumption during the summer months, when space heating is normally switched off, will give the base load which is production-based, not weather dependent. This base load can subsequently be subtracted from the total annual consumption to give an idea of the consumption attributable to space heating. This method is only valid for factories with reasonably consistent production patterns.

A half-hourly profile of total site power use over an extended period can be interesting. Fig 6 shows a typical pattern for a company working day shifts where 30% of peak demand is used even when not making products. Is the same happening in your company?

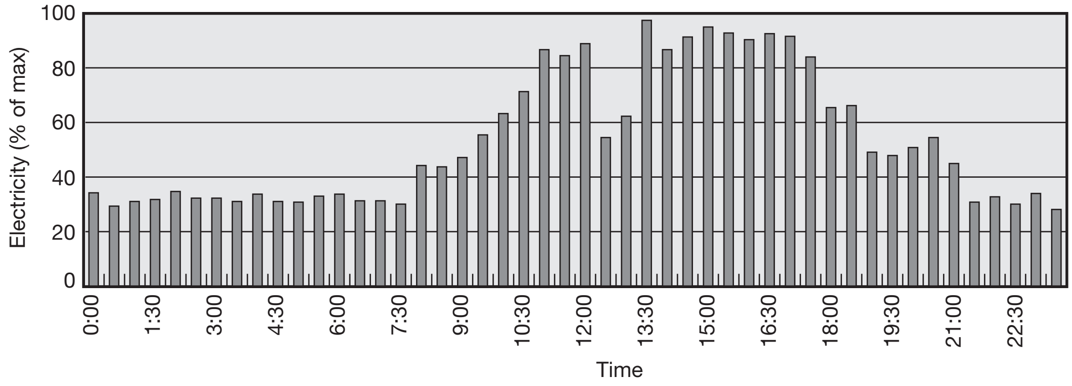

Fig 6 Electrical demand (% of maximum) against time

Meters are not there just for the utility companies to read when calculating your bills. By reading site meters and tank levels at the end of shifts you can establish your day-to-day and shift usage. Request a half-hourly profile of total site electricity use from your electricity supplier, who probably uses a remotely interrogated meter. This information may be available free or for a small fee. Produce your own half-hourly profile over a suitable period, and look at the base load use.

Do you know what energy is being used in non-productive periods? Take a walk round the factory during a 'non-productive' period, e.g. lunchtime or at tea breaks, and look and listen for **where** the energy is being used, e.g.:

- motors left running;
- lights and machine heaters left on in empty rooms;
- the hiss of steam and compressed air leaks;
- cooling water pumps running continuously.

Ask yourself whether there are good reasons for keeping machines idling until the next production run. Check on simple maintenance measures and ask questions about 'accepted' practices. Is it insulated? Is the insulation in good condition? Has insulation been disturbed for maintenance and never replaced? Are light fittings dirty or broken? Why are the motors that size? Would smaller motors be more efficient? Does the compressed air pressure need to be so high? Does the steam pressure need to be so high? More details about **what** to look for specifically and **how** to make energy savings are covered later in this Guide.

3.2.3 *Metering and Monitoring Separate Electricity Users Within a Site*

Electricity usage can basically be split into two categories:

- **Specific.** Easily assigned to specific products and production such as machine motors, heaters, handling equipment and dedicated utilities such as hydraulics, compressed air and vacuum.
- **General.** Utilities used over many production areas including compressed air, cooling water and chilled water systems and factory lighting.

You may be surprised at how much of your energy consumption falls into the second category and is difficult to assign to production. It may be practical at some time to fit steam, air and water flow meters so that more usage is measured and will, therefore, come into the first category.

3.2.4 *How to Measure Your Electricity Use*

One option for measuring energy consumption is to use portable ‘clamp’ meters connected to an automatic data logger, which can be programmed and left over the measuring period. Data logging sets can be hired from equipment suppliers or bought relatively cheaply and prove a very cost-effective option if used in detailed investigations. Data analysis is covered in Section 3.2.6.

It will not be practical to measure all your electricity users, so you need to examine your electricity distribution system to find a sensible number of groupings to measure. Often all the motors, heaters and ancillaries for an individual moulding or extrusion machine are supplied from the same substation, distribution board or feeder cable. Meters on all the possible measuring points on your list are unlikely to be cost-effective.

Once you have an idea of where the energy is consumed, use the information to determine the level of energy use that is sensible for your factory and identify where energy is being wasted.

3.2.5 *Demand Cycles of Electricity*

Peak demand can have a big influence on energy costs. Part of your electricity bill is probably based on your allowed site maximum demand, so load scheduling can save money. Other tariffs that may affect your operation are discussed in Section 15.2.

3.2.6 *Useful Charts for Production*

No matter whether you obtain your energy and production measurements from bills, main meters, portable meter readings or sub-meters, it is important to get the analysis right, without it being too time consuming. Consultants will be able to provide experience in analysing the data produced if you wish to use outside help. Many commercial, spreadsheet-based analysis systems are available to help in-house data analysis, and once set up they are simple and quick to use.

Some useful charts can be used to illustrate energy usage to management and employees. Don’t keep good news to yourself. If, as a result of taking energy-saving steps you save money, make sure people know about it. Display charts near relevant equipment or on notice-boards to demonstrate the savings made. This will help keep people motivated to follow energy-saving policies. Cost could be substituted in the majority of the charts if required.

Suggested charts include:

- **Overall monthly energy usage.** The current year’s energy usage on a monthly basis against previous years. Plot electricity, fuels + total energy in kWh/month (most informative where production is fairly constant).
- **Specific energy.** The kWh of energy/unit of production (kg, tonnes, number etc.)/month. This is the best measure of efficiency. This can be split for electricity, fuels + total energy. However, because of the standard base load (heating, lighting, utilities etc.) a good production month would give apparently good energy figures and vice versa.
- **Monthly production.** Units of production/month. This is useful to check against previous ‘similar’ monthly’ production levels to allow meaningful comparisons of specific energy performance in conjunction with the specific energy chart.
- **Heating.** The fuel figures from the monthly energy use charts should give a good indication of the annual heating load. Take an arbitrary line across the values for June, July, August and September, then subtract the total below the line from the annual total usage to give the approximate annual heating load.

Once you have accumulated figures for 12 months you will be able to start making annual totals and comparisons, e.g. an annual rolling total. This technique eliminates seasonal variations and produces more meaningful comparison. As well as internal comparison, you can return to Section 2 of this Guide to benchmark your new figures against those of your competitors. You can also obtain other benchmark figures, e.g. by asking the machine manufacturers.

More complex analytical techniques can be used (more details of these techniques can be found in the Energy Efficiency Best Practice Programme publications listed below) e.g.:

- plotting monthly heating in kWh against degree days;
- using ‘CUSUM’;
- regression analysis.

The following free publications describe how monitoring and targeting can save you money. They are available from the Environment and Energy Helpline on 0800 585794.

GPG 112 *Monitoring and Targeting in large companies*.
GPG 125 *Monitoring and Targeting in small and medium sized companies*.
GPCS 142 *Monitoring and Targeting at a general rubber goods site*.
GPCS 207 *Monitoring and Targeting in a multi-site company*.

3.3 Operating Practices

Once you have started to measure data and benchmark the figures, you should be able to identify where use appears higher than necessary. Now you can take steps to reduce your energy usage.

The first thing to remember is that people and practices can save you money!

The reason companies have such variable levels of energy use is not just due to differences in their products, but also because of differences in their practices. Most systems evolve over time, and the first step towards making energy savings is to look at energy use with fresh eyes.

There are many reasons why the average site has room to improve. Your main business priority is to produce high quality products as quickly as possible - manufacturing costs are secondary so long as you are competitive. Even in highly competitive markets the focus is likely to be on reducing staff and material costs, and energy may be regarded as an overhead, or be low on the list of priorities. Given time to think, most operators could come up with appropriate measures to reduce energy use, but finding time to think about energy efficiency let alone put it into practice in the bustle of production deadlines is another matter!

Energy efficiency is a key contributor to good productivity, not a competing priority or add-on extra. Acquire the habit of energy-efficient operation and you will find it is not time consuming.

3.4 Staff Motivation and Training

This is usually the most inexpensive way to make significant savings. The most cost-effective energy-saving consultants are employees. Training and motivation is the key to energy efficiency, and there is a substantial library of free Energy Efficiency Best Practice Programme literature in this area. Contact the Helpline on 0800 585794 to find out the most appropriate for your situation.

To sustain energy savings, everyone in the company needs to feel:

- Informed - aware of company performance, energy savings potential and achievements, what measures the company plans to take, and those they can take personally.
- Empowered - that energy saving is an issue sanctioned by top management, and they are being given the time to implement it in their area.
- Motivated - that there is some personal benefit from undertaking measures, in recognition, incentives or satisfaction.

Every employee can be a savings champion, and their common-sense is a valuable asset. Effective training need not be formal or expensive: simple sessions on-site will bring results. For example, tying-in the concept of energy saving at work and at home really gets the message across.

3.5 Choosing a Machine for Production

Most sites have more than one processing machine. Each machine varies in capacity, age, design and manufacturer, and even nominally similar machines can have different energy efficiencies as a result of different degrees of wear, or because they are set up or operated differently.

Few machines are exclusively dedicated to a particular product, and most companies process a mixture of polymers and products according to customer demand. It is important to be aware of the different options available and the benefits and costs associated with each. This means that you need good records of how the machine was set and how it performed. For example, a machine ‘throttled down’ to low production relative to its capacity is inherently inefficient.

Before changing any settings on your machine you should consult the manufacturer. This applies to the advice given throughout this Guide.

3.5.1 *Recording Performance and Settings*

Some of these are required for Quality Assurance systems, but in many cases the rest are ‘kept in the operators’ heads’. For a site with a wide range of products it is very difficult to keep track of them all in your head, since ideal settings will change with time as machine components wear.

By building up a historical set of these records your understanding of machine operation should improve. This will not only allow you to select the best machine for a particular job, but will allow you to schedule replacement of components and maintenance on a more logical basis.

3.5.2 *Switching Off Between Jobs*

The only time some machines are switched off is when they break down. This may make good technical sense for larger machines, but it does mean that you are using electricity unnecessarily when machines are idling. Another common example of poor practice is having lines set up in readiness so that the operator can avoid being idle if one line stops. This may be efficient use of operator time, but does it cost more in energy use than it saves in labour costs? Without monitoring you will not know how much these practices are costing you.

The four key guidelines to efficient job changes, set-up and maintenance time reduction, and efficient essential planned maintenance are:

- **Instructions.** Issue clear instructions before the previous job ends so that staff are allocated and the appropriate preparations can be made. Preparing before the previous job ends allows time to make good any breakages, or change plans before the machine is stopped.

- **Preparation.** Locate and check tools, equipment and material, and bring them to the machine. Pre-warm dies or moulds away from the machine. Check if there is a record of previous settings for the product to minimise optimisation time. These actions are frequently ignored or left to chance, even in companies where in-house products are repeatedly set up, and changing tools ought to be a very slick operation.

- **Task planning.** Make sure that fitters or machine setters do not get called away to deal with problems on other machines – setting or maintaining a machine requires their full attention. Interrupted or hurried work can waste energy and materials (Maintenance is covered in Section 3.6).

- **Approval.** Make sure that Quality Assurance staff are on hand in the latter stages of changes so they can issue approval as soon as product is being made within specification. Material can be recycled, but the energy used in producing out of specification product is lost forever.

3.6 Maintenance Matters

Most maintenance sections are doing a good job putting older equipment back into service as soon as it breaks down, and in many cases carrying out enough ‘preventive’ maintenance to reduce the frequency and severity of breakdowns.

However, worn components and bearings will increase reject rates and energy usage long before their condition becomes a threat to production. Therefore:

- monitor and record all aspects of performance for a machine making a particular product;
- quantify the pattern and cost of wear and tear;
- formulate a sensible compromise between the extra cost of increased maintenance and the savings from reduced energy use and rejects.

3.6.1 *Maintenance Schedules*

A maintenance schedule must be tailored to each factory, and so only general information is given here. For detailed advice, refer to manufacturers’ specifications for individual items of plant. Also see GPG 217 *Cutting energy losses through effective maintenance*, available free of charge through the Environment and Energy Helpline on 0800 585794.

Some key maintenance matters that affect energy efficiency are:

- component wear and mechanical alignment;
- bearing condition and lubrication;
- water, steam and air leaks;
- electrical insulation integrity;
- condition of motor commutators, slip rings and brushes;
- general cleanliness;
- optimisation of transmission arrangements.

Rubber processing machinery generally has crucial moving components, such as extruder screws and injection rams. Wear leads to energy wastage from friction and lower product quality. Misalignment can lead to major failures. Routine visual inspections can identify any problems with wear or alignment. Vibration sensors can be fitted that will identify problems early on.

Bearings on all large motors and equipment, including fans and pumps, should be checked regularly. Elevated bearing temperatures can indicate problems which could cause significant damage, and vibration techniques can also indicate deterioration. For very large equipment it may be worth installing permanent on-line condition monitoring sensors. Many companies choose to use external contractors rather than maintain in-house expertise and equipment.

Lubricate bearings and gearboxes to a set schedule as recommended by the manufacturer, noting that frequency, quantity and type of lubricant are important. ‘Energy-saving’ lubricants are available, although additives that reduce friction may degrade some materials in the long-term, for example oils containing chlorine will damage bronze. If you decide to change your lubricant, satisfy yourself that the supplier has test results showing long-term effects (or lack of them). Run some initial trials on equipment that is not critical for production purposes, inspecting the condition after a reasonable interval.

One of the main causes of electric motor burnout is electrical insulation breakdown due to excessive temperature or temperature cycling. Periodic off-line checks of insulation integrity with a meter, although this can be difficult to fit into a tight production schedule, or infrared thermography are useful non-invasive techniques for detecting the first symptoms, or even the causes, before deterioration occurs.

Poor or intermittent electrical contact in electric motors wastes energy. Draw up a schedule for inspecting and cleaning/replacing commutators, slip rings and brushes.

Cleanliness of machinery does not generally affect efficiency, but it allows problems to be spotted much faster (e.g. developing oil leaks). Many factories have ‘clean room’ conditions in selected areas and so their processing machinery is kept spotless. Consider applying this way of thinking to air compressors and boilers.

Most rubber processing equipment is driven indirectly (hydraulically), or by electric motors either directly or through a gearbox. Direct drives are inherently more efficient as there is no intermediate link to increase friction losses. However, for ancillary (product handling) or utility equipment, drive is sometimes transmitted through chains or belts.

- Regularly check chain and belt conditions and adjust tensions correctly.
- Grease chains at correct intervals or as required.
- Regularly check conditions of drive pulleys or sprockets.
- Ensure correct chain or belt is fitted and make sure multiple sets are matched.
- Check pulleys are still aligned correctly.
- Some companies fit perspex guards to drive systems, so that visual checks of alignment and tension can be carried out with the equipment on-line. Make sure that any alterations to drive guards comply with all the safety regulations.

3.7 Achieving Continuous Energy Saving Results

Every employee can save energy, and greater commitment by all employees gives higher cost reductions. In today’s competitive markets continuous cost reductions are vital and it makes sense to commit to good business management of energy, which is probably the third highest cost to the company.

For energy efficiency to be effective on an ongoing basis, it must become part of a company’s culture and processes, rather than simply a one-off success as part of a rigorous, but short-term energy efficiency campaign. The energy management message becomes more effective when reinforced on a regular basis and when all employees become involved, rather than responsibility being left to one enthusiast or energy ‘champion’.

There are several ways to make energy efficiency an everyday practice in your company, for example, including energy management in quality procedures and publishing an energy policy. These are discussed fully in other Energy Efficiency Best Practice Programme publications, such as Good Practice Guide GPG 169 *Putting Energy into Total Quality*. Contact the Environment and Energy Helpline on 0800 585794 for more information.

4. STEAM

Steam is the most common form of heat used in mixers and mills (start-up), in extruders and moulds and for space heating and domestic hot water. In the rubber processing industry steam generation accounts for 67% of energy usage. The common elements of a steam heat supply system are:

- boiler plant;
- steam distribution;
- condensate return.

The overall delivery efficiency of a conventional steam heat supply system is at best about 70%, based on the heat ultimately delivered to the user compared with the energy input to the three elements listed above.

The key issues for energy efficiency relate to the optimisation of boiler efficiency and the control of heat delivery systems. Actions required to maintain high efficiency figures are the main focus of this Section.

4.1 Boiler Plant

Most boiler plants in the rubber processing industry are gas or oil-fired, with some larger plant using coal. Electrical and compressed air systems support the fuel conversion process. At all stages improved efficiency will bring energy efficiency results. The main stages in operating a boiler plant are outlined below.

4.1.1 *Fuel Preparation*

Fuel preparation is particularly important for coal and oil, less so for gas. For coal, choice of fuel is critical since grates are often designed for quite a narrow selection. Characteristics such as size range and ash content are important. For oil, viscosity is the key characteristic to be controlled. Check on the correct temperature needed to optimise oil atomisation with oil supply companies and monitor the burner oil temperature on a regular basis. Clean oil filters each shift.

4.1.2 *Fuel Combustion*

Fuel combustion is dependent on both fuel and air provision, and contributes significantly to system efficiency. Keeping an even spread of coal on the grate, ash removal, under and over-bed combustion, air pressure and coal height are all critical for optimising coal systems.

For heavier oils, cleanliness of the rotary cup, pressure jets etc. is essential. The pressure of fuel and air is critical, particularly at low turndowns when mixing is poor. Poorly maintained burner systems require higher excess air levels giving lower efficiencies. For fluid systems, oxygen trim systems are now finding wide application, although maintenance is an important cost factor. Ask the manufacturers of any burner equipment about the optimum appearance of the flame.

4.1.3 *Heat Exchanger*

Heat exchanger performance requires a check on flue gas exit temperature. For steam or hot water boilers a good figure is one which is 30 - 55°C above the highest steam/water temperature with the boiler at full load. As the thermal load reduces, this temperature difference should decrease since the heat exchange surface area remains unchanged. If this temperature is seen to increase, this indicates that air flow rates are too high and the heat exchanger is operating too far outside its design parameters.

Both fireside and waterside heat transfer surfaces must be kept clean. Fireside with gas firing does not usually present a problem, but oil and coal-fired boilers may need their tubes cleaned on a 12-week and 6-week schedule respectively. In particular, tube cleaning should be carried out when the flue gas working fluid temperature difference increases to 750°C due to fouling. For oil-fired boilers, water injection may help to keep the fireside tubes significantly cleaner.

Gas-fired boilers tend to scale on the waterside, but the timing of cleaning will still be governed by the degree of efficiency loss and its value compared with the cost of de-scaling.

4.1.4 *Boiler Feedwater*

Boiler feedwater must comply with the relevant standards (e.g. BS 2486 for shell boilers below 25 bar pressure), and the relevant water treatment company's standards.

Good control over boiler water conditions based on TDS (total dissolved solids), phosphate level, alkalinity (pH 4 - 11) etc. will minimise scaling. This benefits not only heat transfer but also the action of float-type level control systems. Packaged boilers generally need to be operated with a TDS of 3,000 ppm. Regular checks are required on boiler water to allow feedwater and blowdown conditions to be adjusted. Checks should be carried out once each shift. Modern TDS control systems are making this task easier, but this equipment also must be regularly checked to the manufacturer's instructions.

High Pressure Hot Water (HPHW) Boilers

For HPHW boilers, testing of boiler water conditions is required less frequently. For any boiler, it is essential to comply with Health and Safety Executive Guidance Note 5 to ensure safe operation.

Both steam and hot water boilers should be scheduled to operate at maximum efficiency, using the minimum number of boilers to meet the demand. This way fuel is burned more efficiently, excess air levels are reduced, air purging before and after burner switching on/off either in high/low/off or modulating burner systems is avoided, and ventilation losses are eliminated.

4.1.5 *Steam Generation*

For steam generation, steam and hot water lines should be insulated and steam leakage should be minimised. Lost condensate and flash steam are responsible for significant energy losses (more details can be found in the savings opportunities in Section 4.5.5). Isolate heat supplies that are no longer needed with automatic valves, and also sections where significant losses occur when there is no demand. Check steam trap operation and replace units as necessary. Steam should be generated at the pressure necessary to meet the maximum required by the equipment in the system. Control process and space heating systems to optimum operating times and temperatures. For hot water generation systems, minimise supply temperatures and match pump operation to demand.

Distribute steam at a pressure higher than that required by any user to ensure that the final required pressure is provided. Losses are due to heat emission from pipework and leakage. Heat loss from the boiler casing represents between 2 - 5% of boiler steam output in well-designed and operated systems.

In the rubber processing industry, where steam use has been reduced through introduction of modern processes, many steam systems are poorly loaded so that boiler surface losses are higher than expected and can easily be between 5 - 10% of steam heat content. Overall efficiency of heat up to the delivery point is therefore 65 - 70%.

4.1.6 *Condensate Return*

Use condensate return wherever possible. Condensed steam under pressure flashes when reduced to atmospheric pressure conditions in collection tanks. This flash is usually lost and accounts for 43% of the heat in the condensate. As the condensate at 7 bar pressure carries 26% of the heat in the delivered steam, then the flash represents 11.2% of this figure. If the condensate (now at atmospheric pressure) is lost to drain, this is another 14.8% of input steam heat content lost. Therefore, in sites where all flash steam is lost and only 50% of condensate returned, the overall loss is 18.6%. Heat is also lost from condensate lines.

In tyre plants, returns are lower due to the loss of steam from the moulds which is vented to atmosphere. Also, condensate that has been in contact with the tyre is considered to be contaminated and is rejected to drain.

- Is any condensate needlessly wasted?
- Are check valves fitted when condensate is lifted to an overhead return?
- Can heat be recovered from contaminated condensate?

If condensate is sent to drain, the overall efficiency of heat supply is therefore 45 - 50% (see Fig 7). Sites with long distribution lines, insulation in poor condition and steam leak problems could have efficiencies significantly lower, making heat supplied as steam at the point of use very expensive.

Point considered	**Efficiency %**
Fuel supply to boilers	100
Steam from boilers	80
Steam from boiler plant	75
Steam at the point of use	70
Total including condensate losses	**50**

Fig 7 Heat supply system efficiency

4.2 Health Check

To help improve steam system performance complete Fig 8, which contains 15 short questions that explore your system from the point of steam generation through distribution to the end use, before examining the recovery of the residual energy present in any system. Some preferred options are given for consideration when upgrading an existing system to improve its operational efficiency. Tick the box that most closely reflects your system for each question.

Boiler House

1) Fuel for Steam Raising

A	CHP or dual-fuelled (including incineration of waste)	
B	A single fuel type e.g. gas or fuel oil	
C	Electricity	

2) Boilers

A	Boilers are correctly sized and operating at designed working pressure	
B	Boilers have been de-rated	
C	Boilers are over-rated for current operating conditions	

3) Total Dissolved Solids (TDS) Blowdown

A	Automatic TDS level monitoring system linked to continuous blowdown is in use	
B	Automatic blowdown system is in operation (e.g. timed)	
C	Manual blowdown is carried out (through bottom blowdown valve)	

4) TDS Blowdown Heat Recovery

A	Full heat recovery equipment is employed	
B	Some heat recovery is carried out	
C	No heat recovery is carried out	
D	Blowdown rate is very low so heat recovery is not viable	

Distribution

5) Redundant Pipework

A	Any unused pipes are blanked off or removed	
B	Most unused pipes are blanked off or removed	
C	Manual valves are used to blank off unused pipes	

6) Insulation

A	All pipes, valves, flanges and fittings are insulated to current standards (minimum 50 mm)	
B	All pipes are insulated but some insulation is below current standards or in poor repair	
C	Not all pipework, valves, flanges and fittings are insulated	

7) Pipe Sizing

A	Pipe sizes are usually reviewed when steam loads change	
B	Pipe sizes are sometimes reviewed when steam loads change	
C	Pipe sizes are never reviewed when steam loads change	

8) Steam Leaks to Atmosphere from Pipework and Equipment

A	All leaks that occur around the steam system are attended to promptly	
B	A small number of steam leaks exist around the system	
C	A large number of steam leaks exist around the system	

End Use

9) Zoning Control

A	All steam using areas can be isolated individually to allow for varying shift working patterns	
B	Zoning control is only available to major steam using areas	
C	The entire steam system is either hot or cold	
D	The use of steam is such that all steam using areas always operate simultaneously	

10) Temperature/Pressure Control of Processes

A	Most processes are automatically controlled	
B	Some processes are automatically controlled	
C	Most processes are manually controlled	

11) Process Plant

A	Control of steam usage is related to production throughput	
B	Some steam plant is isolated when not in use	
C	Most plant is kept warm even when not in use	

12) Metering

A	Steam metering equipment is used extensively and forms the basis of a comprehensive Monitoring and Targeting programme	
B	The majority of steam plant is metered but the data could be better used	
C	Little or no steam metering is employed	

13) Steam Trap Performance Monitoring

A	An electronic continuous steam trap monitoring system is in operation	
B	Steam trap performance is checked at least annually	
C	Steam trap performance is rarely or never checked	

14) Condensate Usage

A	Nearly all condensate is returned to the boilerhouse as feedwater	
B	Some condensate is returned to the boilerhouse	
C	Little condensate is returned to the boilerhouse	

15) Flash Steam

A	The majority of flash steam is recovered	
B	Some flash steam is recovered	
C	Very little flash steam is recovered	
D	Steam is used at low pressure so a limited amount of flash steam is produced, and/or there exists no obvious use for flash steam	

Scoring

Each answer corresponds to a score: A = 3
B = 2
C = 1
D = 3

Assessment

Score	**Verdict**
35 - 45	Congratulations! You are benefiting from the investment that has obviously gone into your system. Continuing awareness and practice of energy efficiency measures should sustain the high performance levels that are currently being achieved.
25 - 34	Room for improvement! Your steam system is operating at what must be called an ‘industry average’. There still exists a large number of areas for improvement through investment in heat recovery systems, Monitoring and Targeting programmes or automatic monitoring and control equipment. Medium-term payback periods on the majority of your investment opportunities cannot afford to be missed.
Less than 25	Don’t be disheartened! Your steam system appears to need attention. A greater awareness of energy efficiency measures and some low-cost investments in your system will yield surprisingly rapid paybacks. Remember that investment in an existing system is much more cost-effective than starting again with a different system.

Fig 8 Steam system health check
(printed with the permission of Spirax-Sarco Limited)

However your system fared in this short health check, now is the ideal opportunity to call on the experts in all aspects of steam system design, operation and maintenance. A more detailed review of the major weaknesses identified in this health check could be the next step.

4.3 Leaks

Check the cost of leaks by measuring the length of the steam plume (see Fig 9).

Length of plume (metres)	Steam loss (kg/hour)
0.3	5
0.5	7
1.0	9
1.5	16
2.0	104
2.5	263

Evaluation

Annual operation	Hours	A . . . . .
Boiler fuel cost	pence/kWh	B. . . . .
Steam plume length	kg/hour	C. . . . .
Annual cost of leak = $\frac{\text{A x B x C}}{9.72}$	£	

Indications are for 10 bar steam pressure

Fig 9 Gauge the cost of leaks

4.4 Monitoring and Targeting

Three measurements are essential for steam systems:

- fuel - to measure the major energy input to the boiler plant;
- feedwater - to provide data to allow the calculation of a minor energy input to the boiler plant;
- steam - to provide data on the major energy output from the boiler plant.

If the values of these inputs are known, the overall plant efficiency can be calculated:

$$= \frac{\text{Heat in steam - Heat in feedwater}}{\text{Heat in fuel}}$$

(Aim to achieve 75% or better.)

Blowdown will be dictated by the quality of boiler feedwater, and will influence the efficiency figure. If, however, there is heat recovery from blowdown the change in plant efficiency will be insignificant.

Consider electricity use as part of overall energy efficiency (i.e. include pumping and ancillaries for steam generation), although it is common practice to use just fuel.

Suggested methods for measuring electricity use are:

- kWh/litre fuel;
- kWh/tonne steam;
- kWh/m^3 feedwater.

All these ratios highlight a change in performance. Figures can be calculated based on manufacturers' design data for pumps and fans, not just for boilers but also for auxiliary water treatment, fuel transfer etc. Target figures need to be assessed for individual boiler plants and take into account plant type and age. Large sites may justify steam metering to specific business areas or even to specific processes, e.g. compounding, moulding and curing.

A feedwater meter is particularly important, providing a check on water mass flow through the boiler, since: feedwater (kg) = steam output (kg) + blowdown (kg)

As blowdown quantity is usually small and a constant proportion of feedwater input, this relationship can be used to cross-check the main steam meter.

4.5 Saving Opportunities

4.5.1 *Fuel Preparation Savings*

Heavy fuel oil tank and line insulation. These systems are heated constantly and insulation will usually have a payback period of about two years. Some users experience the formation of an oil layer or skin on the inside of a tank which provides some insulation effect, so it is recommended that tank surface temperatures are checked and calculations made of the value of the heat loss.

Heavy fuel oil temperature control. With some older oil circulation systems, excess oil is returned to the storage tank at a higher temperature than normal oil storage temperatures. Oil at the upper levels of the tank can then be held at a higher temperature than necessary, thus causing higher tank losses. Excess oil should not be returned to the tank but should if possible be returned to the suction of the local circulation pump.

Oil heating by steam. Oil heating systems often use steam (or hot water) with electricity as a standby. Lock settings on thermostats in position to ensure electricity is used only as a standby.

Gas oil standby to gas. Storing gas oil as a standby to gas as boiler fuel can save energy and costs, as the costs of heating and pumping heavy fuel oil are avoided. This is particularly relevant to manufacturing sites that work five days a week for three shifts or fewer when electric heating of heavy oil systems may become operative. On the downside, gas oil storage incurs costs for tank cleaning (due to microbe growth) and has a higher basic fuel cost.

4.5.2 *Fuel Combustion Savings*

Fuel to air ratio control. Excess air is needed to ensure complete combustion. Many systems for controlling excess air levels depend on mechanical linkages between fuel and air flow control equipment. These systems are frequently set up to use more excess air than necessary to avoid poor combustion as linkage settings alter with wear and vibration. Oxygen trim systems avoid these problems, showing savings of 1% when compared with an optimally set burner. In reality, few manually-trimmed burners can be maintained in optimum condition without regular attention between normal service intervals and automatic oxygen trim could add savings of between 1 and 3% of fuel usage.

In its simplest form an oxygen trim system will measure oxygen content in the boiler exhaust gas using a zirconium cell; it then adjusts the air flow to a setting according to the position of the fuel flow control device. More sophisticated systems have self-learning capabilities to optimise excess air levels and control combustion air flow using a variable speed drive on the air supply fan (see Section 12.2). Payback will be shorter for large boilers, and maintenance costs should be carefully considered as part of the investment case.

Computer controlled boilers save 800,000 kWh/year

A food company installed advanced microprocessor control for its boilers to obtain optimum efficiency. The control installed was for small to medium-sized boilers, with a potential range of 10 to 60,000 lb steam/hour. The company achieved energy savings of around 800,000 kWh/year for an investment of £3,000, giving a payback period of 1.2 years.

Water injection. These systems are believed to make savings but the benefit is difficult to quantify, as measurements prior to installation were probably made on the burner in a poorly adjusted state. Various types of system are available using water atomisation and injection into combustion air to improve combustion and claim reduced excess air levels and cleaner fireside heat transfer surfaces as well as reduced NO_x emissions. Although the mechanism by which these systems work is not completely understood, benefits are possible and investigation is recommended.

Combustion air pre-heat. The conventional method of pre-heating combustion air is heat exchanging with the hot exhaust gases. An alternative way to improve boiler efficiency is by ducting combustion inlet air from high level in the boiler house using the temperature gradient to allow temperatures of 10 - 20°C above ambient to be obtained. **The estimated saving is 1% for a 20°C temperature lift.**

4.5.3 *Heat Exchange Savings*

Boiler scheduling. Operating a multi-boiler installation so that boilers are always well loaded (above 50%), avoids inefficiencies due to standing losses and boiler purging. It is essential to be able to isolate boilers that are not in use to avoid ventilation losses. Some large plants have management systems that predict heat demand, but the same result can be achieved manually. Boilers should be shut down if the total load, including peaks and troughs, can be handled by fewer boilers. Savings will depend upon the load change but could be in the range 2 - 5%.

Heat exchange. Build-up of deposits on the heat transfer surfaces, particularly of coal-fired boilers, results in efficiency losses because exhaust temperatures are higher than with clean surfaces. Vibration at the infra and ultra frequency levels reduces this type of fouling, saving around 1% of fuel. This technique is likely to be viable only on larger coal-fired plants.

Isolation dampers. Fit dampers into boiler exhausts, or build them into combustion air/burner systems to avoid ventilation losses. Plants that have economisers may already have flue gas dampers that could be automated. Note: Damper operation must be built into the firing control system for safety reasons.

Heat recovery from flue gas. There are three methods of heat recovery from flue gas:

- recirculation of exhaust gas (gas and oil);
- indirect recovery using a heat exchanger (gas);
- direct recovery using sprayed water into the exhaust from a gas-fired boiler.

Recirculation

Gas recirculation is currently used mainly to reduce NO_x emissions in fluid-fired boilers, with higher boiler efficiency being a secondary, but valuable, additional benefit. Since furnace tube sizes need to be larger and extra convection heat exchange surface is needed to cool the recirculating gas, this option can only be considered in new plant. The cost premium for the new design may be partially off-set by the improved energy efficiency of the system. Careful analysis of manufacturers' data and usage requirements is recommended.

Indirect Heat Recovery

Indirect heat recovery is perhaps the most common system, and is usually applied to packaged gas-fired boilers. Designs are available for oil-fired boilers, but because of the corrosive conditions produced when sulphur dioxide from oil exhaust gases is cooled/condensed, construction materials are expensive and equipment capital cost is high. It is possible that large, well-loaded oil-fired plant could generate sufficient savings to justify heat recovery. Usually where a plant is dual-fuelled, recovery units are installed with a by-pass arrangement for oil-firing where these units cannot withstand the corrosive conditions.

In the case of packaged gas-fired boilers, run-around coils, shell and finned tube-type heat exchangers are generally used to recover heat from the exhaust. Savings of up to 4% of fuel fired are available. Heat is usually recovered into boiler feedwater on the pressurised side of the boiler feed pump.

Direct Heat Recovery

Heat recovery through direct contact between exhaust gases and water may be viable in some large tyre plants. Spray recuperators can produce quantities of warm/hot water in a closed loop system in the temperature range 30 - 50°C, the end-point temperature being dictated by the energy balance for the system. A mixture of direct and indirect heat exchange systems may be justified on large plants where higher end-point temperatures of about 120°C could be possible, again dependent on the energy balance.

Consider this type of opportunity for heat recovery in large tyre plants at the same time as heat recovery from exhausts on tyre moulding and curing plant. In the latter case, heat is recovered essentially from steam/vapour and equipment could therefore be more compact and possibly less expensive per unit of heat recovered.

4.5.4 *Feedwater Savings*

Blowdown heat recovery. Water at temperatures equal to that in the boiler is purged from the boiler to control TDS levels. Flashing the water at low pressure (0.2 - 0.5 bar g) allows clean flash steam to be recovered directly into the feedwater storage tank, while residual hot water is heat exchanged with cold incoming make-up boiler feedwater.

Moulding plant heat recovery. A significant quantity of steam is used in ‘bag-o-matic’ presses in the tyre industry and for autoclaving in rubber processing plants. For heat recovery from the exhaust of these moulds a regular flow of waste heat is needed. Flow rates vary significantly and viability is dependent on the heat available.

Waste heat recovery brings large space heating savings

A rubber processing company introduced waste heat recovery from vent steam by spray condenser, which was transferred to the factory heating system via a heat exchanger. The system heats the factory for nine months of the year. The system cost £51,000 and paid for itself in savings in less than one year.

4.5.5 *Distribution Savings*

Line rationalisation. Optimising steam supply systems will reduce standing losses. Review demands in conjunction with line diagrams of the steam distribution and condensate return system for this updating process.

Line utilisation control. Optimising line usage through the use of slow-opening/closing automatic valves is viable for the larger rubber processing sites or tyre sites where operation is intermittent. These valves need to be linked to central or local control units depending on the size of the site, i.e. consider whether a building management system is needed.

Line pressure control. Sites with a variety of operations working in different shift patterns will cause pressure at the extremity of the system to vary significantly due to pressure loss changes. In this situation, varing the boiler pressure in response to the pressure at the most sensitive part of the system will increase boiler and steam distribution system efficiencies.

Trap maintenance. In general, resources limit the attention which can be paid to steam trap operation to an annual overhaul. However, severe problems need to be identified by checking for steam plumes from condensate receivers that are ‘forced’ rather than ‘lazy’, and should be attended to as soon as possible. More sophisticated systems are available to check steam trap conditions, using central monitoring. Alternatively portable equipment can be used for spot checks on individual traps.

Condensate/flash steam recovery. By recovering as much condensate as possible, savings are made in energy, water, water treatment and effluent costs. Apart from condensate that is available at relatively great distances from the boiler house (say 500 m as an upper limit), most condensate is generally worth returning, although each case must be considered separately. Flash steam is more difficult to recover economically and usually depends on considerations at the design stage of a project. Heating boiler feedwater and combustion air will improve overall boiler efficiency. Recovered heat may also be used for space heating in low temperature hot water or low pressure steam systems.

HPHW flow and pressure control. Two factors influence the demand conditions (flow rate and pressure) for hot water in space heating systems:

- space heater design;
- method of space temperature control.

A heater has an in-built pressure drop that is set by the equipment designer. Since most units are off-the-shelf, the system designer only has the option to oversize the system to decrease pressure drop. However, because there is a square law relationship between pressure drop and flow rate and because most systems are over-designed, spare capacity does exist and, if used, can significantly affect pressure drop.

Space temperature can be controlled by varying convective heater fan speeds (rare) or by varying the flow of hot water to any type of heater. Two-way modulating valves are preferred to allow variations in flow rate, or on/off control, but not three-way valves that maintain constant flow rates. When flow rates vary, Variable Speed Drives (VSDs) can be applied to booster pumps in the system to maintain the required system pressure.

Savings ideas for line insulation are covered in Section 11, and variable speed control of boiler feed pumps is covered in Section 12. Fig 10 summarises the above savings opportunities.

The following free publications describe how to save energy through more efficient use of steam. They are available from the Environment and Energy Helpline on 0800 585794.

GPG 30 *Energy efficient operation of industrial boiler plant*.
GPG 197 *Energy efficient heat distribution*.

Area	**Measure**	**Payback**
Boiler plant	Minimise boiler operating time.	I
	Minimise boiler pressure.	I
	Optimise the number of boilers operating, if necessary using steam management methods.	I
	Keep boiler tubes as clean as possible, particularly if using liquid and solid fuels.	S
	Ensure all hot equipment on boiler/auxiliary plant is properly insulated.	S/M
	Minimise system use by matching supply to demand through the use of steam management systems.	I
Fuel prep. (oil)	Insulate tanks and supply lines.	S/M
	Minimise fuel storage temperatures.	I
	Consider gas oil as standby fuel rather than HFO. Avoid pumping and heating costs. This is particularly relevant to five-day operations.	
Combustion	Optimise fuel-to-air ratio control, control of oxygen level (oxygen trim).	M
	Variable speed control of combustion air fans (see Motors and Drives - Section 12).	M
	Pre-heating of combustion air above ambient improves combustion efficiency.	M
Heat exchange	If operating a multi boiler system, ensure above 50% load on each firing boiler and isolate boilers not in use. Standing and purging losses can be avoided.	I
	Fit economiser to heat boiler feed water.	M
	Recover heat from flue gases via heat exchanger to preheat combustion air, boiler feedwater.	M/L
	Fit heat exchanger to recover heat from blowdown.	M
Feed water	Control blowdown to measured total dissolved solids (TDS) either manually or automatically.	I/S
	Variable speed control of feedwater pumps (see Motors and Drives - Section 12).	M
Distribution	Review distribution system and remove or isolate redundant lines.	I/S
	Make sure all lines are adequately insulated.	M
	Reduce line pressure where possible.	I
	Check steam traps (see Health Check Fig 8).	I
	Make sure all condensate is returned to boiler house.	M
Production	Recover heat from curing press vents with spray water condenser.	M

Key: I = immediate, S = short-term, M = medium-term, L = long-term.

Fig 10 Areas for savings in steam and hot water systems

5. HIGH PRESSURE HOT WATER

High pressure hot water (HPHW) systems are used in the tyre manufacturing process for moulding and curing.

5.1 Plant and Equipment

The systems are pressurised by constantly operating pumps and the water is heated by steam in large expansion reservoirs. Boilers can also be used to generate HPHW and these are similar to those for steam boiler plants. The HPHW operation and maintenance tips are similar to those for steam, (see Section 4.1.4).

5.2 Monitoring and Targeting

Heat meters can provide output information where generators are used or where steam/hot water heat exchangers are used to provide HPHW. For hot water boilers, efficiency calculations are more simple than those for steam systems. However, an overall boiler plant efficiency target of 75% should be used for both.

HPHW supply requires more electricity (for pumping) than do steam heating systems and it is necessary to check usage in terms of total energy, i.e. kWh (electricity) + kWh (heat) and total energy (kWh/hour of system operation).

Total electricity usage should cover fans and pumps (boiler or heat exchange circulation and any booster pumps in the circuit).

The savings opportunities are the same as those for steam (see Section 4.5).

6. COOLING SYSTEMS

Cooling is required to remove process heat from rubber and represents almost 2% of all electricity usage in the rubber industry. Heat is generated during compound mixing, milling and extruding.

During the mixing/milling process, cooling is applied to the chamber walls on the inside of both the rotors in the mixer and the drums in mills. The extrusion process requires cooling of the extrusion tool and subsequent cooling of the extrudate.

6.1 Plant and Equipment

Cooling water is usually provided by a recirculating water system. Warm water returns to a cooling system, has heat removed and is then returned to the process.

Most rubber processing facilities use wet cooling tower systems where warm water returning from the process is cooled by direct contact with the air. Evaporation is fundamental to the cooling performance of this type of tower and can only occur at the surface of the water. The warm water is distributed by spray nozzles over a packing material inside the tower.

A good distribution of water over the cooling tower and the evaporation of a relatively small amount of water (approximately 3 kg/kW of heat rejected) contribute to 80% of the cooling load. The remaining 20% is achieved by sensible heat transfer to the ambient air.

Water can be only be cooled to 4 - 6°C higher than the wet bulb temperature of the entering air. The temperature difference between water entering and leaving ranges from 3.5 - 11°C depending on the application.

Dry coolers are rarely used in the rubber processing industry so they are not covered in this Guide.

6.2 Operation and Maintenance

Water distribution in the cooling tower. It is important that re-circulated water is evenly distributed over the entire cooling tower packing and that the packing is correctly stacked and undamaged.

Air distribution. Air inlet louvres should remain free of obstructions to allow air to pass through the packing. The tower-fill should also be free of obstructions and must be thoroughly cleaned periodically to ensure correct air and water distribution.

Water temperature control. During periods of reduced process load or when ambient temperatures are low, the cooling tower circulation fan can be cycled on/off according to the cooling water temperature required. Check the thermostat sensing the pond temperature is working correctly and its set point is correct. Avoid short cycling of the fan and long off periods. Short cycling causes excessive ‘wear and tear’ on the fan drive system and is less energy efficient, while excessively long cycles allow water temperatures to rise above the maximum process requirement.

Water treatment. As the recirculating water comes into contact with a heated surface, a proportion of the water evaporates. Depending on the water hardness, solids are deposited on the heated surfaces. This build-up reduces the effectiveness of heat transfer resulting in increased energy consumption. Treat water to prevent build-up of solids and microbial growths such as Legionella. Older wooden cooling towers will be more difficult to treat in this respect.

Trace heating can be used to prevent freezing of exposed pipes. Trace heating and sump immersion heaters should be temperature controlled **so that they do not operate unless dictated by weather conditions.**

Control is necessary to ensure the correct temperature for the process; poor control will affect product quality and lead to high energy consumption. Cooling operation should coincide with hours of production as unnecessary operation adds to high energy usage. When cooling water is fed to a refrigeration plant providing chilled water, temperatures should be as low as possible. Chilled water is increasingly being applied to mixer cooling circuits.

6.3 Monitoring and Targeting

Measuring key parameters allows simple comparisons to be made of typical values for cooling tower performance. Monitor energy usage against set targets, but remember to take into account the relevant variables.

Electrical consumption (kWh) gives the total energy consumed by the cooling tower system over a period of time. Multiply this by the average electricity unit cost to find the utility running costs. These costs will vary according to production levels and weather conditions.

Hours run/production hours checks if the utility has been operating longer than necessary.

Cooling water flow and return temperatures allow the calculation of cooling tower duty and range.

Pressure (cooling water). Pressure gauges at the inlet and the outlet of the cooling water circulating pumps allow the total pressure developed by the pump or pumps to be determined. This pressure can then be checked against the pump curves to give the flow rate of the pump. The pump efficiency can be checked by closing the pump discharge valve and relating the total developed pressure to zero flow on the pump curve. If the developed pressure is less than that shown on the pump curves, an overhaul may be required.

Dry bulb/wet bulb temperature. Measure the air temperatures to allow comparison of the cooling performance with manufacturers' data.

Production volumes. The amount of cooling required will vary with the level of production. By collecting the above data it is possible to make the following calculations/comparisons:

$$\text{Cooling tower duty } Q = m\,Cp\Delta T\ [\text{kW}]$$

Where:

Q = cooling done to water [kW]　　　m = water flow rate [kg/s]
Cp = specific heat of water 4.18 [kJ/kg]
ΔT = return water temperature - flow water temperature

$$\text{Cooling tower range} = \text{return water temperature} - \text{flow water temperature}$$

$$\text{Cooling tower approach} = \text{wet bulb temperature} - \text{flow water temp } (\Delta T)$$

The information gained will allow you to compare your cooling tower performance with manufacturers' published data. This check is best carried out when a high cooling load coincides with a high wet bulb temperature. If there is a deviation from manufacturers' data, investigate the condition of the tower packing and water distribution over the tower packing.

A chart of kWh vs production volumes can be produced using 12 months' rolling figures. This graph can highlight excessive consumption as a result of poor time/temperature control settings or operation but it should be noted that low production volumes are the biggest contributors to poor figures.

6.4 Saving Opportunities

6.4.1 *Fans*

Temperature control. Cooling towers and dry coolers are designed/selected to achieve a specified amount of cooling at a maximum design dry bulb/wet bulb temperature. In reality, these conditions only exist for a small part of the year so for most of the year fans can be cycled on/off according to water temperature. This creates an excellent opportunity for saving.

Step-controller increases energy savings and throughput

A step-controller was fitted to three cooling tower fans linked to a temperature sensor in supply water at a chemical company. This measure increased throughput and energy savings by eliminating intermittent operation and cost £4,600 to install. Payback period was 1.5 years.

6.4.2 *Pumps*

Pumps are selected to deliver a flow rate to meet the maximum cooling requirement of the process overcoming the distribution pipework resistance. Design safety factors are often applied to both the cooling requirement and the pipework resistance, resulting in an oversized pump and motor. This in effect has the motor running at low load and operating at typically 50% efficiency instead of 70%. Pumped volumes can be matched to demand by:

- pump sequencing;
- 2-speed single pump;
- VSD to single pump.

Variable speed drives (VSDs) should be considered for motors over 10 kW (for savings opportunities see Section 12.4). Combinations of the three options above can be used, e.g. for a set of pumps, the lead pump could have a VSD and the others could be sequenced to maintain a system pressure.

6.4.3 *Distribution*

Few energy-saving opportunities exist in the distribution of cooling water.

- Deliver cooling water at the highest possible temperature for the process. Examine separate ‘chilled’ supplies for small users requiring lower temperatures.
- Insulate pipes running through high temperature areas to prevent heat gains, e.g. above autoclaves or where they run parallel with steam pipes.

6.4.4 *Process*

Opportunities for energy saving at user level are mainly related to varying production levels and production times. Cooling water to processes must be controlled if savings are to be made.

Cooling water upgrade increases energy savings and throughput

Upgrading a cooling water system (at a cost of £10,000) allowed four mills and one banbury mixer at a rubber processing company to operate together at full rate during summer conditions. The benefits included increased throughput and energy savings through elimination of intermittent operation.

Local thermostatic controls can be fitted to mixer/blenders to monitor the cooling demand at each appliance and adjust the cooling water flowrate to demand.

Isolate cooling water. Prevent cooling water flow to appliances when they are not in use, either manually or with solenoid valves installed in the cooling water pipework to each appliance. These valves should be electrically interlocked with the respective control circuit. A run-on timer to maintain operation of the cooling circuit may be installed to ensure removal of residual heat. The viability of isolating cooling water depends on the number of appliances.

Time control. Fit automatic shutdown of ancillaries with timers which run on after the main plant stops. This would also include an overrun to remove residual heat.

The savings opportunities for cooling water are summarised in Fig 11.

Section	**Measure**	**Payback**
Fans	Reduce operating times.	I
	Control water temperatures.	S
	Fit variable speed controls.	M
Pumps	Sequence pumping controls to match delivery pressure and flow rate.	M/L
	Fit variable speed controls.	M
Distribution	Operate cooling water at the highest possible temperature (except where cooling water is supplied to refrigerant condensers).	I
	Insulate pipes to prevent heat gains.	L
Process	Fit solenoid valves in pipework and electrically interlock.	L
	Fit timer to shut off ancillary equipment.	M/L

Key: I = immediate, S = short-term, M = medium-term, L = long-term.

Fig 11 Summary of energy-saving measures for cooling systems

The following free publications describe the efficient use of cooling systems. They are available from the Environment and Energy Helpline on 0800 585794.

GPG 170 *Reduced water pumping costs in the steel industry*.
GPG 225 *Industrial cooling water systems.*

7. CHILLED WATER

Chilling accounts for just 1% of overall utility energy consumption in the rubber processing industry, but this figure is increasing.

Chilled water can be maintained at a constant temperature all year round, whereas cooling water from cooling towers or dry coolers can vary between 10 - 30°C during the year. For this reason, chilled water is beneficial for some processes such as mixing.

Typical chilled water temperatures suitable for most rubber processing are 6°C flow/10°C return. Chilling requires a refrigeration system and most, if not all, is carried out by vapour compression systems.

The plant items can vary in type but operating principles remain the same, incorporating a closed system with the refrigerant fluid contained at all times. In the rubber industry, the chilling requirement is usually quite small and the duties are mostly served by factory-assembled packaged units.

7.1 Operation and Maintenance

Monitor system refrigerant pressures (see also Section 6.3) as this could highlight refrigerant leakage, among other conditions that affect operational efficiency. Loss of refrigerant results in a total loss of cooling but only a slight reduction in power consumed by the compressor.

The **condenser heat exchange surface** must be kept clean. A dirty air-cooled condenser affects plant efficiency in two ways. Firstly, the compressor absorbs more power at higher condensing temperatures, and secondly, condenser fans consume more electricity because they operate for longer periods. Similarly water-cooled condensers must be kept clean and free of fouling.

Water temperature controls. It is important that the control thermostat is operating correctly, that the sensing bulb is in the correct location, away from extraneous heat sources. If the set point is too low it will cause the refrigeration system to run for longer and less efficiently.

7.2 Monitoring and Targeting

Follow the same parameters as detailed for cooling water above (see Section 6.3).

7.3 Saving Opportunities

Minimise demand for chilling. Use cooling water where possible. If the process requires cooling over a wide temperature range to a final temperature below that of cooling water temperature, then cooling water can be used for the upper part of the range and chilling for the lower part to minimise the chilling load.

Refrigeration system. Low condensing pressure coupled with high evaporating pressure offers the most efficient conditions for a refrigeration system. Evaporative condensers give lower condensing pressures than air-cooled condensers and should be used where possible. Condensing pressures should be allowed to fall as the ambient temperature falls, to a level that can still operate the expansion device. Electronic expansion valves allow ‘floating’ head pressure on a system which gives the biggest savings in compressor power (in the region of 20 - 30%).

Distribution. The chiller must have a constant flow rate through the heat exchanger part to prevent water freezing. Pump control is therefore not straightforward.

Use. The savings opportunities are as previously described for cooling systems (see Section 6.4).

Fig 12 gives a list of energy-saving measures for chilled water systems.

Measure	**Payback**
Maintain the highest possible chilled water temperatures.	S
Maintain evaporating pressure as high as is feasible.	S
Maintain condensing pressure as low as is feasible.	S
Minimise system operating time.	S
Maximise compressor loading in multi-compressor installations.	S
Optimise pump operations as for cooling water.	S/M
Consider utilising condenser heat.	S/M
Fit VSDs to secondary chiller water pumps with local temperature control at appliances.	M
Minimise system operating time.	S
Ensure insulation with a sound water barrier is provided on all cold surfaces.	S/M
Optimise compressor loading in multi compressor installations.	S/M
Operate chilled water at highest possible temperature.	S
Interlock chilled water supply with operation of appliance (eg. mixer).	M
Consider heat recovery by re-utilising condenser heat.	L

Key: S = short-term, M = medium-term, L = long-term.

Fig 12 Recommended energy-saving measures for chilled water systems

The following free publications decribe more energy-saving ideas from chilled water. They are available from the Environment and Energy Helpline on 0800 585794.

GPG 59 *Energy efficient selection and operation of refrigeration compressors.*
GPG 236 *Cut the cost of running your refrigeration plant.*

8. HYDRAULICS

Hydraulic systems account for 2% of the total electrical energy used in the rubber processing industry, forming part of the main process equipment used in the industry. Small individual machines and larger centralised units are both used.

Hydraulic systems are used mainly to operate hydraulic presses for rubber curing. Often two hydraulic systems are used: 30 - 40 bar hydraulic fluid for press closure, and about 200 bar on the press piston. The resulting pressure in the mould is usually 35 to 100 bar, which is necessary to exclude air bubbles and achieve accurate moulding.

8.1 Plant and Equipment

Pumps create a flow of fluid, although not pressure (other than that needed to overcome the resistance to flow in the circuit). There are two groups of pumps - non-positive displacement and positive displacement. Table 1 summarises of the efficiencies of hydraulic pumps.

- The use of non-positive displacement pumps (typically centrifugal) in power hydraulic circuits boosts the supply to the main positive displacement pump.
- Positive displacement pumps are the main pumps in hydraulic circuits. The two major categories are rotary and reciprocating.

Table 1 Efficiency ranges of hydraulic pumps

Pump type	Volumetric efficiency (%)	Overall efficiency (%)
Positive displacement		
Piston:		
Plunger	99	95
Radial	95	90
Axial	95	90
Non-positive displacement		
Precision gear pump	95	90
Vane pump	90	80

Hydraulic accumulators are devices for storing energy in the form of hydraulic fluid under pressure. They act as buffer vessels and provide a high flow rate of fluid over a short period of time. A pump with a low delivery rate can be used to charge the accumulator over a long period of time. Accumulators also dampen delivery pulsations and pressure surges in the circuit.

8.2 Operation and Maintenance

Hydraulic pumps. Lack of maintenance accounts for most efficiency problems with reciprocating pumps. The efficiency of rotary and screw pumps does not deteriorate quite so rapidly.

System cleanliness. About 80% of all breakdowns in hydraulic systems can be directly or indirectly attributed to fluid contamination. Efficiency can be severely affected by increased pressure drop through filters. Carry out regular checks at sampling points built into the system in lines where there is relatively constant flow. Valves with very large pressure drops allow sampling to atmosphere with low fluid velocity. Analyse contamination by particle count or chemical analysis. Clean oil to reduce breakdowns using an in-circuit cleaning filter, or by hiring or buying a portable filter pump unit.

Hydraulic circuit leaks. Hydraulic fluid leakage occurs both internally and externally. Excessive internal leaks reduce system efficiency and generate heat, causing deterioration of fluids. Some internal leakage is designed for component lubrication although wear leads to excessive internal leaks which reduce system efficiency. Checks should be made during regular maintenance. External leaks are not only messy but are often hazardous and costly because of lost fluid replacement. Vibration, mechanical knocks and hydraulic shocks cause leaks as a result of loosened fittings and components, fatigue of pipes and wear between touching parts. Leaks occur through seal deterioration, due to excessive temperatures and/or contaminated fluid.

8.3 Monitoring and Targeting

The instrumentation requirements and monitoring for a hydraulic system are similar to those for a compressed air system. Large systems could benefit from the inclusion of a fluid flow meter, which would allow a chart of kWh/week against m^3 to be prepared, as for a compressed air system.

8.4 Saving Opportunities

Good maintenance is responsible for the major energy savings for this utility (see Fig 13 and also Section 3.6).

Area	Measure	Payback
Hydraulics	Minimise plant operating time.	S
	Avoid no-load operations.	S
	Optimise the number of pumps operating.	S/M
	If feasible, separate different pressure systems.	S/M

Key: S = short-term, M = medium-term.

Fig 13 Recommended energy-saving measures for hydraulics

9. COMPRESSED AIR

Compressed air systems account for almost 4% of the total electrical energy used by rubber processors.

One of the main uses for compressed air is to power the rams on the mixers; other users are fluidised beds for powder transfer, automatic weighing stations and for control air. Compressed air is used at pressures between 3 bar g and 15 bar g, but is always generated at the highest pressure required in the plant.

The most popular compressors are reciprocating and screw compressors with auxiliary equipment being used to provide dry and oil-free qualities. Generally, a ring main is the most effective method of supplying compressed air to a point of use.

9.1 Operation and Maintenance

The following is a summary of maintenance matters that can affect the efficient operation of compressed air systems.

Compressors. Lack of maintenance significantly affects the efficiency of reciprocating piston compressors, particularly the oil-free type. **Typical deterioration is between 10 and 12.5%.**

Air treatment. Excessive pressure drop through the dryers/filters wastes energy. Check pressure drops across such components regularly and replace filters as required.

Distribution system. Carry out routine surveys to find any sources of leaks. Good places to look for leaks are:

- Condensate traps - check they are functioning correctly. Automatic drain traps are not always reliable. Modern, electronically operated condensate traps are very reliable. (See GPCS 369 *Compressed air leakage reduction through the use of electronic condensate drain traps.*)
- Pipework - ageing pipework is a prime source of leaks. Replacement of corroded pipework will not only improve the system but also improve system safety.
- Fittings and flanges – leaks here are frequently caused by pipe strain due to inadequate supports, inadequate joints or twisting.
- Flexible hoses – hoses are used to make connections between the rigid pipe network and points of use. Leaks can be caused by abrasion, deterioration (e.g. heat sources) or sudden mechanical impact.

To evaluate leakage, run the compressor plant with all consuming plant and equipment shut down. You may be surprised at your findings. To assess the cost of individual leaks, see Fig 14.

Gauge the cost of leaks by assessing the leak diameter.

Diameter of leak (mm)	Loss volume (m^3/min)	Loss power (kW)
1	0.075	0.6
2	0.260	2.0
3	0.600	4.4
4	1.100	8.8
5	1.700	13.2

Evaluation

Annual operation	Hours	A . . . . .
Electricity cost	Pence/kWh	B. . . . .
Power loss for leak diameter	kg/hour	C. . . . .
Annual cost of leak = $\frac{\text{A x B x C}}{100}$	£	

Indication is for 10 bar air pressure

Fig 14 Assessing compressed air leak costs

9.1.1 *Dryers*

Ambient air typically contains 12.5 g of water per 1 m^3 of free saturated air at 15°C. The rise in air temperature in the compressor prevents condensation, but when air passes through an after-cooler a large amount of water condenses. Some water remains as vapour, but if the air temperature falls below its starting temperature (i.e. 15°C) there will be further condensation.

There are many different types of dryer available to remove moisture (see Table 2 for classification):

- desiccant dryers (Class 1.1.1 quality air);
- sorption dryers (Class 2.3.1 quality air);
- deliquescent (absorption) dryers;
- refrigeration dryers (Class 4.4.5 quality air).

Cool, clean, dry intake air will lead to more efficient compression. Outside air should be used wherever possible (see Table 3). **For every 4°C drop in intake temperature there is a 1% increase in efficiency.**

Table 2 Air quality classification ISO/DIS 85731

Quality (class)	**Dirt (particle size) (microns)**	**Water (pressure dewpoint) 0°C (ppm vol) at 7 bar g**	**Oil (including vapour) (mg/m^3)**
1	0.1	-70 (0.3)	0.01
2	1	-40 (16)	0.1
3	5	-20 (128)	1
4	40	+3 (940)	5
5	–	+7 (1,240)	25
6	–	+10 (1,500)	–

Table 3 Recommended standards (guidance)

Application classes	**Typical quality classes**		
	Oil	**Dirt**	**Water**
Air agitation	3	5	3
Air bearings	2	2	3
Air gauging	2	3	3
Airmotors	4	4-1	5
Cleaning of machine parts	4	4	4
Conveying, granular products	3	4	3
Conveying, powder products	2	3	2
Fluidics, power circuits	4	4	4
Fluidics, sensors	2	2-1	2
Hand-operated air tools	4	5-4	5-4
Machine tools	4	3	5
Pneumatic cylinders	3	3	5
Pneumatic tools	4	4	4
Process control instruments	2	2	3
Paint spraying	3	3	3
Welding machines	4	4	5
General workshop air	4	4	5

Regulation of compressor output may be achieved by the following methods:

- constant speed cylinder unloading;
- constant speed inlet throttle valves;
- stop/start control;
- variable speed control.

Various forms of automatic sequencing control exist for optimising the operation of multiple compressor systems. Operation of compressors can be rotated to equalise wear.

9.2 Monitoring and Targeting

As with the other utilities, sufficient instrumentation is required in order to determine how well a compressed air system is operating. As a minimum, use:

- A kWh meter - this will give the total energy consumed by the compressed air system. Knowing the unit cost of electricity, kWh can easily be converted into a running cost. The energy consumed will vary according to production levels and, to a lesser degree, weather conditions.
- Hours run/production hours - this highlights if the utility has been operating longer than necessary. It is advisable to have total hours run as well as hours run on load, to enable the cycle frequency to be monitored and the system to be maintained at the optimum control settings.
- Temperature - air temperature gauges at the outlet of the compressor and in the receiver will help detect any fouling of the after-cooler heat exchanger.

- Pressure **-** pressure gauges on the receiver and at selected points along the distribution system provide a pressure profile across the site.
- Airflow **-** if it can be justified financially, install an air flow meter to provide valuable information for managing compressed air costs.

With the data available you can calculate the following:

$$\text{Average compressor capacity [litres/sec]} = \frac{\text{Air flow m}^3}{\text{Time on load (seconds) x 1,000}}$$

This allows an approximate performance check against manufacturers' data.

The chart for kWh versus air flow (m^3) can easily be plotted and will allow the specific energy consumption figure to be calculated: kWh/m^3 or it may be expressed as £/m^3.

The weekly/monthly specific energy consumption figures can then be plotted using CUSUM to highlight upward/downward trends in energy consumption.

9.3 Saving Opportunities

9.3.1 *Generation*

Pressure setting. The compressed air system may be running at higher pressure levels than actually required at the point of use. Air should be generated at the lowest possible pressures, allowing for line losses at peak demand. The result is lower line losses and 7% generation energy saved for every bar reduction. Some applications may require air at a lower pressure than the main system and if a separate system cannot be installed, use a pressure regulator.

Avoid no-load operation. A compressor that loads and unloads is using power all the time. When off load, the power can be as much as 60% of the full load power. For compressors up to 1,000 litres/sec no-load operation can be minimised when the off-load cycle is relatively long by turning off the compressor. Automatic stop/start control stops the compressor after a period of no-load running, usually 10 - 15 minutes, and then automatically restarts the machine on demand for air. Examine the on and off-load running times to ensure that the number of stops and starts are within the recommended criteria for the motor.

Piston machines with unloading give the best part-load efficiencies. Screw machines are available with both two-step unloading and modulating control with a changeover switch. Modulation is inefficient at low loads and should only be used if the load is over 75% - below this, two-step unloading is more efficient.

Variable speed control of drive motors. Using variable speed drives (VSD) on piston and screw compressors offers many control and efficiency advantages. Consideration should also be given to new integrated VSD compressors.

Multiple compressor plant. In the case of multiple compressor installations, base compressor sequencing on as narrow a pressure band as possible to achieve the minimum generation pressure at all times.

Computer based controls. For multiple compressor control, various microprocessor-based systems are available. These have much more accurate pressure control than pressure switches, and avoid large pressure differentials and energy waste. Energy is also saved by reducing the period of time that machines in a multiple installation are running off-load using predictive switching which shuts down a machine immediately it goes off-load. When demand increases, the next machine in a rotational sequence will start, enabling the first to stay off, thus preventing excessive starting and eliminating off-load operation.

Computer control brings energy savings

A computer-controlled compressed air plant at one industrial site cost less than £12,000 and saved £12,000/year in energy, giving a payback period of under one year.

Heat recovery. Over 90% of the energy consumed by a compressor is turned into heat. This heat is low grade and is usually wasted, but in many cases it can be recovered. Possibilities include pre-heating of domestic water and air heating for space heating. Where the heat recovered can be fully utilised, simple payback periods of under two years are frequently achieved.

9.3.2 *Air Quality*

Drying. Air treatment costs in terms of energy depend on the quality of air required. A desiccant dryer consumes up to 15% of the compressor power for heated regeneration (Class 1.1.1 quality air) and causes pressure drops on the system of up to 1.5 bar.

Lower quality air can be produced by sorption and refrigeration dryers, which also use energy and create pressure drops. Deliquescent (absorption) dryers do not consume energy and create pressure drops of only 0.1 to 0.4 bar, but they are not regenerative and incur both material and labour costs. These are the least expensive and are very energy efficient, but only produce dewpoints about 60°C below the inlet temperature.

Use the minimum quality air needed. The higher the quality, the higher the energy cost.

Filtration. Filters cause pressure drops and to save energy it is recommended that only the minimum filtration requirement is met. Make sure filters are adequately sized for the duty.

9.3.3 *Distribution*

Leakage. Leakage is not only a direct source of waste, it is also an indirect contributor to operating costs. As leaks increase, the system pressure drops. Often the solution is to increase the pressure to compensate for the losses, which also increases generating costs. The first step in tackling leaks is to recognise the costs involved and make a commitment to a plant-wide awareness programme to stop them. Regular, continuous attention to the compressed air system, coupled with proper maintenance will lead to effective progress in minimising leaks. Distribution pipework should follow the shortest and most direct route possible to the process.

These suggestions are summarised in Fig 15.

Section	**Measure**	**Payback**
Generation	Reduce compressor operating time.	I
	Reduce generating pressure.	I
	Avoid no-load operation (single compressor) by fitting new controls.	S
	Consider VSD control to compressor drive motors.	M/L
	Avoid no-load operation (multiple compressors) by fitting a new control system.	M
	Update with energy efficient compressors.	L
	Compression heat recovery.	M
Air quality	Make the correct choice of dryers.	L
	Make the correct choice of filters.	L
Distribution	Repair compressed air leaks.	I

Key: I = immediate, S = short-term, M = medium-term, L = long-term.

Fig 15 Summary of energy-saving measures in compressed air systems

The following free publications describe more energy-saving ideas from compressed air. They are available from the Environment and Energy Helpline on 0800 585794.

GPG 126	*Compressing air costs*.
GPG 216	*Energy saving in the filtration and drying of compressed air*.
GPG 238	*Heat recovery from air compressors*.
GPCS 133	*Energy and cost savings from air compressor replacement*.
GPCS 277	*Refurbishment of a compressed air system*.

10. VENTILATION

Ventilation (including local exhaust ventilation (LEV) systems) account for 4% of the electrical energy used in the rubber processing industry.

Ventilation systems are required for compliance with health and safety legislation for many stages of rubber processing, e.g. the removal of airborne powders during mixing, cooling of compound in festoon coolers, extraction of solvents from proofing equipment, extraction of fumes from salt bath curing, and cooling of extrudates.

10.1 Plant and Equipment

Two types of ventilation are used:

- dilution ventilation;
- local exhaust ventilation.

Ventilation systems can be used for purposes other than the control of airborne contaminants, e.g. removal of heat from extrudate in the festoon coolers.

Dilution ventilation provides a flow of air into, and out of, a work area, but does not give any control at the source of the contaminant. The background concentration is reduced by the addition of fresh air but it has little effect on the concentration levels at the process.

Local exhaust ventilation (LEV) reduces the concentration levels of airborne contamination by removing process dusts, mists and fumes as they are generated. Materials of concern to the rubber processing industry come mainly in powder or pellet form and are handled both manually or in bulk systems. In manual systems, bags are opened and their contents emptied into hoppers above weigh stations. Bulk systems use blowers to convey materials from road tankers to silos for transfer to high-level storage bins. In both handling methods, supply to weigh stations is by gravity. The generation of dust is inevitable whatever the transfer method.

Dust collectors are used in LEV systems to separate large quantities of dust from an air-stream. This is usually achieved with fabric filters in the rubber processing industry. The contaminated air passes through the fabric which captures the particles of dust on its surface. Most of the collected dust can be released by automatically shaking or by blowing high-pressure air (from the compressed air system) back through the filter.

Airborne dust falls within the size range 0.1 - 75 µm, the main dust size likely to be handled in the rubber industry.

Many types of fan are in use in the rubber processing industry (see Table 4).

Table 4 Summary of fan types, applications and efficiencies

Fan type	Fan static efficiency (%)	Application
Forward curved centrifugal	50 - 60	All low and medium pressure atmospheric air and ventilation plants. Has steep rising power characteristic and can overload.
Backward curved centrifugal	70 - 75	Medium and high pressure applications such as high velocity ventilation systems. Has good efficiency and non-overloading characteristic. Relatively higher sound level than forward curved centrifugal.
Paddle bladed centrifugal	45 - 55	Material transport systems and where air volumes have a high dust content. Blades have less tendency to clog up than other types.
Propeller	Less than 40	Mainly non-ducted low pressure applications. Low purchase cost but very inefficient.
Axial	60 - 65	All low pressure atmospheric air applications. Compact and suitable for in-line installation.

Ductwork is used to carry air in all ventilation applications, dilution and LEV. For the rubber processing industry, galvanised sheet steel is the most likely construction material. Systems design should ensure that LEV systems have in-duct air velocities high enough to keep contaminants in suspension and achieve low system-pressure drops. The use of high velocity/low volume systems should be considered although this could require a new ductwork system.

Air cleaning devices are available to deal with air contaminants ranging in size from 0.0005 - 75 µm. Air cleaning devices can be divided into three basic types (see Table 5):

- air filter;
- dust/fume collectors;
- mist, gas and vapour traps.

10.2 Operation and Maintenance

The following maintenance matters can affect the efficient operation of ventilation systems:

- Keep ductwork free of leaks, particularly on the inlet side of the fan (in LEV systems).
- Correctly align and tension belts and lubricate the bearings of fans and drives.
- Close off inlet terminals when not in use to minimise system air flow.
- Although automatic filter cleaning may be in place, check general filter condition periodically for ‘wear and tear’. A torn bag filter will reduce the dust collection efficiency, and increase both the air flow rate and the power absorbed by the fan.

Table 5 Types of airborne contaminant

Contaminant	**Size range (µm)**	**Characteristics**
Dust	0.1 - 75	Generated by natural fragmentation or mechanical cutting or crushing of solids (e.g. wood, rock, coal, metal). Grit particles (usually considered to be above 75 µm) are unlikely to remain airborne.
Fume	0.001 - 1.0	Small solid particles of condensed vapour, especially metals, as in welding or melting processes. Often agglomerate into larger particles as the small particles collide.
Smoke	0.01 - 1.0	Aerosol of droplets, formed by incomplete combustion of organic matter. Does not include ash, e.g. fly ash.
Mist	0.01 - 1.0	Aerosol of droplets formed by condensation from gaseous state, or as dispersion of liquid stage ie. hot open surface tank, electroplating.
Vapour	0.005	Gaseous state of materials that are liquid or solid at normal room temperature and pressure, e.g. solvent vapours.
Gas	0.0005	Materials which do not normally exist as liquids or solids at normal room temperature and pressure.

10.3 Monitoring and Targeting

Ventilation systems are less complex than some of the utilities and therefore fewer items of instrumentation are required. The main readings required are:

- Amps. The current drawn by the fan motor will decrease as the filter blocks, indicating that cleaning is required.
- Pressure drop across the filter/collector. This can be measured by a manometer. In an LEV system the filter/collector creates the largest pressure drop. A relationship can be established between fan motor current and filter pressure drop as electricity use is dictated by air flow rates. This can achieve an optimum filter cleaning period. Too frequent automatic cleaning of bag filters will therefore lead to excessive consumption by the fan motor. The optimum solution is to fit a variable speed fan motor! Pressure drop will also indicate simple system diagnostics, e.g. broken fan belts.
- Hours run/production hours: a simple comparison can be made to check unnecessary running.

10.4 Saving Opportunities

For electrical energy, fans are the only area to consider.

Usage. Fan power is proportional to the cube of the volume flow rate; consequently large energy savings can be made for a relatively small reduction in volume flow rate e.g. by modifying inlet terminals to create a high velocity for particulate capture. More efficient dust capture minimises the air flow requirement and a pulley change can slow down the fan accordingly.

Minimise air volumes. Reduce air volumes required to achieve effective dust/vapour capture. Fan power is also proportional to volume flow x system pressure. Close down any inlet terminals not in use.

Distribution. Excessive duct leakage will result in a lower air volume flow rate at the inlet terminals, and an increase in fan speeds, which unnecessarily uses extra power for effective dust capture at the inlet terminals.

The volume flow rates of an LEV system will vary as the filters fill up and become blocked. The system should still deliver an adequate extraction flow rate when the filter is full and this means that flow rates will be well above requirements when the filter has just been cleaned. As the power use of the fan is proportional to the system flow rate, this means that excessive power will be used if a fixed speed fan is running on clean filters.

A variable speed drive on the fan will greatly reduce energy use after the filter is cleaned, and solve the energy use problem.

Heat recovery. Large amounts of heated air are extracted and discharged to atmosphere. This is wasteful, as an equal supply of heated outdoor air is required to replace it. Consider using an air-to-air plate heat exchanger or run around coil to recover up to 60% of the heat before it is discharged and re-use it to pre-heat the supply air. The choice of heat recovery device will depend on the ductwork layout; plate heat exchangers are preferred.

For every 1 m^3/s at 18°C discharged to outside at 0°C, an equal supply of air at 18°C will require 22 kW of heating.

A summary of energy-saving measures for ventilation/LEV systems is shown in Fig 16.

Measure	**Rating**
Modify LEV inlet terminals and reduce fan duty.	S/M
Install VSD control to fan motors above 10 kW.	S/M
Consider heat recovery.	L
Shut off LEV inlet terminals not in use.	I

Key: I = immediate, S = short-term, M = medium-term, L = long-term.

Fig 16 Summary of energy-saving measures for ventilation/LEV systems

The following publication describes more energy-saving ideas from ventilation systems. It is available from the Environment and Energy Helpline on 0800 585794.

GPG 62 *Occupiers manual: Energy efficiency in advance factory units.*

11. INSULATION

Heat plays a major part in rubber processing. Thermal insulation works by providing a barrier that slows down the rate of heat transfer. There are many reasons for insulating process plant and steam and hot water service pipework, the most important of which is cost. Thermal insulation can minimise heat losses and hence reduce the energy input needed to maintain the temperature of an item being vulcanised or ‘cured’.

The thermal conductivity of insulating materials varies considerably according to the type of material, its density and operating temperature. Table 6 details a representative selection.

Table 6 Thermal conductivity of insulating materials

Material	**Density (kg/m^3)**	**Thermal conductivity (W/(m.K)) Temperature (°C)**		
		50	**100**	**300**
Calcium silicate	210	0.055	0.058	0.083
Expanded nitrile rubber	65-90	0.039	–	–
Mineral wool (glass)	16	0.047	0.065	–
	48	0.035	0.044	–
Mineral wool (rock)	100	0.037	0.043	0.088
Magnesia	190	0.055	0.058	0.082
Polyisocyanurate foam	50	0.023	0.026	–

11.1 Potential Energy Savings

The following charts and simple calculation sheets (Figs 18 - 28) allow a quick assessment of savings. They are based on insulation with a thermal conductivity of 0.05 - 0.07 W/(m.K) for the pipe and tank sizes indicated.

As most of the savings are achieved by the insulation nearest to the heat source, only 25 mm insulation has been considered. Thicker insulation will save more energy but the return on investment is much less (Fig 17).

To give an example, Fig 17 indicates the effect of insulation thickness on energy savings for a two-inch nominal bore (n.b.) pipe carrying 10 bar steam with a temperature of 184.13°C.

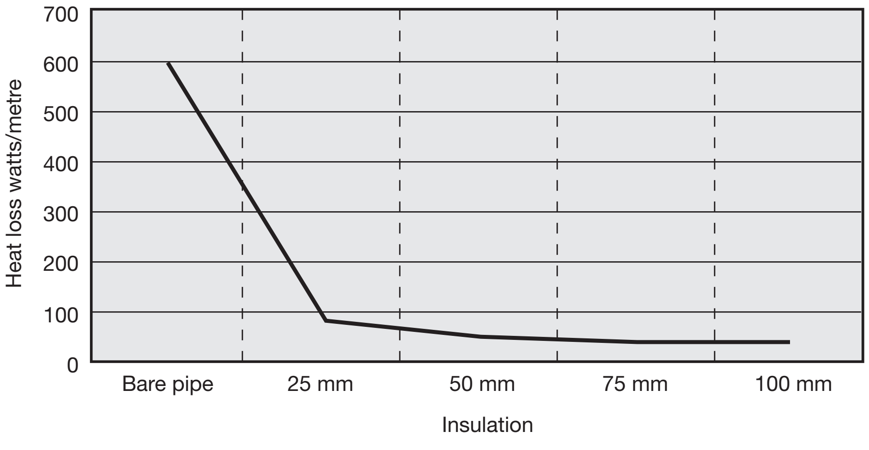

Fig 17 The effect of insulation thickness on energy savings

Item		Amount
Annual operation time	hours	A . . . . .
Fuel cost	pence/kW	B . . . .
Pipe nominal bore	inches	C . . . .
Pipe length	metres	D . . . .
Temperature of pipe surface (For steam take from steam tables for relevant pressure)	°C	G . . . .
Ambient temperature (For inside assume 20°C and 8°C for average outside temperature)	°C	H . . . .
Temperature difference = G – H	°C	J . . . .
From Fig 19 or 20 look up heat loss for relevant pipe size (C) and temperature difference (J)	watts/metre	K . . . .
Calculate saving = $\dfrac{K \text{ x } D \text{ x } A \text{ x } B}{75{,}000}$		£ . . . .
Evaluate against installed insulation cost		

Fig 18 Evaluation of pipe insulation

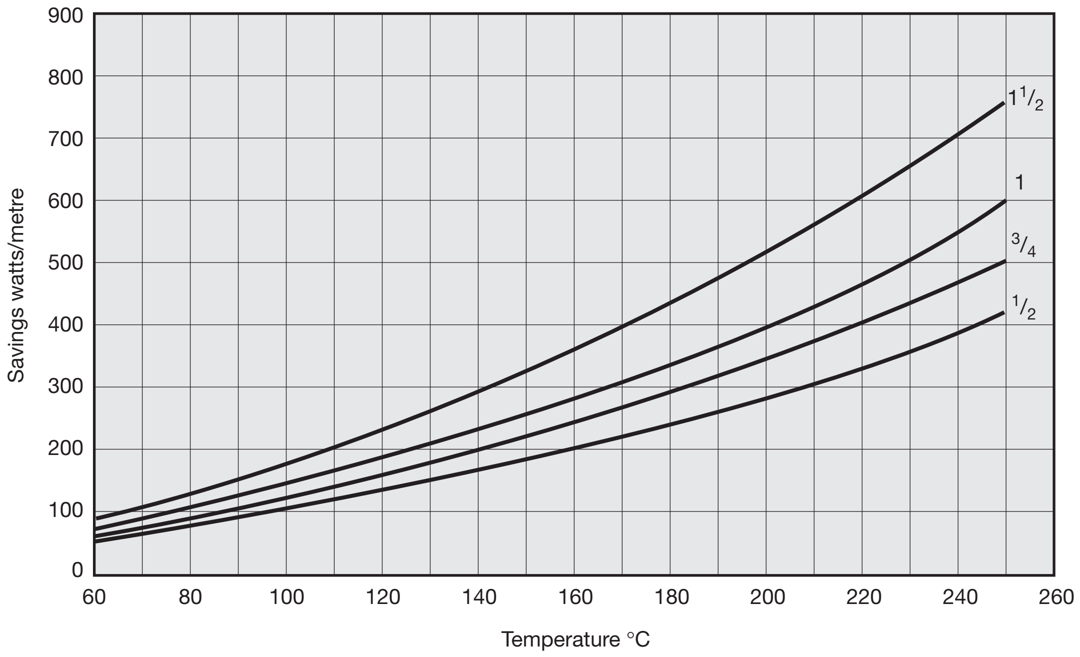

Fig 19 Energy savings with 25 mm insulation for pipes sizes $^{1}/_{2}$ inch to $1^{1}/_{2}$ inches n.b.

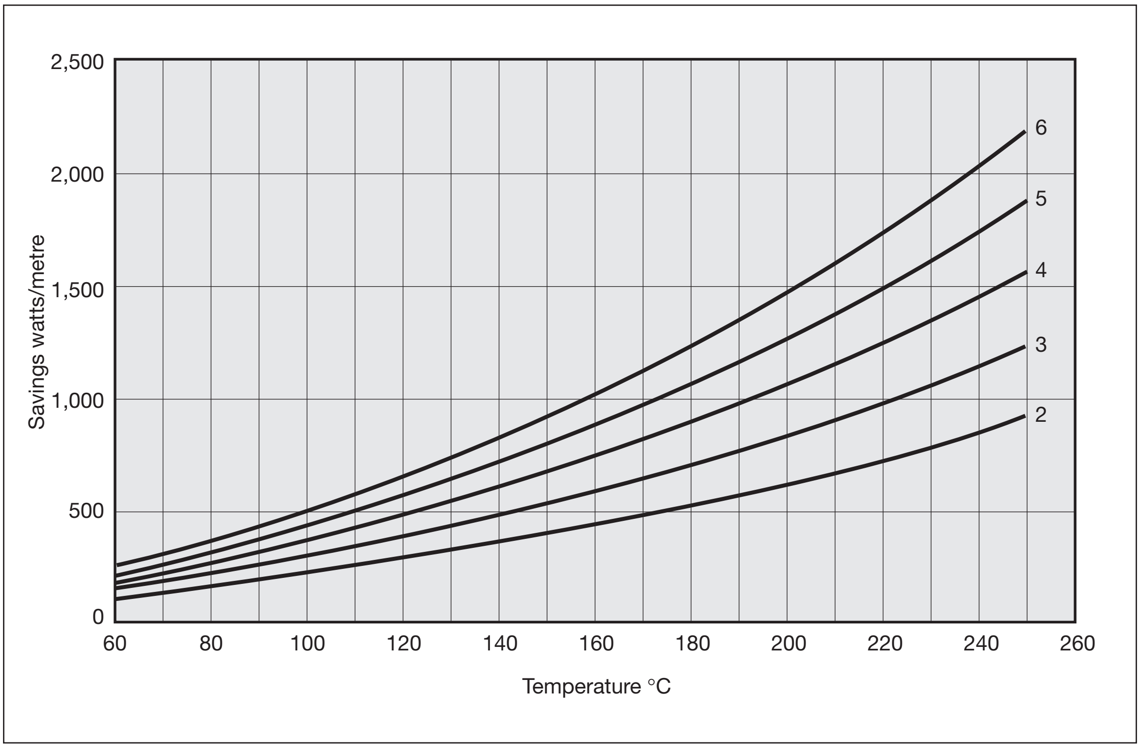

Fig 20 Energy savings with 25 mm insulation for pipes sizes 2 inches to 6 inches n.b.

Item		**Amount**
Annual operation time	hours	8,000 assumed
Fuel cost	pence/kW	B . . . .
Tank diameter	feet	C . . . .
Tank height	feet	D . . . .
Surface temperature	°C	G . . . .
Ambient temperature (For inside assume 20°C and 8°C for average outside temperature)	°C	H . . . .
Temperature difference = G – H	°C	J . . . .
From Fig 22 or 23 look up heat saving for relevant tank diameter (C) and temperature difference (J)	kWh/height (feet)	K . . . .
Calculate annual saving = K x D x B x 106.7		£ . . . .
Evaluate against installed insulation cost		

Fig 21 Evaluation of insulation of round tanks

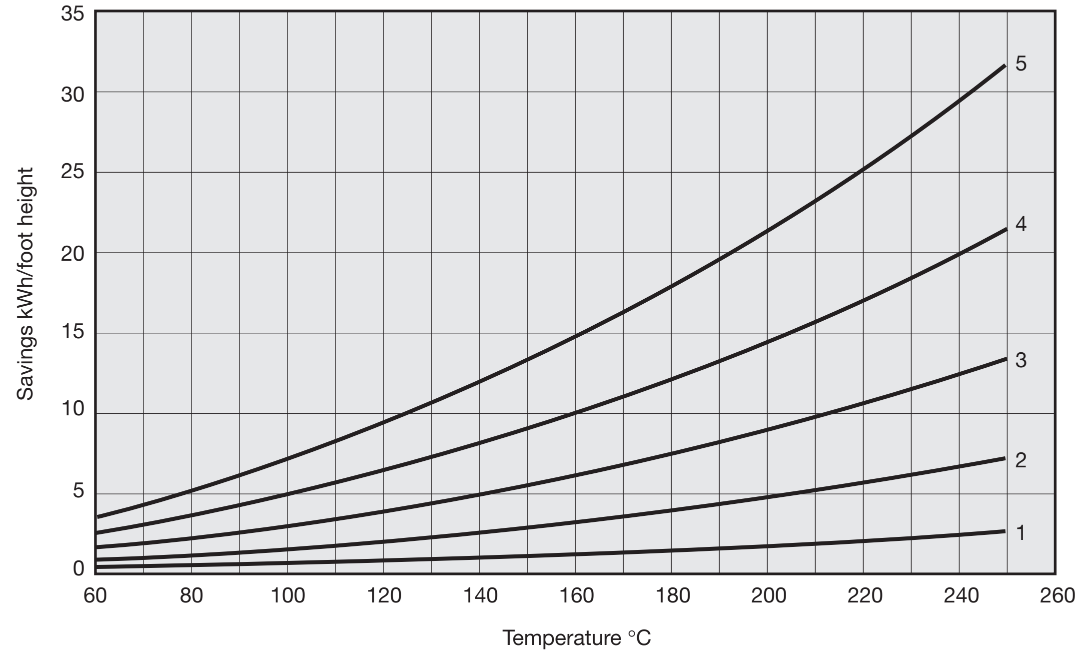

Fig 22 Energy savings with 25 mm insulation for tanks 1 - 5 feet in diameter

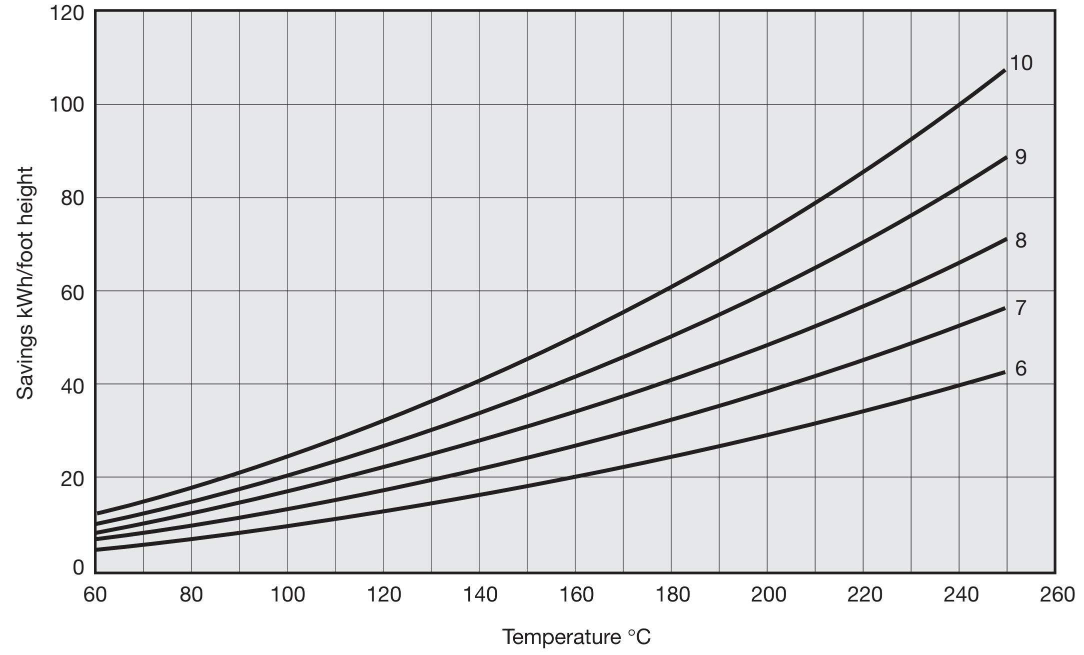

Fig 23 Energy savings with 25 mm insulation for tanks 6 - 10 feet in diameter

Item		**Amount**
Annual operation time	hours	8,000 assumed
Fuel cost	pence/kW	B . . . .
Tank length	feet	C . . . .
Tank width	feet	D . . . .
Tank height	feet	E . . . .
Calculate surface area for 1 foot of height of tank = 2(C x D) + 2(C + D)	feet	F . . . .
Surface temperature	°C	G . . . .
Ambient temperature (For inside assume 20°C and 8°C for average outside temperature)	°C	H . . . .
Temperature difference = G – H	°C	J . . . .
From Fig 25 or 26 look up heat saving for relevant tank size (F) and temperature difference (J)	kWh/height (feet)	K . . . .
Calculate annual saving = K x E x B x 106.7		£ . . . .
Evaluate against installed insulation cost		

Fig 24 Evaluation of insulation for rectangular tanks

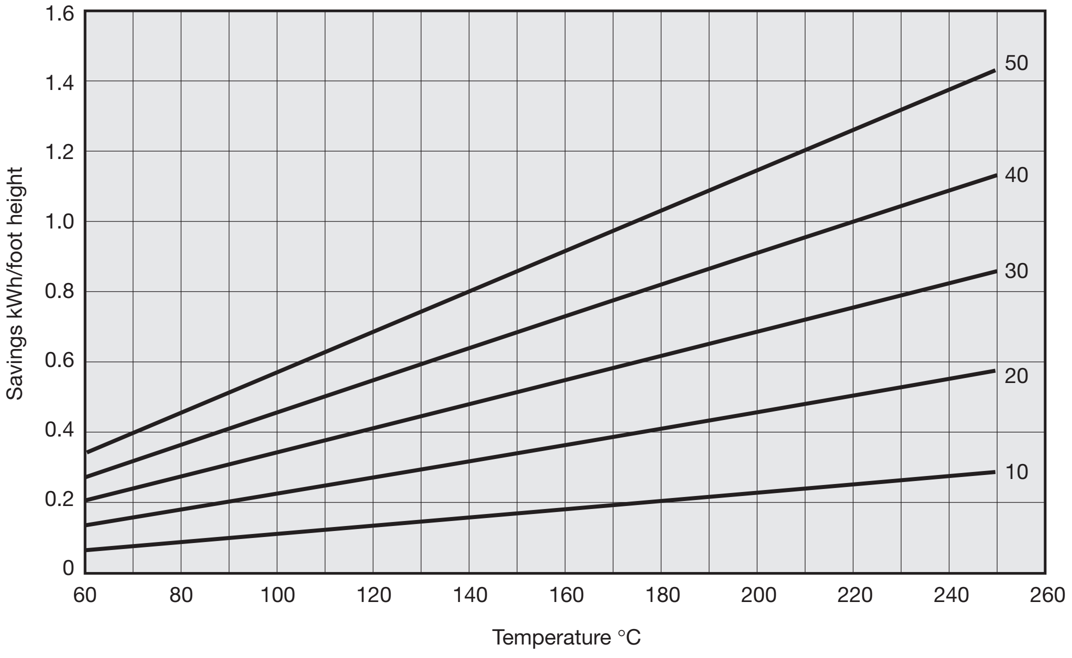

Fig 25 Energy savings with 25 mm insulation for rectangular tanks 10 - 50 square feet

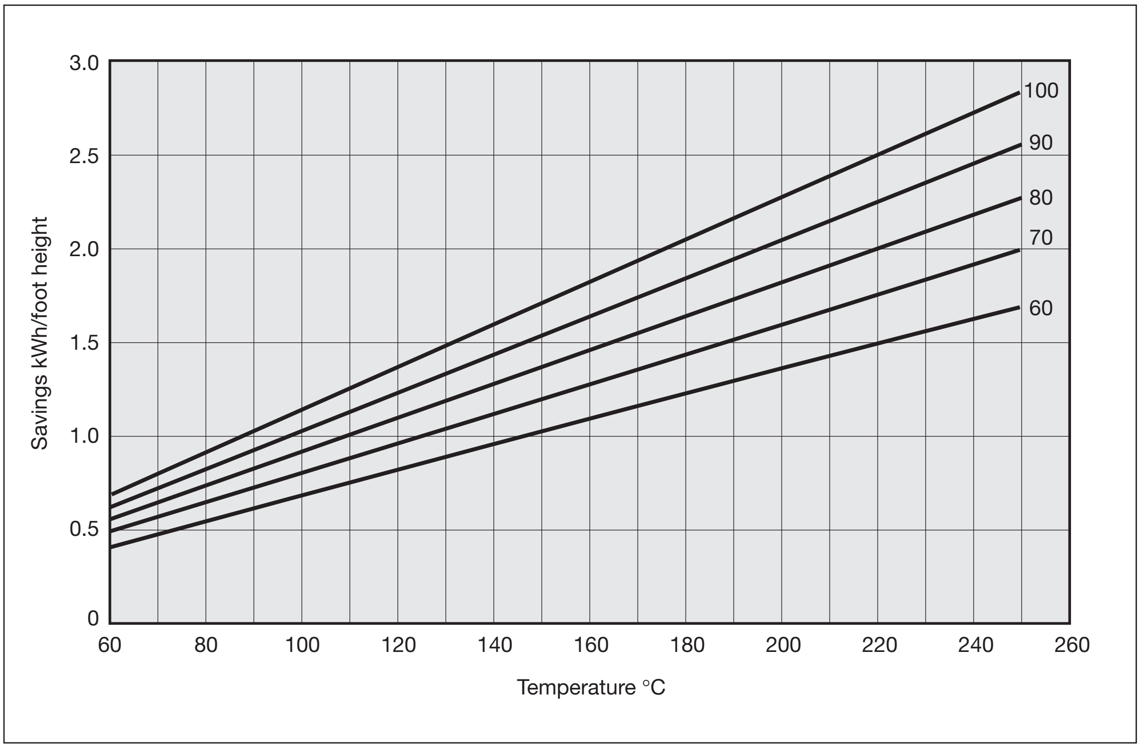

Fig 26 Energy savings with 25 mm insulation for rectangular tanks 60 - 100 square feet

Item		**Amount**
Annual operation time	hours	A . . . . .
Fuel cost	pence/kW	B . . . .
Measure surface area of machine to be insulated	square feet	C . . . .
Surface temperature	°C	G . . . .
Ambient temperature (For inside assume 20°C and 8°C for average outside temperature)	°C	H . . . .
Temperature difference = G – H	°C	J . . . .
From Fig 28 look up heat loss per square foot of machine surface for temperature difference (J)	watts/cubic feet	K . . . .
Calculate saving = $\frac{K \text{ x } C \text{ x } B}{9.37}$		£ . . . .
Evaluate against installed insulation cost		

Fig 27 Evaluation of insulation of plant and equipment

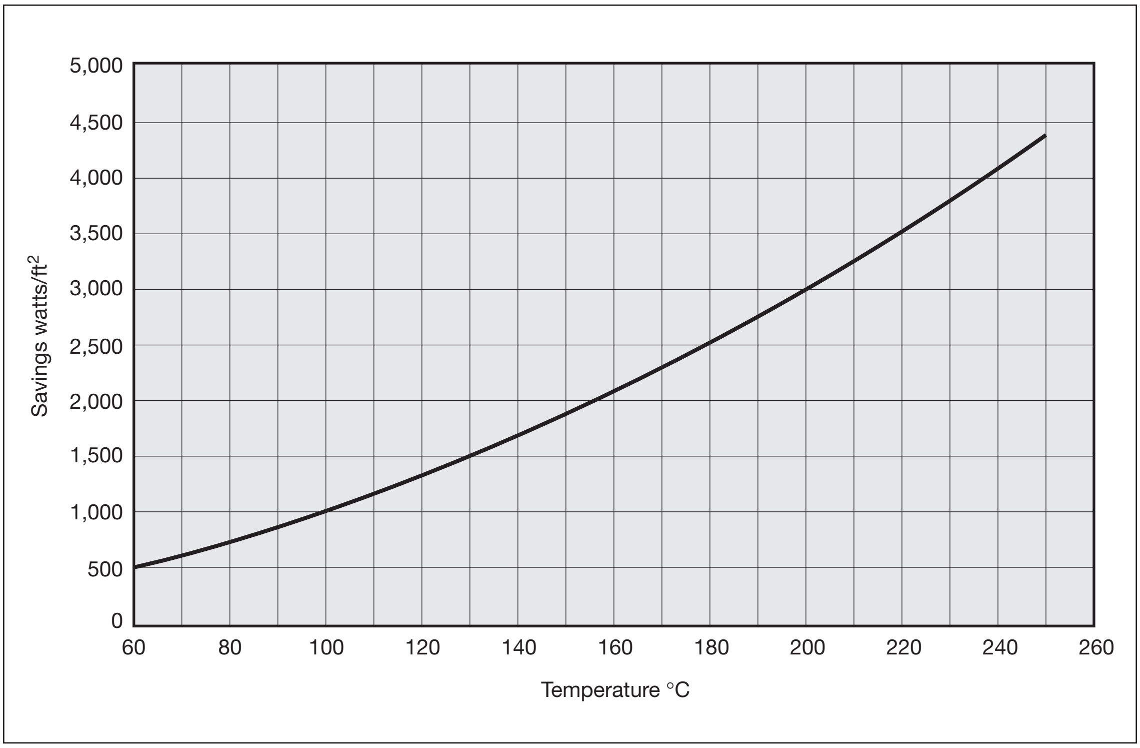

Fig 28 Energy savings per square foot of plant or equipment

11.2 Operation and Maintenance

Insulation should always be maintained in good condition and needs continual supervision by the maintenance engineer. Take care to ensure insulation (including that of valves) is replaced after maintenance, especially breakdowns. Make sure new pipework installations and modifications are insulated immediately.

11.3 Saving Opportunities

The whole purpose of insulation is to save money and, with the help of the preceding charts, savings can be easily quantified.

The following free publications describe more energy-saving ideas from insulation. They are available from the Environment and Energy Helpline on 0800 585794.

GPG 197 *Efficient heat distribution*.
FEB 8 *The economic thickness of insulation for hot pipes.*
FEB 16 *The economic thickness of insulation for existing industrial buildings*.

12. MOTORS AND DRIVES

Most rubber factories have large electric motors, particularly within compounding, milling and extrusion equipment. Because of this, demand profile, control and efficiency should be considered.

12.1 Demand Profile

To assess the demand profile of a motor, its operation needs to be monitored. Portable monitoring systems are available, although for motors above 20 kW permanent metering should be considered. When monitoring a motor consider:

- What is causing the demand?
- Wear on machine components (extruder screws, bearings) wastes energy in friction.
- Why is the machine running at the current settings? Is more mechanical work being put into the rubber than is needed to achieve acceptable product characteristics?

Categorise the demand profile in the following ways:

- Is the use continuous or cyclic?
- How many hours per year is the motor actually running?
- Is the motor running when the machine is not making product (particularly relevant for utilities pumps and compressors)?
- What are the peak and average demands as a percentage of the motor rating?

Process demand can be reduced to the minimum through timely maintenance and good settings. Once a motor has been optimised, the demand profile can be compared with subsequent efficiency curves. Follow the maintenance issues covered in Section 3.6. Reduction of energy demand through major machine modification or replacement is covered later in this Section.

Where the demand profile is not well-matched to the motor rating there are a number of methods of control which can save energy. Always start with the most simple. **Again, remember to check first with the manufacturer before changing settings, or even before switching off motors when it appears they are not needed.**

12.2 Control

Switch off motors during idle periods, either by training operators to do so manually, or installing electronic controls. These can be set to react to production schedules and switch off machine and ancillary drive motors, or to machine drives and switch off or isolate services such as compressed air, cooling water, and air extract fans.

Automatic isolation valves are a very good way of eliminating leaks and pressure drops in utility supplies to machines that are not running, and so to reduce demands on pump motors, etc. Thermostatic control valves on cooling water systems should also be considered.

Demand for utilities usually varies over a range of values and is seldom on/off. However, utilities are often supplied by several motors, e.g. several air compressors or several water pumps feeding a main.

Match supply more closely to demand by staged switching off of motors, triggered by flow rate reductions or rises in pressure. Look at soft-start systems where motors are likely to be switched in and out regularly.

Soft-start devices reduce the mechanical stress on the motor and equipment, allowing it to be switched on and off frequently without excessive wear and tear. Soft-start devices also reduce the drop in motor efficiency for part-load operation (demand significantly less than the motor rating). Savings vary with the level of motor loading, but are marginal at levels above 50% of motor rating.

Change motor size. If your demand profile for a motor, or piece of equipment suggests that the motor is the wrong size, then change it. For example, if demand will never exceed 3.5 kW but a 7.5 kW motor is fitted, then replace it with a 5 kW motor to reduce consumption by up to 5%.

This is a good low-cost measure for motors with a fairly steady demand, but is only a ‘quick fix’ part-solution where the demand profile varies widely. Replacing existing motors with multi-speed motors can actually be very cost-effective for variable demand profiles where the motor is in use for thousands of hours. This is considered next as a cheaper alternative to full variable speed motor drives. Purchase of new higher efficiency motors in general is covered in Section 12.3.1 and is assessed against the alternative of rewinding motors as they fail.

Multi-speed motors have several sets of windings that can be energised selectively to choose two or more fixed speeds. These motors can be controlled to match demand more closely, in much the same way as staged switching off of motors. Multi-speed motors are particularly suited to process extract fans where the full air volume change is needed in production, but zero air flow is not acceptable when idling or on standby.

Variable speed drive (VSD) systems are the optimum technical answer to continuously variable motive power demands, but are not cost-effective in all cases. Current VSDs electronically modify the AC electrical mains waveform to control the electrical power use and mechanical power output, so that the motor can run constantly at its optimum speed as the load (demand) varies. VSD control is based on process signals such as flow rate or pressure. VSDs often use frequency inverters to modify the waveform, and are sometimes referred to as inverter drives.

12.3 Motor Efficiency

The efficiency with which a motor converts electricity to motive power depends on four main factors:

- design and manufacture;
- load factor;
- operating temperature;
- wear and tear.

12.3.1 *Design and Manufacture*

Typical ‘standard’ modern induction motor efficiencies range from 80 - 90%. ‘High efficiency’ motors are a few per cent better at up to 93%. Always verify the actual quoted efficiency (some ‘high efficiency’ claims can be misleading), and compare manufacturers.

The increased cost of a genuinely more efficient motor can be more than offset by the reduced electricity consumption. Running an 11 kW motor (purchase cost £400) at 100% load for 67% of 12 hours/day, 5 days/week, 50 weeks/year costs about £1,300/year at 6 pence/kWh. A motor using 3% less but costing 30% more saves £40/year, a simple payback period on the extra purchase cost of 24 months, and an overall saving over a ten-year lifetime of £400. Double either the efficiency gain to 6%, or the running time to 24 hours/day, and the payback period decreases to 18 months. Double both, and the payback period is 9 months.

This simple indicator will underestimate the savings for part-load, because high efficiency motors maintain their performance better than the standard versions as load decreases. Savings at 50% load can be double those at full load.

Buying cheap motors can cost you money in the long term. Always get quotes for purchase costs and efficiencies and calculate the figures for your motor applications.

Replace or rewind? Nearly all refurbished motors suffer a drop in efficiency ranging from 0.5 - 3.5%, due to differences in the rewinding operation. Check whether your motor repairer can demonstrate a high standard of repair, and can keep losses to about or below 0.5%.

GPG 2 *Energy savings with electric motors and drives* (available free of charge through the Environment and Energy Helpline on 0800 585794) contains guidance on deciding between rewinding or replacing failed motors.

12.3.2 *Load Factor, Operating Temperature and Wear and Tear*

Load factor is covered in detail in Section 15.2.1. Running motors at high temperature reduces their efficiency, since the electrical resistance of the windings increases with temperature. Higher electrical resistance means more current dissipated as heat, which in turn raises temperature further. Running at excessive temperature can also reduce the lifetime and reliability of the motor. Check that the motor is well ventilated so that the integral cooling fin can do its job, and consider whether a simple baffle or duct could channel cooler air to the rotor.

Wear and tear can be kept under control by routine and timely maintenance. Maintenance matters are covered in detail in Section 3.6. Key topics worth consideration are:

- mechanical alignment;
- condition of bearings;
- electrical integrity of insulation;
- condition of commutator, slip rings and brushes;
- general cleanliness of motor;
- optimisation of transmission arrangements.

12.4 Saving Opportunities

1. Is the equipment still needed?
   - Changing technology and requirements may now allow a process stage or piece of equipment to be eliminated.

2. Switching off the motor:
   - Time the switching according to a fixed programme or schedule.
   - Monitor system conditions and switch off motor when it is not needed.
   - Sense the motor load, so that it is switched off when idling.

3. Reducing the load on the motor:
   - Is the system doing a useful and necessary job?
   - Is the transmission and drive efficient?
   - Is the maintenance programme adequate?
   - Have losses due to ancillaries such as pipework, ducting and insulation been minimised?
   - Is the control system still effective?

4. Minimising motor losses:
   - Is the motor a high efficiency specification?
   - Ensure repairs are to a standard which gives high efficiency.
   - Avoid greatly oversized motors.

- Consider permanent star connection as a no-cost way of reducing losses from lightly loaded motors.
- Check that voltage imbalance, low or high supply voltage, harmonic distortion or a poor power factor are not causing excessive losses.

5. Reducing the speed:

In a pump or fan application where a cube law applies, even a small reduction in speed can greatly reduce the demand and consequently the power usage:

- Use variable speed drives, as the extra expense is compensated for by the very high flexibility with respect to energy savings delivery.
- Use multiple speed motors where up to four distinct speeds are required.
- For belt drives only, a low-cost option is to change the pulley.

The following free publications describe more energy-saving ideas from motors and drives. They are available from the Environment and Energy Helpline on 0800 585794.

GPG 2	*Energy savings with electric motors and drives*.
GPCS 35	*Variable speed drive on a boiler fan*.
GPCS 89	*Variable speed drives on cooling water pumps*.
GPCS 215	*Automatic switch-off of power presses*.
GPCS 222	*Purchasing policy for higher efficiency motors*.
GPCS 270	*Variable speed drive on a cooling tower induced draught fan*.

13. LIGHTING

In the rubber processing industry, electric lighting accounts for 9% of the total electrical energy used.

This Section considers industrial lighting in general terms and then discusses the application of lighting specifically in the rubber processing industry. Illuminance is the amount of light per unit area. The unit of measurement is lux.

There have been substantial developments in lamp technology across a range of lamp types used in industrial and domestic environments: improved lamp energy efficiency coupled with improved colour rendering being the main areas.

General lighting is the simplest layout that provides an approximately uniform illuminance over the whole working area. This has the advantage of flexibility but the disadvantage that energy can be wasted in lighting non-critical areas.

Localised lighting is designed to provide the required illuminance in specific work areas or for specific tasks, with a lower illuminance for surrounding areas. This system is not as flexible but would normally consume less energy.

Local (or task) lighting provides illumination for a small task area and its immediate surroundings. General background lighting is provided for circulation and non-critical tasks. This system can be an efficient method of providing adequate task illumination, particularly where high illuminance is required.

13.1 Controls

Methods of control fall into three broad categories: manual, automatic control, and processor control (intelligent).

Manual methods rely on good housekeeping. Automatic controls include time-based, photo-electric control and occupancy-based controls. These turn lighting on and off as appropriate. Processor control, or computer-based lighting management systems, can address every luminaire to programme the appropriate lighting in individual areas. This intelligent control is usually a function of a building energy management system (BEMS) which would also control lifts, fire alarms, air conditioning systems etc.

13.2 Lighting in the Rubber Industry

The typical approach to lighting for rubber processing is to provide uniform illuminance over the whole plant area and supplement with local lighting as required.

Lighting considerations mainly concern the condition of the environment being lit, such as high ambient temperatures (e.g. positioning near autoclaves) and areas with large quantities of airborne dust, or combinations of both. Use lamps, luminaires and controls appropriate to each situation (see Table 7). Note: the light output of fluorescent lamps reduces at high ambient temperatures.

In addition to dust-proof (IP54) luminaires it is good practice to lay out luminaires so that they can easily be reached and maintained. Clean luminaires on a regular basis to maintain lighting levels.

Rubber is matt and often black and so has very low reflectance, which can cause problems in discerning detail and calls for a higher level of illuminance. Light obstruction by mixers, curing presses etc. may mean that machines need individual lighting. Recommended standard service illuminance values for rubber processing are shown in Table 7.

Table 7 Standard service illuminances

Rubber products	**Standard service illuminances (lux)**	**Limiting glare indices**
Stock preparation - plasticising, milling	200	25
Calendering, fabric preparation, stock cutting	500	25
Extruding, moulding, curing	500	22
Inspection	1,000	–

13.3 Operation and Maintenance

The following are maintenance matters that can affect the efficient operation of lighting.

The IP rating should be suitable for the environment in which the lighting is installed. Dust causes a reduction in light output. Too high a temperature causes premature failure; in the case of fluorescent lamps, the light output falls markedly if the ambient temperature is abnormally high. The external surfaces of luminaires require regular cleaning.

Replace discharge lamps as they fail, as energy will still be consumed by the control gear, even with no light output. When lights are not protected by a luminaire, the lamps themselves will need cleaning. Good housekeeping is essential to ensure that areas are not over-illuminated and lights are switched off when not required.

13.4 Monitoring and Targeting

Little instrumentation can be applied to lighting systems for managing energy costs. The basic requirements are the hours run/production hours.

An estimate of kWh used by lighting can be calculated using the installed lighting load. The installed lighting load is the sum of the installed light fittings and their rating, multiplied by the hours of operation. The figure is of little use in managing electrical consumption but indicates the significance of lighting energy usage. It can also be used to quantify savings achievable by the implementation of modern lamp technology.

13.5 Saving Opportunities

Lights should not be switched on longer than necessary; the hours switched on can be reduced in some areas where natural daylight is sufficient. In many cases light output exceeds the actual requirement for a task. Daylight from windows may contribute to lighting, causing lighting levels to be too high. Arrange lighting circuits to allow lights near windows to be switched off when there is sufficient daylight.

Distribution. Consider local lighting to reduce general illuminance levels. Make lighting systems more flexible so that large out-of-use areas do not have to remain lit to provide light for small, in-use areas.

Fittings. Luminaire design for fluorescent lamps has resulted in improvements in efficiency compared with older luminaires. Refurbishment of older luminaires using modern equipment can often result in substantial energy savings in addition to improved visual conditions (see Fig 29).

It is possible to use local luminaires that will operate with compact fluorescent lamps, adding to the luminaire's energy efficient operation.

It is important that fluorescent lights used near a moving machine have high frequency ballasts to prevent problems of stroboscopic effects.

Measure	**Payback**
Replace failed 38 mm fluorescent tubes with 26 mm tubes.	I
Replace high pressure mercury lamps (MBF & MBTF) with high pressure sodium (SON) or metal halide (MBI).	S/M/L
Replace tungsten lamps with compact fluorescent lamps.	S
Replace opal diffuser with specula reflectors.	M/L (if fewer Luminaires needed)
Install automatic lighting controls.	S/M/L
Replace lighting over 10 - 15 years old.	M/L
Localised lighting.	L

Key: I = immediate, S = short-term, M = medium-term, L = long-term.

Fig 29 Summary of recommended energy-saving measures for lighting

The following free publications describe more energy-saving ideas from lighting. They are available from the Environment and Energy Helpline on 0800 585794.

GPG 62 *Occupiers manual: Energy efficiency in advance factory units.*
GPG 158 *Energy efficiency in lighting for industrial buildings.*
GPCS 157 *Energy efficient lighting in warehouses.*
GPCS 158 *Energy efficient lighting in factories.*

14. HEATING

Within the rubber processing industry there is a large variation of heating requirements as some processes, moulding, curing, extruding, mixing etc. give out process heat. However, in the industry generally it can still account for up to 12% of the total fuel energy used.

This Section deals with industrial heating in general terms and applications specific to the rubber processing industry.

Heating requirements vary from site to site but are usually associated with the storage temperature requirements for natural and synthetic rubbers, and their associated adhesives, chemicals etc. Heating is also provided for comfort (see Table 8).

Table 8 The recommended design values for air temperature

Type of activity	**Air temperature (°C)**
Factory production area occupied	
Sedentary work (generally seated bench work)	19 - 21
Light work (light bench, walking)	16 - 19
Heavy work (heavy bench work, strenuous activity)	13 - 19
Stores	15 - 19
Factory production area - unoccupied (night set back)	
Minimum for frost protection	5
Minimum for condensation protection	10
Office areas	
General (seated at desk)	20 - 22

14.1 Systems

Direct-fired heaters have never been popular in the rubber processing industry due to possible fire risks. This should always be a serious consideration. The industry prefers steam or hot water heaters, e.g.:

- overhead radiant panels;
- high-level unit heaters;
- floor standing warm air heaters;
- radiators, usually low temperature hot water (LTHW);
- convectors, usually medium temperature hot water (MTHW).

Most units have basic timers or thermostat temperature control. Some factories control their heating using BEMS.

14.2 Operation and Maintenance

Maintain burners in the direct-fired units twice-yearly to ensure correct combustion and continued reliability. Units mounted at high level may be difficult to access. Nevertheless, do not neglect them.

Steam and hot water mains may have very high standing losses due to site layout, poor or badly maintained insulation, extended running hours and excessive circulation when demand is low. Maintain doors and draught seals in good condition. Repair water steam leaks and steam traps.

14.3 Monitoring and Targeting

Determining the energy used for space heating can be difficult where there is no separate metering of fuel. If heating and hot water are on the same system it is reasonable to assume 80% of the load is heating and that fossil fuel usage, whether gas or oil, is a total figure including heating, hot water and process use. Ideally, secondary metering of the service would allow complete accountability but if this is not possible, use the simple assessment method outlined in Section 3.2.2.

14.4 Saving Opportunities

This Section is used to discuss cost-saving opportunities in heating systems. There are three main areas for consideration: the building fabric, the boiler plant and space heating systems.

14.4.1 *Reduce Air Infiltration*

- Draught-proof windows and doors.
- Fit automatic closure devices on external pedestrian doors and install draught lobbies.
- Install automatic/fast acting doors for goods/vehicle entrances. Electric contacts can be fitted to roller shutter doors that allow air heaters to function only when the door is closed.
- Reduce number of doors in use where possible.
- Install strip curtains/automatic doors between working areas within buildings.
- Improve thermal insulation.
- Insulate roof or roof void.
- Install cavity wall insulation.
- Reduce excessive glazing areas/fit insulated in-fill panels.
- Double glaze.

14.4.2 *Boiler Plant*

This is covered in full in Section 4 for boilers, and Section 11 for insulation/pipe insulation, etc.

14.4.3 *Space Heating*

- Avoid overheating.
- Check thermostats are set correctly. **Turning the air temperature down by just one degree can save 5% of heating costs.**
- Turn off space heating in unused rooms.
- Use frost protection thermostats outside occupation periods.
- Install zone controls for areas with differing times of use or temperature requirements.
- Install weather compensating controls. Install accurate thermostats and thermostatic radiator valves (tamperproof type).
- Reduce temperature gradients.
- Install de-stratification fans in high buildings.
- Reduce distribution losses.
- Install weather compensation controls.
- Isolate space-heating circuits in summer months.
- Use local heaters for hot water.

15. PURCHASING

Fuel prices can be affected by world/political changes, such as the collapse of oil prices and latterly the privatisation of the gas and electrical production and distribution. However, fuel is subject to standard commercial pressures and careful negotiation can result in good deals. The electricity industry is complex and this is reflected in the following Sections.

15.1 Fossil Fuels

Purchase fossil fuels, coal, oil and natural gas on a competitive basis with suppliers tendering for the supply of fuel at their best price for the supply location.

Coal and oil have always been handled in this way and now with the deregulation of the gas market, natural gas must be part of this tendering/negotiating routine.

15.1.1 *Natural Gas*

Gas can be purchased on two types of contract:

- firm supply contract;
- interruptible supply contract.

Firm supplies are for the smaller end of the market including the domestic market. Contracts may be entered into over a 12-month period or a longer time frame if it is felt that market gas prices may rise during the contract period and a fixed price would therefore result in savings over time. If long-term contracts are signed, it is important that a clause is included within contracts for early termination. In this way if the market price trend alters and falling prices are evident then the long-term contract can be terminated and re-tendering can occur.

Cheaper gas is available by using an interruptible supply contract. Interruptible supplies are normally for the larger gas consumer with annual consumptions in excess of 200,000 therms or 5.86 million kWh. The basis of an interruptible contract is that the supplier can ask for consumption to stop over a contracted period ranging from a number of hours to several weeks. In order to cope with this interruption it is necessary to have a stand-by fuel and a dual-fuel firing capability.

15.2 Electricity

How you purchase your electricity does not save you energy directly, but can save you money. It is also a very important factor in providing a justification for many energy-saving measures. Energy efficiency improvements can give a smoother, less peaky, electrical demand profile which will reduce charges based on maximum demand and power factor.

15.2.1 *Contracts*

With the deregulation of the electricity market, all users are entitled to approach independent electricity supply companies for a competitive quote for their electrical requirements. Commercial organisations should undertake a competitive tender procedure.

Contract structures can be very varied and the type of contract offered should be designed to suit the operational pattern of the customer and give the best financial benefits.

The contract elements can consist of a price per unit (pence/kWh) and additional supplementary charges with different prices for different time periods of the day or night, which depend on:

- available capacity;
- maximum demand (MD);
- power factor (PF);
- load factor.

Available Capacity

The available capacity of the site will have been calculated and agreed when the site was connected to the distribution system. A charge is made against this capacity on a monthly basis. Over a period of time the actual power requirement of the site (as measured by the maximum demand) may change. If the available capacity is breached, the level will be increased automatically. If the MD of the site is significantly below the available capacity (i.e. 20% or more) then negotiated reductions can often be achieved. Some supply companies will automatically adjust available capacities to track changes in maximum demand.

Maximum Demand

Maximum demand is a measure of the power drawn by the site, aggregated over a half-hour period. It may be quoted and charged for either in kW or kVA, the difference being power factor (see below).

In the deregulated market all sites with a maximum demand above 100 kW will be fitted with an electronic meter, either a Code 3 or a Code 5 meter. These meters measure and store MD information for every half-hour throughout the month. This information is downloaded, by means of a modem connection, by UK DCS which is the central data manager for the supply industry. This information is then passed on to the supply companies which use it for billing purposes. The information is also available to customers that request it and can be used to monitor electricity usage. Valuable information may be gleaned from the MD profiles about what loads are being left on unnecessarily and/or out of hours, which can in some circumstances lead to improved energy efficiency.

Where charges are based on MD values, you should stagger start-up of machinery to minimise the MD value compared to your actual running load. This is particularly significant with machinery such as compounders and mills.

Power Factor

The PF relates to the distribution system capacity limits, which are defined as the maximum voltage and current (kVA). These maximum values are the amplitude of the sinusoidal electrical waveforms. Actual energy consumption rate (power in kW) is the product of the amplitude and the cosine of the phase shift angle between the voltage and current waveforms.

$$\text{KW} = \text{kV x A x cos} (\phi)$$

This factor of cost (ϕ) is known as the power factor (PF). Electrical machinery induces a phase shift between supply voltage and current if it has a high reactive impedance (inductance or capacitance). Lightly loaded machinery tends to have a high phase shift, and thus a low power factor. The chargeable units of electricity consumption are kWh. Electricity suppliers dislike low power factors, since it means that they must maintain a high distribution network capacity for a low consumption charge. Low power factors also cause problems with running the distribution network. In some supply areas, an additional charge is made if the PF is below a given value.

Running electric motors energy efficiently means power factors closer to one.

Load Factor
Load factor is a measure of the relationship between consumption and maximum demand. It is calculated as follows:-

$$\frac{\text{monthly kWh consumption}}{\text{number of hours in the month x kW monthly maximum demand}}$$

15.2.2 *Negotiating Contracts*

The competitive tender exercise usually results in two or three supply companies offering the most competitive rates. It is usually possible to negotiate a further small discount (say 5%) by asking these companies if they have any margin to reduce their tendered price.

A more competitive rate can usually be achieved if a number of customers can band together into a single contract. Therefore if a group contract can be negotiated via a parent company better deals are usually available.

An alternative route is to use an independent consultant to undertake the tendering exercise and/or to act as a bulk purchaser for a number of small customers, effectively bringing them into a group contract.

We are only a small company with a very peaky demand profile. How can we get a good deal out of a large electricity supplier?

Many independent consultants specialise in tariff selection, giving advice and negotiating and maintaining a purchasing plan for the user, ensuring they are kept abreast of changes that may arise. Fees are usually based on the savings made, making this an attractive route for some. It is still a good idea to try consulting your local supply company before going to such a consultant.

A few consultants run clubs for small energy purchasers. The consultant is able to negotiate from a strong position based on the aggregate demand profile of all of the members, reducing the amount of effort on the suppliers’ part to secure a substantial consumption revenue.

16. FURTHER HELP

Following the advice in this Guide will help your company to start to save energy and money. If you need further help and advice you can contact the Environment and Energy Helpline on 0800 585794, which can:

- Send you free copies of Energy Efficiency Best Practice Programme and Environmental Technology Best Practice Programme publications.
- Provide free, up-to-date information on the technologies described in this Guide and other environmental issues.
- Tell you about relevant environmental and other regulations that could affect your operations.
- Arrange for a specialist to visit your company, if you employ fewer than 250 people, at the discretion of the Helpline manager.

PUBLICATIONS REQUEST FORM

To obtain any of these free publications, fill in your details, tick the appropriate boxes, and fax this form to **01235 433066.**

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Good Practice Guides

GPG 2	*Energy savings with electric motors and drives*	☐
GPG 30	*Energy efficient operation of industrial boiler plant*	☐
GPG 59	*Energy efficient selection and operation of refrigeration compressors*	☐
GPG 62	*Occupiers manual: energy efficiency in advance factory units*	☐
GPG 112	*Monitoring and Targeting in large companies*	☐
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GPG 167	*Organisational aspects of energy management*	☐
GPG 169	*Putting energy into total quality*	☐
GPG 170	*Reduced water pumping costs in the steel industry*	☐
GPG 197	*Energy efficient heat distribution*	☐
GPG 216	*Energy saving in the filtration and drying of compressed air*	☐
GPG 217	*Cutting energy losses through effective maintenance*	☐
GPG 225	*Industrial cooling water systems*	☐
GPG 236	*Cut the cost of running your refrigeration plant*	☐
GPG 238	*Heat recovery from air compressors*	☐

Good Practice Case Studies

GPCS 35	*Variable speed drive on a boiler fan*	☐
GPCS 89	*Variable speed drives on cooling water pumps*	☐
GPCS 133	*Energy and cost savings from air compressor replacement*	☐
GPCS 142	*Monitoring and Targeting at a general rubber goods site*	☐
GPCS 157	*Energy efficient lighting in warehouses*	☐
GPCS 158	*Energy efficiency in lighting in factories*	☐
GPCS 163	*A co-ordinated approach to energy management*	☐
GPCS 207	*Monitoring and Targeting in a multi-site company*	☐
GPCS 215	*Automatic switch-off of power presses*	☐
GPCS 222	*Purchasing policy for higher efficiency motors*	☐
GPCS 270	*Variable speed drive on a cooling tower induced draught fan*	☐
GPCS 277	*Refurbishment of compressed air system*	☐
GPCS 369	*Compressed air leakage reduction through the use of electronic condensate drain traps*	☐

General Information Reports

GIR 12	*Aspects of energy management*	☐
GIR 13	*Reviewing energy management*	☐

Miscellaneous

FEB 8	*The economic thickness of insulation for hot pipes*	☐
FEB 16	*The economic thickness of insulation for existing industrial buildings*	☐

The Government's Energy Efficiency Best Practice Programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry, transport and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice Programme are shown opposite.

Further information

For buildings-related publications
please contact:
Enquiries Bureau
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Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R & D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Energy Efficiency in Buildings: helps new energy managers understand the use and costs of heating, lighting etc.