GOOD PRACTICE GUIDE 260

Optimisation of industrial paint and powder coating

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

GOOD PRACTICE GUIDE 260

OPTIMISATION OF INDUSTRIAL PAINT AND POWDER COATING

This Guide is No. 260 in the Good Practice Guide series. It provides guidance and practical advice on techniques that can be used to optimise energy costs within the industrial liquid and powder coating application and curing processes.

The Guide is intended to be read and used by production/plant managers who want to optimise their processes and improve the quality of their products. It uses the experience of real companies to offer new ideas and a fresh approach and should help to resolve many of the problems and bottlenecks that occur within the industrial paint and powder coating industry.

The Guide gives opportunities to apply simple controls and commonsense procedures to bring finishing operations into line with a more engineered approach, and so produce quality finishes at reduced cost.

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The Paint Research Association
Peatey's Coatings
The Institute of Metal Finishing
The Surface Engineering Association
British Coatings Federation Ltd

First published February 1999

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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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1.1 What This Guide Can Do for You

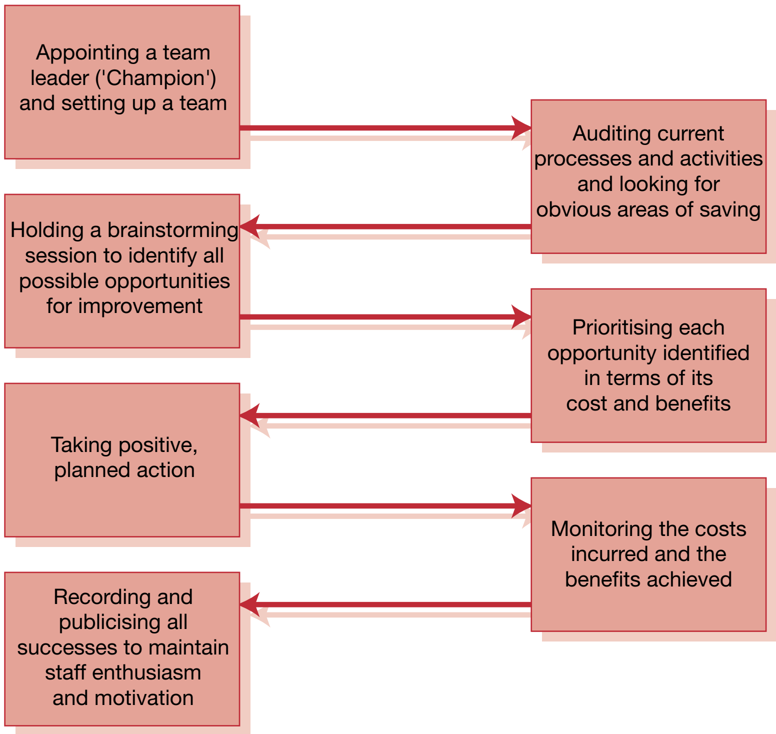
The application of industrial coatings is a vital but costly process that can be extremely wasteful in terms of energy, time and materials if not managed well. Little formal training is available, and the industry has long depended on trial and error and on the experience of a few.

This Guide will help you to optimise the processes for which you are responsible, particularly in relation to energy use. As a result, you will save energy and improve product quality. The very significant cost reductions associated with this exercise will have a direct impact on your company's profits and competitiveness.

You can use the Guide in two ways:

- as a simple reference source providing information on money-saving opportunities;
- as a workbook for an optimisation programme.

An optimisation programme is your best way forward. It allows you to look at opportunities for improvement in a structured way, and it helps to ensure that savings made initially are maintained over time.



The Guide examines the optimisation process and its benefits within the context of the industrial paint and powder coating industry.

Checklists are provided throughout the Guide to aid the optimisation process. These checklists are also available as single sheets in the folder at the back of the Guide. You can photocopy these single sheets for distribution to members of your optimisation team.

Throughout the Guide there are examples of what other companies have done to achieve energy savings and quality improvements.

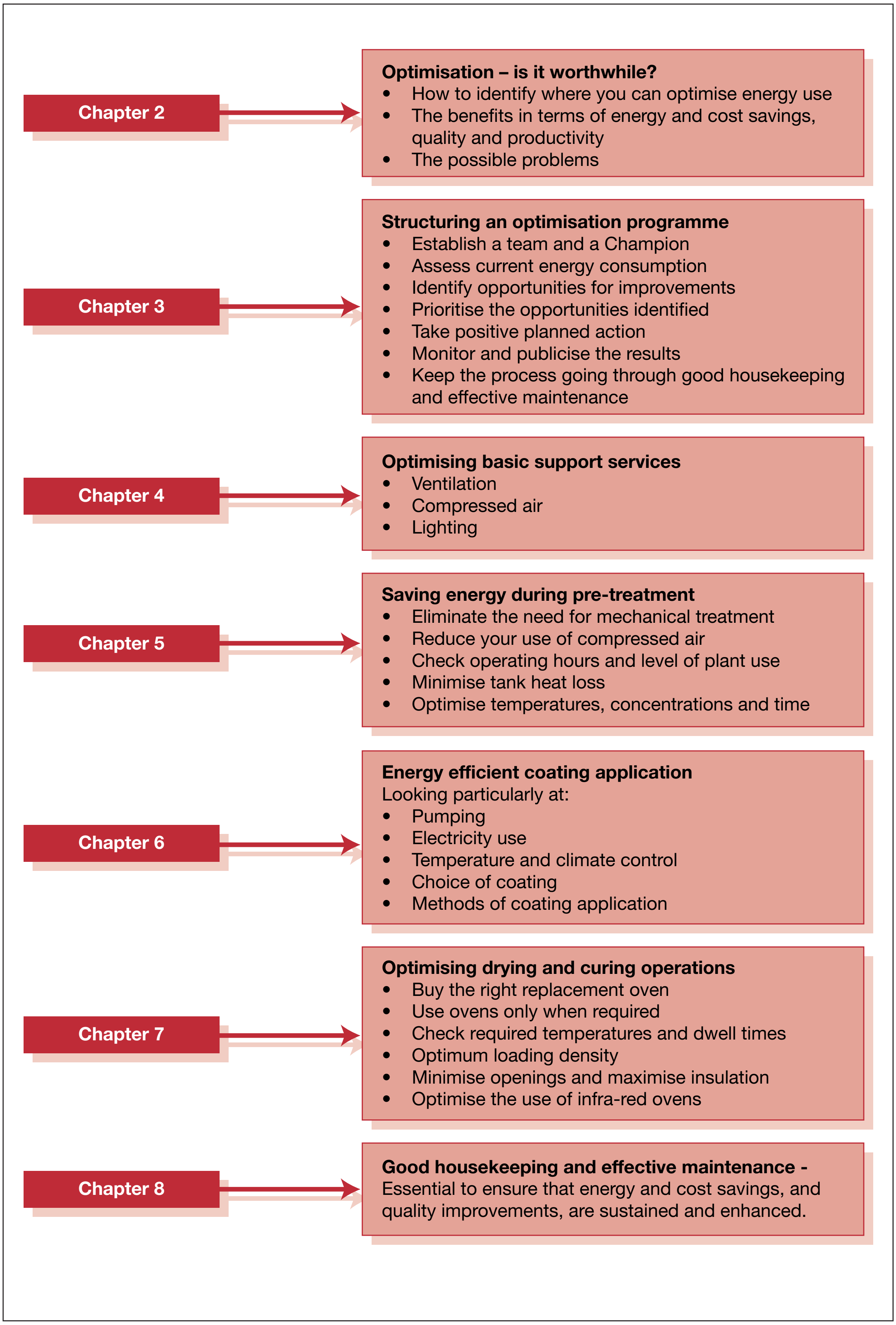


Fig 1 Process optimisation: an on-going management technique

Continuous improvement is vital for profitable growth in today's competitive environment, and this Guide, together with other relevant publications and new initiatives within the industry, is designed to generate change.

You would also benefit from a series of Guides from the Environmental Technology Best Practice Programme[1] that deal with materials and waste in industrial coating processes. These publications focus particularly on waste minimisation and quality improvement:

Good Practice Guide GG15	*Vapour degreasing*
Good Practice Guide GG50	*Cost-effective paint and powder coating: materials management*
Good Practice Guide GG51	*Cost-effective paint and powder coating: surface preparation*
Good Practice Guide GG52	*Cost-effective paint and powder coating: coating materials*
Good Practice Guide GG53	*Cost-effective paint and powder coating: application technology*

1.2 Industrial Coatings and Their Application

The application of industrial coatings is a complex process rooted in many disciplines that each require a specific knowledge and understanding. Coatings are technically and commercially important to manufacturing industry for:

- protection - resistance against corrosion;
- appearance - meeting customer needs;
- specific properties - 'non-stick', 'non-slip', anti-graffiti, colour identification etc.

Most surfaces require some protection, while visual appearance, colour and feel play an important part in purchasing decisions. Coating is therefore a vital element in any sales and marketing effort, and meeting the quality standard required at the first attempt is essential.

A typical industrial coating facility has three basic operations (Fig 2):

- ***Pre-treatment*** Pre-treatment is the preparation of a contamination-free surface prior to coating. It always involves cleaning (using mechanical or chemical techniques) and it may include the application of a conversion coating (such as chromate or phosphate) to enhance the adhesion of the main coating and/or protect the surface.

- ***Application*** Coating material is applied to the contamination-free surface as a continuous, even film. It may take the form of a powder or a liquid. In the latter case the coating is dissolved or suspended in a solvent or diluent.

- ***Drying/stoving/curing*** Liquid coatings dry by natural evaporation or by the application of heat. Heat is also required for curing. Powder coatings are heated, fused and, usually, cured or allowed to harden off in air.

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1 The Environmental Technology Best Practice Programme is a joint Department of Trade and Industry and Department of the Environment, Transport and the Regions programme. It offers free advice and information for UK businesses and promotes environmental practices that increase profits for UK industry and commerce, and reduce waste and pollution at source. Further information and copies of Programme literature are available free of charge from the Environment and Energy Helpline on 0800 585794.

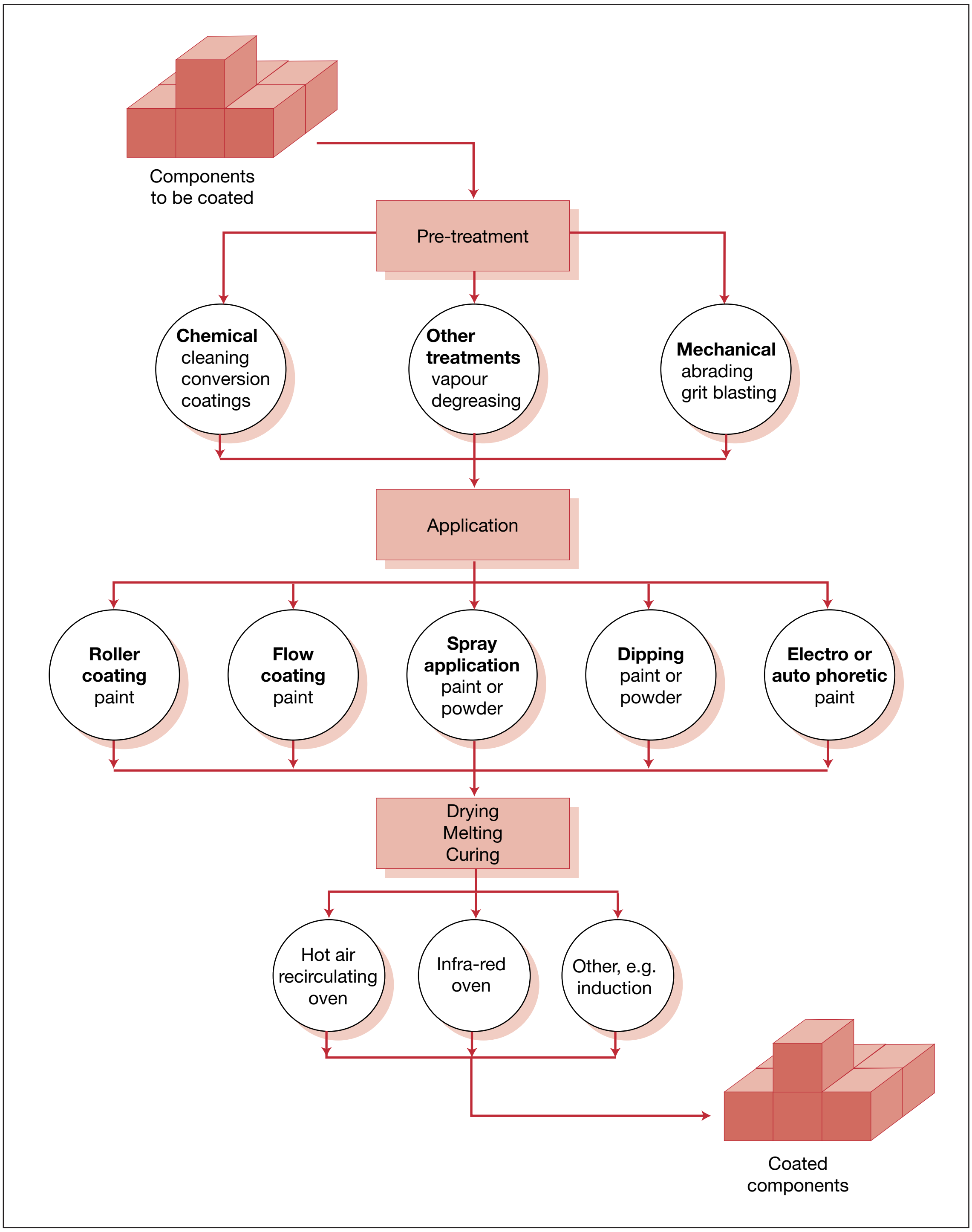


Fig 2 Component coating procedures

1.3 Energy Use in Coating

Energy is used in each coating operation (Fig 3), often in significant amounts. It is obvious that energy is used in large drying and curing ovens and for heating pre-treatment tanks. It is also used for certain less obvious items such as ventilation and the provision of compressed air:

- Adequate ventilation is essential if a company is to meet health, safety and environmental guidelines. Large quantities of air must be extracted to minimise the concentration of solvents, water, powder and dust, and this air must be replaced, often with heated and filtered air. Controlling your exhaust and replacement air systems can provide numerous cost benefits.

- Many processes use compressed air, which is both costly to produce and easily wasted. It is also an area in which you can readily make savings.

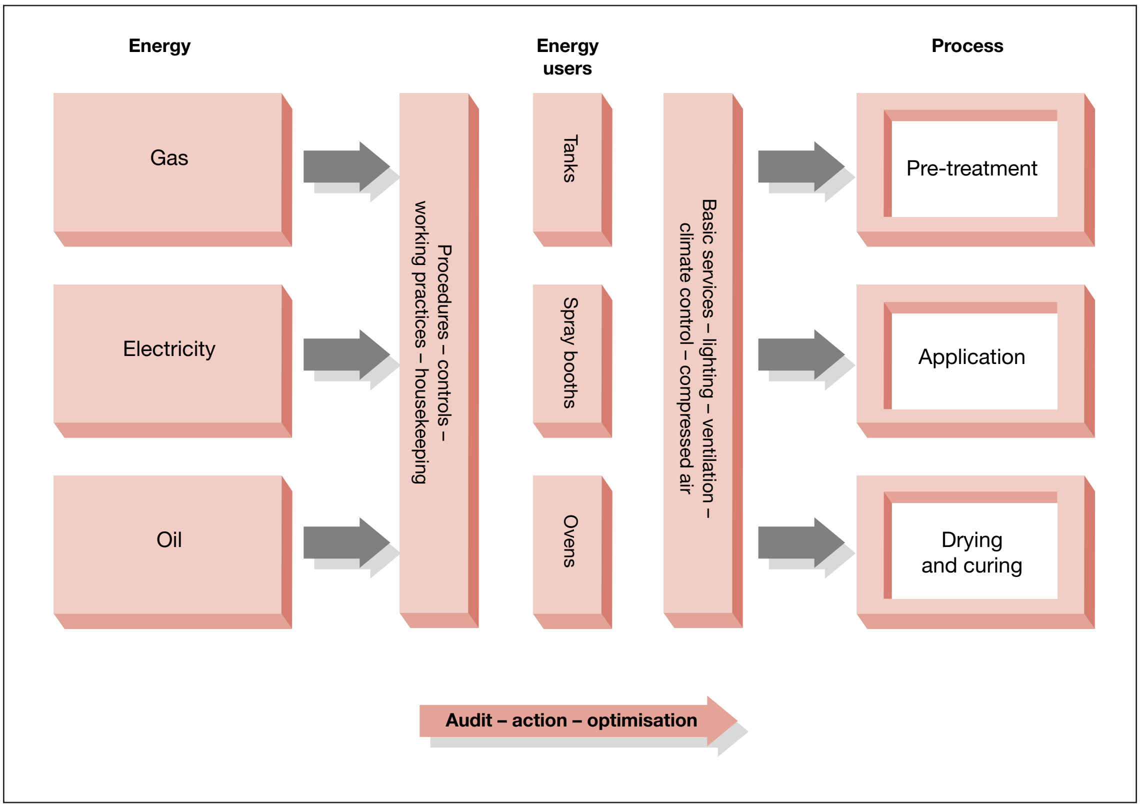


Fig 3 Energy use in coating

1.4 Energy as a Coating Cost

The costs of coating are usually measured in terms of materials and labour, and companies do not always estimate the energy component of the coating process or pass it on to their customers.

However, energy is not a fixed cost. It is a controllable cost. If you introduce energy efficiency measures and use energy more carefully, you may be able to reduce your energy costs by 10 - 25%, possibly with a rapid return on your investment. You will also reduce your overall costs and improve your company's 'bottom line'.

There are many simple controls and commonsense procedures that allow you to adopt a more engineered approach to your basic finishing operations and thereby produce quality finishes at reduced costs. 'Surface engineering' is the term that is being widely adopted in this context.

Optimisation and improvement are excellent first steps in the adoption of engineering principles that have proved highly successful in advanced manufacturing industries such as aerospace, automotive, electronics and other quality-conscious enterprises.

When did you last estimate the cost of the energy used for coating and pass it on to your customers?

2. OPTIMISATION - IS IT WORTHWHILE?

2.1 Identify What You Can Optimise

If you are to optimise your coating processes, you will need to examine each of the resources that you are using - and possibly wasting. In many cases you will find that you can optimise their use, thereby saving both materials and money. To achieve this saving you will need both the opportunity and the determination to act.

Checklist 1 indicates where energy is used in a typical coating company. Quickly go through the list and identify where energy is used in your company, ticking the relevant boxes. Add any other areas of energy use that you can identify.

Checklist 1 Company energy use

Energy type	Process for which energy is used	Yes	No
Electricity	Providing compressed air for: air tools spray guns pumping cleaning down powder recovery units		
	Lighting		
	Fans for: ventilation air input exhaust spray booths ovens powder recovery		
	Pumping		
	Heating pre-treatment tanks		
	Heating and cooling for coating dip tanks		
	Heating ovens for drying		
	Heating ovens for curing		
	Coating process: electrostatic electrophoretic		
	Solvent recovery		
Gas	Workplace space heating		
	Heating pre-treatment tanks		
	Heating for coating dip tanks		
	Heating ovens for drying		
	Heating ovens for curing		
Oil	Workplace space heating		
	Heating pre-treatment tanks		
	Heating for coating dip tanks		
	Heating ovens for drying		
	Heating ovens for curing		

Every time you tick the 'Yes' box, you are identifying an opportunity for trimming costs.

2.2 The Benefits

Optimisation offers three clear incentives that no company can afford to ignore:

- ***Energy savings*** - A typical industrial coating plant provides many opportunities for saving energy and thereby reducing costs. A reduction in energy costs of 10 - 25% is usually feasible with only limited capital expenditure.

- ***Quality improvement*** - Optimisation requires you to re-examine your processes. This will improve your level of understanding and process control. This, in turn, will give rise to improvements in quality.

- ***Improvements in productivity*** - 'Working smarter and not harder' and coating correctly first time will improve productivity.

An engineering company in Northern Ireland was seeking to improve its productivity without significantly increasing costs. An energy survey was carried out to establish a 'benchmark' against which subsequent changes could be measured, and the assessment team noted that 17% of the components coated were being rejected by Quality Control because of defects.

The team pointed out that if all the components were coated correctly first time there would be a 17% increase in productivity and a reduction in rectification costs.

Action was taken and, although it proved impossible to achieve a 'zero defects' situation, the company easily improved productivity by 10% as a result of a training initiative and the establishment of new working practices.

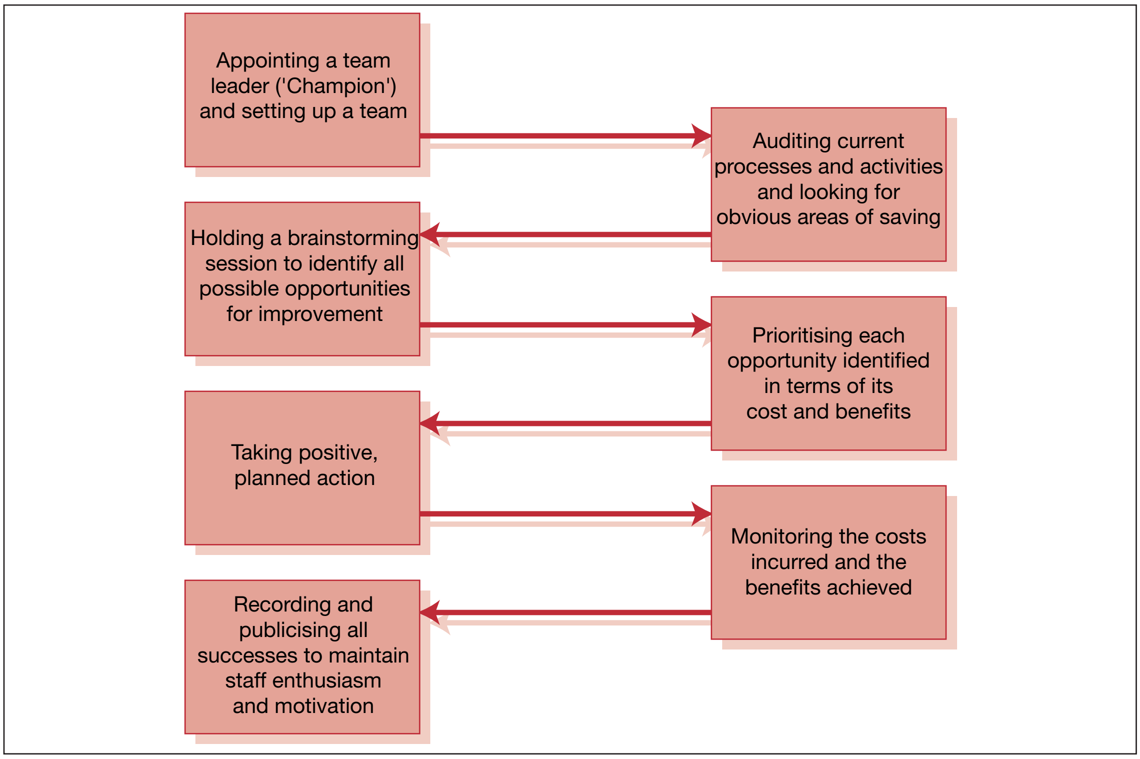
2.3 The Possible Problems

It is not always easy to make the alterations to processes, procedures, methods and materials that are necessary during optimisation. You and your staff may need to change the habits of a lifetime if you are to optimise your energy use fully. This can be difficult and, at times, uncomfortable, particularly as many operatives in the coatings application industry are self-taught and likely to be resistant to change. However, in the current competitive industrial environment, change will be necessary.

In view of the potential benefits, can you afford **not** to optimise your processes?

3. STRUCTURING YOUR OPTIMISATION PROGRAMME

Optimisation is best achieved using a structured optimisation programme. As indicated in Section 1.1, such a programme consists of a sequence of initiatives:



3.1 The Optimisation Team

Champion
Your first essential task is to nominate a Champion, perhaps you, who will drive the optimisation process forward. The Champion should set meetings, check activities and encourage the team to agree on priorities and action. The Champion does **not** have to do all the work! He/she should delegate tasks to other team members.

Team
The team selected should be representative of everyone involved in the coating process. It should include those who are in direct contact with the process or have an influence on coating activities. It should also include production and maintenance staff, technical department/project management personnel, supervisors and any others who can provide a valuable input and influence progress. A team member from the finance department might also be helpful when it comes to costing improvements. An initial meeting should set the scene.

Team members must take responsibility for the work that they do. Responsibility and accountability create motivation and enthusiasm, particularly when measured success becomes evident.

Senior Management
Any optimisation programme will require an allocation of time and resources if it is to be effective, so support from top management is essential right from the start.

All Other Staff
It is equally important to get every member of staff involved and properly motivated. You can achieve this by:

- Asking the boss to spell out the potential improvements for the company and the likely effects on staff.

- Encouraging all staff involved in the coating operation, from management to operatives, to read those parts of the Guide that are relevant to their activities. This will encourage them to give some thought to possible actions that they can take and improve their level of involvement in, and motivation for, the optimisation process.
- Reinforcing the initial motivation by implementing a 'reward scheme' that recognises positive inputs from individuals. A gift token or even an individual's name on the notice board in recognition of a valuable contribution can improve motivation and drive success.

The Champion is responsible for communicating up and down the chain of responsibility, making sure that everyone is aware of changes and achievements and of the vital role that optimisation can play in the well-being of the organisation.

Checklist 2 will help you to establish whether you are ready to proceed with an optimisation exercise.

Checklist 2 Are you ready to undertake an optimisation exercise?

Activity	**Yes**	**No**
Have you appointed a Champion?		
Have you introduced all relevant staff to the idea that they can make improvements by optimising the processes in which they are involved?		
Have you given all relevant staff the opportunity to read those parts of this Guide that are relevant to their activities?		
Is everyone committed to 'having a go'?		
Will there be a scheme that allows staff to express their ideas, e.g. a simple suggestions scheme with benefits?		
Do you intend to acknowledge any positive input by your staff to improve their level of satisfaction? If so, have you decided how you will do this?		
Have you made sure that all staff who might contribute to the programme are involved - from maintenance to management; from accountants to cleaners?		
Are you willing to provide new process instructions and work procedures and to adopt new methods to ensure that improvement is sustained and becomes part of normal plant activity?		
Is your Managing Director enthusiastic and motivated to help rather than hinder?		
Are you prepared for your first Optimisation Team meeting?		

If you have answered 'No' to even one question in Checklist 2, it could be disastrous for your optimisation initiative. Make sure that your first action is to do whatever you have to do to change any 'No' to a 'Yes'.

3.2 Assess Your Current Energy Consumption

If you are to acquire a full understanding of the cost savings that can be achieved by optimisation, you must first establish your current performance, preferably in monetary terms. Good information of this type is required if the programme is to be effective: it is essential to have a 'benchmark' against which to measure success.

Your next task is therefore to carry out an energy audit. This will allow you to attribute energy consumption to individual items or areas of plant. Knowing how much energy is being used in your plant will help you to prioritise actions and estimate more accurately the savings that can be made. Use Checklist 3 to help you.

Checklist 3 What costs do you already know or can you estimate?

Question	**Actual**	**Estimate**
What is the cost of the electricity used for each process? Pre-treatment Application Curing Other finishing processes Total		
What is the cost of the gas used for each process? Pre-treatment Heating Curing Other finishing processes Total		
What is the cost of the oil used for each process? Pre-treatment Heating Curing Other finishing processes Total		
What is the cost of the energy consumed by your compressed air systems?		
Total energy cost		

Where you need to make estimates, you may find the following helpful:

- Make a quick sketch of your plant - or find a site drawing - and identify the main items of energy-using plant. Fig 4 provides an example.
- Make a second sketch that shows the main energy inputs. Fig 5 shows an example. Identify any sub-meters[2] that already exist, and ask an electrician to show you the electrical distribution board (or wiring diagram) and where the main electrical feeds are located.

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2 Sub-meters are any electricity, oil or gas meters that your company owns and that are extra to the main meters monitoring overall energy use for billing.

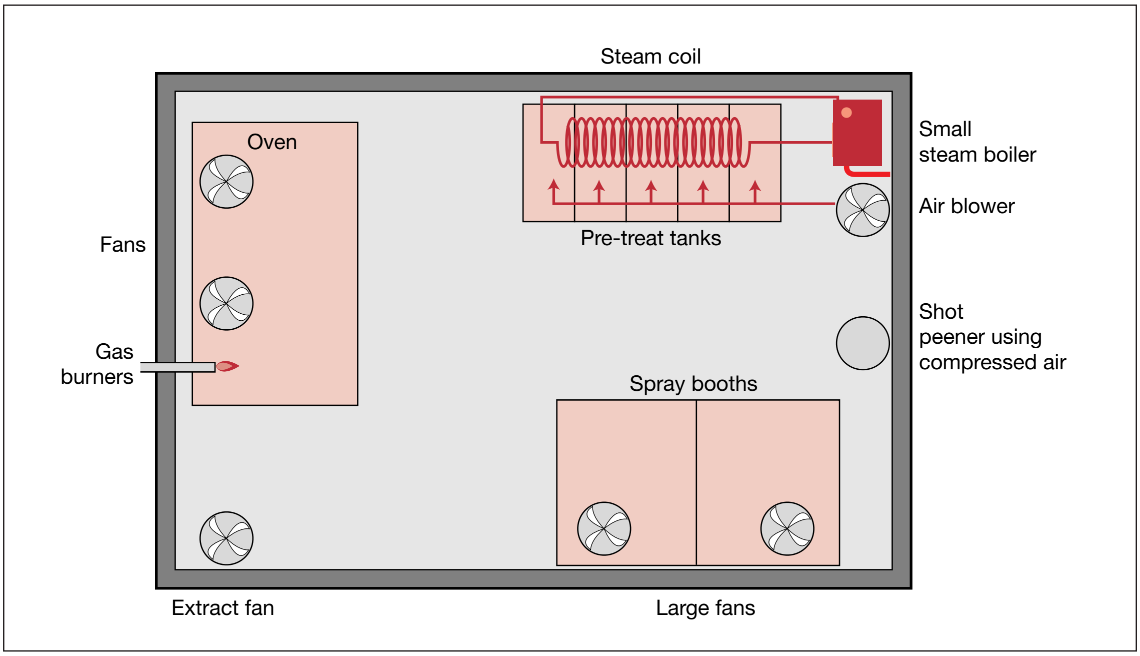

Fig 4 Example of plant layout showing main energy users

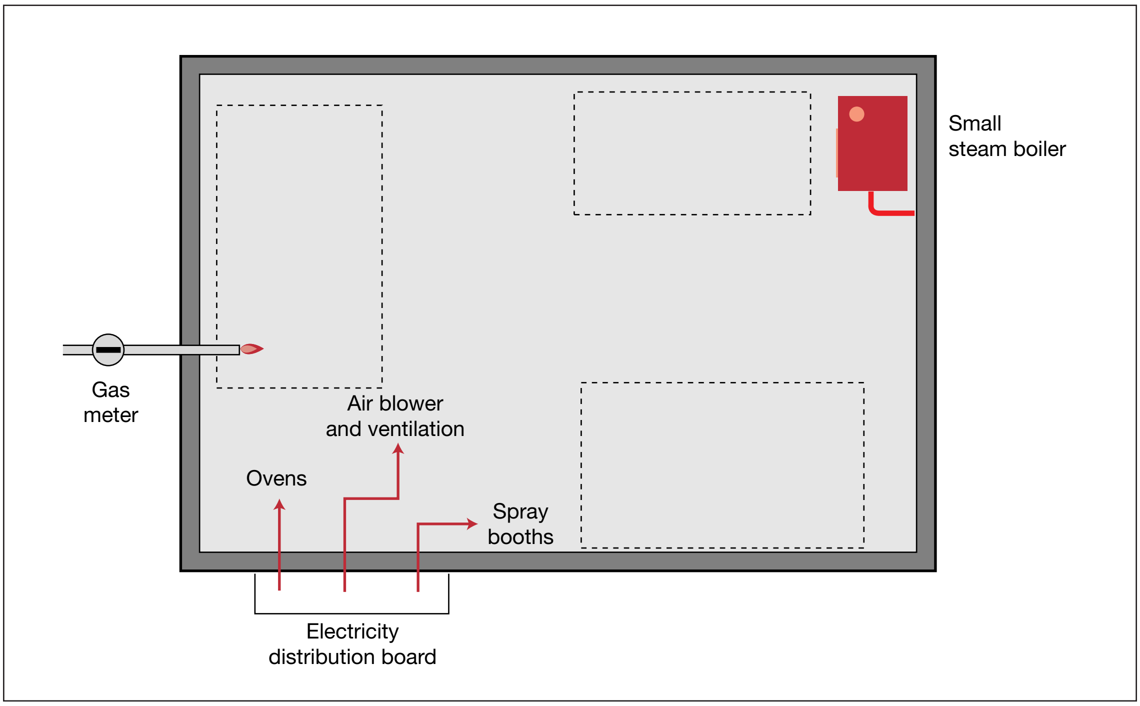

Fig 5 Example of plant layout showing main energy inputs

Where sub-meters are already installed on individual plant items or buildings, take readings at regular times over several shifts/days. This will show whether consumption is fairly even or irregular. Work out the average value for a shift/day for each sub-metered item, and estimate the annual consumption by multiplying the average value by the number of shifts/days on which the plant is operational in the year.

Where no sub-meters exist you have several options:

For Oil and Gas

- Install individual sub-meters to plant with a high energy consumption. Installing gas/oil meters requires the supply to be shut down to insert the meter into the pipeline. A simple oil meter of the ‘ball in the clear tube’ type will cost £300 - £500. Depending on the size and installation costs, it will cost between £800 and £1,000 to fit a meter to a gas oven. Nevertheless, if your oven consumes energy worth £10,000 or more each year and your optimisation process generates a 15% saving, your meter will have paid for itself in the first year.

- Use the quiet Saturday morning approach (see example opposite) and check the consumption of each piece of equipment individually.
- Ask your maintenance staff for help, or obtain advice from your utilities companies. These companies have specialist staff who can help you to assess energy consumption.

For Electricity

- If equipment is not sub-metered, ask an electrician to measure the electricity consumption of individual plant items from the electricity distribution board.
- This can be done with a clip-on ammeter. This simple piece of equipment can be clipped around a wire to show the current passing through that wire (in amps). It is easy to use and very cheap (around £100 to buy and even less to hire). Do not try to do this yourself - you **must** ask an electrician to help you identify the main wires of interest from the distribution board, to ascertain the voltage in each case and to advise you on safety. Note the reading given by each wire and work out the electrical consumption using the following information:

  volts x amps = Watts

  1000 Watts for 1 hour = 1 kWh

Clip-on ammeter

- Check the consumption figures given by the manufacturer (for an electric motor, heater or burner, this will be a rating in kilowatts) and, if the device is working at full load, simply multiply the rating given by the hours of operation. As a first approximation for motors, work on a loading of 50%.
- Electricity sub-meters are relatively cheap and simple to fit.

Your staff may be able to suggest other ideas for estimating the energy use of individual items of equipment. Try initiating a brainstorming session for this purpose.

Once you have assessed your energy consumption and costs in the degree of detail you regard as necessary, you will be able to work out the range of savings that are potentially available to you by completing Table 1 below. The average potential savings given in the table are based on industrial finishing industry norms.

Table 1 Total energy costs and potential savings

Energy source	**Your current energy cost per year £**	**Industry average energy cost savings potential**	**Your energy cost savings potential £**
Electricity		10 - 25%	
Gas		12 - 18%	
Oil		8 - 12%	
Total			

It should be clear now that this energy cost savings potential is worth realising.

One Project Champion - in this case the Finishing Plant Team Leader - decided to spend a Saturday morning investigating the energy consumption of individual plant items - ventilation, compressors, ovens etc. He first ensured that all the plant items were closed down and then read all the gas and electricity meters. It was then a simple task to switch on each piece of plant and monitor its energy use under different conditions. He calculated the gas consumption of the curing oven while reaching temperature and while maintaining that temperature. He also allowed the oven to cool for a period equivalent to a lunch-break to establish how long the oven required to regain its working temperature.

One of the results of this analysis, apart from the establishment of real costs, was the installation of a low temperature setting on the oven for use in tea-breaks and at lunch time. The savings are estimated at £550/year, with an installation cost of £115.

A sub-contract coater monitored energy consumption and quantity of work completed, thereby generating a benchmark for energy consumption per item of product in kWh/number of items produced. This was done as a means of helping to monitor the improvements resulting from optimisation.

Operator attention became focused on detail that had never before been considered, and a competitive spirit was engendered between teams to achieve and beat the benchmark. Every day the plant supervisor checks current figures against the benchmark.

3.3 Identify Opportunities for Improvement

Your next task is to hold an initial Optimisation Team meeting. Generate ideas for energy savings through brainstorming and studying Sections 4 - 7 of this Guide. For brainstorming, ask why are things done this way? Is there a better way? Does the equipment need to be operational throughout the shift, etc? Lateral thinking is an advantage at this stage, and nothing should be ruled out until it has been given careful consideration. Complete the Action column of Checklist 4 as you work through the ideas put forward.

You will need to work at your list of opportunities for a while to identify all the energy-saving options. You may achieve better results by asking everyone to come to the first meeting armed with a couple of ideas and some initial costings/estimates. If, between you, you can identify six opportunities, you probably have enough to start with.

The role of the Champion at this stage is to facilitate. He/she should ensure that ideas are fully considered and that participants are not afraid to put forward their own thoughts.

You can facilitate the whole process by encouraging key personnel to provide that vital input - helping to establish costs, recommending changes and, even more importantly, accepting change and making optimisation work.

3.4 Prioritise the Opportunities Identified

Once the team has drawn up a number of ideas, the next task is to prioritise them in terms of monetary benefit, the time input required and the cost of implementation.

One well tried and tested approach is to apply the priority assessment techniques detailed in *Failure Mode Effect and Criticality Analysis*. For every idea, each issue is given a score out of ten:

• Time required for optimisation exercise	long = 1	short = 10
• Benefit of optimisation	low = 1	high = 10
• Cost of optimisation	high = 1	low = 10

The values are multiplied together, the highest priority then being given to the idea with the highest score.

Use Checklist 4 to help rank your own priorities. The team will need to discuss the time, benefit and cost scores and compare assessments. Table 2 gives examples from real companies.

Checklist 4 Opportunities and priorities

Action	Time	Benefit	Cost	Priority

You will then need to estimate the monetary value of the savings potential. Completing Checklist 5 will help you to do this. Table 3 will give you some ideas.

Checklist 5 Assessing the results and monetary benefits of your improvements

Objective	Actions required	Monetary benefits

Table 2 Examples of priority assessments of energy-saving opportunities made by operational companies

Action	Scores and comments				
	Time	Benefit	Cost	Total	Priority
1. **Only use the oven when it is needed.** Avoid switching it on at the beginning of a shift and leaving it at operating temperature all day. Instead, analyse the requirement and decide whether to switch it off or just reduce the temperature when it is not in use. See Section 7: Drying and curing.	10 Time required only for instruction and supervision.	10 Perhaps a 25 - 30% reduction in energy consumption.	10 No cost involved.	1000	The highest priority.
2. **Cure all compressed air leaks** by combining improved maintenance with new equipment. Look for alternatives to using compressed air - vacuum cleaners etc. See Section 4.2.	5 Time required for mending existing equipment and for sourcing new fittings etc.	5 A small saving in compressed air consumed.	5 Some expense incurred in the purchase of new fittings etc.	125	Not very high priority but represents positive action that can be achieved as you move through the optimisation process.
3. **Review the coatings used** and seek possible process cost savings by choosing alternatives that will give equal or better quality properties at lower energy costs. See Section 5.1.	3 Time required to seek out alternatives.	8 The rewards can be considerable.	10 Little additional cost.	240	This is a longer-term project that can be accomplished alongside other strategies.
4. **Review the design and presentation of components for coating.** Are there problems that could be avoided at the production stage, thereby reducing costs all round? See Section 5.1.	5 Time will be required for observation.	8 Introducing defects is unwarranted.	10 No additional costs involved.	400	There might be some resistance to change from the engineering side.
5. **Install electric I.R. preheat** to gas-fired recirculating oven to get components up to temperature quickly. See Section 7.2.	6 Time required to specify and commission new equipment.	10 Major productivity increase of 25%.	3 This is a major investment and energy costs will increase overall (but not per component).	180	An expensive but effective option. Ensure no/low-cost actions are undertaken first.
6. **Audit the pre-treatment process.** Aim to reduce running costs by optimising the process through chemical, temperature and process control. See Fig 8, Section 5.1.	4 The monitoring of process change will take time and effort.	10 Considerable reductions in process costs.	8 Some costs incurred for reworking the process, new pipework, lagging, and chemicals.	320	This can be a long optimisation process that needs co-operation from suppliers. The results can be worth the effort.

Table 3 Examples of estimating the potential monetary benefits

Item	Objective	Actions required	Monetary value of savings
1	Only run spray booths when required - the action of spraying initiates start-up.	Fit simple controllers/timers to spray booths - £200 per timer plus a few hours for installation. Reduction in use of three hours per day.	£1,000+/year
2	Use a vacuum cleaner instead of blow-off guns for cleaning powder spray booth.	Replacement of four guns, each used for 1 hour 20 minutes per day and consuming 310 litres/minute of compressed air. 2% fewer rejects because of contamination. Colour change 20% faster - 40 minutes more production per day.	£62/year £4,000/year £17,280/year
3	Reduce the need for dressing out deep scratches or grinding marks.	Increase in productivity of several hours per day; compressed air savings.	£8,000/year
4	Change from a single pack liquid coating requiring a high stove temperature to a two-pack material requiring forced drying only.	Reduction in oven temperature from 120°C to 60°C. Introduction of new working practices.	£9,800 in first year
5	Ensure effective use of equipment. Stagger oven and pre-treatment start-up and shutdown times.	18% reduction in gas consumption. Production increase of one hour per day for no extra costs.	£23,400/year
6	Review the parameters under which the pre-treatment plant operates.	Reduction and evening out of process temperature over the five stages. Reduction in final oven temperature. Chemical concentrations increased. Tanks lagged. Water contraflow system introduced.	Assessed 25-30% reductions in operating costs, amounting to around £10,000/year

3.5 Take Positive, Planned Action

After prioritising your actions, pick ONE of the best high priority opportunities identified and implement it. Many companies make the mistake of starting too many projects and never finishing any of them. Make sure you ‘pick a winner’, as a real success at the start will generate enthusiasm and motivation, and this will drive subsequent actions and encourage more success.

3.6 Monitor the Savings and Publicise the Results

Once your initiatives have been monitored and shown positive results, make sure the Champion publicises both the improvements and the savings throughout the company. This will help to motivate team members. It will also encourage the involvement of other staff in future optimisation initiatives.

3.7 Keep the Process Going

Process optimisation should become 'a way of life' that is continuous over time (Fig 6). This will require an on-going programme of good housekeeping and maintenance to ensure that the plant is operating correctly.

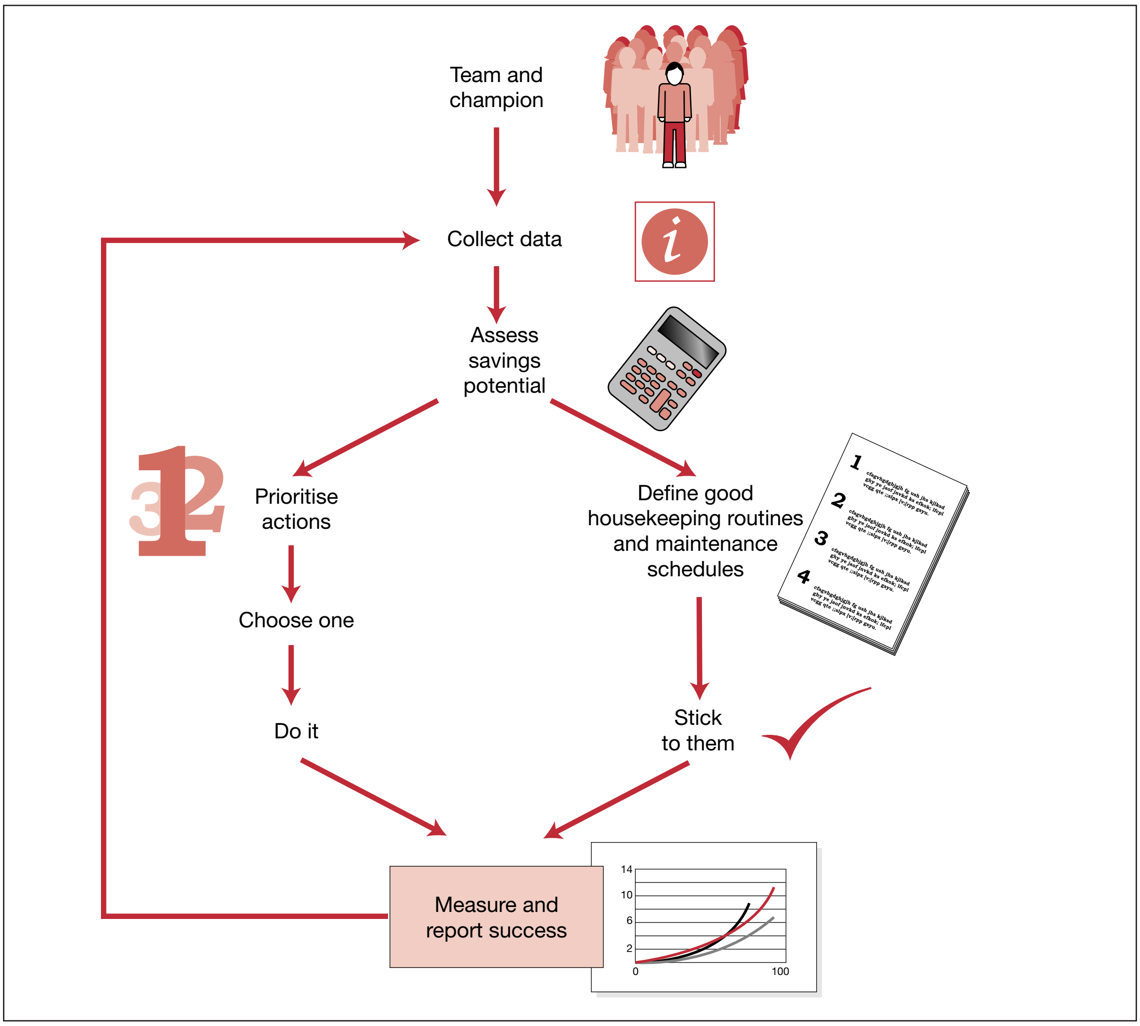

Fig 6 Process optimisation: an on-going process

4. BASIC SUPPORT SERVICES

There are two support services within a typical finishing plant that provide major opportunities for improvement and energy saving: ventilation and compressed air. Another essential service where benefits can be achieved is lighting.

4.1 Ventilation Systems

The application of coatings and the associated ancillary processes usually generate dust, vapours and odour. Planned air movement or local exhaust ventilation (LEV) is therefore mandatory in most coating processes to ensure that health, safety, comfort and environmental requirements are met. These requirements are provided in a series of standards and Health and Safety Executive (HSE) Guidance Notes (see Appendix 2).

The relevant ventilation standards are often expressed in terms of velocity of air movement past the operator into the extraction system. Alternatively they may require you to ensure that occupational exposure limits (OEL) are not exceeded.

4.1.1 *Measuring air extraction*

Although the control and extraction of large volumes of air from the pre-treatment and application areas of the plant is a costly exercise, you must know how much air is being removed and where it has come from. This is a requirement of the Control of Substances Hazardous to Health (COSHH) Regulations and may necessitate workplace monitoring.

The simplest way of measuring the *volume* of air extracted is to measure the *velocity* of air movement through an extraction duct and multiply this by the cross-sectional area of the duct. Where an area has more than one extraction duct you will need to repeat this exercise for each duct and calculate the total volume of air being extracted from that area. You can then check the value obtained against the standards.

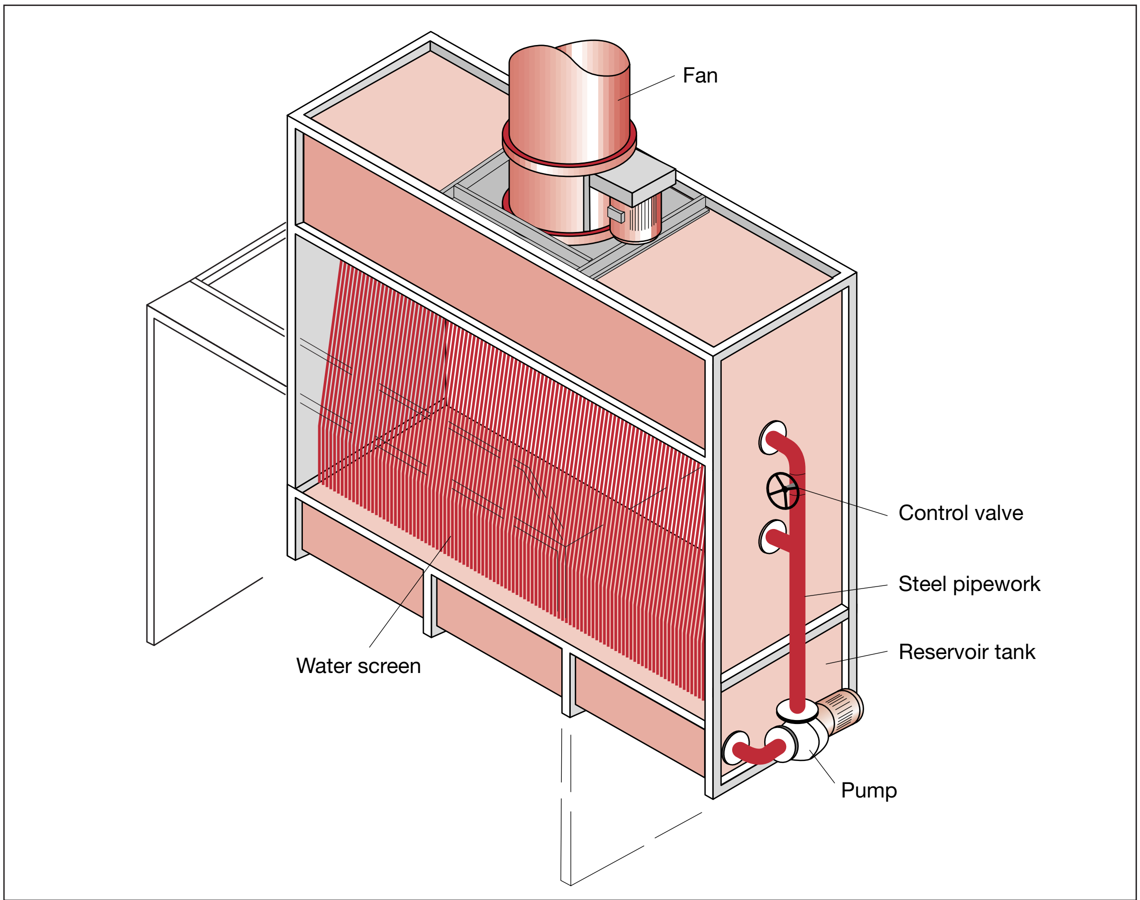

Fig 7 Example of a spray booth

You can make similar calculations for spray booths (Fig 7) and other items of plant. In the case of a spray booth, multiply the velocity across the face of the booth by the area of the face. You can check the value obtained against the standards.

Use the worksheet below to help you calculate the actual and required extraction values and any variation that exists.

> Volume of air extracted = velocity of air extracted x area over which it

Air *velocity* can be measured using an anemometer, a small hand-held instrument that is placed in an air flow to indicate the speed of air movement. Anemometers can be hired or purchased.

- A simple vane-type unit is generally used to measure air velocity within the work area, the number of vane rotations per second being converted by the instrument into an air speed. Such a unit will cost a little over £25.
- The slightly more expensive 'hot-wire' anemometer has a much smaller probe and uses the cooling effect of air on a hot wire to measure velocity in ductwork.

The normal temperature range for anemometers is up to 120°C. Special instruments are required to measure higher-temperature air flows.

Worksheet for calculating the volume of air being extracted

Extraction source	**Velocity m/sec A**	**Area of measurement m^2 B**	**Volume extracted m^3/sec A x B**	**Extraction rate required by standards C**	**Excess extraction Actual - Required**
Example *Spray booth*	*0.7 m/s*	*4 m^2*	*2.8 m^3/s*	*0.5 m/s*	*2.8 - (4 x 0.5) = 0.8 m^3/sec or 2,800 m^3/hour*
Duct					
Spray booth*					
Other					
Other					
Total					

* Spray booths should be designed so that there is no excess ventilation. If you have identified excess ventilation, either your system was incorrectly designed or it is not operating correctly. Take this as a cue to check maintenance, water levels etc.

The whole measurement exercise is designed to ensure that the requirements are being met correctly without being exceeded. Remember that excessive ventilation will result in unnecessary energy consumption as well as making the workplace uncomfortably cold for operators.

4.1.2 *Providing appropriate replacement air*

If air is being extracted from your buildings, it will need to be replaced. This may be allowed to happen naturally, with cold outside air filtering in through open doors, air-bricks etc. to replace warm workplace air. However, the extraction of warm air and its replacement with cold air potentially creates draughts and makes the workplace uncomfortable. Many quality conscious companies now heat and filter the air that is pulled in to the application area. Apart from the staff comfort issue, there are two other reasons for doing this:

- Coatings should usually be applied at temperatures of 15 - 25°C and never at temperatures lower than 10°C. Furthermore, high-tech solvent-based coatings require controlled environments for ‘flashing off’ the solvents and curing. Heating the input air to maintain the correct ambient temperature is therefore essential, particularly on cold days.
- Most quality problems and rejects are associated with surface contamination, and clean air is often the solution. The input air should therefore be filtered to prevent contamination of the coating surface prior to drying/stoving/curing. Maintaining a slight positive pressure in the application area, i.e. ensuring that the amount of air extracted is slightly less than the amount of air being replaced, will also keep out contamination.

So, although heating and filtering incoming air that will be extracted a few minutes later appears initially to be a waste of energy, the principle is sound, and you can offset the cost of the energy involved against the greater proportion of right - first-time coatings.

Air replacement systems require only simple controls for effective operation. Simple pneumatic and electronic controls can be used to balance input against extract.

4.1.3 *Opportunities for saving energy*

By adopting two simple strategies you will create many opportunities for saving energy:

1 Use ventilation systems only when they are required. This sounds obvious, but most companies do not control their air extraction units. Make sure *your* extraction units operate only when the equipment that requires extraction is operating. You can do this in one of three ways:

- Manual control.
- Using a simple timer switch.
- Installing simple electronic controls so that operating certain equipment automatically triggers the relevant ventilation system. For example, operating a spray gun should trigger spray booth ventilation - the spray booth should switch off automatically ten minutes after the gun has ceased operating to ensure that all excess powder is captured.

A small engineering company originally switched on the ventilation to its three spray booths at the start of the shift and left them on all day. It then installed a control system operated by the spraying device. Ventilation started up as soon as the spraying device trigger was pulled and continued for several minutes after the application process had ceased.

To analyse its costs and savings, the company fitted an hours-run meter to each booth. These showed that the period of ventilation operation had fallen by 2.7 hours per booth per day - an overall reduction of more than 40 hours per week. Each fan was rated at 10 kW and, with electricity costing 5.5 pence per unit, cost savings amounted to £22/week or £1,056/year. A further cost saving is associated with the heated factory air that is no longer being extracted. The control system was installed by a local electrician for a minimal cost.

2

If your calculations show that your ventilation systems are extracting more air than is required to meet the legislation requirements, you need to provide a greater measure of control. The most usual way of achieving this is to alter the duct dampers to reduce the air flow. Dampers in ductwork tend to open gradually as a result of vibration during ventilation use. As a result, the quantity of air extracted from each duct gradually increases. You can resolve this problem by determining the correct position for the damper, marking it clearly and monitoring it regularly.

Clearly mark the correct damper position. Check damper position regularly.

Water wash spray booths will, depending on design, extract more air when the water level is allowed to subside. This will increase fan motor operating costs and may shorten its useful life.

4.1.4 *Calculating the potential savings*

Once you have identified the energy-saving opportunities, calculate the likely results. Use Checklists 4 and 5 to help you, and make sure that you pool ideas. Keep a record both of your expected benefits and of the eventual results - it could be useful not only for motivational purposes but also during the next salary review!

The following examples provide a guide to costs and savings.

- *The cost of operating electric motors.* If electricity costs 5p/kWh, a 10 kW electric motor running for one hour at 60% load will cost 30 pence. Assuming two-shift operation over a full year, the cost of motor operation is around £1,440. You could make useful savings by reducing the number of hours run for each electric motor.
- *The cost of heating.* The cost of gas for raising the temperature of a workspace volume by 1°C can be £1/hour if the air is being extracted at 360 m^3/minute. This is the average extraction rate for a three-metre-wide water wash spray booth. To this must be added the operating costs for an associated 10 - 12 kW extraction motor (30 - 40p/hour).

You can reduce heating and extraction costs by making sure that you extract only the amount of air that is necessary to meet the legal requirement.

4.2 Compressed Air Systems

The use of compressed air is essential to most industrial coating processes. However, compressed air is often wasted, despite the fact that it is expensive to produce.

Several Energy Efficiency Best Practice Programme Good Practice Guides focus on the general use of compressed air in industry[3]. This Section deals with the use of compressed air specifically in the industrial coating, stoving and curing sectors.

The main problem in the finishing industry is that most compressors are started up at the beginning of the shift and are not switched off until the end. If the production and use of compressed air are not controlled, the compressor will always be working hard and taking maximum current. However, by introducing controls you can vary the energy consumption with the demand.

Assuming that electricity costs 5p/kWh, an uncontrolled 15 kW compressor will incur electricity costs of £6.00 per eight-hour shift, whether the compressed air generated is being used or not. The cost for a plant operating two shifts is £3,600/year.

Your objective should be to control first the production of compressed air (i.e. compressor operation) and then its use.

4.2.1 *Assessing your compressed air costs*

Table 4, which is derived from GPG 126[3], shows guideline operating costs for three different sizes of compressor and different levels of use. The table makes an allowance for motor losses and assumes an electricity cost of 4.5p/kWh and an operating pressure of 7 bar gauge.

Table 4 Guideline compressor operating costs

Compressor capacity			Annual costs (£) 48 hr/week operation		Annual costs (£) 120 hr/week operation	
l/sec	cfm	kW	75% utilisation	50% utilisation	75% utilisation	50% utilisation
55	110	18.0	1,700	1,100	4,200	2,800
110	220	37.5	3,500	2,300	8,700	5,800
250	500	85.0	7,800	5,200	19,500	13,000

Source: GPG 126, *Compressing air costs*

Today, the costs of generating compressed air can be estimated, as a rule of thumb, at around 5 pence per litre per year.

Table 5 summarises the compressed air consumption and cost of typical coating plant items. By counting up the number of items you have in each category and multiplying by the cost, you can make your own reasonably accurate assessment of consumption and cost. However, if your system experiences significant air leakage, then your costs will be very much higher, as indicated in Table 6.

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[3] GPG 126 *Compressing air costs*
GPG 216 *Energy saving in the filtration and drying of compressed air*
GPG 238 *Heat recovery from air compressors*
GPG 241 *Energy savings in the selection, control and maintenance of air compressors*

Compressed air consumption = (Number of pieces of equipment x Item usage) + Air leaks

Table 5 Compressed air consumption and costs based on actual use in a typical coating plant

Equipment	Air pressure required	Volume of air used	Annual cost*
Conventional spray gun	< 90 psi	250 - 700 litres/minute	Up to £2.05
HVLP spray gun	< 60 psi	250 - 500 litres/minute	Up to £1.50
Manual powder spray gun	< 60 psi	250 litres/minute	Up to £0.75
Blow gun for cleaning	< 150 psi	200 - 300 litres/minute	Up to £0.90
De-ionising air gun	< 90 psi	100 litres/minute	Up to £0.30
Air-fed mask	< 60 psi	< 100 litres/minute	Up to £0.30

* Assuming four hours' operation per day and a 40-hour week

Table 6 The cost of compressed air leaks

Diameter of hole	Air leakage at 7 bar		Power required to compress the air being wasted	Annual cost of leak	
				48 hour week	120 hour week
mm	l/s	cfm	kW	£	£
0.4 (pin head)	0.2	0.4	0.1	12	30
1.6 (match head)	3.1	6.2	1.0	120	300
3.0	11	22	3.5	420	1050

Source: GPG 126, *Compressing air costs*

4.2.2 *Opportunities for saving energy*

1 Eliminate air leaks. The largest - and most wasteful - leaks can be detected by listening. Most leaks can be fixed simply by tightening joints and replacing worn connectors and damaged hoses.

2 Avoid the use of blow guns except for specialist applications. More specifically, avoid their use for certain purposes:

- Use a vacuum cleaner rather than a blow gun to *clean down booths* in powder coating plants. Blow guns are not only generally wasteful in terms of compressed air use, they also spread dust and enhance the electrostatic charge, thereby making the powder more difficult to remove. This causes contamination and results in rejects.
- Use low-pressure, low-volume de-ionised air guns instead of blow guns to *remove dust from components*. The former are a more effective way of cleaning components prior to coating because they use small volumes of low-pressure air which remove the electrostatic charge (rather than enhancing it) and dust off the surface to be coated.

De-ionised air gun unit

A powder coating company used two vacuum cleaners to replace four blow guns previously used to clean down powder spray booths. The guns had been used for 1 hour 20 minutes per day, and each had consumed 310 litres of compressed air per minute (1,240 litres/minute in total).

Financial benefits were achieved in three areas:

- Compressed air savings amounted to £62/year.
- There was less contamination because powder was no longer dispersed around the factory. This resulted in a 2% reduction in rejects, saving the company around £4,000/year.
- Colour changes could be achieved 20% more quickly, increasing production by around 40 minutes/day. This productivity increase was valued at around £17,280/year.

Overall financial benefits totalled more than £20,000/year, and there was also a reduction in health and safety problems.

3 When you need to purchase new equipment, consider installing items that use less compressed air - or none at all. More specifically:

- Use equipment that works effectively at lower air pressures. In the case of spray guns, a reduction of 10 psi in operating pressure can result in an energy cost saving for this equipment of 5 - 7%.
- Use low volume de-ionised air guns instead of blow guns.

Checking air pressure on an HVLP gun

Consider installing a stand-alone compressor to service the treatment/coating area, rather than connecting this part of the plant to the site's compressed air ring main. Advantages will include:

- The provision of compressed air only when it is needed.
- Compressed air of the correct purity and pressure. Liquid and powder coating areas often require compressed air of a higher purity but a lower pressure than other departments, and it is much cheaper to compress air to the required pressure rather than take higher-pressure air and reduce the compression at the point of use.

4.2.3 *Calculating the potential savings*

Once you have identified the energy-saving opportunities, calculate the likely results. Use Checklists 4 and 5 to help you, and make sure that you pool ideas. Keep a record both of your expected benefits and of the eventual results.

Sometimes the operating costs and potential savings for individual items of equipment can seem insignificant. It is important to remember that lots of small costs, when added together, represent a considerable cost to the company.

Further details about the potential savings associated with compressed air use can be obtained from the Good Practice Guides listed above.

The intrinsic efficiency of compressed air systems is poor in relation to the amount of energy that is required to power them. Poor operation will make them even less efficient.

4.3 Lighting

Your staff will achieve a good finish only if they can clearly see what they are doing. When asked to identify the one change that would improve the quality of their work, staff who apply coatings often stipulate better lighting. This would be a good exercise for you to carry out in your own coating plant.

You would also need to check your lighting levels and compare them with the standard. You can hire or buy a light meter for this purpose. Purchase costs are around £75 - a small price to pay for not having to process work twice. UK standards suggest a minimum of 600 lux at the point of manual application. Alternatively, ask a lighting supplier for a free survey.

Improving the lighting provides opportunities for both greater energy efficiency and better product quality. For example, replacing the typical 'fat' 36 mm diameter fluorescent tube that is used in most industrial light fittings with the more efficient 'thin' 24 mm diameter tube known as a T8 can reduce energy consumption by 8% for no extra cost.

Savings of up to 25% can be achieved by switching to high frequency electronic ballasts, but the capital cost of this change is much higher because the entire light fitting has to be changed. This is a task that is best undertaken as part of a refurbishment initiative.

One company with 50 industrial fluorescent fittings (fat tubes) that consume energy worth £1,200/year at 6p/kWh has decided to refurbish its lighting by switching to modern, high frequency fluorescents. Once installed, the new system will save the company around £200/year.

An aerospace company has reduced the amount of reworking required by improving the lighting in its spray booths. When lighting levels in the application area were assessed they were found to be 30% below the levels recommended. The improvements undertaken not only rectified the quality issue, thereby saving time and money, they also eliminated the animosity that had been felt by the sprayers towards the quality control personnel because most work had to be rectified.

5. PRE-TREATMENT

Pre-treatment is a key area for optimisation and is the subject of a Good Practice Guide looking specifically at pre-treatment, conversion coatings and electroplating. This Section outlines some initial steps that you can take to obtain immediate benefits.

Energy use during pre-treatment can be significant:

- Mechanical treatments such as grit blasting and powered methods of abrading the surface use large quantities of compressed air. A grit-blasting unit may use more than 1,000 litres of air per minute.
- The application of phosphate and chromate conversion coatings often involves heating large quantities of the chemicals into which components are dipped. Furthermore, as these are mainly aqueous-based systems, drying is involved.

The first question is, do you really need this pre-treatment? Is pre-treatment being used to rectify problems introduced during manufacturing or storage? Think carefully about exactly why each pre-treatment stage is necessary - use Checklist 6 below to help.

Checklist 6 Identify your pre-treatment processes and their purpose

Process	Energy requirement	Fundamental purpose of process
Sanding Abrading with hand tools	Compressed air	
Grinding with hand tools	Compressed air	
Grit blasting	Compressed air	
Degreasing using vapour, solvents or aqueous systems. Manual Automatic	Heating Ventilation	
Application of conversion coatings Phosphating Chromating	Tank heating Pumping Ventilation	
Drying	Electricity Gas	

5.1 Opportunities for Saving Energy

1 Can you eliminate the need for mechanical treatment?

- It may be possible to treat metals differently during welding or cutting, thereby eliminating the need for grinding or 'dressing'.
- Plastic components can often be improved by adjusting the moulding process or even the mould itself to minimise the need to remove 'flash'. Is this an option in your situation? Changing a mould is expensive - but so is the time involved in mechanical treatment.
- Wooden products can benefit similarly by being smoothly finished at the sanding stage.
- Reducing storage time or improving storage conditions may reduce the requirement for removal of rust and other oxides.

> One company had, for many years, spent considerable time, labour and energy on 'dressing out' deep scratches in formed and welded components. An optimisation Champion started asking questions and quickly established that this finishing operation had never been questioned or investigated. Subsequent analysis resulted in the welders changing their equipment and methods, eliminating the particularly abrasive grinding wheels that they had been using to dress the welds.
>
> The original finishing operations are now no longer required, and cost savings of more than £8,000/year have been achieved by eliminating the labour, compressed air and hundreds of abrasive pads previously required for this work.

2 Reduce your use of compressed air:

- Grit blasting is often the only suitable process for pre-treatment work, but the abrasive nature of the materials used can cause leaks when particles become trapped in the fittings. Check regularly for leaks and, when you find them, repair them.
- Using compressed air for tank agitation is wasteful as the pressure is usually too high for this purpose. Using air at too high a pressure results in large fluid losses from the tanks, both from excessive agitation and increased evaporation. Air can be reduced in pressure before it enters the tank, but this is an inherently wasteful process. Instead, use a low-pressure blower.
- Pre-treatment processes often involve the use of pneumatic hand tools. You can reduce compressed air consumption in this area by:
  - ensuring that tools are used correctly;
  - fixing leaks as a matter of course;
  - purchasing lower-consumption tools whenever possible;
  - ensuring that tools are not oversized for their purpose.

Remember that an industrial pneumatic grinder uses between 350 and 850 litres of air every minute it is operated and that 500 litres of air cost £25/year. You may find that you can carry out simple abrading operations using a smaller unit.

3 Check the operating hours and level of use of your pre-treatment plant. Pre-treatment plants are costly to run, and start-up and shut-down times can have an important role to play in saving energy. For instance, chemical pre-treatment is the first process and is usually the first plant to be started up. Therefore, it should also be the first plant to be shut down.

- Make sure that your pre-treatment units are being heated/operated only when they are being used.
- Check out any opportunities for batching work.
- Aim to control production schedules and operating practice so that pre-treatment plant is always fully used when operational.
- Identify simple changes that will allow a reduction in operating time.

4 Minimise tank heat loss. The greatest energy loss from heated tanks is by evaporation from the surface - 50% of the supplied heat is lost this way. Hence it is very important to make every effort to retain this heat.

- Cover heated tanks where possible, using lids or plastic balls or floats. *Always* cover tanks at night.
- Lag tanks effectively.

5 Optimise your process for time and/or cost by varying the parameters of temperature, concentration, current and time. There are many opportunities for saving energy by adjusting the strength of chemicals and the temperature of the various cleaning and conversion coating operations. There is a trade-off between temperature, time and concentration, and all three variables can be used to optimise the process. For example, if the process time is kept constant, pre-treatment can proceed using a low chemical concentration at a higher temperature or a higher chemical concentration at a lower temperature. If it is possible to process components for a longer period of time, both chemical concentration and temperature can perhaps be reduced.

To determine the most cost-effective solution for your process, you will need to balance the costs of chemicals, heat energy input, other process energy such as ventilation, and productivity. Remember that heat loss increases dramatically as tank temperature increases.

Draw up your own process flow sheet with temperatures, processing times and concentrations. Discuss with your suppliers possible ways of reducing processing times and costs. Look for obvious energy-saving opportunities, e.g. where there are large temperature differences between adjacent tanks. You may, for instance, be heating a component for one process, then rinsing it with cold water, then raising its temperature again in a second heated process. This is a procedure that wastes both time and energy (money), and you may be able to save both by increasing the temperature of the rinse tank.

Use Checklists 4 and 5 to help you list, prioritise and cost the actions that are likely to show positive benefits in your plant.

If you cannot identify significant improvement opportunities, either you completed this exercise at an earlier date or you need to look at your process again.

Remember - few pre-treatment process plants are managed efficiently.

A company using an iron phosphate pre-treatment system subjected components to:

1. A hot degreasing wash followed by a cold water rinse.
2. Immersion in the hot phosphating tank.
3. Cold intermediate and final rinses.
4. Heating to 180°C in a drying oven.

An audit and evaluation suggested some changes and the whole pre-treatment process was reworked (Fig 8) to include:

- a slight increase in chemical concentrations;
- a reduction in degrease and phosphating tank temperatures;
- lagging of the tanks to minimise heat loss;
- heating of the rinse tanks.

The reworking also incorporated a water counterflow system. Water from the final rinse tank now passes first to the penultimate rinse tank and then to the first rinse tank. De-ionised water was introduced to eliminate any possibility of salts being precipitated from mains water.

The overall flow of water was reduced without any side effects, and the oven temperature was reduced by 30°C.

Assessments indicate that pre-treatment system operating costs have fallen by 25 - 30%.

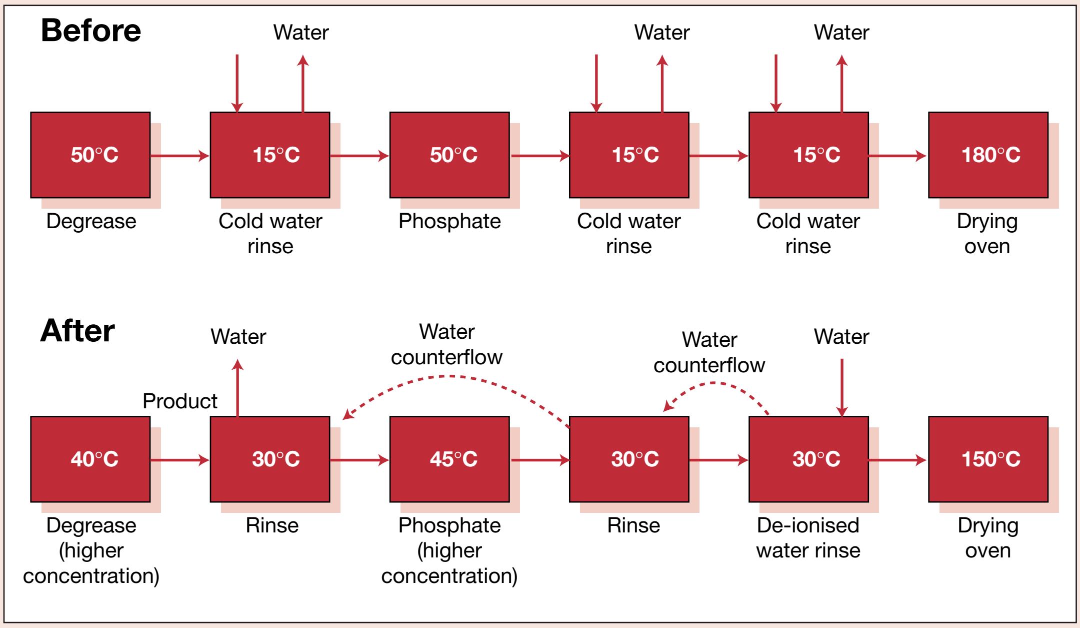

Fig 8 Pre-treatment temperatures before and after process revision

6. COATING APPLICATION

Many companies believe that little can be done to save energy during coating application, but focusing on the process can often result in improvements in productivity and product quality. Furthermore, even small contributions to energy saving can add significantly to the overall process savings achieved. It is therefore worth initiating small changes wherever possible, notably in five main areas:

- the provision of basic materials (pumping with filtration);
- the use of electricity in both electrostatic and electrophoretic applications;
- temperature and climate control;
- the coating materials used;
- methods of coating application.

Complete Checklist 7 to help you identify where process improvements might be made. Then use Checklists 4 and 5 to help you list, prioritise and cost your energy-saving initiatives in each of the areas examined below. Remember to include the capital costs of any new processes in your optimisation exercise.

6.1 Pumping

Many coating materials and their solvents are now pumped to the point of use. While there is little potential for improving the use and efficiency of peristaltic and electrically driven units, air-driven pumps and agitators are often wasteful and inefficiently used and provide opportunities for optimisation.

1 The greatest potential for energy savings lies in the selection of more efficient air-driven equipment. Your choice should take into account not only the pressure and volume of liquid pumped and/or agitation power, but also the air consumption.

Ideally, you should use electrically driven pumps and agitators as these are more energy efficient. However, the capital cost of explosion-proof (Exe) units is often prohibitive.

Therefore specify efficient air-driven equipment - for example:

- An air-driven piston pump that is capable of delivering up to four litres of paint per minute at 60 psi may use 230 litres of air per minute when operational.

  An air-driven diaphragm pump delivering the same amount of paint at the same pressure would use approximately 80 litres of air per minute during operation.

  N.B. A double-diaphragm pump will generally, depending on quality and performance, be less expensive to purchase than the alternative of a positive displacement piston pump.

Checklist 7 Identifying the potential for process improvement

Process	Energy-using element	Potential for savings
Dipping	Ventilation Pumping	
Electrophoretic treatments	Electrical contact Equilibrium of dip tank Temperature control Pumping and filtration	
Autophoretic treatment	Temperature control Pumping and filtration	
Spraying	Compressed air Ventilation Electrical contact - electrostatic	
Roller or flow coating	Pumping Temperature control Ventilation	
Automatic spray application	Ventilation reduction Temperature Earthing Compressed air use	
Powder coating	Ventilation Humidity Temperature Earthing Compressed air	
Alternative processes and/or materials Two-component technology Liquid coating to powder Powder to liquid coating		

- A poorly designed paddle-type agitator may use 550 litres or more of air per minute to agitate a 150-litre tank.

  An efficient agitator designed for the purpose would consume 180 litres of air per minute or less.

6.2 Electricity Use

Electricity is used for both electrophoretic and electrostatic coating operations. Although you can do little to reduce electricity consumption in either case, you can make considerable improvements to the effectiveness of electricity use, thereby enhancing product quality. You can achieve this in several ways:

1. Make sure there is good contact between the conductors on an electrophoretic plant, from the component through to the conveyor pick-up.

2. Ensure good isolation between charged components where required.

3. Make sure that earthing is good, particularly on electrostatic plants. Poor earthing is a serious contributor to poor quality: it is also a safety hazard, increasing the potential for solvent and dust ignition.

6.3 Temperature and Climate Control

Temperature, ventilation and humidity control is important for quality reasons, and is vital for the more sophisticated powder coating applications, particularly thin film applications and the electrostatic application of coatings to insulating substrates.

Ensure that:

- temperatures - both ambient and coating material temperatures - lie within a specified range and are neither too high nor too low;
- humidity levels are controlled for water-borne coatings;
- ventilation meets the requirements, but is not excessive (see Section 4).

1. Control heat loss from tanks by lagging them properly. Use lids and/or plastic balls or floats on the surface of the liquid as a means of temperature control.

2. Use a single, centralised heating and cooling system for installations where the temperature has to be closely controlled, e.g. for phoretic-type applications. These systems use heat transfer oils to service each unit of the process and can produce a gentler temperature change - the system avoids the On/Off fire of all other systems and can easily control tank temperatures to ± 1°C.

3. Avoid over-thinning solvent- or water-borne coatings. Low ambient or material temperatures are often counteracted by adding extra solvent - often up to 10% - to reduce coating viscosity to a level suitable for application. This can result in the over-thinning of coatings as well as the over-use of solvents.

4. Enclose any automatic processes. When personnel are absent, you can reduce extract and inlet ventilation rates while still maintaining levels that will limit the risk of solvent build-up.

5. Control your powder coating recovery systems. Increasing the efficiency and filtering of powder handling systems will allow heated air to be recovered and ducted back to the application area instead of being wasted. This helps to reduce the cost of climate control.

A small, two-sprayer installation, designed for powder-coating large fabrications, contained a cyclone and after-filter powder-recovery system that was powered by two 18 kW electric motors. The system was normally started up when the first person arrived for work, and was left running throughout the day, including morning, lunchtime and afternoon breaks, irrespective of whether it was being used. The electricity wastage incurred was compounded by the fact that the first person who arrived came 30 minutes early to fire up the pre-treatment plant and curing oven - even though the latter was not required for at least one hour after the start of processing.

An audit showed that the powder-recovery unit was left running unnecessarily for more than 2.9 hours per day. This was equivalent to 25,000 kWh/year. Shutting down the unit proved simple, and the net result of a little thought and some discipline was a saving to the company of more than £1,250 for no additional cost.

6.4 Choice of Coating

Although changing the coating material is a complex topic that cannot be examined in depth in this Guide, altering materials and processes has resulted in significant cost reductions for many companies and you should at least give the matter some consideration.

Your first task is to establish what you use and why. Ask questions of your Sales and Marketing, Works Management and Design and Engineering sections to determine why a particular coating has been chosen. Keep your eyes open for new/alternative coating techniques. Consider, depending on your process, the many opportunities that exist for change:

1. Reduce the number of coats used by opting for different materials.
2. Reduce energy consumption by drying at ambient temperature or force drying (60 - 80°C) rather than stoving at 120 - 200°C+.
3. Consider the relative merits to your situation of solvent-borne versus water-borne liquid coatings.
4. Consider using two-component materials.
5. Assess the relative merits of liquid systems versus powder coating. Changing to powder coating reduces the need for costly air replacement.
6. Where you do retain a liquid coating, consider using hot-spray coatings. Heating the coatings lowers viscosity, thereby reducing the need for solvent, and reducing the flash-off time required prior to stoving. Your assessment will have to weigh the cost of heating against the improved application and the reduction in solvent emissions.

It is impossible to be prescriptive here as each business is different - but there may be significant savings (see example).

One end-user compelled a coating company to switch from a stoving paint to two-component materials that only required a low-bake dry and cure process. The changeover proved difficult to achieve initially as the new materials were perceived to be difficult to use and apply. However, after a few mistakes and a little re-training, effective processing was restored.

The change proved highly effective. The oven was modified to operate at a lower temperature (60°C instead of 120°C), and oven operational procedures were altered and improved, heat-up time was reduced, and oven operating costs were more than halved overnight.

The oven modification cost £2,500, but the annual savings are £12,300, achieving payback in two and a half months.

6.5 Methods of Coating Application

You must have a detailed knowledge and understanding of the processes and materials involved if you are to optimise your coating application processes and make appropriate savings. Work closely with both operators and material manufacturers to acquire this.

1. Consider changing from manual to automatic application, thus reducing ventilation rates.

2. Consider asking an outsider to appraise your systems. An outsider can often bring a fresh approach to a problem, while those who have been close to the process for a long period may find difficulty accepting and implementing innovation.

7. DRYING AND CURING OPERATIONS

There are two main types of oven used in the engineering sector: hot air recirculating ovens (Fig 9), which are often fired by gas, and infra-red ovens, which use either electricity or gas. Speciality ovens which use induction, ultraviolet and electronic beam techniques are also available for specific purposes.

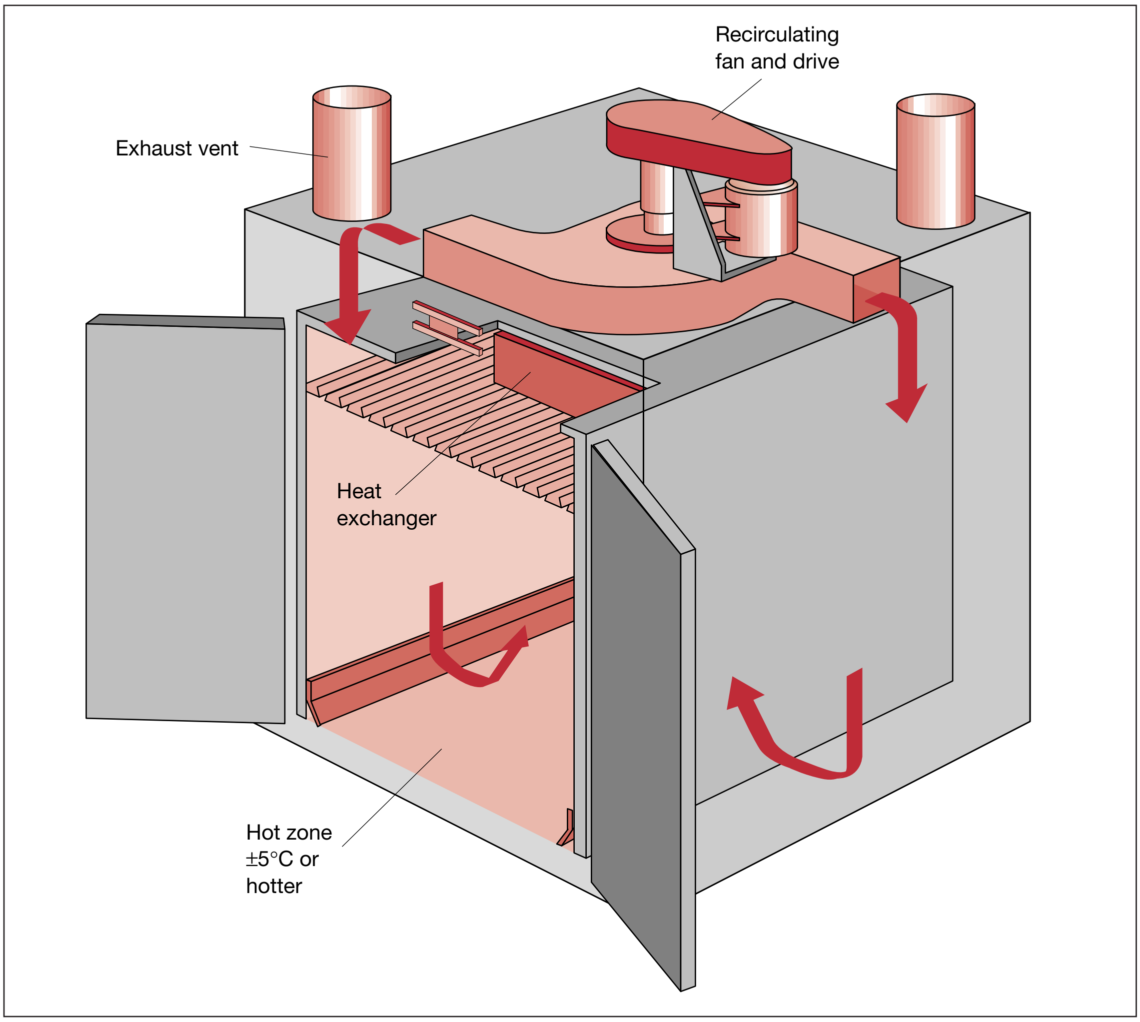

Fig 9 Example of a hot air recirculating box oven

7.1 Factors Affecting Stoving/Curing Speed

If coatings are to be effective, they need to be correctly cured. You should therefore avoid either under-curing or over-curing, both of which adversely affect coating performance. In addition, over-curing wastes energy and often causes coating discoloration.

Whichever type of coating you use, the manufacturer will specify the required time period and temperature for curing. However, it is important to understand exactly what these specifications mean:

- For industrial liquid coatings, '120°C for 30 minutes' means that components should be *in an oven* at that temperature for 30 minutes.
- For thermosetting powders, '120°C for ten minutes' means that the *substrates should achieve* 120°C for ten minutes.

7.1.1 *Hot air recirculating ovens*

The stoving/curing speed in hot air recirculating ovens is affected by several factors:

- Oven heat-up time.
- The thermal mass of the substrate. A heavy, dense component will absorb the heat and the coating will not begin to cure until the whole item is at cure temperature.
- Individual coating requirements. It is important to maintain the correct temperature/time gradient during component/coating warm-up. The solvent in liquid coatings must be allowed to evaporate, and coating powders must be allowed to flow. The temperature in the oven must then be maintained at the required level by controlling the energy input and the flow of hot air around the component.
- Heat loss control. Heat can be lost through the oven walls, floor, extraction ducts and doors. The biggest heat loss is usually through the doors, and the door silhouette should be kept to the minimum commensurate with the size of the workpieces involved.

7.1.2 *Infra-red ovens*

The stoving/curing speed in an infra-red oven depends on a different range of factors:

- Component shape. Infra-red travels in straight lines, so flat panels of sheet metals will cure rapidly because uniform heating is directionally applied and the coating film is of uniform thickness. Convoluted shapes on the other hand may require an oven that makes efficient use of the hot air generated by the infra-red emitters, and that can rotate the component within the oven during the curing process. Over-cure can be a problem if the emitter-to-component distance is not controlled.
- Component thickness and conduction. Shadowed areas will only heat by conduction through the metal, so different metals with different thermal conductivities will cure at different rates. Aluminium, for example, is a better conductor than steel. Components with a section of 50 mm or more, and non-metallic components, will cure more quickly in an infra-red oven than in a hot air recirculating oven because the coating will reach stoving temperature before any significant quantity of heat is conducted into the main component substrate.
- Condition of prepared metal surface. Bright surfaces reflect the heat away from the coating whereas dull surfaces absorb more heat energy into the metal, thereby heating/curing coatings in areas where the infra-red does not reach. This is clearly beneficial for items of a complicated shape.
- Coating thickness. Where thick coating films are being cured, it is important to limit the power intensity to prevent solvent boil, and bubbling/scorching of the coating. Zoned control can be used to speed up the stoving time.

7.1.3 *Infra-red as pre-heat*

You can gain considerable benefits by using infra-red emitters for pre-heating components before they are placed in a hot air recirculating oven. The infra-red section is placed immediately before the opening to the main oven where it rapidly increases component temperature, reducing the lag time in the oven before the coating begins to cure. This effectively extends the length of the oven but, because infra-red is an intense heat source, involves only a small amount of floor space.

A well-known company that powder coats aluminium sections for the architectural market wanted to increase the productivity of its powder coating line but recognised that the oven constituted a bottle-neck in the existing process. The oven was a tunnel-type, gas-fired hot air recirculating system in which the conveyor was already operating at the maximum speed that would allow components to achieve the time/temperature requirements stipulated by the powder manufacturer.

Although no further improvement appeared to be possible, an audit of the heating profile showed that, if components could be heated before entering the oven, a 20 - 25% increase in conveyor speed would be possible.

A two-metre-long electric infra-red section was added to the existing oven. The new unit can be accurately controlled. Its sensors closely monitor the components' surface temperature, and power is pulsed only at the times and in the quantities required to maintain those temperatures.

The company has achieved a productivity increase of 25% for only 25% of the cost of replacing the main oven and with an increase of only around 10% in energy consumption.

7.2 Opportunities for Saving Energy

There are substantial benefits to be gained from optimising your drying and curing operations. Energy savings in these sectors can often exceed those achieved in other parts of the plant, and the potential is likely to be of considerable interest to management. Time and effort spent reviewing current practices, making the appropriate measurements and then optimising these processes will not be wasted. They are likely to make a significant contribution to improving the company's bottom line.

Use Checklists 4 and 5 to help you prioritise and cost the various energy-saving options outlined below - and remember to monitor the results of the initiatives you select.

1 When you need to buy a new oven, make sure that it is the right type for your needs and that it is optimised for energy efficiency.

2 Ovens are expensive to operate and should supply heat only when heat is required. Yet they are often switched on in the morning and left on all day irrespective of levels of use. This is not cost-effective, and your first task should be to make sure that you are maximising oven use and minimising your consumption of energy:

- Consider batch firing your ovens, scheduling or controlling production so that the ovens are always fully utilised when they are on. Review your regular production schedules/typical operating practice. You may be able to make simple changes that will reduce oven operating times.
- Remember that infra-red ovens heat up rapidly from cold and can therefore be switched on and off as required. Make sure they are always switched off when not in use.
- Hot air recirculating ovens require longer warm-up periods but do not need to be fully powered all the time. Consider turning the oven down or off during tea and lunch breaks. You can decide whether or not this is cost-effective by auditing the oven to determine heat-up times and costs (use the quiet Saturday morning approach examined in Section 3.2). This will allow you to evaluate how long the oven can be switched either off or to a low setting to economise on energy.

3 Manufacturers' requirements for temperature and dwell time tend to be forgotten or approximated over time. Make sure you know exactly what the requirements are - and compare these values with those currently being applied.

- Make sure you are not over-curing or under-curing the coating. Over-curing - too high a temperature or too long a dwell time - wastes energy and creates quality problems in terms of brittle coatings and discoloration. Under-curing can cause premature coating failure.
- Construct a temperature profile through the oven to make sure that the manufacturer's requirements are being achieved. You can do this by passing an uncoated component, with thermocouples attached, through the oven and downloading the results to a computer for analysis and graph construction. Mechanical devices can also be used for this purpose but, although they are less expensive (around 50% of the cost of electronic equipment), the results are more difficult to analyse. You can either hire or purchase the necessary equipment. Hire costs are around £80 - £100/day. Purchase costs are between £1,000 and £2,500.

4 Combustion control is an important component of energy efficient gas- and oil-fired oven operation. Many burners have a high/low setting which varies the amount of oil/gas being fed to the burner. However, although the air:fuel ratio is critical for efficient burner operation, there is usually only one air setting - the one that is correct for the high fuel setting. Combustion at low fuel settings is therefore often inefficient because there is too much air, and the result is a very yellow flame. You can remedy this situation by adding proportional control units to each burner. Although this is not a cheap option (up to £1,000/burner), you will make significant improvements in oven performance and operating costs. Temperature control will improve and burners will always operate with the most efficient air:fuel ratio. If you buy a new oven, make sure it is fitted with proportional controls.

Fitting a proportional control unit can reduce a burner's energy consumption by 5 - 15%, depending on demand. Where an oven uses energy worth £10,000/year or more, the cost of such a unit will be recouped in the first year.

5 To make sure that your burners continue to operate efficiently over time, have them serviced regularly. An authorised service engineer equipped with a combustion analyser will be able to retune a burner within minutes. It is often advisable to clean out the burner box and service all the ancillary equipment associated with the burner, i.e. fans and control equipment, on a regular basis.

Regular servicing of your burners will pay dividends. An increase of only 2% in the efficiency of a burner operating at 75% efficiency will save you £3 for every £100 worth of gas consumed.

6 Make sure that the air movement in hot air recirculating ovens is not too high. If components swing, then air movement is excessive. Furthermore, if the coatings touch, you will get rejects and there will be an increased danger of contamination. Excess air will also affect heat-up and cool-down periods and the distribution of heat within the oven.

Excessive air movement may mean that too much air is being taken in from the factory. Alternatively, the oven may simply need rebalancing, i.e. the dampers need readjusting to give the correct air movement. Although dampers and adjustable doors are set appropriately when the oven is commissioned, they tend to work loose with time. Readjustment is not a difficult task, but it needs to be done by an oven expert.

7 Load your components into the oven in such a way that it maximises the loading density.

8 Check that the air exhaust from the oven is not excessive. The amount of air removed has a dramatic effect on oven energy consumption and, while it is essential to remove the products of combustion together with flammable solvents and water, it is important to maintain a balance that combines safety with energy efficiency.

Your first task is to calculate the flammable solvent load and the level of the combustion products (see Appendix 3). You will find that a powder coating oven can operate with much lower air removal levels than one used for drying, stoving and curing liquid coatings.

Once you have identified the correct extraction level and set the ductwork dampers appropriately, mark each damper position clearly so that you can easily check their position in the future.

9 Oven doors are a major source of heat loss and, although some loss is inevitable, you should make every effort to minimise this. Where the door silhouette is much larger than any of the components passing through, it should be reduced. Options include fixing a sliding door or even fixing a plate over part of the existing door.

10 If the outside of your oven is too hot to touch, consider increasing the level of insulation. Recommended and cost-effective levels are 150 mm over the entire oven.

11 Make sure that the distance between any infra-red emitter and its target is appropriate. The energy transfer between infra-red panels and components will be most efficient at a set distance. If the distance in your unit is greater than this set distance, the energy will dissipate and be wasted. Check the correct distance with your infra-red supplier, and make sure that each batch of components is correctly positioned to optimise energy use. This is all part of optimisation through better process control.

12 Investigate the possibility of using infra-red as a means of pre-heating components before they enter a hot air recirculating oven as discussed in Section 7.1.3. This will effectively increase the capacity of the oven, allowing you either to coat components with a greater thermal mass (larger, thicker components) or increase your productivity by speeding up the conveyor.

A plastic moulding company found that its switch to environmentally-friendly water-borne paints had escalated its stoving costs. Experiments showed that the paints could be dried and cured more rapidly, not by increasing the time at a given temperature but by increasing the amount of air circulating at the ‘flash-off’ stage. The company also introduced water-absorbing filter media which removed around 10 kg of water per hour and recycled some of the air. This enabled the stoving schedule to be reduced.

Instead of supporting an increase in energy costs of 30 - 40% the company was able to reduce its costs by 25% and be environmentally compliant. Although the initial equipment cost was high, the outlay was repaid within ten months.

A Yorkshire-based company audited the use of its gas-fired curing oven and found that the plant supervisor's first task of the day was to switch on the oven. It remained on all day and, correctly, was the last piece of plant to be shut down.

Specific measurements were taken to determine:

- how long the oven required to reach its operating temperature;
- how much of each day the oven remained empty.

Questions were asked to ascertain whether the oven could be safely and easily switched off during the day and/or operated at a lower setting.

As a result of the findings, the oven was not switched ON until after the first components had left the pre-treatment plant and just before they were powder-coated.

Subsequently, plant start-up and shut-down were staggered. Operators began work and left at different times and breaks were staggered. As a result, it proved possible to set the oven to 'low fire' for 50 minutes of each day. The true production day was extended by one hour at no additional cost, and the company reduced its oven gas consumption by an estimated 18%.

8. GOOD HOUSEKEEPING AND EFFECTIVE MAINTENANCE

Good housekeeping and effective maintenance play an important role in the optimisation process. They lock in the benefits that have been achieved and ensure that you continue to make the savings in future years that you achieved initially.

Planned housekeeping and maintenance activities help to minimise coating rejects and loss of productivity. Although good housekeeping and maintenance both contribute to the effective performance of the organisation, many companies still seem to adopt the attitude that there is never time for housekeeping and maintenance but there is always time to put faults right. Such an approach cannot be justified or sustained in today's competitive environment.

To make sure that you implement an effective housekeeping and maintenance programme, begin by drawing up specific schedules for your particular processes. These should cover:

- normal standards of operation - i.e. defining temperatures, air extraction rates, water levels, pressures etc.;
- daily housekeeping and maintenance routines - for lighting, compressed air leaks, noise levels etc.;
- weekly tasks - checking filters, ovens, conveyors and tools;
- monthly tasks - will depend on suppliers' recommendations;
- annual servicing of key plant - will depend on suppliers' recommendations and will often be carried out by the supplier.

You should ensure that all the relevant equipment settings and routines are clearly and obviously displayed. Everyone should be aware of the reasons for these settings and procedures. Everyone should take responsibility for quality and on-going optimisation. At the very minimum you should identify and display the settings listed in Table 7.

What subsequent housekeeping and maintenance tasks you undertake, and how often, will depend on the type and size of equipment, its level of use, and the manufacturers' recommendations. Checklists 8 - 13 list the housekeeping and maintenance required, but as it is impossible to be prescriptive, photocopy and fill in the frequency column after discussion and agreement with your Maintenance Department.

Good Practice Guide 217 *Cutting energy losses through effective maintenance - Totally Productive Operations* shows how energy, as well as other costs, can be reduced by effective and efficient maintenance.

Table 7 Equipment settings that should be clearly displayed

Pre-treatment	Fluid levels in tanks Temperature settings and dwell times for dryers Temperature settings and dwell times for tanks Chemical concentrations Air pressures required for each piece of equipment Tank pre-heat times
Coating application	Extract rates Ambient temperature Light levels Fluid levels in spray booths Atomising pressures Fluid flow Coating material temperature
Curing	Oven temperature and dwell times Oven pre-heat times Position of dampers in ducts for correct extraction rate

Preventative action is important:

- **Use routine inspections and maintenance to identify where breakdown is likely to occur.**
- **Encourage your staff to report abnormalities and listen to their comments.**
- **Be prepared to act and don't ignore a potentially damaging situation.**
- **Make sure your operators and maintenance staff work together to prevent and solve equipment problems. In some companies there is a big divide between the two groups. However, it has been shown that, where the two work together and where operators understand and accept responsibility for the equipment, there is a much reduced failure rate.**

Checklist 8 Housekeeping and maintenance for ventilation systems

Frequency	Requirement	Benefit	Action	Date completed
Daily	Ventilation systems at the correct extraction rate	E	Visual inspection - check position of dampers.	
Daily	Heated air input balanced to extraction	Q	Check operation.	
Daily	Ambient temperature control	Q	Check temperature.	
	Effective filters in air replacement units	Q E	Replace old filters. Check old filters to ascertain change cycle.	
	Clean and effective fans	E	Clean and listen to check balance - a noisy fan will indicate a problem. Check fan to ascertain cleaning cycle.	
	Clean and effective ductwork	E	Clean to remove contamination and blockages.	
	Servicing of control equipment	Q E	Arrange for a specialist contractor to carry out task. Arrange calibration.	

Key

E Minimises energy use

Q Prevents contamination and reworking - maintains quality

Checklist 9 Housekeeping and maintenance for compressed air systems and equipment

Frequency	Requirement	Benefit	Action	Date completed
Daily	Clean and effective filters	Q E	Visual inspection - make sure filters and dryers within the coating area are kept clean and free of water.	
Daily	No air leaks	E	Listen. Repair air leaks as a matter of course.	
Daily	Identification and replacement of faulty equipment and fittings	E Q	Visual inspection. Invite comment. Act immediately to replace faulty items.	
	Filter change as recommended	Q E	Replace old filters. Check old filters to ascertain change cycle.	
	Elimination of worn nozzles that may be using more air	E Q	Clean and listen.	
	Clean refrigerant dryers	Q	Check for water. Check operating temperature and filters.	
	Effective after-coolers, filters and, in some cases, lubricators	Q E	Visual inspection. Clean and replace as required.	
	Compressor service	Q E	Compressors are normally fitted with an hours-run meter - keep a check. Follow the manufacturer's instructions.	

Key

E Minimises energy use

Q Prevents contamination and reworking - maintains quality

Checklist 10 Housekeeping and maintenance for lighting

Frequency	Requirement	Benefit	Action	Date completed
Daily	Adequate illumination	Q	Visual inspection. Replace bulbs/tubes as required.	
	More efficient existing lighting	Q E	Clean fittings.	
	Upgraded lighting	E	Schedule the installation of more efficient luminaires.	

Key

E Minimises energy use

Q Prevents contamination and reworking - maintains quality

Checklist 11 Housekeeping and maintenance for pre-treatment

Frequency	Requirement	Benefit	Action	Date completed
Daily	Correct operation of hand tools and other mechanical equipment	Q	Check operation.	
Daily	Proper temperature control	E Q	Monitor chemical temperatures.	
Daily	Correct chemical strengths and fluid levels	Q M	Monitor chemical strengths. Titrate as required.	
Daily	Effective vapour-degreasing plant	Safety	Visual and olfactory inspection.	
	Effective filters	E	Keep filters clean. Check filters to ascertain cleaning cycle.	
	Effective tank heaters	E	Visual inspection. Clean. Check operation.	
	Effective ovens and dryers	E Q	Clean out and service drying units. Check burners.	
	Effective control equipment	E Q	Arrange for a specialist contractor to carry out servicing. Arrange calibration.	

Key

E Minimises energy use

M Minimises materials use

Q Prevents contamination and reworking - maintains quality

Checklist 12 Housekeeping and maintenance for coating application

Frequency	Requirement	Benefit	Action	Date completed
Daily	Material control	Q M	Visual inspection - check the viscosity and temperature of coating materials.	
Daily	Properly functioning equipment	Q E	Check operation to ensure that equipment is functioning correctly. Examine the quality of application.	
Daily	Ambient temperature control	Q	Check ambient and component temperature.	
Daily	Correct film weight	M Q	Assess wet film thickness and dry film thickness.	
Daily	Correct fluid levels in spray booths	E M	Visual inspection.	
	Effective booth filters	Q	Replace old filters. Check old filters to ascertain change cycle.	
	No leaks on coatings pumps and seals	M E	Visually inspect for leaks. Replace as required.	
	Equipment service	Q E	Maintain application equipment as recommended by the supplier. Arrange calibration if required.	

Key

E Minimises energy use

M Minimises materials use

Q Prevents contamination and reworking - maintains quality

Checklist 13 Housekeeping and maintenance for drying, stoving and curing

Frequency	Requirement	Benefit	Action	Date completed
Daily	Equipment operating correctly		Listen for noisy fans and electric motors. Visually inspect the colour of gas flames. If these are too yellow, there is a problem. Visually inspect infra-red panels for evenness of colour.	
Daily	Correct oven operation and use	E	Check operation. Schedule operations to minimise oven ON time. Switch off when not in use.	
Daily	Oven temperature control	E Q	Check thermometers.	
	Correct filter operation	Q E	Replace old filters. Check old filters to ascertain change cycle.	
	Oven interior	Q	Vacuum to remove loose materials. Check debris removed to ascertain cleaning cycle.	
	Servicing of equipment	E	Inspect equipment. Arrange for a specialist contractor to carry out servicing.	
	Servicing of burner units	E	Arrange for a specialist contractor to carry out servicing. Arrange calibration.	

Key

E Minimises energy use

Q Prevents contamination and reworking - maintains quality

APPENDIX 1

CONVERSION FACTORS

Air pressure (pounds per square inch)	1 psi = 0.069 bar 1 psi = 0.07 kg/cm^2	1 bar = 14.5 psi 1 kg/cm^2 = 14.2 psi
Air flow rate (cubic feet per minute)	1 cfm = 0.47 litres/sec 1 cfm = 0.00047 m^3/sec	1 litre/sec = 2.12 cfm 1 m^3/sec = 2118.6 cfm
Energy - natural gas (kilowatt hours)	1 kWh = 0.034 therm* 1 kWh = 3.3 cubic feet	1 therm = 29.31 kWh 1 cubic foot = 0.303 kWh
Energy - fuel oil (kilowatt hours)	1 kWh = 0.091 litres 1 kWh = 0.000084 tonnes	1 litre = 11 kWh 1 tonne = 11,900 kWh

* 1 therm = 10^5 BTUs

APPENDIX 2

SOURCES OF ADDITIONAL INFORMATION

UK and European Standards

Manual paint spray booths	prEN 12215
Manual powder spray booths	prEN 12981
Automatic paint spray booths	BS EN 50176: 1997
Automatic powder spray booths	BS EN 50177: 1997

Available from:

BSI
389 Chiswick High Road
London
W4 4AL
Tel: 0181 996 7000
Fax: 0181 996 7001

Environmental Protection Act

Secretary of State's Guidance Notes:

PG6/15	Coating in Drum Manufacturing and Reconditioning
PG6/23	Coating of Metal and Plastic
PG6/31	Powder Coating Processes
PG6/33	Wood Coating Processes

Testing of Coatings:

BS 3900	Testing of Paints - includes industrial coatings
BS 6496	Powder coatings for architectural purposes
BS 6497	Powder coatings for architectural purposes

Available from:

The Stationery Office
PO Box 276
London
SW8 5DT
Tel: 0171 873 9090
Fax: 0171 873 0011

Health and Safety Standards

HS(G) 16: Evaporating and other ovens
HS(G) 37: An introduction to local exhaust ventilation
HS(G) 38: Lighting at work
HS(G) 54: Maintenance, examination and testing of local exhaust ventilation (2nd ed. 1998)
HS(G) 178: Spraying of highly flammable liquids (1998) (this has superseded the old EH9)

Available from:

HSE Books
PO Box 1999
Sudbury
Suffolk
CO10 6FS
Tel: 01787 881165
Fax: 01787 313995

Other

Code of Safe Practice for the Electrostatic Application of Powder Coatings

Available from:

British Coatings Federation Ltd
James House
Bridge Street
Leatherhead
Surrey
KT22 7EP
Tel: 01372 360660
Fax: 01372 376069

APPENDIX 3

WORKED EXAMPLE: EXTRACTION FROM OVENS

Extraction from ovens is required to remove solvents and the products of combustion. The level of extraction is critically related to energy consumption so it is important to get it right. Extraction must be at a high enough level to meet safety criteria without being so high that it wastes energy.

Guidance on how to calculate the extraction rate is given in HSE Booklet HS(G)16: *Evaporating and other ovens*. This Appendix summarises the main points.

1. The desired level of extract air is set so that the solvent concentration in the oven does not exceed 25% of the lower flammable limit (LFL).

2. As a rule of thumb 50 - 60 m^3 of ventilating air is needed to remove one litre of solvent.

3. Unless there is information to the contrary, it is assumed for the purpose of safe oven design that all solvents in the liquid coating will evaporate in the oven area.

4. Solvent-borne coatings may contain up to 85% of volatile solvent by volume. Generally the solvent content will be between 35% and 65%. The actual content is given in the Manufacturer's Data Sheets.

5. The volume of solvent released per minute can be calculated from the:

- surface area of coated product;
- production rate;
- coating thickness;
- solvent content of liquid coating film on the component.

Determining the volume of ventilating air for a conveyorised oven

HS(G)16 states that, as a rough working rule, 60 m^3 of fresh air should be introduced into the oven for every litre of solvent evaporated. Assuming that the load on a conveyorised oven is constant, a simple calculation may be made to establish the amount of solvent being evaporated.

The components consist of flat metal sheets, 1.75 m high by 1.0 m long. The sheets are sprayed on both sides, giving a total coated surface area for each component of:

1 x 1.75 x 2 sides = 3.5 m^2.

If the spacing between components on the conveyor is 0.25 m then, at a conveyor speed of one metre per minute, 0.8 components are coated per minute, i.e. 2.8 m^2 are coated per minute.

The liquid coating is applied at a wet film thickness of 100 microns to give a dry film thickness of 50 microns.

The amount of liquid coating applied to components per minute is therefore:

2.8 x 0.0001 = 0.00028 m^3 or 0.28 litres.

As the liquid coating is 50% solvent (50% solids) and as 70% of the solvent will evaporate in the oven, the total quantity of evaporated solvent in the oven is:

0.28 x 0.5 x 0.7 = 0.098 litres per minute.

The volume of air required is therefore:

0.098 x 60

= 5.88 litres per minute.

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

BRECSU

Building Research Establishment
Garston, Watford, WD2 7JR
Tel 01923 664258
Fax 01923 664787
E-mail brecsuenq@bre.co.uk

For industrial and transport publications please contact:
Energy Efficiency Enquiries Bureau

ETSU

Harwell, Didcot, Oxfordshire,
OX11 0RA
Fax 01235 433066
Helpline Tel 0800 585794
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.