GOOD PRACTICE GUIDE 168

Cutting your energy costs

A guide for the textile dyeing and finishing industry

ENERGY EFFICIENCY
BEST PRACTICE PROGRAMME

GOOD PRACTICE GUIDE 168

THE UK TEXTILE DYEING AND FINISHING INDUSTRY

This booklet is No. 168 in the Good Practice Guide series and provides practical advice to those who operate in the textile industry on how to improve the efficiency of their very energy intensive dyeing and finishing processes. The main methods of dyeing and finishing are reviewed and their energy use analysed. A range of energy-saving ideas is presented for each, and both low-cost measures and those involving capital expenditure are discussed.

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Other titles in the Good Practice Guide Series

1. GUIDANCE NOTES FOR THE IMPLEMENTATION OF SMALL-SCALE PACKAGED COMBINED HEAT AND POWER
2. GUIDANCE NOTES FOR REDUCING ENERGY CONSUMPTION COSTS OF ELECTRIC MOTOR AND DRIVE SYSTEMS
3. INTRODUCTION TO SMALL-SCALE COMBINED HEAT AND POWER
13. WASTE HEAT RECOVERY FROM HIGH TEMPERATURE GAS STREAMS
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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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THE UK TEXTILE DYEING AND FINISHING INDUSTRY

1. INTRODUCTION

Textile dyeing and finishing covers a variety of treatments and processes used to alter the appearance and properties of textile products. The most basic of these are cleaning (scouring), bleaching and dyeing, but there are many other processes which can be used to meet particular requirements. The product may be dyed and finished as a yarn or thread, as a fabric, or even as a completed garment.

Some companies carry out the entire textile manufacturing process, from the production of thread or yarn, to the weaving or knitting of fabric and the making-up of final consumer products. Such companies generally carry out their own finishing processes as part of their fully integrated manufacturing structure. Other companies, whilst specialising in a particular area of textile production, may also have their own 'in-house' finishing operation.

In addition, there are a large number of 'commission' dyers and finishers who have no textile manufacturing operation, but work under contract for other organisations.

This Guide shows how a number of approaches can make energy savings and cut energy bills within the industry:

- Section 3 briefly explores some of the management techniques which can be used, often at little or no capital cost, to make significant energy savings through changes in working practices.

- Sections 4 - 10 look closely at the energy aspects of commonly used textile dyeing and finishing processes. Typical energy consumptions are given, together with a list of suggestions for the best opportunities for making savings.

- Sections 11 - 13 consider energy usage in the context of overall site utility needs and look at general ways of reducing the cost of services such as electricity and water supplies, steam raising and effluent discharge.

The Guide contains a number of equations which can give a first indication of the expected energy usage for a number of machines operating under different conditions. These calculations can be used to give an initial target for reductions in energy usage.

At the back of the Guide is a list of publications which provide further information on many of the topics discussed in this Guide.

Throughout the Guide energy use is expressed in terms of gigajoules (GJ) where:

1 GJ = 277.8 kWh
1 GJ = 9.48 therms
1 GJ = 0.022 tonnes oil equivalent

> One gigajoule is roughly equivalent to the amount of energy contained in 40 kg (88 lb) of coal or 25 litres (5 gallons) of oil

2. THE UK TEXTILE DYEING AND FINISHING INDUSTRY

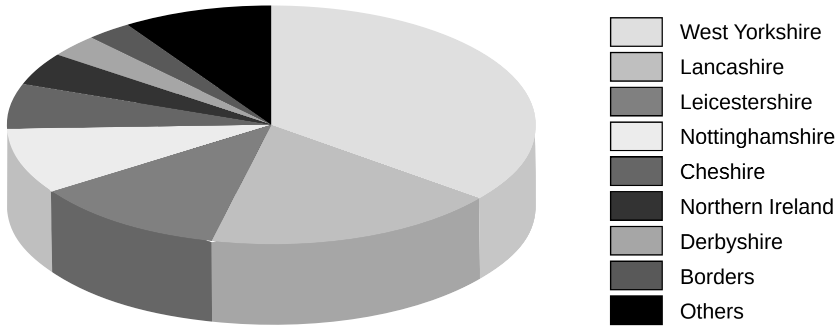

Fig 1 Distribution of dyeing and finishing sites

2.1 Energy Use by the Textile Finishing Industry

The industry is estimated to have an annual output of some 45 million kilograms of bleached and dyed yarn, and 700 million metres of bleached and dyed fabric. The processes involved in this work (scouring, bleaching, dyeing, printing and finishing) are very energy intensive (energy usage accounts for 12 - 16% of total production costs); therefore it is vital that energy costs are accurately identified and analysed. For an individual company, comparisons can then be made with other organisations running similar businesses to pinpoint areas where savings can be made.

Primary energy data most relevant to the textile dyeing and finishing industry are summarised below in Table 1. Primary energy use takes account of the total fuel required to generate useful energy (usually called the delivered energy). This is particularly relevant to electricity purchased from the grid, which is generally produced at an efficiency of about 30%.

Table 1 Estimated primary energy used by the textile dyeing and finishing industry
(data taken from the 1989 purchases enquiry)

Textile Category	**Energy use (Million GJ)**	**Energy cost (£M)**
Woollen & worsted	11.25	40.2
Hosiery & other weft knitted goods and fabrics	9.54	32.5
Warp knitted fabrics	1.84	6.3
Textile finishing[1]	13.25	41.6
Total	**35.88**	**120.6**

[1] Textile finishing includes most of the companies involved in such processing, although there is a certain amount of overlap with other sectors, notably the woollen & worsted and knitting & hosiery industries

The energy requirements of individual dyeing and finishing sites generally fall within the range 15 - 90 GJ/tonne of finished product. This wide variation takes into account both the number of processes carried out, and the quality of finish achieved.

2.2 An Overview of Textile Dyeing and Finishing Processes

Textile dyeing and finishing covers a wide range of processes, from scouring and bleaching to dyeing, printing, coating and laminating. The selection of the right process depends, to a certain extent, on the type of yarn or fabric, the blend of fibres if a mixture is involved, the quantity of yarn or fabric and the designated end-use.

The scouring and bleaching process involves cleaning and improving the base-colour of the textile by removing oils, fats, waxes and residual matter. Dyes and chemicals are then applied and fixed to the material, after which chemical or mechanical finishing techniques are used, if necessary, to produce the required properties.

Most of the machinery used for these operations falls into one of six main categories:

Wet batch processors (pressure) (see Section 4)	kiers, jigs, jets, beams, package, loose stock, hank dyeing machines
Wet batch processors (atmospheric) (see Section 5)	jigs, winches, paddle dyeing machines
Continuous wet processors (see Section 6)	washing ranges
Contact dryers (see Section 7)	steam cylinders
Hot-air dryers (see Section 8)	stenters, print ovens
Hot-air/steam heaters (see Section 9)	stenters, bakers, thermosol units, steamers

Common pieces of equipment which do not fall into these categories but play an important part in processing include:

- *singeing* machines - with gas fired burners to remove extraneous material from fabric prior to preparation;
- *raising, glazing and schreinering* machines - finishing machines requiring electrical power only;
- *calenders and sanforisers* - steam heated finishing machines - with heated cylinders not involving drying.

Other plant, such as dyeing ranges and preparation ranges, tend to be a mixture of more than one category. They may involve padding, impregnation, steaming, washing and contact drying in succession. Table 2 shows the typical energy requirements of a number of textile finishing processes.

Table 2 Typical energy requirements of textile finishing processes

Product form/machine type	**Process**	**Energy requirement (GJ/te)**
Desize unit	Desizing	1.0 - 3.5
Kier	Scouring/bleaching	6.0 - 7.5
J-box	Scouring	6.5 - 10.0
Open width range	Scouring/bleaching	3.0 - 7.0
Low energy steam purge	Scouring/bleaching	1.5 - 5.0
Jig/winch	Scouring	5.0 - 7.0
Jig/winch	Bleaching	3.0 - 6.5
Jig	Dyeing	1.5 - 7.0
Winch	Dyeing	6.0 - 17.0
Jet	Dyeing	3.5 - 16.0
Beam	Dyeing	7.5 - 12.5
Pad/batch	Dyeing	1.5 - 4.5
Continuous/thermosol	Dyeing	7.0 - 20.0
Rotary Screen	Printing	2.5 - 8.5
Steam cylinders	Drying	2.5 - 4.5
Stenter	Drying	2.5 - 7.5
Stenter	Heat setting	4.0 - 9.0
Package/yarn	Preparation/dyeing (cotton)	5.0 - 18.0
Package/yarn	Preparation/dyeing (polyester)	9.0 - 12.5
Continuous hank	Scouring	3.0 - 5.0
Hank	Dyeing	10.0 - 16.0
Hank	Drying	4.5 - 6.5

One gigajoule is roughly equivalent to the amount of energy contained in 40 kg (88 lb) of coal or 25 litres (5 gallons) of oil

3. GOOD HOUSEKEEPING AND ENERGY MANAGEMENT TECHNIQUES

The following Sections discuss the main areas in which energy efficiency can be enhanced in your industry and suggest ways to help you reduce your energy costs and cut consumption. They also include a number of measures based on the management of equipment. These two separate threads of energy efficient operation (which can be operated in isolation, but work best together) can be summarised as follows:

- make sure that you run the installed equipment in the most efficient manner;
- install the most intrinsically efficient equipment you can afford.

This Section expands on the first thread, outlining techniques that managers and operating staff can put into place to achieve more efficient running. The key to minimising inefficient running is the effective control of energy use, and this can be achieved by addressing a number of questions.

- HOW MUCH energy are we using?
- WHERE are we using it?
- WHEN are we using it?
- WHY are we using it?

Which leads on to two further questions that are more difficult to answer:

- HOW MUCH energy should we be using?
- WHY are we using more?

and then DOING something about it.

For energy efficiency projects to be successful, it is vital that people are involved and that they are well-informed, motivated and empowered to make the necessary changes that will cut down energy wastage. The measures to be introduced might be very simple, such as switching off unnecessary lights and closing doors to prevent heat loss; conversely, they might require complex changes to working patterns.

For example, in Section 9 it is suggested that stenter oven exhausts could be isolated (or at least partially closed) during batch changeovers, to reduce air losses while ovens are idling. This change could be implemented easily with automatic computer control; but at many sites the operators would have to change the damper setting manually. During a batch changeover, the operators have other concerns, and since a changeover only takes 10 - 15 minutes it is easier to leave the exhausts open (which also avoids having to remember to change the setting back!). Making the extra effort to close the dampers is often not seen to be worthwhile.

In this case, one possible way of improving staff awareness and motivation might be to:

- measure the energy use by the stenter during idling with the damper fully open, then (partly) closed;
- from the number of batch changeovers in a year, calculate the total annual energy loss and, therefore, the cost arising from not closing the dampers;
- present this calculation to the operating staff, explain the company’s commitment to reducing the energy wastage;
- agree a responsibility for closing the dampers, plus an incentive if appropriate.

The formal methodology used for controlling energy use, by measuring consumption and setting targets for reduction, is known as monitoring and targeting (M&T). The system was developed in the early 1980s and was later tailored to individual industry sectors. Descriptions of the techniques can be found in Good Practice Guide (GPG) 31, *Computer aided monitoring and targeting for industry*. To obtain your copy of this Guide please contact the Energy Efficiency Enquiries Bureau (details on page 37).

The more detailed the measurements, the better the analysis, understanding, and energy savings will be. However, there is no need to start by spending a fortune on metering. Many small companies do not specifically meter their energy use, but use invoices and consumption readings from their fuel and electricity suppliers. By starting simply, energy savings are achieved and understanding grows. In time, the limitations of current measurements are identified and meters can be added gradually.

Appendix 2 contains a number of equations which can give a first indication of the expected energy use for a number of machines operating under different conditions. These calculations can be used to give an initial target for reductions in energy use.

4. WET BATCH PROCESSING UNDER PRESSURE: JET AND BEAM DYERS AND KIERS

4.1 Background

Machines which fall into this category include jet and beam dyers, and kiers used for preparatory work. These machines are usually heated indirectly by steam, so they do not suffer evaporative losses of energy; but dyeing machines in this category lose a significant amount of their energy as they are deliberately cooled.

4.1.1 *Jet Machine*

The jet machine was initially developed in the early 1960s to allow polyester to be dyed without loss of quality. The early machines were basically pressure winches and it was not until the late 1960s that the first true jet machine was introduced. This was used initially for dyeing textured double-jersey fabrics. The new jet gave the fabric much better ‘handle’, more rapid and level dyeing and less creasing. It also had a significantly lower *liquor* ratio which made it more energy efficient. However, the machines were capital intensive, difficult to maintain, and the processing of delicate fabrics was often difficult.

Later developments, such as fully flooded, soft-flow and low-liquor machines, further reduced creasing and enabled more delicate fabrics to be dyed. The new generation machines were more compact, produced less foam and in particular reduced liquor ratios to less than 5:1.

In a jet machine, dye liquor is heated by circulating it past a steam/water heat exchanger, and then back to the jet. The cooling cycle then utilises the same exchanger, which is valved off for water/water operation, to slowly cool the liquor and fabric. The cooling water can then be re-used as make-up water for the next batch, although the initial liquor temperature is usually restricted to about 40 - 50°C to prevent uneven dyeing.

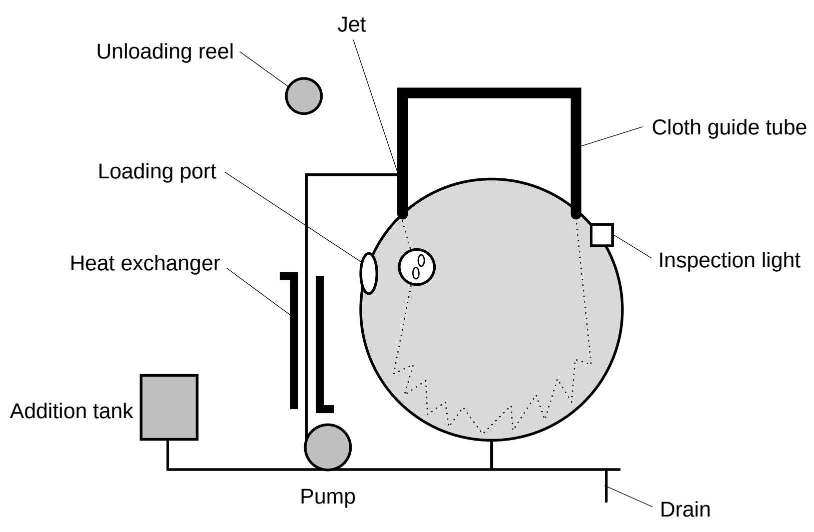

Fig 2 Jet-dyeing machine

4.1.2 *Pressure Beam*

Beams are heated by high-pressure steam via an internal or external heat exchanger. During dyeing, the liquor is circulated at 120 - 130°C in 2 - 3 minute cycles, predominantly from the core of the beam to the outer edge. The dye liquor is usually cooled using the same exchanger system but with the steam and condensate valved off.

Most of the electrical requirement for beams comes from the main circulating pump. This can be rated at up to 60 kW but is more typically 10 - 20 kW. A smaller pump is used to pressurise the beam itself to enable the required operating temperature to be reached.

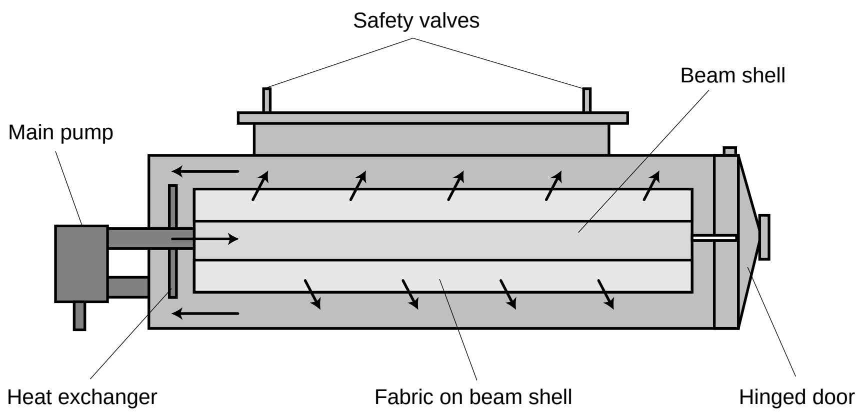

Fig 3 Beam-dyeing machine

4.1.3 *Kiers*

Kiers used for preparatory work are gradually being replaced by J-box (rope), or continuous open width processing. However, there are still a number in service, as scourers and bleachers for large batches of cellulosic fabric or yarn. Kiers provide even loading with good impregnation and liquor circulation.

Kiers have been largely superseded by continuous preparation processes such as steamers or j-boxes, and by jigs or winches for batchwork.

4.2 Energy Use

The energy requirement for wet batch processing machines operating under pressure is calculated as the energy required to heat process water, plus an allowance for radiation and convection losses.

The annual energy breakdown of a jet machine used for scouring and dyeing batches of polyester fabric is shown in Table 3. The high-energy content of the effluents and the cooling water demonstrates the importance of recovering heat from water flows.

Table 3 Annual energy breakdown for a jet-dyeing machine

Component	Energy content (GJ/year)	% of total	Water discharge temp (°C)
Scour effluent	278	18	40
Dye effluent	448	29	60
Cooling water	653	43	61
Radiation/convection losses	145	10	
Total	**1524**	**100**	

The energy and water requirements for common processes serviced by jets, beams and kiers are summarised in Table 4.

Table 4 Typical energy and water requirements for pressure-dyeing machines

Process	Specific energy consumption (SEC) (GJ/te)	Specific water use (SWU) (m^3/te)
Jet scour/dye (polyester)	4.5[3]	57.0[1]
Beam scour/dye (nylon)	11.5[3]	82.0[1]
Kier scour/wash (cotton)	4.3	30.0[2]
Kier bleach/wash (cotton)	2.7	30.0[2]

1 not including cooling water

2 fabric passed through rope washer after scour

3 although these processes are similar, there is a wide variation in both energy and water requirement; this may be due to the use of different classes of dyestuffs to satisfy customer specifications

4.3 Energy Efficiency Opportunities

There are many opportunities for saving energy and water on wet batch pressure-dyeing machines. The systematic approach is to consider each of the following in turn.

- ***Reduce the Liquor Ratio***

  The reduction of liquor ratio is potentially the most valuable opportunity for energy saving. Early jet machines typically had a ratio of 15:1. Modern machines have a reduced ratio of 5:1 or less, with a 70% saving in water heating, although care must be taken to ensure that the solubility and dispersion stability characteristics of the dyestuff being used are compatible with low liquor levels.

  It may be possible to introduce another process altogether, such as foam application (with a liquor ratio of just 1:1) or pad dyeing at 2:1.

- ***Reduce the Process Temperature***

  A reduction in the process temperature may also be achieved by introducing alternative processes. For example, under suitable circumstances, direct dyeing operated at 100 - 120°C, may be replaced with reactive dyeing at 40 - 60°C, thus minimising water heating, fabric losses and radiation/convection losses.

- ***Reduce the Process Time***

  Processing times can sometimes be reduced simply by making modifications to the temperature profiles for certain dyeing cycles. This has been achieved at a number of sites, saving energy and improving productivity. Preparatory processes can also be speeded up just by the use of different chemical formulations. One example, which involved modifying a kier scour/bleach formulation, reduced processing times from ten hours to just over two hours.

- ***Combine Preparatory Treatments***

  Combining preparatory treatments such as the de-sizing, scouring and bleaching of a cotton fabric could lead to a reduction from the original eight-stage process to just two stages, using a steam purge and cold pad/batch technique. This eliminates three intermediate washings, one hot kier and a cold acid process, reducing the energy requirement by as much as 80%.

- ***Reduce the Need for Re-processing***

  One of the main causes of re-processing is the difficulty and time-consuming nature of fabric sampling procedures, especially on older machines. It is therefore vital that dyehouses aim to achieve correct shades quickly and consistently. This may be done simply by improving manual control through better staff training. For large installations there are complete dyehouse management and control systems. These are capable of:

  - real time machinery supervision;
  - dye cycle editing;
  - production scheduling.

  Dyehouse control systems are gradually shifting away from the more rigid read only memory (ROM) programmes, to flexible software programming which enables schedules and processes to be tailored on-site. Product quality and productivity can be improved whilst the use of dyes, chemicals, water and energy are optimised.

  Some dyehouses have introduced a policy of blind dyeing, accepting that a small percentage of the product will always need to be re-dyed. The success of this method depends partly on the fibre/substrate involved; cotton might need considerable adjustment even on repeat shades, whilst consistent shading can generally be achieved on man-made fibres such as polyester and nylon. Improved control will typically lead to just 5% of the product requiring shading, with a resultant energy saving of around 10 - 12%.

- ***Fit Insulation to Machines***

  Insulation can save up to 9% of the total energy requirement on wet batch processing machines, with payback times typically less than 18 months. The nature of the process means that insulation material may be exposed to water, chemicals and physical shock. Any insulation should therefore be covered or coated with a hard-wearing, chemical/water-resistant outer layer.

- ***Re-use Liquors***

  The recovery and re-use of liquor is becoming more important as the costs of effluent discharge and treatment continue to increase. In addition, the re-use of hot (or warm) liquors can significantly reduce energy requirements. For example, the warm rinse water in a kier can be used to make up the next scour liquor, producing energy savings of more than 10%.

Similarly, spent dye liquor has been re-used at a hosiery dyeing company, where the number of dye shades was limited, and there was opportunity to route the contaminated liquor from a given shade to the next batch of the same shade. In most dyehouses, where the work is done on a commission basis, this approach would have limited application.

- ***Avoid Overflow Rinsing***

  Overflow rinsing should be avoided wherever possible because it tends to use excessive amounts of water. However, overflow rinsing is the only option for processes such as polyester dyeing, where oligomer deposition may occur.

- ***Recover Cooling Water***

  Recovery of cooling water can save up to half of the total energy requirement for dyeing under pressure at high temperature. Table 3 (Annual energy breakdown for a jet-dyeing machine) shows that, in this example, the cooling water contains 43% of the total energy input. Much of this energy can be recovered by directing the cooling water stream into a hot water storage system for re-use at 50 - 60°C. However, care must be taken to restrict the initial dye liquor temperature to avoid dyestuff strike-rate problems and fabric creasing.

5. ATMOSPHERIC WET BATCH PROCESSING: JIG AND WINCH MACHINES

5.1 Background

Atmospheric wet batch processing differs from that carried out under pressure because it generally involves machines in which the evaporative losses are a significant proportion of energy consumption. The main machines in this category are the jig and the winch.

5.1.1 *Jig Machine*

This jig is one of the oldest machines used for dyeing woven fabric. The fabric is passed from one roll to another, and back again, through a trough containing dye liquor. The liquor capacity is typically about 500 - 750 litres. Liquor is heated by direct injection of low-pressure steam, or indirectly, using higher-pressure steam through closed coils. Some jigs have both systems fitted, using steam injection for rapid heating and the closed coils for maintaining the dyeing temperature. Modern machines are usually fitted with a hood to help maintain temperature and minimise losses, although this is not always used, since operators find it inconvenient and there may be fears of fabric spotting.

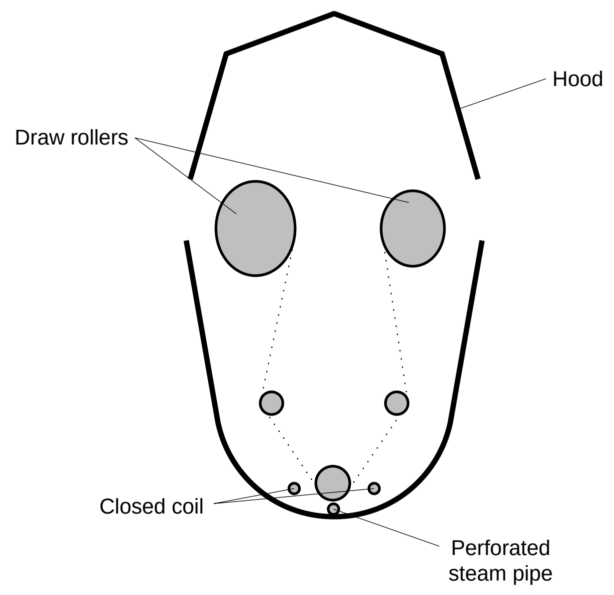

Fig 4 Jig machine

5.1.2 *Winch Machine*

The winch machine differs from the jig because it processes fabric in rope form rather than open width. This method imposes less tension on the fabric, but applies greater mechanical action. The winch is a very versatile machine and can be used for any type of fabric that can withstand creasing, particularly knitted fabrics.

The liquor is usually heated by direct steam injection through a perforated pipe near the salting box. This provides both rapid heating and vigorous agitation at the box, which is used for dye and chemical addition. However, as with all direct steam injection, there is a dilution effect to take into account. As with jigs, most winches are fitted with hoods to help maintain temperature and minimise losses, but it is still a common sight to see hoods open when processing at high temperatures.

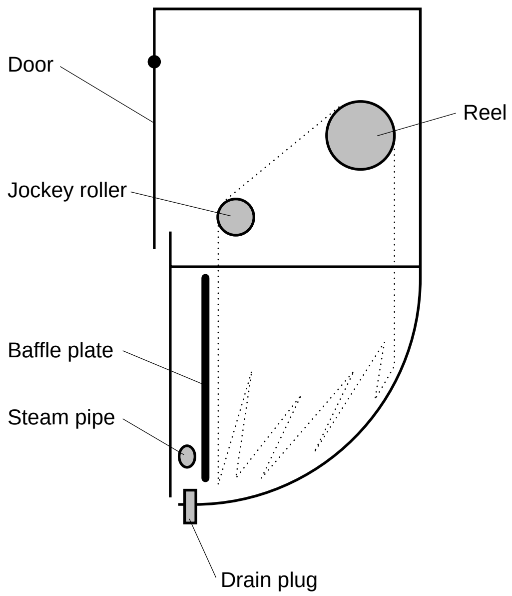

Fig 5 Deep draught winch

5.2 Energy Use

The energy used by atmospheric wet batch processing machines is calculated as the energy required to heat process water, plus an allowance for radiation, convection and evaporative losses.

The annual energy breakdown for a winch dyehouse, processing a mixture of cotton and man-made fabrics, is shown in Table 5. The high-energy value of the evaporative losses demonstrates the importance of minimising evaporation from atmospheric dyeing vessels. In this example, the machine hoods were present, but were not used.

Table 5 Typical energy breakdown in a winch dyehouse

Component	**Energy content (GJ/year)**	**%**	**Water discharge temp (°C)**
Dye effluent	9,861	57	79
Evaporative losses	7,303	43	-
Total	**17,164**	**100**	-

Table 6 relates energy and water usage to the quantity of fabric processed. This gives the average consumption per tonne (or specific consumption) for some of the most common jig and winch processes.

Table 6 Typical energy usage for atmospheric dyeing machines

Process	Specific energy consumption (GJ/te)	Specific water requirement (m^3/te)
Jig scouring/dyeing (heavyweight cotton)	6.7	12.0
Jig dyeing (mediumweight cotton)	5.6	21.0
Winch bleaching (wool)	16.0	48.0
Winch dyeing (acrylic)	12.5	22.0

5.3 Energy Efficiency Opportunities

- ***Installation and Use of Covers or Hoods***

  Using covers or hoods may seem obvious, but many jigs and winches are operated at high temperatures with hoods open. Using covers or hoods can reduce evaporative losses by approximately half. Evaporation is particularly important above 60°C.

- ***Careful Control of Temperature***

  Overheating, and in particular overboiling, is a common problem. It is most often caused by poor control and especially affects older machines. The maximum achievable temperature in an atmospheric vessel is 95 - 100°C. Once the dye liquor is boiling, further heat input will not raise the temperature, but will increase evaporation. Although a faster boil does lead to greater agitation of the fabric, this can be achieved more efficiently by fitting a circulator. At temperatures above 80°C, live steam breakthrough may occur; as much as 15% of steam can be lost in this way. Table 7 illustrates the energy savings that can be achieved by reducing temperature and by consistently closing the hoods on jig machines.

Table 7 Steam used by a jig machine with varying temperature and conditions

Operating temperature (°C)	Steam use (kg/hour)	
	Hood open	Hood closed
80	50	23
90	61	28
95	73	34
100 (simmer)	91	55
100 (vigorous boil)	218	127

The energy savings, even for small reductions in operating temperature, are significant; a jig machine set at 95°C uses only about 33% of that needed for a vigorous boil (both with hoods open). Closing the hoods makes even more difference. Just changing from a vigorous boil to a simmer (keeping operating temperature at 100°C) and closing hoods reduces energy use by 75%. The use of computer based control systems can not only provide an opportunity for closer control, but also the ability to log the operating conditions.

- ***Introduction of Effluent Heat Recovery***

  Effluent heat recovery in a dyehouse may be difficult since the effluent consists of both hot (exhausted dye liquor) and cold (rinse water) streams. Where pressure vessels are used there is the possibility of re-using the cooling water, which may drop the hot effluent temperature down to about 60°C. The effluent from atmospheric vessels could be significantly hotter than this. Table 5 showed an average dye effluent temperature of 79°C, which is not unusual. If the temperature of the combined effluent streams from a dyehouse falls to below 40°C after the introduction of the cold rinse water, conventional heat recovery cannot normally be justified.

  However, it may be worth considering segregation of hot and cold streams, either automatically or manually. This would be followed by balancing heat recovery and make-up water storage.

6. CONTINUOUS WET PROCESSING

6.1 Background

Continuous wet processing generally applies to washing-off after preparatory processes such as scouring, bleaching and mercerising, or washing-off after dyeing. A continuous washing range is made up of a number of tanks, compartments or becks connected by tension compensators and nip rollers. The fabric is threaded, open width, around a series of rollers in each tank. The rollers help to increase liquor agitation and the transfer of impurities, to improve washing efficiency.

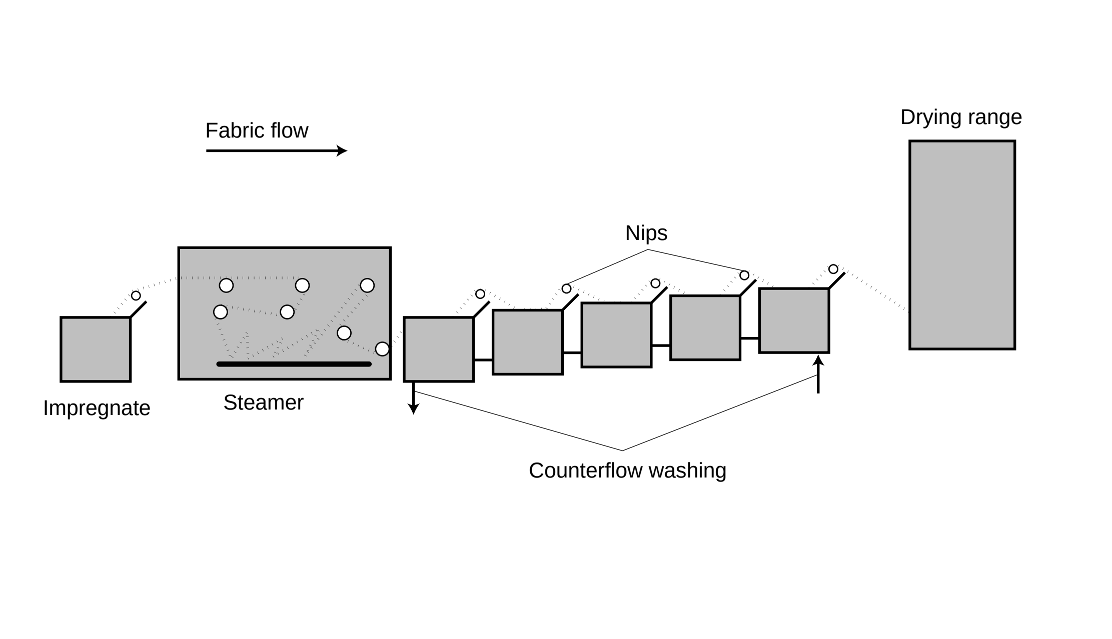

Fig 6 Continuous washing range

The energy usage of a continuous wet process is calculated as the heat required to raise water temperature, plus allowances for nip losses, radiation, convection and evaporative losses.

The annual energy breakdown of a seven-tank washing range, used to wash off mediumweight cotton fabric after bleaching, is shown in Table 8. In this example, six of the tanks are operated at 80ºC and four are counterflow. Water is used at a rate of 20 m^3/te (cubic metres of water per tonne of fabric), and is heated directly, using live steam. A large proportion of the losses occur at the nips between each tank.

Table 8 Typical energy breakdown for a washing range

Component	**Energy content (kW)**	**%**
Water heating	563	50
Nip losses	401	36
Radiation and convection losses	22	3
Evaporation losses	128	11
Total	**1,114**	**100**

Table 9 illustrates the range of energy and water requirements for washing-off after a number of different processes.

Table 9 Typical energy and water requirements for a washing range

Process (washing-off after...)	**Washing range**	**Specific energy consumption (GJ/te)**	**Specific water requirement (m^3/te)**
Bleaching	5 hot standing tanks	7.5	10.4
Bleaching	4 tanks, fully counterflow, with heat exchanger	2.8	4.3
Scouring/bleaching	5 tanks, fully counterflow, with heat exchanger	3.0	5.5
Dyeing	4 tanks counterflow and 1 cold standing tank	6.6	8.2
Printing	4 hot counterflow and 3 cold individual flow	10.5	35.0
Printing	4 hot counterflow with heat exchanger and 3 cold individual flow	5.5	35.0

6.2 Energy Efficiency Opportunities

- ***Install Covers on Nips and Tanks***

  Table 8 shows that the losses at the nips are considerable; in some cases they can exceed 40% of the total energy input, so it is important to cover them as well as the hot tanks. Any covers fitted should be easily removable to allow quick access.

- ***Convert Ranges to Counterflow Operation***

  In counterflow operation, the liquor flows in the opposite direction to the movement of the fabric, reducing both energy and water usage compared with standing tanks that have separate water flow and heating. Washing efficiency is similar in each case. In a typical conversion, a nine-tank Mather and Platt continuous washer had a counterflow system retrofitted to its seven heated tanks. A total of 62% savings were made in both energy and water usage, without any loss in washing performance.

- ***Fit Automatic Valves***

  Automatic stop valves which link the main drive mechanism of the range to the water flow can save considerable quantities of energy and water by shutting off water flow as soon as a stoppage occurs. With manual control, the water flow may not be switched off until the machine has stopped for more than 30 minutes. A series of shorter stoppages may well account for up to 20% of a given shift, but in general both the water flow and the heating will have been left on throughout the interruptions. It is not uncommon for the capital cost of automatic stop valves to be recouped in just four or five weeks.

- ***Introduce Heat Recovery Equipment***

  Installing heat recovery equipment on a continuous washer is usually a simple but very effective measure, since water inflow and effluent outflow are matched, eliminating the need for holding tanks. The effluent from these machines can become contaminated with fibrous material, so it is important to install a heat exchanger capable of handling such loads. One option is a self-cleaning, rotating element exchanger which has an efficiency of about 70%. Another is to fit a simple plate heat exchanger with a pre-filter, which may have a higher initial cost, but is capable of efficiencies in excess of 90%. (See GPCSs 28, 30 and 31-*Heat recovery from contaminated effluent.*)

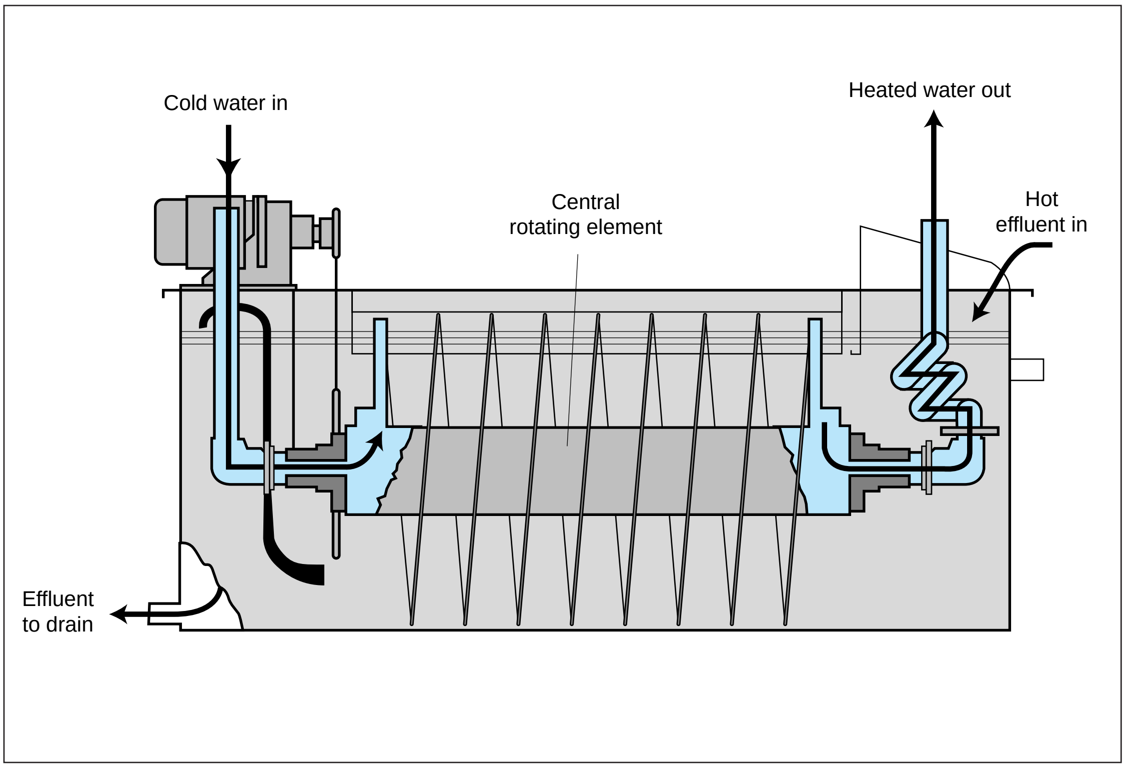

Fig 7 Rotating plate heat exchanger

Table 9 illustrates the energy saving potential of a heat exchanger on a continuous washer. In this example, the range was used for washing-off after printing. Without heat recovery, the machine operated at a SEC of 10.5 GJ/te fabric processed, and an SWR of 35.0 m^3/te. A rotating element heat exchanger was fitted to the hot counterflow section of the range and the average SEC dropped to just 5.5 GJ/te.

- ***Improve Flow Characteristics***

  Improvement of the flow characteristics and the washing efficiency of washing ranges needs to be addressed by manufacturers. Ideally, the range should comprise smaller tanks, each containing less water than at present and with an improved shape to eliminate relatively stagnant regions. In addition, washing action and water removal could be improved by employing suction between the tanks in place of nip rollers. However, the running costs of this option are about three times higher than those for nips per kg water removed. Research work done by the British Textile Technology Group and others has led to the specification of an 'ideal' energy and water efficient washer. These are the basic requirements:

  – counterflow operation;
  – wash water flow rate matched to washing requirements;
  – large number of stages or tanks (up to 80);
  – washing parameters identical for each stage;
  – wash water to be brought into intimate contact with the textile (this is achieved by throughflow which dictates either suction or pressure action).

- ***Improve Washing Action***

  Except for washing-off after scouring where hot water is required to prevent precipitation of the soap products, washing on the ideal machine could be done cold, thereby saving a considerable amount of energy without reducing the washing efficiency.

- ***Reduce Live Steam Pressure***

  A reduction in live steam pressure can prevent steam breakthrough, thus improving heat transfer efficiency in direct steam heating applications. Similarly, reducing steam pressure in closed coils carries the advantage that lower pressure steam has a higher latent heat content.

- ***Fit Thermostats/Temperature Indicators***

  Manual control of steam valves must be carefully managed to ensure that tanks are run at optimum temperatures; the fitting of temperature indicators and thermostatic valves can lead to significant energy savings.

- ***Introduce Point-of-Use Water Heating***

  Point-of-use gas-fired water heaters can be used to enable processes to be run independently of site central boiler systems. This means that the boiler and distribution losses associated with centralised systems (which can be as much as 50% of the gross fuel input) can be eliminated. Point-of-use heating also offers greater flexibility since it allows operation of processes outside main boiler operating hours.

Many of the measures highlighted above can be introduced on existing machines at relatively low cost and the energy and water savings that they achieve mean that the new equipment will pay for itself quickly.

7. CONTACT DRYING USING STEAM CYLINDERS

7.1 Background

Contact drying is the simplest and cheapest method of drying woven fabrics. It is mainly used for intermediate drying, rather than final drying (since there is no way of controlling fabric width), and for pre-drying prior to stentering. Fabric is passed around a series of cylinders, or cans, which are heated by steam supplied at pressures varying from 35 psi to 65 psi. Cylinders can be used to dry a wide range of fabrics. However, as the surface becomes compressed, the process is not suitable for fabrics with a raised surface effect.

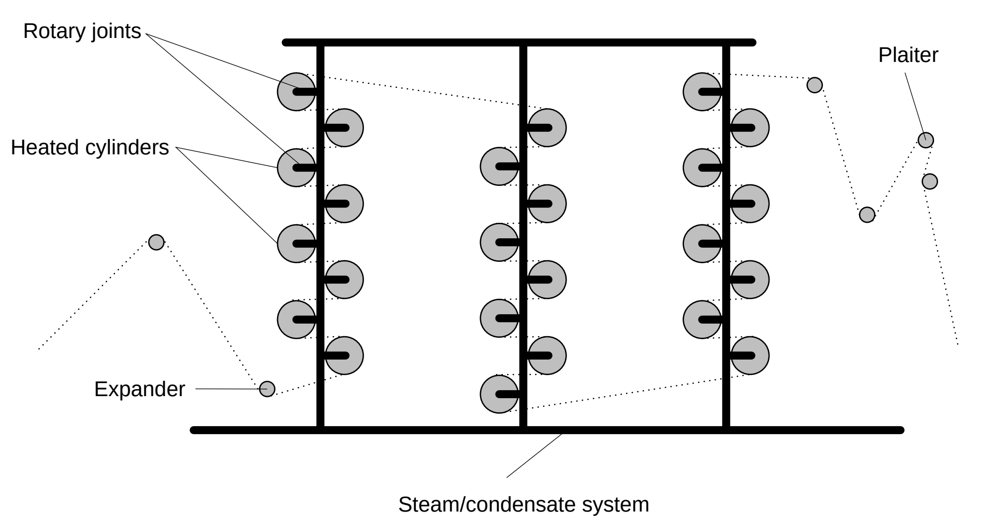

Fig 8 Drying cylinders

A typical energy breakdown for a set of 12 cylinders, heated by steam at 60 psi, and being used to dry a cotton fabric from 55% to 5% moisture content, is shown in Table 10.

Table 10 Energy breakdown for a set of steam cylinders

Component	Energy content (MJ/kg)	%
Evaporation	1.35	52
Radiation and convection losses	0.87	34
Fabric	0.16	6
Moisture	0.14	5
Friction	0.07	3
Total	**2.59**	**100**

In this example the water removed amounts to 50% by weight of fabric, and evaporative losses account for more than 50% of the energy requirement. Fabric is often dried from over 100% to bone dry, increasing evaporative losses to around 75% of the total.

7.2 Energy Efficiency Opportunities

Opportunities for making energy savings on drying cylinders may involve the introduction of replacement or additional equipment, or simply a change of working practices to improve the energy efficiency of existing plant:

- ***Introduce Mechanical Pre-drying***

  Mechanical pre-drying methods such as mangling, centrifugal drying, suction slot or air knife de-watering are used to reduce drying costs by removing some of the water from the fabric prior to contact drying. In order to select the best method, the limit retention capabilities of each system are balanced against their running costs. For instance, a slot is three times more energy intensive than a typical mangle, but consistently provides lower water retention rates over a range of fabric types.

  The effectiveness of mangling depends on a number of factors: the diameter and hardness of the bowl; the pressure applied; the temperature of the water in the fabric; and the fabric speed.

  Suction slots can quite easily be located in front of a stenter or set of cans. The slots draw air through the fabric which runs at speed over a slot configuration. The extracted air/water is then filtered and passed through a water separator. Although they are very effective, slots require a high electrical power input (up to about 50 kW). Narrower fabrics are accommodated by covering the lengths of slot at either side of the fabric with a rubberised blind. As well as de-watering, the slot can be used to recover excess chemicals padded onto the fabric. These additional savings can be used to offset the running costs of the system.

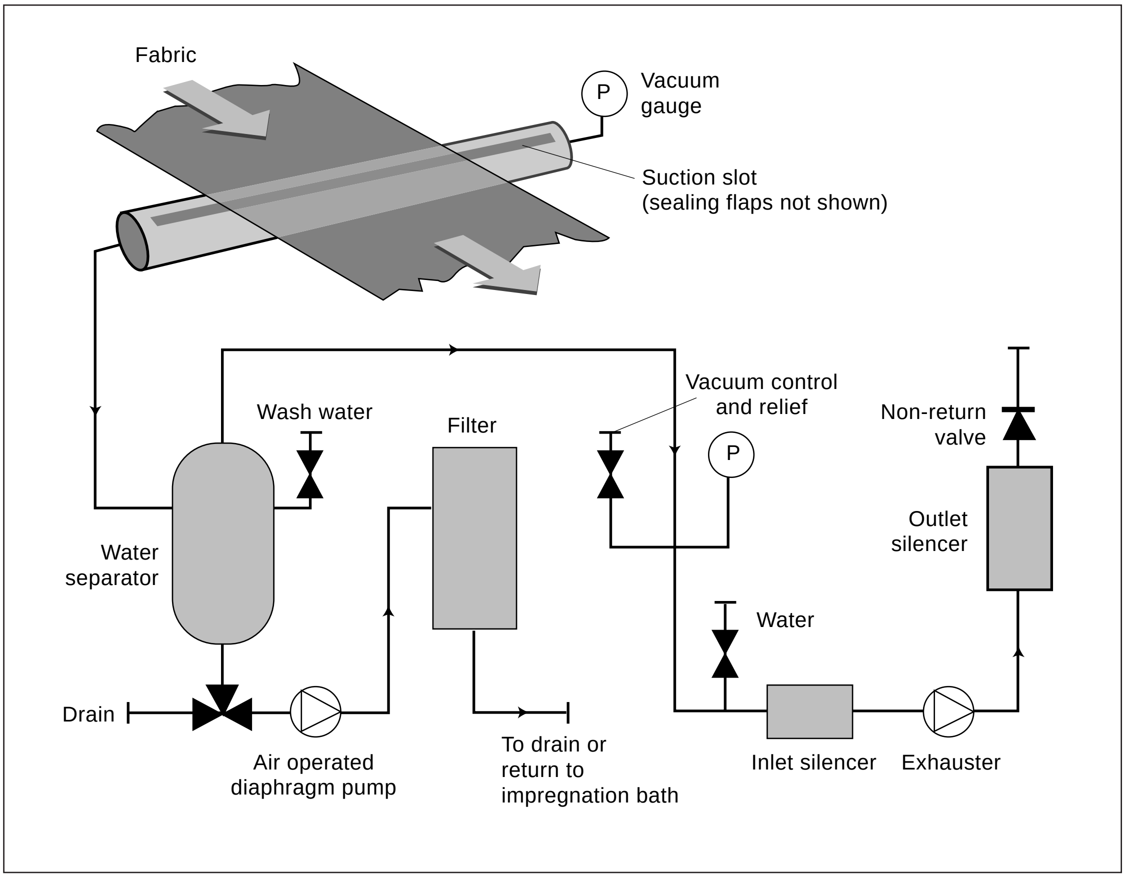

Fig 9 Suction slot

Typical limit retentions (%) for a variety of fibres, using mangles and suction slots, are shown in Table 11.

Table 11 Typical retention limits for a number of fibres

Fibre	**Mangle retention (%)**	**Suction slot retention (%)**
Cotton	45 - 70	40 - 55
Viscose	60 - 100	60 - 80
Diacetate	40 - 50	27 - 40
Nylon 6.6	20 - 40	14 - 30
Polyester	20 - 30	10 -16
Wool	58 - 60	35 - 55

Centrifugal drying may also be used for some fabrics, although its tendency to cause creasing means that the process is mainly used to de-water yarn or staple. In terms of cost and performance, centrifuges fall between mangles and suction slots.

Table 11 indicates that, in general, lower retention rates are achieved by the suction slot. This is particularly true when it is used to de-water *hydrophobic fibres*. In practice, the figures given for mangling are seldom achieved, and performance can be quite poor. For example, it is quite common to see retentions of only 80 - 100% for cotton. This makes the suction slot seem attractive even for the *hydrophilic fibres*, but its relative energy consumption must be taken into consideration.

- ***Selection of Hybrid Systems***

  The performance of steam cylinders can be enhanced by the use of directed air, either at ambient or elevated temperatures. In the latter case, the air is a second means of heat transfer and the process is a combination of contact and hot-air drying. There are two examples of ambient temperature directed air equipment which are essentially means of dispersing evaporated moisture. One is the ATIRA Rapidry system, an Indian development, which uses air jets and claims increased drying rates of around 25 - 30%. The other is the Shirley Hood which was sometimes used for sizing and coating operations. It could increase the drying rate by as much as 40%.

- ***Recover Condensate and Flash Steam***

  Wherever possible, condensate should be recovered and returned to the boilerhouse. It is a valuable source of hot, treated water so should never be put down the drain. Similarly, flash steam which is produced when condensate is reduced to atmospheric pressure can be recovered as low-pressure steam, and used to heat water or other low-pressure steam processes. Alternatively, but more expensively, the condensate system can be pressurised to ensure that all the recovered energy is returned to the boilerhouse.

- ***End Panel Insulation***

  The insulation of end sections on small diameter cylinders may not be practicable because the steam, condensate pipework and safety valve get in the way. For cylinders with a diameter of one metre or more, however, insulation may well be worthwhile.

- ***Select Processes for their Low Water Add-on Characteristics***

  Before looking at water removal it is worthwhile checking the process to see whether it could be modified or replaced, to minimise the amount of water introduced to the fabric. In particular, the application of finishes using foam, lick roller or spray application methods could be considered.

- ***Avoid Intermediate Drying***

  Considerable savings in energy can be made by avoiding intermediate drying between processes. For example, there are systems which allow finishes to be applied 'wet on wet' to reduce drying requirements (although this is less beneficial for dyeing).

  Typically a fabric is dried two, three or even four times during its passage through a finishing works. As well as being energy intensive, drying tends to be the bottleneck operation. If just one of the drying stages could be eliminated there would be a substantial improvement in both energy efficiency and production capacity.

- ***Avoid Overdrying***

  Overdrying of fabric is a very common problem. Fibres have an equilibrium regain, or natural moisture level, below which it is pointless to dry. For some fibres the regain value can be quite high. It is therefore important to control the speed of the drying cylinders so that the equilibrium moisture level is not exceeded. Typical regains at 20°C and 65% relative humidity (RH) are shown in Table 12.

Table 12 Typical regain values for a number of fibres

Fibre	**Regain value (%)**
Cotton	7.0
Wool	16 - 18
Viscose	12.5
Diacetate	6.9
Triacetate	4.5
Nylon 6.6	4.3
Nylon 6	4.4
Polyester	0.4
Acrylic	1.5
Polypropylene	0.0

On sites where it is common practice to dry fabrics to 'bone dry' condition, the potential for making savings is considerable. Hand-held moisture meters can be used with a roller sensor to monitor the moisture content of fabric leaving the drying cylinders to ensure that optimum drying is taking place.

- ***Reduce Idling Times and Using Multiple Fabric Drying***

  Careful scheduling of fabric batches arriving at the cylinders can reduce idling time, therefore saving energy. Similarly, efficiency can be improved by making cylinders extra wide to allow two batches of narrow fabric to run side by side.

- ***Operating Cylinders at Higher Steam Pressures***

  Cylinders can be operated at higher steam pressures and temperatures to reduce radiation and convection losses compared to evaporative energy.

- ***Maintenance***

  Common leak sites for steam cylinders are the vacuum breakers, air vents, rotating joints and steam traps. A single bank often comprises 32 cylinders, so the potential for leakage is considerable. It is therefore important to have a good maintenance regime which should include periodic checking of steam traps using an ultrasonic steam-leak detector.

8. HOT-AIR DRYING USING STENTERS

8.1 Background

Stenters have an important role to play in dyeing and finishing works. As well as drying, heat setting and curing they also affect the finished length, width and properties of the fabrics. Fabric can be processed at speeds from 10 - 100 m/minute and at temperatures in excess of 200°C. Sophisticated feed and transport mechanisms mean that the fabric is presented to the oven in a way which ensures that the finished product will meet customer requirements.

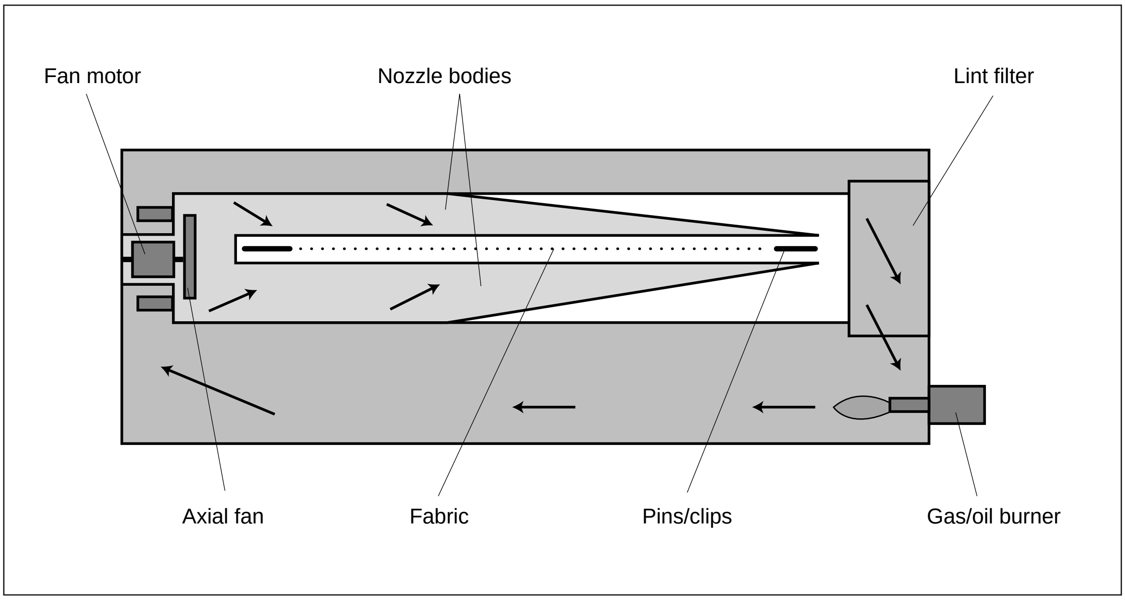

Fig 10 Direct-fired stenter (cross-section)

Stenters can be heated in a variety of ways, although the most common method is by direct gas firing. A few units are still indirect gas-fired but their efficiencies are poor when compared to direct fired systems. Gas-fired stenters are highly controllable over a wide range of process temperatures.

Thermal oil heating for stenters requires a small thermal oil boiler (usually gas-fired) and its associated distribution pipework. It is less efficient than direct gas firing and has higher capital and running costs. However, like gas, it can be used over a wide temperature range.

Oil itself can be used as a means of heating stenters, but the problems of incomplete combustion mean this heating can only be done indirectly via a heat exchanger. This system, as with indirect gas firing, is relatively inefficient so is no longer commonly used.

Finally, there are a number of steam-heated stenters. Because of their low temperature limits (usually up to a maximum of 160°C) these ovens can only be used for drying; they are not suitable for heat setting or *thermofixing* of fabrics.

In all stenters the air is heated, forced against the fabric, then recirculated. A fraction of this air is exhausted and made up with fresh air. To provide better control, stenters are split-up into a number of compartments, usually between two and eight, three-metre sections, each fitted with a temperature probe, burner/heat exchanger, fans, exhaust and damper.

A typical energy breakdown for a stenter being used for hot-air drying is shown in Table 13. By far the greatest users of energy are the evaporation and air heating components. It is therefore imperative that fabric moisture content is minimised before the fabric enters the stenter, and that exhaust airflow within the oven is reduced. Many stenters are still poorly controlled, relying on manual adjustment of exhausts and operator estimation of fabric dryness.

Table 13 Energy breakdown for a typical stenter

Component	Energy content (GJ/te)	%
Evaporation	2.54	41.0
Air heating	2.46	39.7
Fabric	0.29	4.6
Case	0.39	6.3
Chain	0.09	1.5
Drives	0.43	6.9
Total	**6.20**	**100.0**

8.2 Energy Efficiency Opportunities

- ***Introduce Mechanical De-watering or Contact Drying Before Stentering***

  Stentering is an energy intensive process, so it is important to remove as much water as possible before the fabric enters the oven. This can be achieved using mechanical de-watering equipment such as mangles, centrifuges, suction slots and air knives; or by contact drying using heated cylinders. Contact drying is roughly five times more energy intensive than suction slot de-watering, but nevertheless uses only half to two-thirds the energy of a stenter. Pre-drying fabric to about 25 - 30% regain before passing it through the stenter still allows fabric width to be adjusted to suit customer requirements.

  Other techniques used to reduce drying costs include infra-red and radio frequency drying. Gas-fired infra-red has been used for the pre-drying of textiles prior to stentering. This can have the effect of increasing drying speeds by up to 50%, thereby relieving production bottlenecks which tend to occur at stenters. In addition, energy savings in the region of 50 - 70% can be achieved, compared to conventional stenter drying. If an efficient means of pulling the fabric out to width could be devised for a short hot-zone length, then infra-red could be used to do all the drying.

  Radio frequency drying is used extensively for the drying and dye fixing of loose stock, packages, tops and hanks of wool and sewing cotton. The energy requirement of radio frequency drying is approximately 70% that of a conventional steam-heated dryer. However, its use is limited to loose stock and packages. It cannot be modified, as yet, to accommodate knitted or woven fabric since the traditional pins and clips of the stenter transport mechanism interfere with the radio frequency drying field, causing discharge.

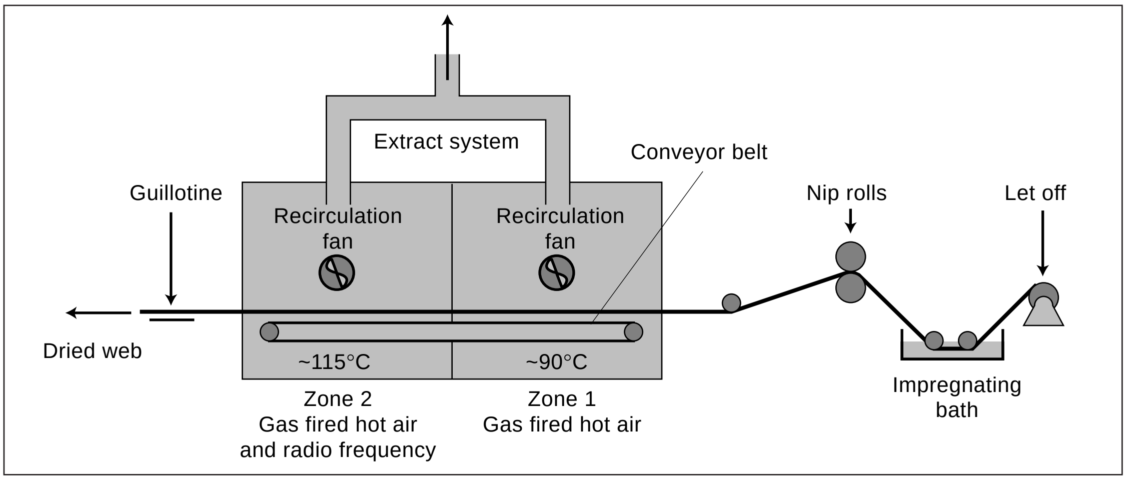

Fig 11 ARFA dryer

- ***Avoiding Overdrying***

  The high-energy cost of running a stenter means that it is vital to avoid overdrying. Automatic infra-red, radioactive (source) or conductivity-based moisture measurement systems can be linked to the stenter speed control to ensure that the appropriate fabric regain value is achieved.

- ***Close Off Exhaust Streams During Idling***

  Commission dyers and finishers often operate with relatively small batch sizes. In extreme cases this may mean that the fabric feed to machines is being changed every hour. It is common practice to leave the exhaust systems running during these changeovers, which may take 10 - 15 minutes or more. Since stenters have a large air-heating requirement it is important, whenever possible, to isolate the exhausts, or at least partially close them down, during idle periods.

- ***Drying at Higher Temperatures***

  Drying at a higher temperature, if the fabric will tolerate it, means that radiation and convection losses become relatively small compared to evaporation energy.

- ***Close and Seal Side Panels***

  On older machines the side panels may become damaged, upsetting the air balance within the oven sections. All faulty panels should be repaired or replaced to provide an effective seal around the oven.

- ***Insulation***

  Improving stenter insulation is not usually practicable, although on some older machines it may be cost-effective to insulate the roof panels.

- ***Optimise Exhaust Humidity***

  Table 13 showed that the main energy requirements for a stenter are for air heating and evaporation. In order to optimise drying rate and energy use, air flow through the oven (and therefore exhaust rate) must be carefully controlled. A significant number of stenters still rely on manual control of exhausts, although this is actually very difficult and often means that exhausts are left fully open unnecessarily.

  For optimum performance, exhaust humidity should be maintained between 0.1 and 0.15 kg water/kg dry air. It is not unusual to find stenters with an exhaust humidity of only 0.05 kg water/kg dry air, indicating that the exhaust volume is too high and excessive energy is being used to heat air. Equipment is available which will automatically control dampers to maintain exhaust humidity within the specified range, thereby cutting air losses without significantly affecting fabric throughput. Controllers vary from wet/dry bulb temperature systems to fluidic oscillators measuring the variation in sound through a special filter head.

  Drying of solvent-based work requires much greater exhaust volumes for safety reasons, leading to higher air losses. However, many solvent-based systems have now been replaced by aqueous systems to satisfy the requirements of the Environmental Protection Act (EPA).

- ***Install Heat Recovery Equipment***

  Exhaust heat recovery can be achieved by using air-to-air systems such as plate heat exchangers, glass tube heat exchangers or heat wheels. Efficiencies are generally about 50 - 60%, but there can be problems with air bypass, fouling and corrosion. If other measures, such as fabric moisture control and exhaust humidity control, are installed, heat recovery may not be cost-effective.

Air-to-water systems, such as spray recuperation, avoid fouling and clean the exhaust, but may give rise to corrosion. Secondary water/water heat exchange equipment is required and a matching heat requirement must be identified.

If large quantities of volatile organics or formaldehyde are generated by the stenter, some form of scrubber, electrostatic precipitator or even an incinerator may be required to comply with the statutory limits of the EPA. In these cases, it may be sensible to incorporate heat recovery so that at least part of the installation costs can be recovered.

- ***Converting to Direct Gas Firing***

  Compared with other stenter heating systems, direct gas firing is both clean and cheap. When it was first introduced there was concern that oxides of nitrogen, formed by exposure of air to combustion chamber temperatures, would cause fabric yellowing or partial bleaching of dyes. This has since been shown to be unjustified. Unlike steam and thermal oil systems there are no distribution losses. Heating up times are shorter and thermal capacities are lower, all leading to reduced idling losses.

9. HOT-AIR/STEAM HEAT TREATMENTS

9.1 Background

Hot-air and steam heat treatment processes include curing, heat setting, baking, dye fixing and steaming. The main equipment used for heat setting, curing and fixing is the stenter. Hot flues are used for baking and fixing and a variety of steamers for dye fixing and some preparatory work.

Heat setting of fabric to improve stability is generally achieved at temperatures in excess of 180°C. It is particularly important in the treatment of polymeric materials, which may be pre-set prior to preparation and dyeing if they are susceptible to creasing or shrinkage. To prevent permanent creases being formed in polyester fabric, for example, it must be pre-set before scouring and disperse dyeing in rope form on a jet-dyeing machine.

Stenter curing of fabrics is used to complete polymerisation or the condensation reaction of an added substance (usually padded on).

Fixing of dyestuffs can be achieved in a number of ways depending on the fabric, dyestuff and customer requirements.

Thermosol fixing is a means of colour-fixing mainly polyester/cotton fabrics by heat treating at temperatures of 200 - 220°C for up to one minute. The process normally uses specific thermosol units set within a continuous dyeing range, but it can also be carried out in a stenter capable of operating at high temperatures.

Continuous steamers are used for the diffusion and fixing of vat, sulphur and direct cotton dyes. The fabric is passed through a steamer set at 102 - 110°C, with fabric contact times of up to 60 seconds. The minimisation of air in the system reduces evaporation temperature, ensuring rapid heating of the fabric and improved diffusion/fixing of the dyestuff.

Steamers can also be used to provide a means of rapid, continuous preparation. Fabric is impregnated with caustic or hydrogen peroxide prior to treatment in the steam atmosphere.

Table 14 shows a typical energy breakdown for heat setting processes. These tend to be dominated by air losses, which account for about 80% of the total energy input. It is therefore important to minimise air losses by controlling the exhaust.

Table 14 Energy breakdown for heat setting

Component	**Energy content (GJ/te)**	**%**
Evaporation	0.20	4.3
Air heating	3.55	76.2
Fabric	0.25	5.4
Case	0.23	4.9
Chain	0.10	2.1
Drives	0.33	7.1
Total	**4.66**	**100.0**

9.2 Energy Efficiency Opportunities

- ***Select Processes Which Require Less Energy/te Fabric Processed***

  Research work has shown that infra-red panels could be used to improve the energy efficiency of heat setting and dye fixing processes. At the same time:

  – stenter hot zones could be reduced to less than two metres, allowing much faster fabric throughput;

  – 8% shrinkage could be achieved on nylon fabrics at speeds of 30 metres/minute with a hot zone length of 0.25 metre;

  – dye fixing times could be halved, compared with conventional stenter treatments.

- ***Minimise Air Loss***

  Air exhaust is necessary to remove the small amounts of volatiles that are released from the fabric at high temperatures during heat setting and dye fixing processes. The air losses associated with this exhaust account for the bulk of the energy used in hot-air treatments. In theory it should be quite safe to operate stenter ovens with exhaust rates of 10 kg air/kg fabric processed. In practice, finishers tend to employ about 15 kg air/kg fabric. Optimisation by reducing exhaust rates can therefore lead to energy savings of up to 30%. However, there are some fabrics and processes (notably pre-setting of some synthetics) which cause considerable fume problems, leading to a characteristic ‘blue haze’ emanating from the fabric slots. In these cases the stenter may be required to operate with fully open exhausts.

- ***Control and Maintenance***

  A number of low or no-cost measures can be introduced to improve the energy efficiency of hot-air/steam heat treatment equipment. For example, the side and top panels of thermosol units, bakers and steamers can be insulated to minimise heat losses. Heat transfer rates within thermosol units tend to be not very good, so it is important that the fabric entering the unit is as dry as possible. There may be potential to re-use, or recover heat from, the warm water flowing from the exit water seal of steamers.

10. FUEL, STEAM RAISING PLANT AND DISTRIBUTION SYSTEMS

10.1 Background

Textile dyeing and finishing plant generally uses gas or dual oil/gas-fired package boilers for steam raising. Very few companies still operate coal-fired systems, since these are regarded as being dirty and relatively costly. Gas is seen to be a clean, convenient fuel of consistent quality. It does not require fuel storage tanks or heated distribution lines, and produces less corrosive flue gas than either fuel oil or coal.

Most modern boilers used in textile processing plant are of a three-pass shell type, rated at around 150 psi. The combustion chamber is completely enveloped in the boiler shell, enabling heat to be transferred very efficiently. Shell boilers do have some minor drawbacks compared to the older Lancashire or ‘economic’ boilers in that they tend to have limited steam storage capacity and will not tolerate hard water. However, these disadvantages are offset by faster response times and higher efficiency. Site steam requirement is generally in the range 2,250 - 13,600 kg/hr, stepped down from generated pressures to about 40 - 80 psi for most process uses.

Textile dyeing and finishing companies are usually small to medium-sized companies employing less than 500 people. Process energy requirements are normally met by:

- steam from a centralised boiler plant for water heating, contact heating systems and space heating (thermoliers);
- direct gas firing for stenters, bakers, singeing, thermosol units, infra-red panels, coating machines, localised water heating, thermal oil boilers and space heating (infra-red and convection);
- electricity for lighting, overall motive power, compressed air systems and specifically on processes such as raising, glazing, schreinering and beaming.

10.2 Energy Efficiency Opportunities

- ***Minimise Flue Gas and Other Boiler Losses***

  To minimise flue gas losses from a boiler, it is essential to check that the fuel/air mixture at the burner is correct. Too much air will cool the boiler unnecessarily and may even prevent complete combustion of the fuel. Similarly, too little air will lead to incomplete combustion and fuel wastage. When the fuel/air mixture is right, the proportion of carbon dioxide in the flue gases is maximised and combustion efficiency is at its greatest. Automatic control systems are used to monitor flue gas composition (e.g. by measuring oxygen content) and provide feedback to vary the fuel/air mixture to obtain optimum combustion efficiency.

  As well as monitoring flue gas composition on a regular basis, the gas temperature should also be checked. A rise of more than 15 - 20°C above ‘normal’ flue temperatures should be investigated as this may indicate: scaling of the boiler tubes on the water side; sooting up of the tubes on the fire side; or flame impingement on the back plate. Any one of these occurrences will reduce boiler efficiency.

  Unburned fuel is another source of loss from a boiler. For gas and oil this should be zero, and should be checked by testing for carbon monoxide and black smoke respectively. However, for coal there is always a proportion of non-combustible ash and grit which must be taken into account. Analysis of the coal will provide a figure from which these losses can be calculated.

  Radiation losses from a well-insulated modern boiler at high fire will be as little as 2 - 3%. All boilers are most efficient at high fire. At half load, radiation losses increase to 6% and at a quarter output, to 12%. It is therefore important to size a boiler correctly and to run it at full fire if at all possible.

Blowdown, or regular venting of boiler water into a flash vessel, is used to reduce the total dissolved solids (TDS) content of boiler water. For shell boilers, the maximum acceptable TDS level is 3,500 ppm. Although it is an essential process, venting boiler water in this way does mean that some energy is wasted. Where the blowdown rate is high, it may be worthwhile installing a heat exchanger in tandem with the flash vessel. The recovered heat can be utilised in the feed water tank.

- ***Return Condensate to the Boiler***

  Most steam heating in dyeing and finishing plant takes place as indirect, closed coil heating. Direct heating, using live steam, is generally only applied to atmospheric batch vessels and to some wash tanks. To minimise water treatment costs and energy losses it is therefore important to return as much condensate as possible to the boiler. Once this has been achieved, a system of regular steam trap checking and maintenance should be introduced to ensure that the condensate is returned efficiently and that no steam is passed back. Small hand-held ultrasonic steam trap indicators may be used to pinpoint traps that are seized up or are passing.

- ***Lagging***

  Insulation of steam and condensate pipework is essential to prevent large distribution losses, but it is surprising how many sites still have partially insulated steam lines, uninsulated valves and flanges or wholly uninsulated condensate return systems. The capital cost of steam line insulation can usually be recovered in six months, or about ten months for lower temperature condensate lines. It is, therefore, one of the most cost-effective ways to reduce energy wastage. Resistance to lagging may be because, generally, space heating in process areas is minimal, so operatives rely on the heat from processes and from uninsulated steam and condensate lines to keep them warm in the winter. This apparently ‘free’ heat is, however, uncontrolled and leads to excessive ventilation requirements in the summer months when workroom conditions become oppressive.

- ***Flue Gas Heat Recovery***

  Flue gas losses from a boiler are typically 20% or more. As flue gases are exhausted at high temperature, it is relatively easy to recover a large proportion of this heat. The usual use for this would be for process water heating. If the condensate return rate is unavoidably low, perhaps because a high proportion of the steam raised is used for direct injection, flue gas heat recovery is a sensible way of raising the temperature of the boiler feedwater, thereby reducing boiler fuel consumption. Unfortunately the technique is only suitable for gas-fired boilers, and unless the boilerhouse is close to the production area, distribution losses may be excessive.

11. ELECTRICITY SUPPLY FOR MOTIVE POWER, COMPRESSED AIR AND LIGHTING

11.1 Background

On a typical dyeing and finishing site, electricity consumption may be only 5 - 10% of energy usage, but may account for 30 - 40% of the total energy cost. It is, therefore, a significant part of the site's overall production costs. Electricity provides motive power for preparation, dyeing, printing, drying and finishing machinery; for pumping water, air fans/blowers and extraction systems; compressed air systems; lighting and sometimes even for office heating.

Although, historically, textile finishing plants preferred dc power, the cost of maintenance for these systems has meant that the majority of plants now import ac power instead, transforming it to dc locally for the processes that require it.

Care should be taken to ensure that motors in textiles works are well-protected from the dusty, humid atmosphere. For maximum efficiency, they should be carefully matched to the required load; for applications with varying loads, such as fans and pumps, variable speed drives (VSDs) offer flexible, energy efficient control. The installation of high-efficiency motors may be worth considering if motors are required to run continuously for long periods. Their additional cost is relatively small compared with the energy savings they will produce over their life.

Compressed air systems are used to meet a wide variety of duties for preparation and dyeing vessels, cloth guiding equipment and fabric nips for de-watering. Motors for compressors are generally very large, and may be some of the largest in the factory. They are normally in constant use during working hours. In textiles works they are mainly reciprocating type and are usually confined to a centralised compressor facility where the noise levels can be better controlled.

In most areas of a dyeing and finishing works, lighting is provided by 85 watt single and double fluorescent tubes backed by standard reflectors. The exception to this is in larger warehouses and around loading bays where high and low-pressure sodium lamps may be used.

11.2 Energy Efficiency Opportunities

The main opportunities for saving electricity in textile dyeing and finishing are:

- improving power factor;
- installing motor controllers;
- reducing compressor losses;
- recovering heat from compressors;
- installing more efficient lighting systems;
- installing electrical efficiency control systems.

Further information on how to make savings in these areas can be gained from the relevant publications, listed in Section 14 of this Guide.

12. WATER STORAGE, DISTRIBUTION AND USE

Most dyeing and finishing sites use town water as their main process water supply, returning effluent to sewer after minimal treatment. Some sites can extract process water from boreholes and a very few treat their effluent on site. It is common for water and effluent costs to account for as much as 5% of overall site production costs and up to a third of the site energy bill. Since much of the process water is heated, the need for careful management of energy and water usage go hand in hand.

Water usage is generally in the range 100 - 150 m^3/te of fabric processed, so it is important to recover energy from effluent and to re-use water whenever possible. For good consistent results from dyeing processes, water purity must be high. This usually means that only clean water is suitable for dye liquors. There have, however, been successful projects recycling water from exhausted dye liquors, although generally this has been where the number of dye shades is limited. Commission dyeing, which occurs at the majority of sites, is by its nature very variable, so the opportunities for re-using water may be limited to recycling rinse water. On-site cleaning of effluent is feasible, but is often prohibitively expensive.

Heat recovery from effluent is usually carried out locally at the process. The most common applications of water/water heat recovery are continuous washing ranges, where there is no need for storage since water requirement and effluent flow are exactly matched. Elsewhere, effluent heat recovery usually requires the segregation of hot and cold water flows. This can be achieved by modifying drainage systems to allow for automatic segregation of the hot waste dye liquor and the cold rinse water.

Heat recovery is only rarely applied to final mixed effluent, since it generally leaves the factory at less than 40°C.

Table 15 shows a typical water usage breakdown for a single process route at a dyeing and finishing site where cotton is prepared and dyed.

Table 15 Breakdown of water usage for a typical cotton dyeing and finishing site

Component process	**Water requirement (m^3/te fabric)**
Singeing/desizing	2.0
Scouring/bleaching/washing (continuous range)	15.5
Jig dyeing	12.5
Total	**30.0**

13. FUEL, POWER AND WATER COSTS

Energy and water costs account for around 12 - 16% of total site production costs in the dyeing and finishing sector. The choice of fuel and water sources, and their utilisation, therefore have a significant bearing on the profitability of a company.

The type of fuel used may be oil (gas, light or heavy), liquefied propane gas (LPG), natural gas or coal. Natural gas is largely used for direct process heating; LPG for singeing; and oil, gas or coal for boilers. The type of fuel used in the boilerhouse will affect the capital cost and efficiency of the boiler plant, as well as the maintenance and running costs. All of these factors must be taken into consideration, together with the cost of the fuel. Dual fuel capability may be desirable to ensure security of supply and to provide some flexibility in terms of costing.

Industrial consumers, using published electrical tariffs, pay several charges in addition to the unit charge and standing charge. The principal additional component is the maximum demand (MD) tariff. It is usually based on the highest 30 minutes' power consumption in a single month, and may be measured in kVA or kW. This means that a site using a lot of electricity in a short time pays more than a site with a lower steady demand, even though their unit consumption per month is the same. The MD tariff is usually highest in December and January; it is not unusual for it to be the largest component of a site's electricity bill in the winter. From March to October there may be no MD tariff, or it may be very small. The following measures can be put in place to reduce simultaneous electrical demand (and thus MD tariff liability):

- ensuring that machine start times are staggered;
- interlocking machines with a high intermittent demand;
- switching off equipment during peak times;
- reducing compressed air leakage;
- correcting power factor (if MD is measured in kW).

With the consent of the Licensing Authority, fresh water may be abstracted from a borehole or river as an alternative to taking mains water. An annual licence fee is charged on the basis of the maximum permitted abstraction volume (rather than the volume actually taken). Such licences are invariably cheaper than using mains water, provided that the water is of sufficient quantity and quality.

Charges for trade effluent are based on the chemical oxygen demand/biological oxygen demand (COD/BOD) and suspended solids content of a sample compared with average figures for the same period. Most dyeing and finishing companies discharge to sewer, so only have to monitor acidity and temperature. Acidity should be within the range pH6 - pH9, whilst temperature should not exceed 42°C. Typical effluent from dyeing and finishing plants falls within these limits, due to the alkaline nature of most preparatory processes and the high volumes of cold rinse water used in dyeing processes, which reduce the temperature of mixed effluent to about 40ºC.

14. BIBLIOGRAPHY

Key:	ECG	Energy Consumption Guide
	EPP	Expanded Project Profile
	FEB	Fuel Efficiency Booklet
	GPCS	Good Practice Case Study
	GPG	Good Practice Guide
	NPIP	New Practice Initial Profile
	NPFP	New Practice Final Profile
	R	CADDET Result Brochure

ECG 40 *Compressing air costs - generation*
ECG 41 *Compressing air costs - leakage*
ECG 42 *Compressing air costs - treatment*
EPP 309 *Gas fired infra-red panels to increase stenter production*
EPP 310 *Filtering and recycling stenter exhaust air*
EPP 312 *Dyeing and drying using RF technology*
EPP 313 *Fabric dyeing with low liquor ratios*
FEB 2 *Steam*
FEB 8 *The economic thickness of insulation for hot pipes*
FEB 14 *Economic use of oil-fired boiler plant*
FEB 15 *Economic use of gas-fired boiler plant*
FEB 17 *Economic use of coal-fired boiler plant*
GPCS 28 *Heat recovery from contaminated effluent*
GPCS 30 *Heat recovery from contaminated effluent*
GPCS 31 *Heat recovery from contaminated effluent*
GPCS 137 *Compressed air costs reduced by automatic control system*
GPCS 153 *Differential drainage and boiler return system*
GPCS 159 *Energy efficiency lighting in factories (BRECSU)*
GPCS 181 *A novel use for recycled textile fibres*
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GPG 126 *Compressing air costs*
NPFP 25 *ARFA drying of heavy textiles*
NPFP 26 *Suction slot de-watering in textiles finishing*
NPFP 36 *Direct gas firing in the textiles industry*
NPFP 52 *Optimisation of a ‘yankee’ drying cylinder hood*
NPIP 58 *Contract energy management of a heat recovery system*
NPR 23 *Heat recovery and pollution control in textile finishing*
R 25 *Foam processing*
R 29 *Heat recovery*

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APPENDIX 1

GLOSSARY OF TERMS

Air knife	uses an air jet to blow water out of fabric.
Beaming	method of dyeing whereby dye liquor is passed through the fabric.
Centrifugal drying	using centrifugal force to part-dry fabric.
Electrostatic precipitator	a device for negatively charging particles which then precipitate onto earthed plates.
Fluidic oscillators	device for measuring the humidity of an exhaust stream.
Hydrophilic fibres	fibres which have an affinity for water.
Hydrophobic fibres	fibres which do not have an affinity for water, i.e. tend to reject water.
Kiers	large steel vessel in which yarn and cloth are boiled with alkaline liquors for scouring and bleaching. Now often supplanted by continuous processing machinery.
Liquor	solution of dye in water.
Mangling	a mechanical means of removing water from fabric.
Mercerising	treatment of the fabric under tension with caustic soda. This results in increased strength and dye absorption.
Raising	wire-covered rollers or teasels on cylinders revolve over the surface of the fabric to produce a nap.
Shirley Hood	a means of using air jets to enhance the performance of steam cylinders by aiding moisture dispersal.
Singeing	removing protruding surface fibres to reduce piling.
Stenter	machine that holds a fabric by its selvedges while keeping it taut in open width and transporting it through a drying chamber.
Suction slot	system where fabric passes over a slat to which a vacuum is applied. This draws water out of the fabric.
Thermosol units	Thermosol fixing is a means of colour-fixing mainly polyester/cotton fabrics by heat treating at temperatures of 200 - 220°C for up to one minute. The process normally uses specific thermosol units set within a continuous dyeing range, but it can also be carried out in a stenter capable of operating at high temperatures.
Thermofixing	the use of heat to ‘set’ a fabric.

APPENDIX 2

EQUATIONS FOR CALCULATION OF ENERGY USED BY TEXTILE DYEING AND FINISHING MACHINES

The following equations have been derived by the British Textile Technology group to give a first indication of the expected energy usage for a number of machines operating under different conditions. The calculations are within ±5%, which is adequate for most from first principles, working out water heating, power requirement, air losses, fabric losses, radiation, convection and evaporative losses individually.

Wet batch processing under pressure

The energy used by pressurised vessels can be expressed as:

Energy (kJ/kg water) = $4.6\Delta T + 1.5t(T - 30)$

where:

ΔT	=	increase in temperature (°C)
t	=	time at temperature T (hours)
T	=	final temperature (°C)

This equation represents the energy required to heat water to the required temperature, plus an allowance for radiation losses.

Wet batch processing at atmospheric pressure

The energy used by atmospheric vessels can be expressed as:

Energy (kJ/kg water) = $4.6\,\Delta T + \frac{At}{100}(T - 30)^2$

where:

ΔT	=	increase in temperature (°C)
A	=	2.5 if hoods are closed
	=	5.0 if hoods are open
t	=	time at temperature T (hours)
T	=	final temperature (°C)

Evaporative losses from atmospheric vessels increase roughly as a function of the square of the temperature above ambient. It is therefore imperative that covers and hoods are used at temperatures over 60°C.

Continuous wet processing

The energy used by a washing range, where all the heated water is used in a counterflow section can be expressed as:

$$\text{Energy (kJ/kg water)} = 4.2\ \Delta T + \frac{AN}{LP}\ (T - 30)^2$$

where:

ΔT	=	increase in temperature (°C)
A	=	4 for fully enclosed tanks
	=	8 for conventional hooded
	=	12 for open tanks
N	=	number of tanks
L	=	liquor ratio
P	=	productive time (%)
T	=	final temperature (°C)

Recent work at BTTG has enabled more complex systems to be analysed. The detailed calculation breaks down the energy requirement in to four parts - batchwise heating up, complete idling, fabric idling and processing.

Contact drying using steam cylinders

The energy used by single or multiple cylinder contact dryers can be expressed as:

$$\text{Energy (kJ/kg water)} = \Delta R\ (2.7 + \frac{0.6 - 0.3P}{P})$$

where:

ΔR	=	difference in fabric water retention expressed as a fraction
P	=	% productivity expressed as a fraction

Hot-air drying using stenters

The energy used by stenters for hot-air drying can be expressed as:

$$\text{Energy (kJ/kg water)} = 2.7 + \frac{1}{P}\ \{30 + (\frac{T - To}{10H})\}$$

where:

P	=	% productive time expressed as a fraction
T	=	operating temperature (°C)
To	=	ambient temperature (°C)
H	=	exhaust absolute humidity

The following equations may be useful for calculating specific elements of process energy use if, for example, the evaporative losses from an atmospheric dyeing vessel are needed so that the savings from using hoods can be assessed.

Wet batch processing

Water heating:

$$\text{kJ/batch} = 4.2 \times \text{vol (litres)} \times \text{Temp diff (°C)}$$

Radiation losses:

$$\text{Watts} = 6.58\,(Tp - Ta)^{5/4}\,(0.4\,Hu + 0.3V + 0.2\,Hl)$$

Convection losses:

$$\text{Watts} = 5.67\{(Tp + \frac{273}{100})^4 - (Ta + \frac{273}{100})^4\}\,(Mt + 0.8\,Wt)$$

Evaporative losses:

$$\text{Watts} = 1.99\ A\,(Tp-Ta)^2$$

Fabric heating losses:

$$\text{kJ/batch} = 1.38 \times \text{Batch wt (kgs)} \times (Tf - Ta)$$

where :

Tp = process temp (°C) Ta = ambient temp (°C) Tf = fabric temp (°C)
A = exposed water surface area (m^2)

Hu (horiz upper)
V (vertical)
Hl (horiz lower)
Mt (metal)
Wt (water surface)

} Surface areas (m^2)

Continuous washing

Nip losses for a given nip, i:

$$Hni\ \text{(kJ/min)} = M\{Sf(Ti-Ti^1) + Sw(Ti-Tr) - Ri^1(Ti^1-Tr) - Ri^2(Ti^2-Tr)\}$$

where:

Ti	=	water temperature in tank i
Ti^1	=	temperature of mangled fabric from i as it enters next tank
Ti^2	=	temperature of expressed water re-entering i
Tr	=	cold water temperature
Ri	=	water retention on fabric as it leaves tank i (expressed as fraction of dry fabric weight)
Ri^1	=	water retention after nip i
Ri^2	=	that expressed water which re-enters tank i (expressed as fraction of dry fabric weight).
Sw	=	specific heat of water
Sf	=	specific heat of dry fabric.
M	=	fabric throughput (kg/min)

Water heating:

$$Hwi\ (kJ/min) = Sw\{(Wi+bi+vi)Ti - (Wi+1)(Ti+1) - aiTi\}$$

where:

Wi = water counterflow rate out of tank i (l/min)

bi = drainage rate out of tank i (l/min)

vi = volume of tank i (litres)

ai = fresh water inlet rate into tank i (l/min)

Drying and heat setting

Evaporative losses are calculated from the exhaust flow volume, converted to weight/second, and related to fabric throughput:

GJ/te fabric = 2.7 (% moisture removed as fraction)

Air losses:

GJ/te fabric = Wair (Tex - Ta) x 10^6

where:

Wair = Weight of air in kgs of fabric processed.

Tex = Exhaust temperature

Ta = Ambient temperature

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

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Fax 01235 433066
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Helpline E-mail etbppenvhelp@aeat.co.uk

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.