GOOD PRACTICE GUIDE 270

Reducing energy costs for aqueous-based metal treatment processes

GOOD PRACTICE GUIDE 270

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

REDUCING ENERGY COSTS FOR AQUEOUS-BASED METAL TREATMENT PROCESSES

This Guide for operators, managers, supervisors and specifiers, is number 270 in the Good Practice Guide series and will help companies to reduce energy consumption and costs in aqueous-based metal treatment processes.

Potential savings are estimated at between 15 - 20%. How much would that be at your site? About half of these savings can be achieved quickly by adopting simple and cost effective energy saving measures as described in this Guide.

Using this Guide will:

- save 15 - 20% of your energy and water costs;
- reduce processing time;
- improve working environment;
- increase profits.

The Guide provides process managers and operators with:

- a breakdown of energy uses for various types of aqueous-based treatment processes;
- a simple method of assessing energy use and the potential for energy cost savings;
- many practical energy cost savings ideas;
- a method for establishing an Action Plan to implement savings;
- worksheets to help companies collect and calculate data for any site.

The aim of this Guide is to assist metal finishers both in the plating and painting industries to increase operational efficiency, reduce energy consumption and costs.

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LIST OF RELEVANT TITLES

EEBPP *Energy Efficiency Best Practice Programme*

FEB 4	Compressed Air and Energy Use
GPG 2	Reducing Energy Consumption Costs of Elect Motors and Drives
GPG 14	Retrofitting AC Variable Speed Drives
GPG 30	Energy Efficient Operation of Industrial Boiler Plant
GPG 126	Compressing Air Costs
GPG 260	Optimisation of Industrial Paint and Powder Coating
GPG 271	Selecting and Specifying Curing and Stoving Ovens

ETBPP *Environmental Technology Best Practice Programme*

GG51	Cost Effective Paint and Powder Coating: Surface Preparation
GG52	Cost Effective Paint and Powder Coating: Coating Materials
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EG74	Solvent Use for Vapour Cleaning in the Metal finishing Industry
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CDA *Copper Development Association*

116	Electrical Energy Efficiency *(obtainable from Copper Development Association)*

Copies of these Guides may be obtained from:

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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. INTRODUCTION

The purpose of this Good Practice Guide is to promote energy efficiency measures that will reduce energy costs in aqueous-based metal treatment processes.

There is a range of other very useful guides produced by the Energy Efficiency Best Practice Programme and the Environmental Technology Best Practice Programme. They are listed at the front of this guide, and include advice on water, energy use and environmental impact.

Energy costs for aqueous-based treatment processes are estimated at about £100,000,000/year for the entire industry (1998). Energy is used directly for tank heating and electroplating and indirectly for tank agitation, pumping of solutions and extract ventilation.

It is estimated that there are potential energy savings of 15 - 20%. Following the advice in this Guide will help companies start to realise energy savings, often by using simple methods that produce quick results.

1.1 Energy Efficiency in Practice

It is recognised that metal finishers have a number of overriding concerns when considering changes to existing methods of processing, e.g.:

- Will we be able to maintain quality and repeatability of treatments?
- Is there an additional cost to processing?
- What are the safety and COSHH implications?
- We are under customer pressure for quick turn rounds.

The good practice measures discussed in this Guide acknowledge all of the above issues and demonstrate how to make quantifiable improvements. Industry examples throughout demonstrate how some of the techniques are being used in practice.

There are a number of constraints that the managers and owners of finishing businesses need to recognise and address if the benefits of energy efficiency are to be realised. These are:

- a lack of investment for such measures;
- a general attitude that ‘if ain’t broke don’t fix it’;
- fear of jeopardising coating quality;
- operators’ lack of technical understanding;
- lack of time to investigate and implement improvements;
- lack of in-company knowledge and skills concerning energy efficiency.

However, there are also many incentives for overcoming these obstacles.

Energy Efficient practices will:

- add to profits - every pound saved goes straight to the bottom line;
- improve the working environment;
- speed up processing time allowing for higher throughputs;
- impress larger customers particularly those requiring ISO 14001 accreditation from their suppliers;
- help prepare for IPPC regulations where applicable.

1.2 Getting the Most from this Guide

This Guide is for all those involved in metal finishing, and is written for owners, managers, supervisors and operators responsible for the day to day operation of metal treatment facilities. The Guide will be useful to:

- specialist subcontract finishers;
- in-house metal treatment facilities in manufacturing companies;
- designers and specifiers of new metal finishing plants.

The Guide is relevant to all finishers, whether the treatment facility is a specialist subcontracting one or part of a larger production line in an engineering business.

Depending on their in-service usage, most engineering products can undergo several treatment processes. The aqueous treatment processes covered in this Guide fall into two categories:

Pre-Treatments

- Surface cleaning
- Mechanical cleaning
- Solvent cleaning
- Aqueous-based cleaning

Treatments

- Electroplating
- Electroless plating
- Anodising

Other coatings such as paint and powder, and metal coatings such as galvanising and aluminising are beyond the scope of this Guide. However, more information on industrial paint and powder coatings is covered in GPG 260 and GG 51-53 (see front of this Guide). They are available free of charge through the Environment and Energy Helpline on 0800 585794.

Section 2 gives an overview of surface cleaning methods to treatment processes. It discusses the main aqueous-based metal treatment processes used, and gives an overview of their more common applications. It provides metal finishers with a breakdown of energy uses for various types of aqueous treatment processes.

Section 3 describes the various ways and stages where heat and electrical energy is used. It provides a simple method of assessing use. It also highlights the main potential areas for energy cost savings.

Section 4 shows how to calculate and implement energy savings, using worksheets included in Appendix A. Monitoring current and future performance is the benchmark by which the biggest areas for energy savings can be identified, and results recorded.

Section 5 provides a step by step approach to reducing energy costs. It gives many simple cost-saving ideas, lists the benefits of implementing them, and details industry examples to demonstrate the results of putting these ideas into practice.

Section 6 is for those wanting to make major modifications to plant. The measures will also be of interest to equipment manufacturers.

Section 7 describes how to get started on saving energy costs. It covers the areas to think about before starting any energy efficiency programme, such as gaining management commitment, and training employees. It also provides an Action Plan to implementing savings.

Did you know that ‘Evaporative heat loss from treatment solutions is over 50% of the total energy used by tanks’ ?

2. AQUEOUS-BASED METAL TREATMENT PROCESSES

Most metal products are surface prepared or pre-treated to a lesser or greater extent in preparation for the application of coatings for protective (against corrosion, wear or abrasion) or decorative (appearance and texture) purposes.

The actual treatment processes is specific to each application. Therefore a treatment facility can consist of a number of treatment lines each with a series of process tanks. Treatment combinations are programmed for each work piece or batch depending on the size of the work piece and throughput of the facility.

In small treatment facilities, the product is immersed from tank to tank either manually or semi-automatically with a crane lift. Processing time and temperatures are set tank by tank. Each tank may be fitted with an adjustable timer and thermostat.

In a fully automated facility, the work piece transfer and processing sequences (i.e. time, temperature and power requirements) are controlled by a computerised management facility.

In the painting industry, conversion coatings are regarded as an 'intermediate' treatment stage. Phosphating and chromating etch and passivate the work piece, providing corrosion inhibition prior to the application of surface coatings.

2.1 Surface Cleaning

The need for surface cleaning arises from the fact that most forms of metal fabrication result in roughening and/or contamination of metal surfaces. The purpose of surface cleaning is therefore to smooth or remove undesirable films from the metal surface and prepare it for treatments such as conversion coatings, plating or anodising.

Good surface cleaning is essential for a good final finish and therefore most metal preparation methods consist of one or more of the following surface cleaning stages.

- removal of dirt by mechanical means;
- degreasing using detergents, solvents or chemical solutions;
- intermediate rinsing;
- removal of scale or rust or corrosion by acid pickling;
- rinse and neutralise;
- application of conversion coatings;
- hot rinse to dry.

Surface cleaning can be classified into three categories.

2.1.1 *Mechanical Cleaning*

The objective of mechanical cleaning is to remove rough metal protrusions and as a pre-treatment stage it may be deployed for all components.

The cleaning techniques can be summarised as:

- abrasive cleaning/polishing/wire brushing;
- barrelling;
- vibratory deburring;
- abrasive blasting;
- vapour blasting.

Of these cleaning methods, the most energy intensive ones are the abrasive blasting techniques using shot or vapour blasting. Both methods involve either the use of high-pressure compressed air or large electric motors to propel or circulate the abrasive material at high speed against the work piece placed within a blast cabinet or booth. In both cases the main energy used is electricity.

Stopping plant during rest breaks saves waste

An engineering company in the West Midlands has an automated, high pressure shot blast unit through which metal components are conveyed. The shot blast unit consists of five 7.5 kW motors which run continuously during the working day irrespective of how many components passed through. The electricity cost amounts to £3,500/year. It was estimated that the plant was idling for about 60% of the time. As an immediate step, a simple time clock was fitted to stop the plant for rest breaks which amounted to one hour per day (saving £400/year). A variable speed drive is being considered to reduce motor power if a photocell detector on the line detects no components. Potential saving £1,500/year.

2.1.2 *Solvent Cleaning*

Solvent cleaning is widely used in the metal finishing industry as it is a very effective means of cleaning metal surfaces. However, there is a trend away from solvent cleaning to aqueous-based cleaning. For companies that use this method there are steps that can be taken to make it more energy efficient. Further details on reducing solvent use can be found in publications produced by the Environmental Technology Best Practice Programme, which can be contacted via the Environment and Energy Helpline on 0800 585794.

Solvent cleaning is carried out in closely controlled vapour degreasing baths using solvent vapour, cold liquid solvents or ultrasonic cleaning. Due to the nature of the process, dirt is removed quickly and thoroughly and surfaces are left dry, which makes solvent cleaning a serious competitor to chemical degreasing. Ultrasonic cleaning is limited to applications requiring a high standard of cleanliness and the removal of very fine dirt particles.

From an energy use viewpoint, heat energy provided by electricity, gas or steam, is used to vaporise the solvent, which cleans the work piece. In doing so, the solvent is cooled by the immersed work piece and has to be reheated by the energy source as part of a continuous distillation cycle. To prevent the solvent from escaping, a condenser-cooling coil is provided above the working zone. The cooling effect is often by ‘once through’ use of towns water but this method is increasingly being replaced by closed circuit chilled water systems.

Although solvent cleaning itself is an efficient process, excessive energy use can result from the following factors:

- excessive extraction rates in pulling the solvent over the condenser coil;
- excessive drag out by work pieces due to not allowing sufficient time for drainage;
- inefficient condenser cooling;
- lack of tank lids;
- running the bath longer than necessary.

2.1.3 *Aqueous-Based Cleaning*

Aqueous-based cleaning methods consist of:

- detergent washing;
- degreasing;
- pickling;
- electrolytic cleaning.

All of these treatment processes are carried out either in dip-tanks or in custom-built pressure rinsing spray booths. A typical arrangement is illustrated in Fig 1.

Electrolytic cleaning in hot alkaline solutions is preferred for electroplating of most precious metals such as gold, silver and brass. Parts to be cleaned are connected electrically to become the electrode (cathode or anode). Liberation of gases during electrolysis causes solution agitation and promotes rapid cleaning of the work piece.

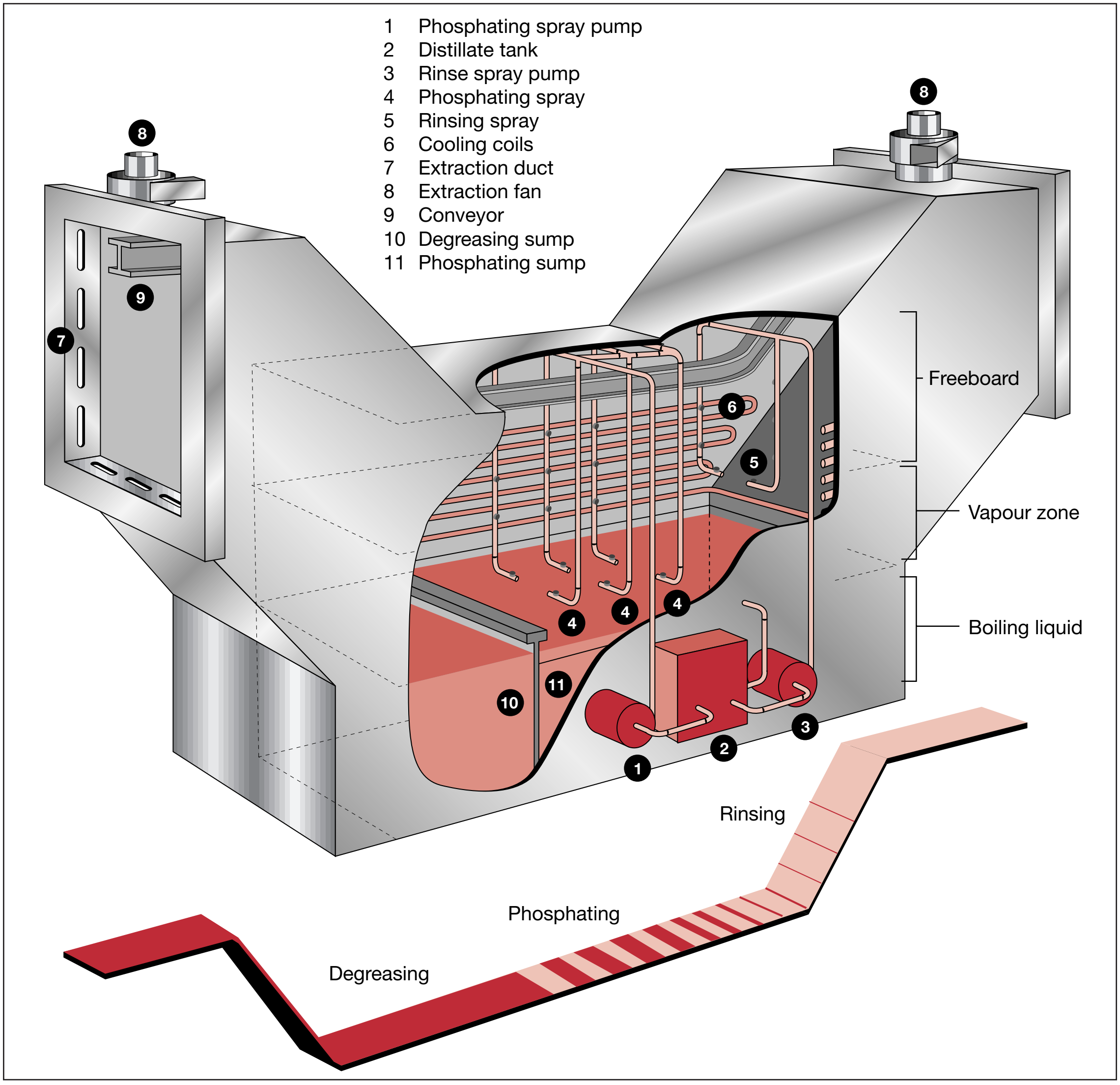


Fig 1 Diagram of typical spray rinsing tank

2.2 Surface Treatments

Depending on the final environmental conditions, after cleaning work pieces are programmed for one or more of the following surface treatments:

- electroplating or electroless plating;
- anodising;
- painting (see more information in GPG 260 and GG52, available free of charge through the Environment and Energy Helpline on 0800 585794.);
- conversion coating;
- other metal coating processes, such as galvanising, hot dip aluminising etc. (which are beyond the scope of this guide).

The efficiency of treatments is dependent on:

- temperature (heat energy);
- solution strength (concentration);
- agitation (solution mixing).

These three parameters can be optimised to ensure high processing efficiency (see Section 6).

Although many current treatments are 'hot' treatments, cold treatments are beginning to emerge, which may prove to be just as effective, and less energy intensive.

2.2.1 *Electroplating*

As a surface treatment, electroplating is commonly applied to metallic products with the specific purpose of providing a product with a protective, decorative or functional finish. A range of metals are electroplated such as chromium, gold, nickel, silver, tin, copper, zinc, zinc alloys and brass. The solutions used are aqueous-based and energy (heating and cooling) is used to control the solution temperatures.

Most plating temperatures range from ambient temperature to 60°C. Low voltage direct current power can vary from a few amperes to thousands of amperes depending on the size of the work piece and thickness of plating required. It is now becoming standard practice to maintain solution consistency using automated dosing systems for chemical additions.

2.2.2 *Electroless Plating*

As the name implies, no current is applied to deposit the desired metal coating which, through appropriate control can be applied to selected surfaces on a work piece. The other distinguishing feature is that a uniform layer is achieved across all sections of a work piece. The two most common uses are for nickel and copper plating. Electroless copper plating is used principally in the electronics industry, electroless nickel plating is applied to many engineering components such as bearings, gears and automotive components as well as plastics.

Nickel requires a high tank temperature (up to 95°C) whereas copper plating is carried out at room temperature, but the process is comparatively slower.

2.2.3 *Anodising*

The anodising process results in the formation of an adherent oxide film during the electrolytic process. The main demand for anodising is for aluminium products, to provide a protective, decorative or functional finish. The largest users are from the construction, aircraft and automotive industries.

The solutions used are mainly aqueous-based acids with sulphuric acid being the most commonly used. Most anodising is carried out at around room temperature but the process actually produces heat, so cooling is required to keep the solution at the desired temperature.

3. ENERGY CONSUMPTION

This section examines the various ways in which energy is used in metal finishing plants. Wasting energy not only costs money, but can actually have a detrimental effect on quality.

3.1 Heat Energy

Although the development of ‘cold’ treatments is increasing, most existing aqueous-based treatments still use large amounts of heat. Energy is required either directly or indirectly to speed up and to improve the efficiency of the treatment process.

Heat energy for tanks is provided in one of several ways:

- by direct fired gas tubular heaters;
- by electric elements;
- by indirect steam, hot water or thermal fluid heat exchangers where heat is generated by a process boiler plant or from a central boiler plant (which also provides space heating of factory and offices).

In most cases, the heating coil or heat exchanger is immersed in the tanks.

Heating is required continuously to overcome evaporative, structural and fluid heat losses - in addition to heat absorbed by the cold work piece. Furthermore, on a typical finishing line more heat is often required to compensate for waste caused by:

- higher than necessary extraction rates;
- excessive agitation which increases evaporation;
- inaccurate temperature levels caused by sensor pockets being coated with precipitates;
- uncontrolled cold water make-up on hot rinse tanks to compensate for evaporation losses;
- insufficient hold time to reduce solution drag-out with the workpiece;
- lack of tank insulation.

Each of these wasteful practices not only affects process quality but increases costs. They can be easily overcome by regular preventative maintenance, better controls and optimising processing programmes as discussed in Section 5.

3.2 Electrical Energy

To find out where electricity can be saved it is important to first find out how much is being used. More information and worksheets to help achieve this can be found in Section 4 but as a general guideline, electricity is used in a number of ways as shown in Table 1.

Table 1 Electricity use by application

Application	Electricity for				
	Current	**Fans**	**Pumps**	**Air compressors**	**Mech. drives**
Plating/anodising	✓				
Moisture removal		✓		✓	
Solution circulation in spray rinse systems			✓		
Extract ventilation		✓			
Solution agitation			✓	✓	✓
Process cooling	✓				
Conveyor systems					✓
Process heating	✓				

3.2.1 *Current for Plating/Anodising*

For electroplating and anodising, low voltage direct current electricity is provided via transformer/rectifier sets. Modernised plating plants use efficient and controllable rectifiers. Electricity consumption for plating can vary significantly depending on the size of the workpiece, stages and thickness of plating required and plant design and operation.

The largest uncontrolled power losses occur where:

- variable resistors are employed to control the plating voltage;
- more than one tank is supplied from one power supply, as a result of which overplating can occur due to compromising power supply settings to accommodate both tank requirements;
- inadequate section of busbar or busbar material is installed;
- oversized rectifier sets are used.

These power losses can amount to 20-30% of the electricity purchased and close attention is required to minimise these losses following the suggestions in this Guide.

3.2.2 *Moisture Removal*

Most painting systems require the workpiece to be moisture free prior to entering a drying oven. Moisture should be removed because the accelerated drying in ovens can causing staining and/or crystallise salts onto the surface, which in turn can lead to flash rusting.

Because compressed air is a readily available factory service, most companies use compressed air jets directed at the workpiece to drive off excess moisture. Not only is this an inappropriate use of an expensive resource but a high degree of waste occurs as the nozzles are uncontrolled and discharge compressed air continuously irrespective of workpiece throughputs. More information on reducing compressed air costs can be found in GPG 126 *Compressing Air Costs*.

This Guide shows you how to replace compressed air for moisture removal with a more energy and process efficient method in Section 5.3.4. Table 2 can be used to estimate the amount of electrical power used by compressed air jets or nozzles in sparge pipes.

Table 2 Power used by compressed air jets or nozzles in sparge pipes

Nozzle diameter mm	Electrical power (kW) used by a nozzle at different air pressures						
	2 Bar	3 Bar	4 Bar	5 Bar	6 Bar	7 Bar	8 Bar
3	1.4	1.9	2.4	2.8	3.3	3.8	4.3
4	2.5	3.4	4.2	5.0	5.9	6.7	7.6
5	4.0	5.3	6.6	7.9	9.2	10.5	11.8
6	5.7	7.6	9.5	11.4	13.2	15.1	17.0
8	10.2	13.5	16.8	20.1	23.5	26.9	30.2
10	15.1	21.1	26.3	31.5	36.7	42.0	47.2
12	22.8	30.4	37.9	45.3	52.9	60.6	68.0
15	35.7	47.5	59.4	71.1	82.7	94.4	106.3
20	63.5	84.5	105.4	126.4	146.8	167.7	188.7
25	99.0	131.6	164.3	196.9	230.0	262.1	295.3

How to Estimate Compressed Air Costs for Moisture Removal

If compressed air is used on your treatment line to remove excess moisture from workpieces before entering a drying oven, you can estimate the energy cost of this facility in the following way:

- measure the diameter of each nozzle;
- for each nozzle refer to Table 2 to estimate the power used;
- add up the power for all nozzles and multiply this by the annual operating hours;
- finally multiply this by the average cost of electricity (which ideally should include demand and capacity charges etc.).

Tip: To calculate the power consumed from volume of air discharged, 1 m^3 per hour of compressed air requires approximately 0.1 kW of power. To calculate the electricity cost, multiply the power by the number of operating hours and the average cost of electricity (pence/kWh).

Example: On a painting plant, moisture removal prior to final drying consisted of four 8 mm nozzles at 4-bar pressure. The company's average cost of electricity is 5 pence/kWh and the plant runs for 16 hours/day, 5 days/week and 50 weeks/year. Referring to Table 2, the power used by each nozzle is 16.8 kW. Total power used equals 67.2 kW and the electricity cost of using compressed air for moisture removal is £13,440/year.

3.2.3 *Pumps for Spray Rinsing*

In spray rinse treatment systems, typically in use in painting plants, electrical energy is used to pump each treatment solution. Pump sizes depend on the pressure requirements and throughput. Pump sizes range from 3 kW upwards.

The most common area of waste is pumps left running continuously when there is no production throughput, such as during rest breaks and long periods of line stoppages. Controls are readily available to reduce this waste (see Section 5.3.7).

How to Estimate Pumping Costs

- Note the pump motor rating (kW) and the total number of pumps on the line.
- As a first approximation assume a load factor of 50% for each pump.
- Add up the total power used, multiply by load factor (0.5) and multiply this by the annual operating hours.
- Finally multiply this by the average cost of electricity (which ideally should include demand and capacity charges etc.).

Tip: A more accurate method is to measure the current and voltage drawn by each pump motor using a clip-on meter and assuming a power factor of about 0.8, calculate power in kW (i.e. amps x volts x 0.8 = kW).

Example: A medium size engineering company in Herefordshire manufactures aluminium castings which undergo a pre-treatment process of degreasing and conversion coating in a spray rinse system. The six pumps for the spray rinse tanks are rated at 48 kW in total but using a clip-on meter showed a consumption of 24 kW. The plant is run on a two-shift system for 4,000 hours/year. The overall electricity cost is 4.7 pence/kWh and the cost of running the pumps alone is £4,500/year.

3.2.4 *Extraction Fans*

Extraction systems are often necessary to improve the working environment and to remove noxious fumes. However, depending on the solution and hours of use, they are not always necessary. The correct level of extraction should be provided - enough to comply with regulations and to provide an acceptable working environment, but no more.

Excessive extraction:

- means that electric motors are running longer than necessary - increasing your electricity bill;
- extracts heated air from the shop - this is wasteful and costly as it must be replaced by more heated air - increasing your gas/oil bill;
- will require increased maintenance on your extraction system.

In addition, designers often oversize extraction systems, making excessive extraction even more wasteful. Systems often have little or no control. It is clear that savings can easily be made if systems are controlled to achieve just enough, but not too much, extraction.

More details are provided in Section 5.3.6 on how to control usage.

How to Estimate Extraction Costs

- Note the motor rating of all extract fans associated with finishing lines.
- As a first approximation assume a load factor of 50%.
- Add up the total power used, multiply by load factor (0.5) and multiply this by the annual operating hours.
- Finally multiply this by the average cost of electricity (which ideally should include demand and capacity charges etc.).

Tip: A more accurate method is to measure the current and voltage drawn by each fan motor using a clip on meter and assuming a power factor of about 0.8, calculate power in kW (i.e. amps x volts x 0.8 = kW).

Example: At a small specialist treatment facility in the Midlands, a six-tank treatment line has a ducted lip extraction system with the fan rated at 4 kW. Using a clip-on ammeter it was found that, the actual power used was about 1.95 kW. Although the plant is run on a single shift system for 2,500 h/year, the fan is left running continuously day and night (8,736 hours). The electricity cost is 6 p/kWh. The electricity cost for running the fan extraction fan is £1,025/year. Clearly there is a good potential here for reducing costs and heat losses from the factory as a result if extraction at night can be reduced.

Where individual tank extraction systems are part of one big central system, the better option may be to reduce the level of extraction at night by fitting a two-speed motor. Alternatively, a damper may be fitted as the next best solution; dampers will reduce air loss but only reduce motor power very slightly.

3.2.5 *Air for Agitation*

The main reason for agitating tank solutions is to improve the efficiency of the process. In many instances this is accomplished using compressed air as it is a readily available factory resource. Some operators are misguided in thinking that compressed air is a free resource because air compressors are already running for other uses.

Uncontrolled waste occurs because tanks are often not in continuous use but the sparge pipe discharges air continuously. One way of minimising this loss would be to fit a solenoid valve to cut off the mains air supply after each batch is processed. However a more cost-effective way of agitating the same tank would be by using a low-pressure blower and an example is discussed in Section 5.3.3.

How to Estimate Compressed Air Costs for Tank Agitation

If compressed air is used on your treatment line to agitate tanks you can estimate the energy cost of this facility in the following way:

- measure the circumference of one nozzle on the pipe manifold (or the sparge pipe if it is a single outlet) and calculate the diameter by dividing the measurement by 3.142;
- refer to Table 2 to estimate the power used;
- multiply this by the annual operating hours;
- finally multiply this by the average cost of electricity (which ideally should include demand and capacity charges etc.).

Tip: To calculate the power consumed from volume of air discharged, 1m^3 per hour of compressed air requires approximately 0.1 kW of power.

Example: In a steel tubing pre-treatment plant a single 12 mm compressed air sparge pipe is used to agitate the soaping solution prior to tube drawing. The tank is 15 metres long x 1.4 metres wide x 1 meter high. The air is throttled to deliver approximately 2 - bar pressure. The company's average cost of electricity is 4.5 p/kWh and the plant runs for 24 hours/day, 6 days/week and 48 weeks/year. Referring to Table 2 the power used by a 12 mm diameter nozzle is 22.8 kW. Using the above method, the electricity cost amounts to £7,092/year.

3.2.6 *Cooling of Plating Solutions*
Most plating solutions need to be kept at a constant temperature (many at just above room temperature) requiring the removal of excess heat using heat exchangers. With careful planning some of this waste heat could be reused for space heating of the plating building or to preheat fresh air to the facility.

3.2.7 *Conveyor Systems*
The electricity used in motor drives to transport workpieces from tank to tank is small compared with other uses.

3.2.8 *Process Heating*
Process solutions can be heated by steam, gas or electricity. The selection of the appropriate heating source is discussed in Section 6.2.

3.3 Breakdown of Energy Uses

Section 4 enables you to work out actual data for your site, but this section gives an overview of energy use problems in the main process types of tanks. From this it is possible to see where energy is commonly lost - and thus where is the potential for energy savings.

3.3.1 *Dip Tanks*
In a dip tank, energy is used in a number of ways as illustrated in Fig 2.

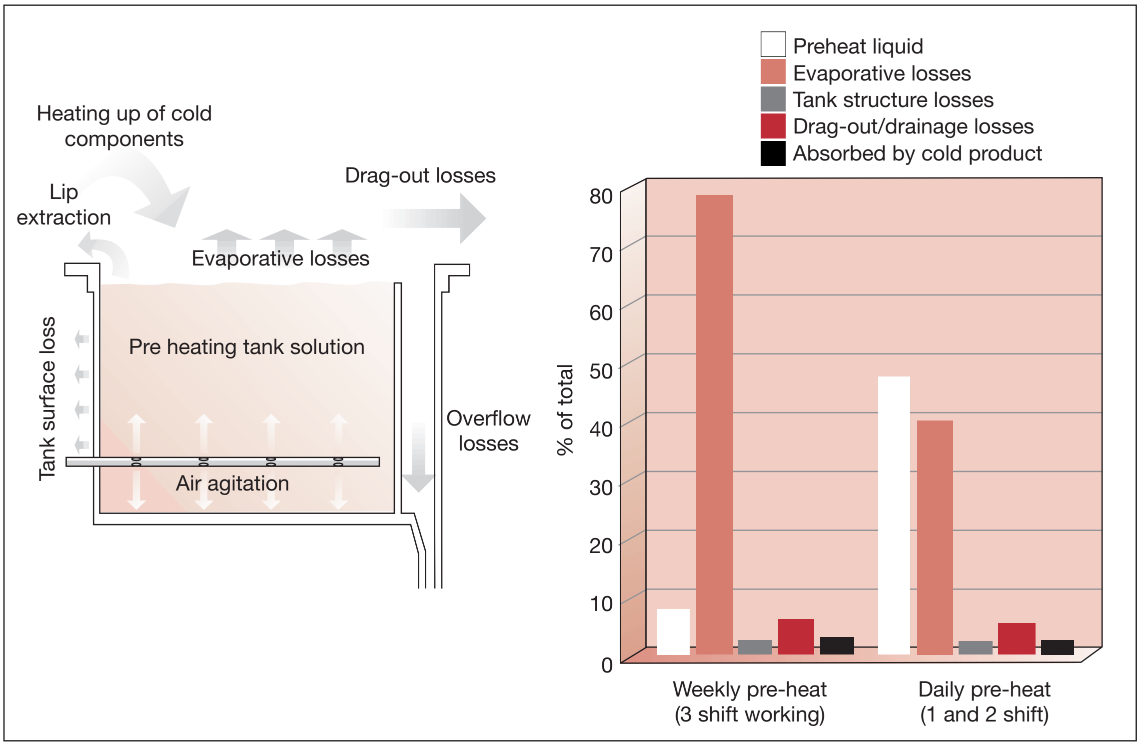


Fig 2 Typical breakdown of heat energy use for a dip tank

A typical breakdown of **heat** energy uses for a dip tank is illustrated graphically. From this comparison it can be seen that the way energy is used differs significantly between tanks that are pre-heated daily and weekly. The breakdown also provides good indicators for cost saving opportunities.

For three shift working weekly pre-heat is practised and the greatest energy loss by far is evaporative losses. This can be reduced by keeping tanks covered. Other losses are harder to deal with immediately and probably not cost effective.

For single and two shift working daily pre-heat is practised and the larger heat loss is due to daily pre-heating needs. To ensure that heat already in the tank is retained as much as possible tanks should be covered and tank insulation increased.

Electrical energy is also used on those dip tanks where compressed air is used for tank agitation. In these circumstances, the electrical energy can represent a significant proportion of total energy use as illustrated in the previous section.

3.3.2 *Spray Rinse Tanks*

Pressure or spray rinsing is a rapid method of cleaning and is best suited to automatic or semi-automatic wash systems with high throughput of workpieces. The main advantage is the combined action of physical force of spray and cleaning chemicals to remove dirt rapidly, thus reducing processing time. With good filtration, the solution can be re-used for longer periods thus reducing down time for sludge removal and tank cleaning.

In a typical spray rinsing tank energy is used (or lost) in several ways as Fig 3 illustrates.

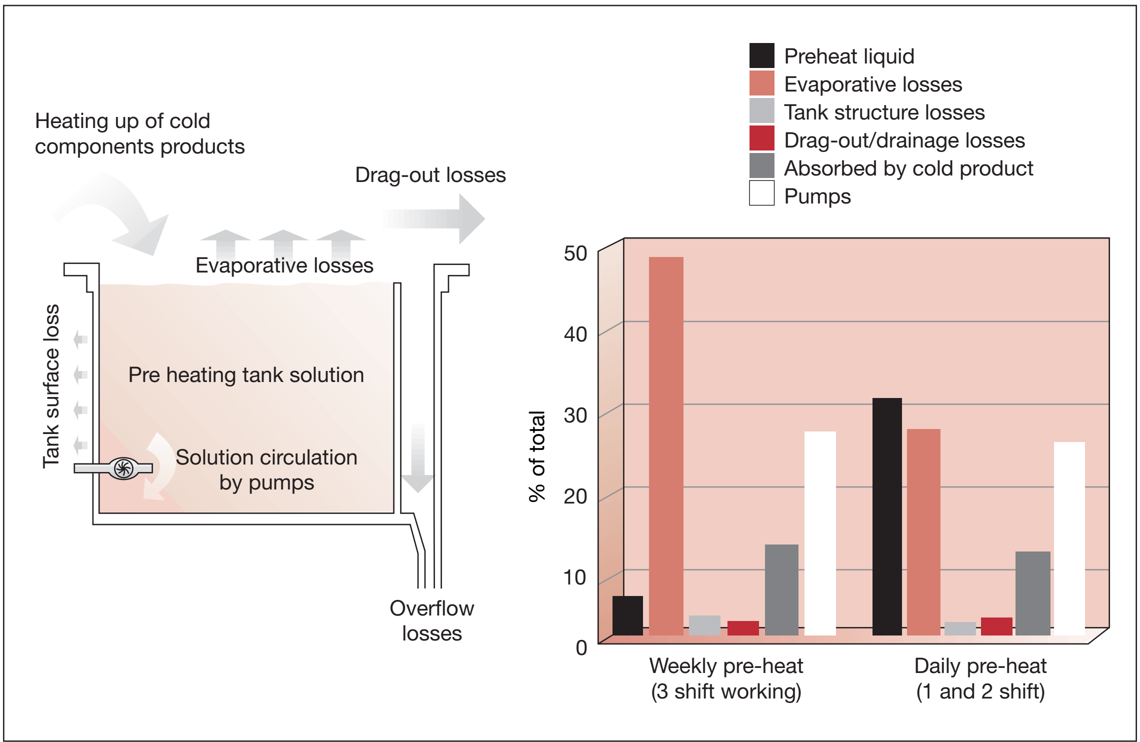


Fig 3 A typical breakdown of heat energy use for a spray rinse tank

A typical breakdown of heat energy uses for a spray rinse tank is illustrated graphically. From this analysis the major areas for savings are:

- evaporative losses - where a higher loss occurs due to the spray effect;
- daily pre-heating is significant for tanks allowed to cool excessively overnight;
- spray pumps are also a major user of energy (electrical).

3.3.3 *Plating Tanks*

In a typical plating/anodising tank energy is used (or lost) in the ways illustrated in Fig 4.

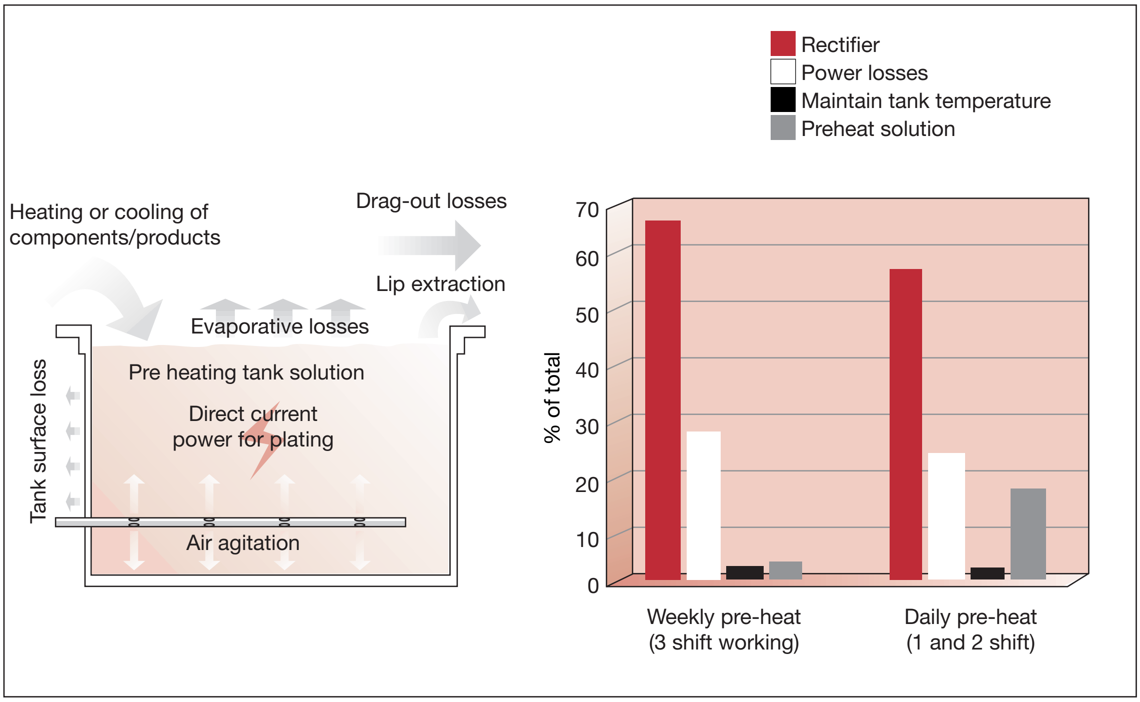


Fig 4 A typical breakdown of major heat and power uses for plating/anodising tanks

A typical breakdown of major heat and power uses for a plating/anodising tank is illustrated graphically. Electrical power usage for plating represents the largest proportion of total energy requirements.

Opportunities for savings wll come from:

- controlling power to rectifiers;
- minimising power losses;
- minimising daily pre-heating by not allowing tanks to cool excessively overnight.

Tank agitation using compressed air or blowers is not required on barrel plating lines but tends to be used on rack lines. This proportion of tank energy use is not shown in Fig 4 as not all tanks are agitated in this way but where it is used it will represent a significant energy use as illustrated in the previous section.

3.3.4 *Extract Ventilation*

As a general rule, extraction systems are fitted to most treatment tanks to comply with health and safety regulations. Extraction is important for control of harmful emissions and also worker comfort, but too much extraction is wasteful.

Systems tend to be over-specified with the result that high energy costs are incurred (see the previous section) especially where the system runs continuously. Often a simple measure such as covering the tanks and turning off fans not only saves you electricity but reduces space heating costs.

3.4 Alternative Future Technologies

Treatment techniques that can improve process efficiency and reduce costs continue to be developed. Three that merit consideration and may become accepted technologies in the future are:

Cold Treatments

A number of 'cold treatment' techniques have been developed in recent years. One such treatment is known as reactive coating metal treatments (RCMT). RCMT claims to replace conventional aqueous and solvent-based pre-treatment processes. The benefits compared with conventional treatment techniques are:

- it is aqueous-based;
- it does not require heat;
- it is non rinsing;
- no drying is required;
- it has multi metal application;
- no extraction is required;
- no post rinses are required.

Pulsed Drying

As the term implies it is now possible to obtain pulsed air drying systems for removing moisture from components. Hot air is 'pulsed' in short bursts into a drying chamber thus promoting high convective heat transfer rates. This method is claimed to be more effective than blowing warm air continuously across components and requires less energy.

Heat Exchangers

More recent developments in heat exchanger technology suggest that heat energy, lost through heat exchangers on anodising lines or from fume extraction systems, can now be recovered and re-used either for pre-heating other solutions or make-up air.

This is generally not cost effective as a retrofit measure but may be worth considering at the design stage.

4. COLLECTING DATA ABOUT TREATMENT TANKS

'If you do not measure performance, you cannot manage effectively,'

4.1 Where to Start

The recommended starting point for working out where energy can be saved most cost-effectively at any site, is to evaluate current performance. Most finishing plants have been modified at some stage and often no accurate records are available. You should therefore start by collecting information for each finishing line.

For each tank you need to record:

- process type (i.e. degreaser or hot rinse, etc.);
- internal tank dimensions (i.e. length, width and height in contact with solution);
- solution temperature using a calibrated portable thermometer;
- tank thermostat setting;
- operating hours (i.e. per day, per week and per year)

With the above data you can assess how much energy you are using on each tank and finishing line using the techniques described in this section and then the potential for savings using the several savings techniques identified in Section 5.

Having assessed the potential savings and costs of implementation of all the possible measures, decisions need to be made on priority measures, affordability and the optimum time to implement them, such as at the next factory shutdown.

Finally, it is important to get feedback on the success (or failure) of measures and this will require some form of ongoing procedure of monitoring energy usage.

As a guide the following management framework will be of assistance in implementing the above steps leading to energy cost reduction measures.

4.2 Collecting Data

To manage treatment lines effectively, it is important to collect data about tanks, total energy and water consumption and throughput data. Carrying out surveys is essential, as modifying your production processes on the basis of inadequate information could prove expensive.

The starting point is to compile an inventory of all treatment tanks using Worksheet 1 (see Appendix A) which can be photocopied for your use. Table 3 is an example of how to record relevant data on Worksheet 1.

Table 3 Tank data collection form

Tank no.	Treatment process	Extract ventilation/ tank agitation	Length m	Width m	Height m	Op temp °C	Hrs/ day	Days/ wk	Total hrs per week
1	Degreaser	Yes	4.1	2.2	2.3	60	10	5	50
2	Hot rinse	No	4.2	2.4	2.2	50	10	5	50

Next collect resource utilisation and throughput data using Worksheet 2 (see Appendix A). An example is shown in Table 4.

Table 4 Utility resources collection form

Resource	**Units**	**Annual (A)**	**Cost £ (B)**	**Average unit cost (B/A)**	
Electricity	kWh	395,000	£23,262	£0.05889	£/kWh
Gas/~~Oil~~	kWh	2,986,500	£21,915	£0.007338	£/kWh
Water	m^3	5,000	£5,000	£1.00	£ /m^3
Production throughput	kg or tonnes of metal	1,500 tonnes			

Total energy cost	= *Electricity + gas costs*	***£45,177***
Total utilities cost	= *Total energy + water costs*	***£50,117***

Total energy cost per tonne of production	= *Total energy cost/production throughput*	***30.12***	£/tonne
Total utilities cost per tonne of production	= *Total utilities cost/production throughput*	***33.45***	£/tonne

4.3 Initial Assessment of Savings Potential (Tank Temperature Rating Method)

Processing temperature has a major influence on treatment methods and the heat energy used can be significant. Before carrying out detailed investigations into the potential for heat energy savings, and as an initial guide to the scope for energy savings, the following quick assessment method is recommended.

A unique feature of the method is that it is based on energy rating tanks by their operating temperature and hours of usage.

4.3.1 *How to Use the Assessment Method*

Complete Worksheet 3 (see Appendix A) using the data collected in Worksheet 1 for all treatment tanks as detailed below. Table 5 shows a worked example to help you.

Step 1 For each treatment tank, enter the total weekly operating hours for each tank in the appropriate temperature range;

Step 2 For each temperature range add up the total number of operating hours (enter totals A - D);

Step 3 Express total hours in each temperature range as a % of the grand total of hours.

Table 5 Worked example of savings potential assessment

		Tank temperature range			
		20 - 35 °C	**36 - 55 °C.**	**56 - 75 °C**	**>76 °C**
Tank No.	**Treatment process**	**h/wk**	**h/wk**	**h/wk**	**h/wk**
1	*Can Clean 1*			*55*	
2	*Can Clean 2e*			*20*	*35*
3	*Hot Rinse*			*55*	
4	*PyroCleane*		*40*	*15*	
5	*Cold Rinse*	*55*			
6	*Phosphate*			*55*	
7	*Chromate*		*55*		
8	*Cold rinse*	*55*			
9	*Hot Rinse*				*55*
Total hours for temp range		A= *110*	B= *95*	C= *200*	D= *90*

Total hours t = A+B+C+D	*495*

	Temperature Rating of Tanks			
	20 - 35°C	**36 - 55°C**	**56 - 75°C**	**>76°C**
	No significant savings	Low potential for energy reductions	Good potential for energy reductions	Very good potential for energy reductions
% hours of use in each temperature range	= A/t %	= B/t %	= C/t %	= D/t %
Enter score from above	*22*	*19*	*40*	*18*

Interpreting the Tank Temperature Ratings

- If your highest score is in zone C or D, the potential for energy savings is high and it recommended that a detailed assessment is carried out as discussed in this Guide;
- If your highest score is in zone B, your heat energy use is low and the best potential for savings would be to focus on ancillary uses of energy such as electricity for extract ventilation or tank agitation by compressed air and preventative maintenance;
- If your highest score is in zone A, the overall potential for savings is low.

In the example shown in Table 5, over 50% of the tanks are heated and operated at temperatures over 55°C and there is therefore a good potential for implementing energy savings.

Tip: Worksheet 3 can be set up as a spreadsheet computer program to speed up the analysis and later on you can use the same method to compare your tank temperature performance before and after improvement measures. For example if you progressively move towards cold treatments or you eliminate unnecessary stages or reduce temperatures, the % score in zones A and B will represent a larger % of the total, providing confirmation that you are now using less energy in your finishing lines.

4.4 Estimating Energy Usage and Costs

From Section 4.3, having assessed that the potential for savings is high, further energy calculations are necessary which serve three important purposes:

- to calculate the annual cost of operating each tank on a finishing line;
- to evaluate the benefits of cost saving improvements;
- to benchmark the performance of individual treatment tanks or lines.

The calculation method described here is a relatively simple one requiring no expert knowledge of heat transfer. It can be used iteratively to estimate present energy operating costs and for projecting the running costs with various improvements.

4.4.1 *The Calculation Method*

This method has three steps:

- Step (a) calculates heat energy used;
- Step (b) calculates electrical energy used;
- Step (c) calculates the total energy used

Step (a) Calculating Heat Energy

This is based on the fact that the heat energy for tank heating is proportional to the operating temperature i.e. the higher the operating temperature the higher the heating requirements to maintain the tank at optimum operating conditions. Previous research and analysis of several treatment tanks carried out for this Guide show that evaporative losses account for 50% of the total heat required for tank heating as shown in Fig 5. Therefore to calculate evaporative and total tank losses requires just three parameters to be established:

- tank operating temperature (°C);
- solution surface area (m^2) of the tank;
- presence of lip extraction, tank agitation or tank lids.

This data is obtained from Worksheet 1. By using the information in Figs 5a and 5b, the evaporative heat losses and total tank heat losses can be obtained. Follow the worked example below.

Note: if the tank solution is always covered with a lid or insulation spheres, evaporative losses are reduced by 50% and therefore total tank losses proportionally less also. Depending on the efficiency of the energy source the final energy use and cost per tank can be established.

Step (b) Calculating Electrical Energy

This requires the estimation of electrical energy uses associated with each tank. This is done by adding together the electrical loadings of circulation pumps (on spray rinse tanks), rectifiers (on plating/anodising tanks), extraction fans and tank agitation by blowers or compressed air. Look back at Section 3 for details of how to calculate this.

Step (c) Calculating Total Energy Usage and Cost

Add all energy uses for the tank and calculate the total energy cost.

Worked Example

A degreasing tank measuring 4m long x 2m wide x 2m high is heated by an indirect gas fired tubular heater with a overall efficiency of about 75%. Operating temperature is 70°C.

The tank has a compressed air sparge pipe with one 4 mm nozzle throttled to about 4 bar pressure to agitate the solution.

This tank is part of a six tank treatments line which has a common lip extraction system fitted to all tanks. The level of extraction is low and approximates to Still Air movement. However, the extract fan draws 4kW of electrical power and runs continuously day and night except at weekends.

Tanks are in use for 10 h/day, 5 days a week and 50 weeks per year.
Cost of gas is 1p/kWh, electricity is 5p/kWh and water costs £1/m^3.

Step 1 Calculate heat energy used
Surface area is 4 x 2 = 8 m^2
Temperature = 70°C
Operating hours = 2,500 hrs

Using Figure 5a, curve 1, for tanks at 70°C with no lip extraction and no lid, evaporative losses are approximately 5 kW per m^2.

Thus energy use for evaporation is 5 x 8 = 40 kW and **doubling** this figure gives the total tank heat energy use of 80kW. (If the tank is always covered with a lid or has insulation spheres, curves 2-4 give the reduced evaporative loss).

To calculate the consumption of the tank, the efficiency of the heater must be included (0.75).
Annual Energy Consumption for heating the tank = 80 x 2,500/0.75 = 266,667 kWh per year
Annual Cost of Heating the tank = 266,667 x £0.01/kWh = **£2,667 per year**

Step 2 Calculate the water loss
Water loss reduction can be estimated from Figure 5b, curve 2:
At 70°C, water loss = 7 litres per hour per m^2
Water loss = 7 x 8 x 2,500 = 14,000 l/yr = 140 m^3/yr
Annual cost of water loss = 140 x £1/m^3 = **£140 per year**

Step 3 Calculate the electrical energy used
3.1 Compressed Air
From Table 1, the power used by a 4mm diamter compressed air nozzle is 4 kW
Annual Electrical Consumption = 4 x 2,500 = 10,000 kWh
Annual Cost of electricity = 10,000 x £0.05/kWh = **£500 per year**

3.2 Lip Extraction
The lip extraction fan of 4kW runs continuously. It is probable that the fans will not be pulling their rated power; as a first approximation, a loading of 50% will be used.
Therefore Annual Consumption = 4 x 24 x 365 x 0.5 = 17,520 kWh
Annual Cost of electricity = 17,520 x £0.05/kWh = £876 per year for all 6 tanks and **£146 per year** for the degreaser tank.

Step 4 Total energy used
The Total Cost of Operating this Degreasing Tank = 2,667 + 140 + 500 + 146 = **£3,453 per year.**

Potential Savings

- Covering the tanks with insulation spheres will save 50% of the evaporative heat loss. Saving **£667**
- Reduced water loss **£140**
- Using a low-pressure blower instead of compressed air will save at least 3 kW (or 75%). Saving **£375**
- Switching off the lip extraction fan at weekends (48 hrs per week) would save **£83** for one tank

Total potential savings £1,265 per year or 37% of current costs!

Remember this is for one tank and the same calculation needs to be done all tanks to arrive at the potential savings for the whole of a finishing line.

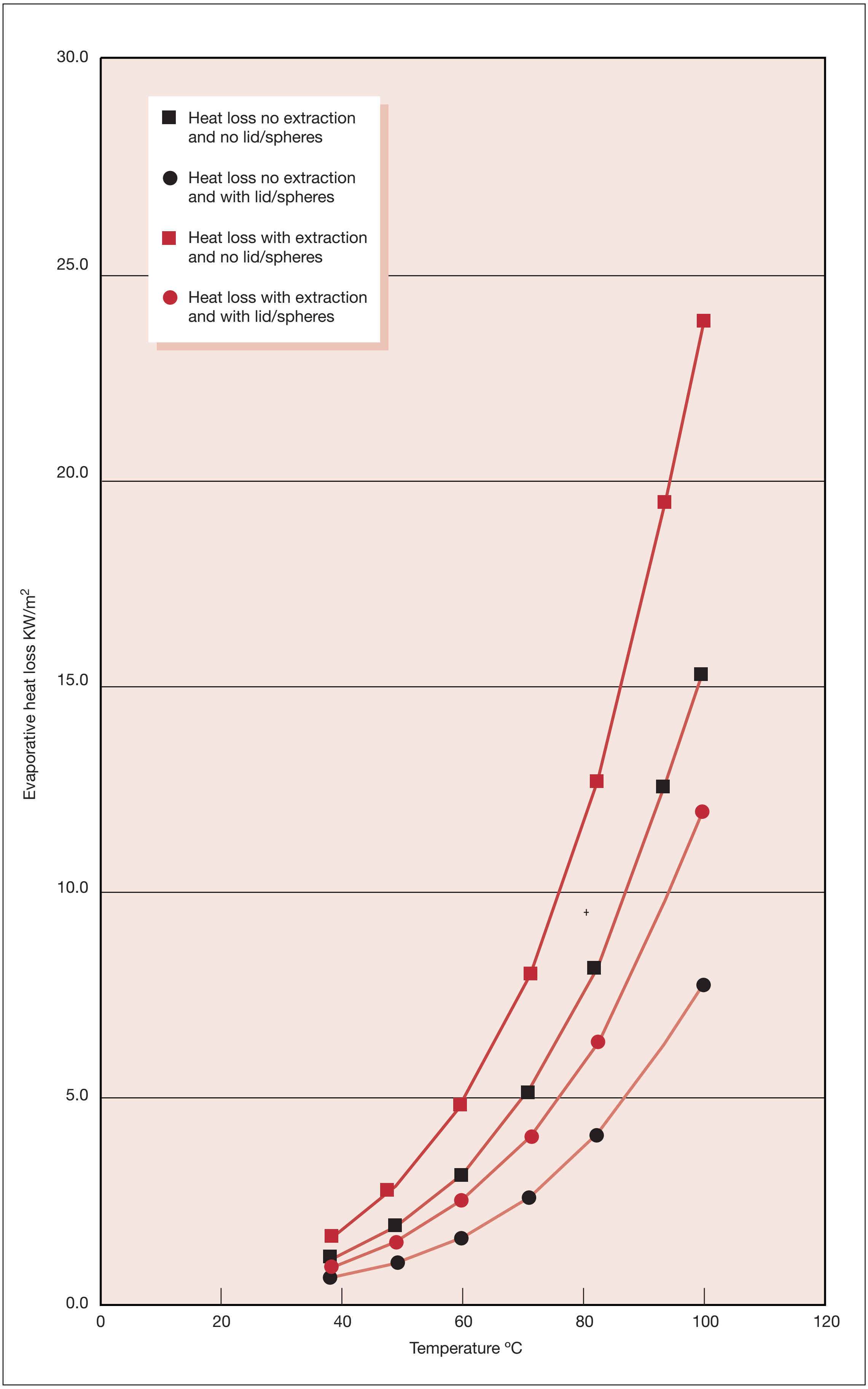


Fig 5a Evaporative heat loss from tanks with extraction and lids/spheres

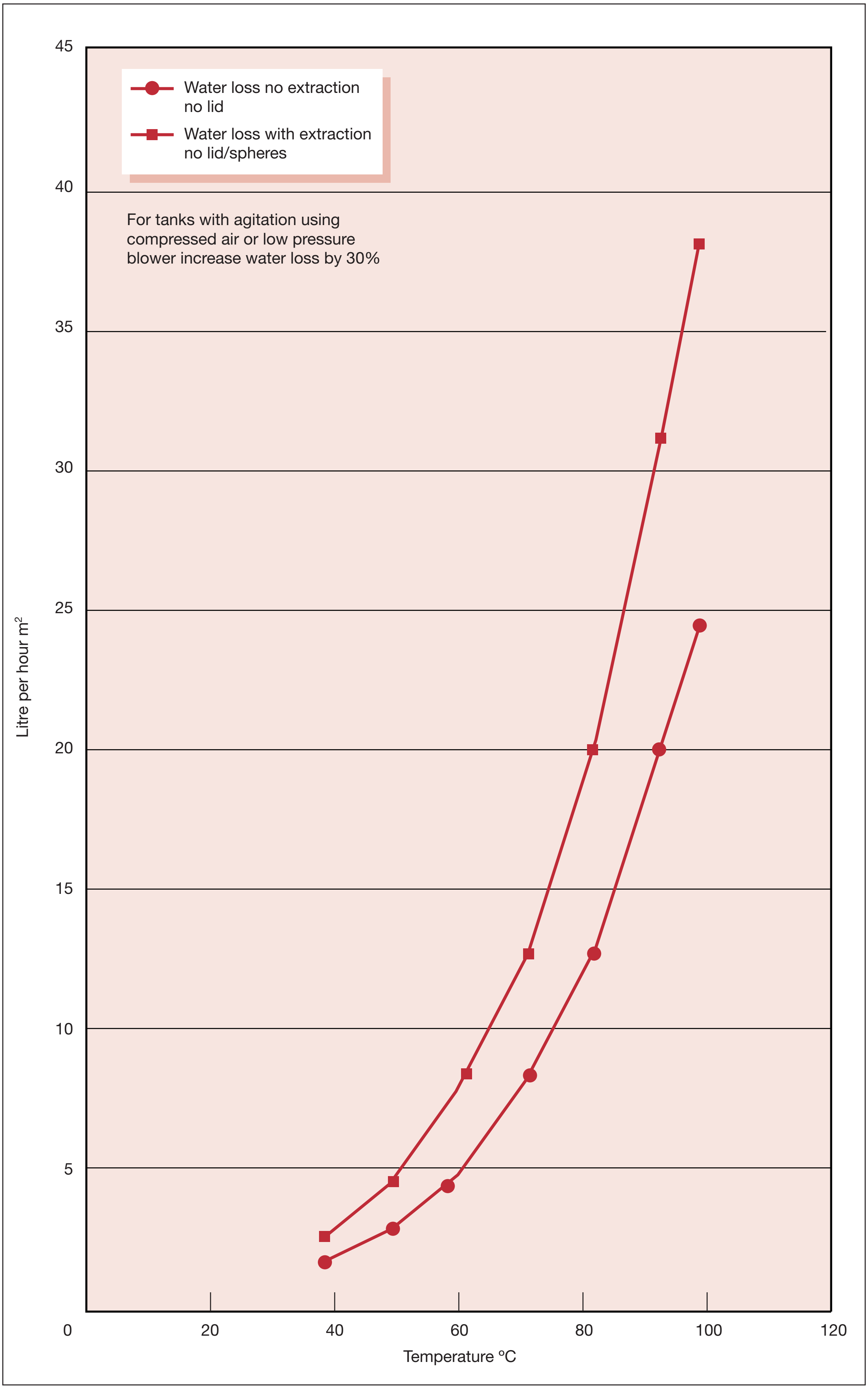


Fig 5b Evaporative water loss from tanks

5. A STEP BY STEP APPROACH TO REDUCING ENERGY COSTS

5.1 The Step by Step Approach

Section 3 identified the various ways in which energy is consumed and highlighted opportunities for savings. This section shows you the level of savings achievable for each measure.

Energy usage and costs can be reduced substantially by adopting the following three-step approach.

Step 1 — Implement reduction and control measures to existing processes

↓

Step 2 — Improve efficiency of existing processes

↓

Step 3 — Specify energy conscious design for new or replacement equipment

5.2 STEP 1 - Implementing Reduction and Controls Measures

The following measures have been successfully implemented by metal finishers. Most of these measures do not require extensive analysis, can be implemented quickly and are cost effective giving paybacks of less than two years. Measures shown below are in order of priority.

5.2.1 Reducing Evaporation Losses

Heat loss caused by surface evaporation of the treatment solutions represents over half of the total energy used by tanks. The higher the tank temperature the greater the heat loss. Excessive tank agitation and extract ventilation also increase this evaporative loses substantially.

You can reduce this loss by over 50% by:

- covering tanks with an insulated lid;
- covering the solution with floating, insulating spheres or similar;
- turning down tank agitation to a minimum;
- regulating the level of extraction.

Further cost reductions will result from:

- minimising the loss of expensive solutions;
- reducing harmful emissions to the working environment.

Benefits

- Heat energy reduced by up to 50%.
- Water losses reduced by up to 50%.
- Improved work environment.

Hexagon layer reduces heat loss

Durham Tube is a processor of steel tubes. The zinc phosphate tank has a liquid surface area of 21 m^2 and is maintained at 78°C. Two different methods of reducing heat loss were considered; one using heavy duty polypropylene insulating spheres and the other using a new product which is in the shape of insulating hexagons (see Fig 6).

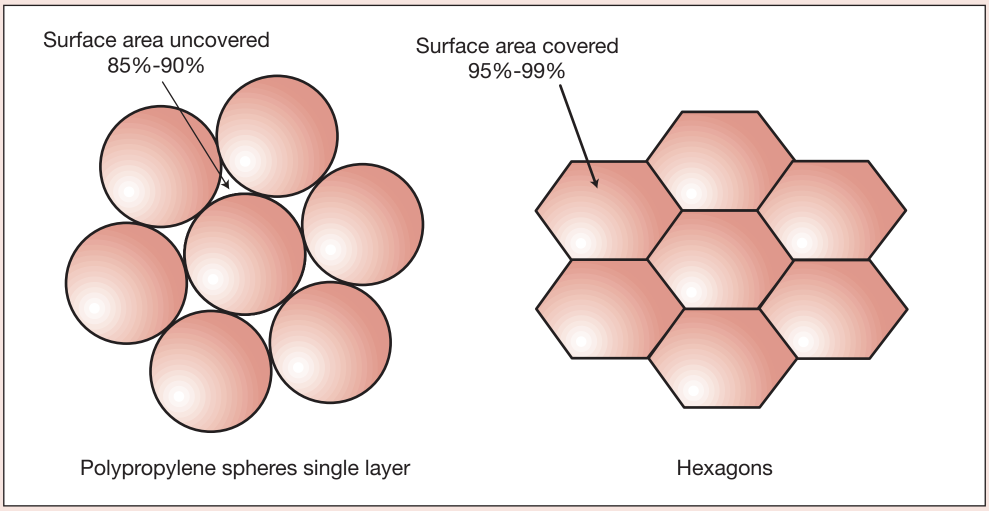


Fig 6 Comparison between single layers of polypropylene spheres and hexagons

(a) Using heavy duty polypropylene spheres
For full coverage, two layers were specified (as one layer has an effective coverage of only about 80-90%). 10,000 spheres of 70 mm are required at a cost of £3,000. Heat saved is about £4,000/year. Spheres are currently used at Durham Tube, but have to be replaced regularly because they are easily lost and damaged.

(b) Using Hexagons
This is a new product and due to its shape provides an interlocking layer over the liquid with a claimed effectiveness of 95-99%. Only one layer is needed and the hexagons are indestructible. For the Durham Tube's zinc phosphate tank, some 2,000 hexagons of 100 mm would be needed at a cost of £2,500 and savings of £4,000/year.

5.2.2 *Reducing Heat Losses at Night*

Tanks left uncovered outside working hours will continue to lose heat and will have to be reheated the next day before the tanks can be used.

Lids keep the heat in

In a Midlands treatment facility, where the extraction system runs continuously, it was found that although the tank sides were fitted with 50 mm of insulation, they still cooled down at night to half their daytime operating temperature because there were no lids. For example the degreaser tanks cooled from 72°C to 36°C. and the phosphate tank from 74°C to 35°C. With lids on the tanks the overnight temperature fell by only 10°C.

Thus tank temperature drops can be reduced significantly by covering tanks overnight with an insulated lid or blanket. Most tanks are designed for a 4-6 hour warm up. With a lid the warm up time can be less than two hours.

Benefits

- Heat energy reduced by up to 30%.
- Faster pre-heating and reduced waiting time by reduced need for fume extraction.

5.2.3 *Minimising Drag-out Losses*

Some solution is inevitably lost when the workpiece is removed from the tank/spray facility. But if the workpiece is moved too quickly, drag-out loses can increase substantially. If this solution is heated you will waste heat as well as chemicals.

Minimise this drag-out loss by programming suitable delay periods between tanks.

Other benefits include less spillage and cross contamination of solutions.

Benefits

- Heat energy saved.
- Solution losses reduced.
- Less cross-contamination.

5.2.4 *Controlling Tank Overflows*

To reduce contamination in rinse tanks and to introduce higher strength solutions many tanks have either continuous overflows or are emptied too often. Excessive use of rinse or top-up water results in unnecessary loss of heat and water.

Fit automatic top-up controls to minimise loss of heated water and solutions. A typical control system is shown in Fig 7.

The typical cost of installation for an individual tank is about £150 but this is reduced if multiple rinse tanks are monitored from one controller.

Benefits

- Heat energy reduced by up to 50%.
- Solution loss reduced.
- Water costs reduced by up to 50%.
- Lower effluent costs.

Example: A 2 m^3 hot rinse tank at 60°C was arbitrarily set to overflow at about 10% of its volume/hour. The tank is used for about 2,500 hours/year. Heating costs were £200 and water costs £500/year. Fitting an automatic water controller saved 50% of the above cost.

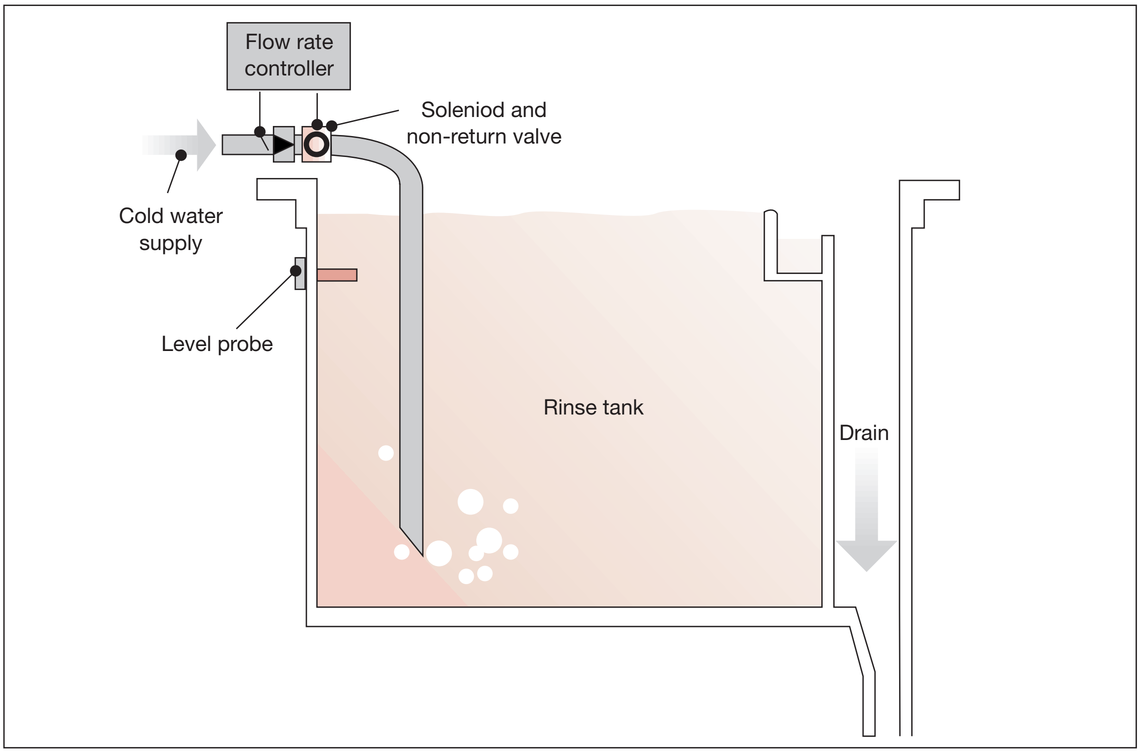


Fig 7 Typical flow controller arrangement

5.2.5 *Controlling Tank Temperature*

Tanks without good temperature control will either under heat and jeopardise product quality or overheat, wasting energy and money.

Example: At a large painting plant actual tank temperatures were on average three degrees higher than the thermostat setting because the temperature sensor became heavily encrusted with deposited phosphate. See Fig 8.

Fig 8 Encrusted temperature sensor

An additional 1°C rise in solution temperature uses about 5% extra heat energy.

Fit at least two good quality temperature sensors and controls and maintain regularly. The cost of good controls should not exceed £50 each.

Regular maintenance and calibration should form part of the quality assurance system. For a large finishing facility, consideration should be given to a centralised temperature monitoring system using a technique known as ‘arbitration’ where the readings of two adjacent located sensors are continuously compared for accuracy.

Benefits

- Heat energy reduced by up to 10%.
- Improved process quality.

5.2.6 *Keeping workpieces Clean*

Keeping workpieces clean can reduce processing time and energy costs. This requires attention to handling and storage methods prior to processing thus reducing the need for extensive degreasing.

Note: Avoid leaving workpieces outdoors because:

- they collect extra dirt;
- they will be several degrees colder in winter thus requiring more heat to warm up in the first process tank.

If this unavoidable, then cover the workpieces if possible and bring in for processing at least one hour before.

Benefits

- Less surface contamination.
- Faster processing time.

5.2.7 *Preventative Maintenance*

Regular preventative maintenance not only ensures that the tanks are working at optimum process conditions but energy and operating costs are also reduced.

Note: Regular cleaning and calibration of temperature sensors will ensure that tanks are only heated to the required processing temperature. Every 1°C error between the sensor and actual solution temperature uses about 5% extra heat energy.

The checklist below can be set up as part of a weekly work procedure for finishing line operatives. Check:

- tank operating temperature against sensor settings;
- tank lids for damage and repair;
- insulation balls are replenished regularly;
- time control on tank extraction system;
- signs of continuous top-ups to hot rinse tanks;
- tank insulation for damage and repair.

5.2.8 *Summary of Potential Savings*

	Reduction measure	**Max. potential for heat energy savings**	**Max. potential for water savings**	**Other**
1	Reducing evaporation losses	50%	50%	Improved work environment
2	Reducing heat loss at night	30%		Faster preheat time
3	Minimising drag out losses	1%		Reduced solution losses. Less cross-contamination
4	Controlling tank overflows	5%	50%	Reduced solution losses. Reduced effluent costs
5	Controlling tank temperatures	5% per °C		Improved process quality
6	Keeping workpieces clean			Reduced surface contamination. Faster processing time
7	Preventative maintenance	10%		More reliable operation

It should be noted that these saving are not cumulative. It depends which measure is implemented first. For some measures the second and subsequent measures will save proportionately less. For example, some users will be able to turn down all extraction systems at night - others, with different solutions, will not. Also if extraction systems are turned down at night, the savings will depend on whether you have two or three shift operation.

5.3 STEP 2 - Improving the Efficiency of Existing Processes

The following measures improve both energy and process efficiency of existing treatment lines. The measures require some analysis and planning to implement and also financial investment. Nonetheless they are cost effective to implement. Measures shown below are in order of priority.

5.3.1 *Optimising Treatment Programmes*

In older automated treatment facilities, or where treatment routines have changed, some stages of processing are either not required any longer or are not required for a particular batch of work. This sounds obvious, but your treatment programmes should be checked to ensure that you are not heating tanks not in use and not dipping workpieces into cold rinse tanks, which happen to be there but are not part of the programme (thus cooling the workpiece unnecessarily).

Fine tuning temperature settings, agitation levels, solution strength and processing power will deliver further efficiency gains.

Benefits

- Heat and electrical energy saved.
- Faster processing.
- Improved quality.

5.3.2 *Optimising Solution Selection*

Selecting the right type and concentration of acids and processing temperature for each job reduces energy requirements considerably and speeds up processing time.

For example, you should put pressure on your supplier of solution technology to formulate a mix that can operate at lower temperatures. Reducing processing temperature from say 60 to 55°C reduces the heat demand and saves money.

Choose acid dips wisely

- Processing time reduced by up to 50%
- Heat energy reduced up to 10%

If your supplier suggests an increase in concentration, make sure you trade off the benefits i.e. increased cost of chemicals versus reduced cost of heating.

5.3.3 *Eliminate Compressed Air for Tank Agitation*

The use of compressed air for tank agitation is an inappropriate use of an expensive resource (see GPG No. 126) and should be replaced with agitation by either hydraulic or a low-pressure blower. Both provide the same effect at a fraction of the cost.

Benefits

- Electrical energy reduced by up to 75%

Energy savings from eliminating compressed air for tank agitation

At Advanced Colour Coatings in Birmingham, there is no use of compressed air for tank agitation. Tank agitation is by a low-pressure blower. The blower delivers about 120 cfm or 204 m^3/hour to 20 treatment tanks using a motor rated at just 2.2 kW. To provide an equivalent amount of compressed air would require about 20 kW of motor power. The energy saved by using a blower as opposed to factory compressed air is 90% or about £3,500/year.

5.3.4 *Eliminate Compressed Air for Moisture Removal*

The use of compressed air for drying or removing moisture carry over is also a prevalent practice.

Again this is inappropriate use of an expensive resource and the preferred method is to replace compressed air with a low pressure blower, which will provide the same effect at a fraction of the cost.

> Benefits
>
> - Electrical energy reduced by up to 75%

> Example: In the example in Section 4.4.1, the moisture removal prior to final drying consisted of 4 x 8 mm nozzles at 4-bar pressure delivering 673 m^3/hour. The power used by the nozzles was 67 kW and the electricity cost of using compressed air for moisture removal was £13,440/year. Installing a 7 kW low pressure blower in an air knife arrangement would provide the same drying effect and save £12,000/year. The cost of the modifications can be recovered in about one year.

5.3.5 *Insulate Tank Sides and Lids*

An uninsulated, heated tank loses 10 times more heat through the tank sides (and lid) than an insulated tank. Moreover it takes longer to pre-heat the tank in the morning.

Fit all heated tanks sides and lids with at least 50 mm of thermal insulation.

> Benefits
>
> - Heat energy reduced by up to 90%

> Example: A tank heated to 60°C, has a tank surface area of 8 m^2. Without insulation this tank would lose 320 watts/m^2 whereas with 50 mm insulation the heat loss is reduced to just 29 watts/m^2 (see Table 4), a reduction of 90% and heat energy worth £90/year. The cost to install is about £150.

5.3.6 *Control Extract Fans (or Dampers)*

Most extraction fans run continuously and there is significant scope to reduce electricity consumption by matching power requirements to extraction rates. This is particularly appropriate where extracts have to be kept running continuously for health and safety reasons or where tanks have a centralised system.

Replace the existing motor with a two-speed motor in conjunction with an electronic timer to reduce extraction outside working hours. Further guidance on this measure can be found in GPG No. 14.

> Benefits
>
> - Electrical energy reduced by up to 20%

> Example: An extraction fan drawing 2 kW of power is required to run continuously. Fitted with a two speed motor and an electronic timer reduced nightly usage by about 20% giving savings of about £262/year at a cost to implement of about £500. Electricity cost 6 pence/kWh.

An alternative would be to fit an isolating damper on branches not in use but it should be noted that this reduces heated air loss but only reduces motor power very slightly.

5.3.7 *Fit Auto-Controls Spray Rinse systems*

Extract fans and pumps on older spray rinse systems tend to run continuously even when there is no workflow.

Fit a photocell based sensor and indexing system to reduce energy use on idling conveyors and pumps. These controls are relatively easy and inexpensive to purchase but integrating them into existing control systems requires careful evaluation and planning.

Benefits

- Electrical energy saved.

6.3.8 *Specify Higher Efficiency Replacement Motors*

Specify higher efficiency motors (HEMs) when replacing failed motors on pumps and extract fans with motor drives rated at over 5 kW.

HEMs are 2-3% more efficient than standard motors, which over the lifetime of a motor will produce significant savings. For further guidance on savings and the selection of HEMs see GPG No. 2.

Benefits

- Electrical energy reduced by up to 3%

5.3.9 *Summary of Potential Savings*

	Reduction measure	**Max. potential for heat energy savings**	**Max. potential for electrical energy savings**	**Other**
1	Optimising programmes	10%		Faster processing. Improved quality
2	Optimising acid selection	10%		Faster processing time
3	Eliminate tank agitation by compressed air.		75%	
4	Eliminate compressed air for drying		75%	
5	Insulate tank sides and lids	90%		Faster warm-up time
6	Controlling extract fans		20% to 40%	
7	Controlling spray rinses	10%		
8	Specify high efficiency replacement motors		2 to 3 %	

It should be noted that these saving are not cumulative as it depends which measure is implemented first. For some measures the second and subsequent measures will save proportionately less.

6. SPECIFY ENERGY CONSCIOUS DESIGN FOR NEW OR REPLACEMENT SYSTEMS

6.1 Making Major Modifications

Opportunities for a complete redesign may be rare, but partial redesign for more efficient energy consumption should always be considered, as often redesigning parts of the manufacturing process is the most cost-effective long-term option. The following best practice measures will improve the operational efficiency of treatment systems. These are most cost-effective when making major modifications to existing plant or when they are built into or specified for **new or replacement** plant. These measures will be of interest to equipment manufacturers.

6.2 Selection of Energy Source for Tank Heating

The advantages and disadvantages of using the different forms of energy for tank heating are summarised in Table 6.

Table 6 Summary of the advantages and disadvantages of different forms of energy for tank heating

Source of heating	Advantages	Disadvantages
Electricity	Compact heat exchanger - more energy per unit area	Expensive to use
	Precise control temperature	High voltages – safety implications
	Electricity 100% efficient at point of use	Easily damaged unless well protected
	Easy to install/replace	
Gas	Cheap to use	Expensive to install
	Rapid heating	Requires larger depth of tank for bottom heating
	High temperature and transfer rates	Heater immersed in dirt sludge
Steam/thermal fluid (Hot water)	Cheap to install if steam is available	Larger tank required
	Good heat distribution	Condensate discarded, expensive on water treatment and use
	Medium cost to use	

As a general rule, electric heating is more cost effective where there are a large number of small tanks, combinations of which are utilised on an infrequent basis. With natural gas now available at most industrial premises and with improved burner design and controls for gas tubular heaters, heating of tanks by gas is now very economical compared with electricity or steam. Where there is a choice between gas and steam, steam should be used if it is already available for other purposes and if the efficiency of delivering steam to the process tanks is better than or equal to gas firing.

6.3 Location of Heaters, Temperature Sensors and Overflows

Several of good practice techniques can be incorporated into tank design as shown in Fig 9.

- Heating coils must be at least 100 mm above bottom of tank to minimise agitation of settled sludge caused by the heating effect.
- Heating coils should be 100 mm below solution surface level to prevent excessive evaporation losses and loss of heated water at the overflow.
- Heating coils must be located opposite side to any over flow to prevent immediate loss of heated water at the overflow.
- Tanks should have at least two temperature sensors.
- The location of temperature sensors requires careful consideration if a representative temperature is to be measured.
- The overflow should be at the end opposite to workpiece entry so that any floating oils etc. move away from the point where water is being added and away from the workpiece being introduced.
- Top-up water should be introduced at bottom of tank as this improves mixing and minimises temperature stratification.

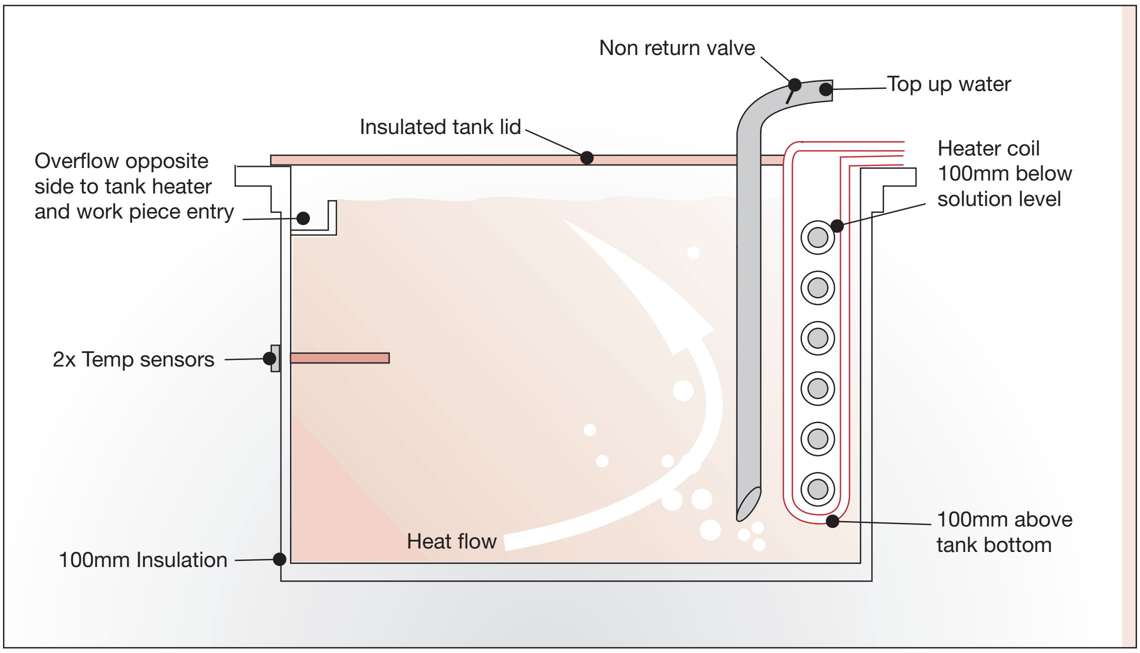


Fig 9 Best practice for tank design

6.4 Tank Heating Power

System suppliers generally oversize the power rating of tank heaters. This is intentional to allow the heaters to cover a wide range of workloads. However, it is clearly necessary to specify good quality temperature controls, otherwise there will be considerable waste.

6.5 HEM's for Pumps and Fans Motors

For motors on pumps and extract fans with motor drives rated at over 5 kW, specify higher efficiency motors, (HEMs) instead of standard motors. HEMs are 2-3 % more efficient than standard motors.

Further guidance on the selection of HEMs can be found in GPG No. 2

6.6 Counter-flow Rinsing

As a general rule for rinsing tanks, water flow must not displace more than 1% of tank volume per minute. Counter flow rinsing with at least two tanks is most economical on water usage requiring only 30% of top-up water compared with a series of single rinse tanks with separate water make-ups (see Table 7).

Advice should be sought from equipment designers on the exact drag-in concentration parameters required for each finishing line but it is possible on existing lines to connect single tanks to achieve the counter flow principle.

Table 7 Water usage counter-flow rinsing

Rinse method	**Single**	**Multi**		**Counter-flow**	
No. of rinses	**1**	**2**	**3**	**2**	**3**
Water usage	100%	61%	27%	3 %	1%

Savings from counter-flow rinsing

At Advanced Colour Coatings in Birmingham, both cold and hot water rinse tanks are counter-flowed. As a result water consumption is only 650 m^3/year compared with 5,000 m^3 if no counter-flow principles were deployed. Effluent volumes are proportionately reduced also. Savings in water and trade effluent costs are about £3,500/year.

6.7 Controlling Tank Extraction

As a general rule extraction systems are fitted to most treatment tanks to comply with health and safety regulations. Extraction is important for removing harmful emissions and also worker comfort, but systems tend to be overspecified with the result that high energy costs are incurred sometimes unnecessarily. Fume extraction design is still based on custom and practice. The main determinants for justifying extraction are the nature of the process solution and operating temperature.

If fume extraction is necessary, localised or individual extraction systems are recommended as these can be designed for each process There are various design guides available but selecting the right level of extraction is an emotive subject with operators and any changes may prove difficult to implement. The following table gives a general guide to maximum extraction rates for various process solutions.

Table 8 General guide to extraction requirements

Process solution	**Operating temperature**	**Is local extraction required?**	**Max. extraction rate per free surface area**	
			$m^3/h/m^2$	**cfm/ft^2**
Alkaline cleaners	Over 60°C	Yes	2,700	150
	Under 60°C	No		
Electrolytic cleaners	Over 60°C	Yes	3,100	170
	Under 60°C	No		
Acid pickling/etch	Over 30°C	Yes	3,600	200
	Under 30°C	No		
Electroplating	All temperatures	Yes	3,100	170
Electroless plating	All temperatures	Yes	3,600	200
Conversion coatings	Over 60°C	Yes	3,100	170
	Under 60°C	No		
Hot rinses	Over 60°C	Yes	2,300	130
	Under 60°C	No		

Assessment Method:
As can be seen from Table 8 not all solutions need an extraction system. The type of process and tank temperature determines the requirement for extraction ventilation. Therefore the following assessment method is recommended to ascertain whether extraction systems are oversized.

Step 1: Using the table above for each treatment tank, find out whether extraction is required or not. If extraction is not always necessary, try a reduced extraction rate. If successful it will save you electricity and reduce space heating costs also.

Step 2: If extraction is necessary, check your actual extraction rate at the tank by measurement with an anemometer (which can be hired). An anemometer measures air velocity in metres per second which when multiplied by the cross-sectional area of the extraction duct gives the volume of air passing through in cubic metres per second. Several readings should be taken and an average calculated. Then divide this calculation by the tank liquid surface area and compare with the level recommended in Table 8. If there is scope for reducing the extraction level and thus energy costs, reduce flow rates by either fitting two-speed motors or dampers as discussed in Section 5.3.8.

Example: An acid tank measuring 1.5 x 1.0 m has an extract duct at one end of the tank. The duct measures 100 mm high by 1500 mm long giving a total area of 0.15 m^2. An anemometer was hired and several readings taken at various points along the length of the duct. The average air velocity was 10 m/s. Therefore volume of extraction is 1.5 m^3/s and multiplying by 3600, which is equivalent to 5,400 m^3/h. Dividing this result by the tank liquid surface area (1.5 m^2) gives 3,600 $m^3/h/m^2$. Referring to Table 8 it can be seen that the extraction for this tank is not excessive.

6.8 Plating Plant Rectifier Design and Control

Several energy saving measures can be incorporated in new or replacement plating plants and in particular by paying close attention to the design of associated electrical plant. Although more expensive to buy initially, these will save enough energy to recoup the extra investment and provide ongoing savings.

6.8.1 *Specifying Rectifiers*

- Low energy loss silicon rectifiers are preferred.
- Design and operate rectifiers near their rated output. Losses can be as high as 10% if rectifiers operate well below rated output.
- Automatic current density control will provide accurate plating current preventing overplating and resulting in reduced power usage and plating material savings.

6.8.2 *Specifying Electrical Equipment*

- Ensure rectifiers are close to the plating lines thus keeping busbars connections short, with well made joints to reduce stray voltage drops.
- Ensure that the busbar cross-section is adequate. Copper rather than aluminium busbar material is preferred as copper is a more efficient conveyor of power per area of cross-section.
- Ensure that the total resistance of the system is calculated to work out the total power loss and install busbars of adequate cross-sectional area to reduce power loss. Although the initial cost will be higher, the savings in energy will quickly repay the higher cost of installation. Particular attention should be paid to voltage drop. If the supply voltage is low and if undersized busbars are used, the voltage at the plating bath will be reduced unacceptably. Appendix B provides a first guide to selecting the optimum size of busbar[1].
- Recover and re-use waste heat from water cooled rectifier cooling systems, which can be at temperatures of 40-50°C, in hot pre-rinses or use a water to air heat exchanger to provide space heating for the area.
- Ensure you are not being penalised for poor power factor. If there is a power factor charge on your electricity bill, investigate the cost of power factor correction. This is a black box of electronics (containing capacitors) which will improve your power factor. Payback is usually around 18 to 24 months.

[1] Further guidance and a computer program called ‘Economic sizing of Busbars’ can be obtained from the Copper Development Association on Tel: 01727 731200.

A good example of specifying energy efficient equipment at the design stage is illustrated below.

Automated Barrel Plating Line

The Electrolytic Plating Company in Walsall, West Midlands built a new purpose-designed plating facility comprising a 20-tank line which is fully automated. The following energy and quality best practices were specified at the design stage of the plant:

Best Practices

- Close control of tank temperature and therefore heating rates.
- Close control of plating current per tank.
- Auto-dosing of plating solutions to maintain solution strength thus maximising plating effect and speed.
- Batch coding information i.e. plating current, temp etc., logged for quality control and future verification
- Mild steel tanks insulated.
- Water use metered with automatic water control on rinsing tanks.
- Counter-flow rinsing employed.
- Computerised control operated under Microsoft Windows environment with software designed to run the plant at optimum efficiency. Also controls effluent treatment plant.
- Plant capability of replicating plating conditions.

6.9 Increasing Efficiency with Improved Heat Exchangers

In the anodising industry in particular, final product quality is dependent on maintaining constant bath temperature - requiring large amounts of electrical energy and water for heating and cooling. Plate or coil heat exchangers are an excellent way of improving efficiency and recovering heat. The advantages are:

- they are more responsive to heating and cooling needs;
- the same exchanger can be used for heating or cooling;
- temperature can be controlled quickly and accurately due to high flow rates through the heat exchanger;
- there is no need for agitation;
- there is more room for workpieces as heat exchanger can be mounted externally to the tank.

6.9.1 *Optimum Thickness of Tank Insulation*

Uninsulated tanks lose heat excessively and this can be avoided at low installation cost. The thickness of insulation and heat losses for various tank temperatures is shown in Table 9.

Table 9 Typical heat loss from treatment tanks

Solution temperature	Typical heat loss in W/m^2 tank metal surface			
	Thickness of insulation on tanks			
	None	50 mm	75 mm	100 mm
100°C	640	58	30	22
80°C	480	44	23	17
60°C	320	29	15	11
40°C	160	15	8	6

From Table 9 it can be seen that simply by fixing 50 mm of thermal insulation, 90% of heat loss can be saved. Fixing 100 mm will save 96.5% of heat loss. As a design guide and at today's energy prices, it is economical to specify 100 mm of thermal insulation to be fitted to tanks sides and lids.

6.10 Summary of Potential Savings

	Reduction measure	**Max. potential for heat energy savings**	**Max. potential for electrical energy savings**
1	Choice of heating source		
2	Location of heaters, sensors, overflows	5% per °C	
3	Tank Heating Power	Considerable	
4	HEM for fans and pumps		2 to 3%
5	Counter flow rinsing	30%	
6	Tank extraction		Up to 50%
7	Plating plant rectifier design and control	20% to 30%	10%
8	Heat exchangers	Up to 20%	
9	Optimum thickness of tank insulation	Up to 30%	

7. IMPLEMENTING ENERGY COST SAVINGS USING AN ACTION PLAN

7.1 Using an Action Plan

The purpose of an action plan should be to implement measures that will reduce energy costs and improve the operational efficiency of the treatment facility.

Commitment and Energy Policy

A successful action plan also requires the commitment of management and operators. This is a critical factor to the long-term success of such initiatives. The establishment of a written company energy policy is an excellent way of demonstrating this commitment to all employees.

Management Issues

Gaining management commitment is an important first step in an energy efficiency programme. Although many measures are easy to implement and produce quick results there will be a certain amount of effort required from both employees and management to make it work. A systematic approach is the best way forward. Results will have to be measured to see if actions taken are working - and the cost savings seen to be achieved will provide incentives to take the next steps. Section 5 gives plenty of ideas on good practice measures that will get any energy efficient programme off to a good start.

Decision Making

Get operators and supervisors involved in the decision making, implementation and maintenance procedures. Employees may have to learn new ways of working and it is important that they realise why changes are being made.

Decide on Priorities

Start with the simple, easy to implement measures. For each measure decide who will implement it, how and by when.

For example, routine maintenance measures such temperature checks should be made the responsibility of treatment line operatives and they should be given the means of performing the tasks such as:

- portable temperature probes;
- logs to record actual temperatures and thermostat settings, the condition of tank insulation, use of tank lids at night, time settings on extract fans.

Training

Operatives should be made more energy conscious by explaining to them the energy costs of operating a particular finishing line and the practices that lead to energy waste. They should also be trained to recognise and report the first signs of energy waste. Finally operatives will become more energy and cost conscious if they are required to routinely collect performance data and if they are then told of their finishing line performance on say a monthly basis using a simple monitoring and targeting method.

Monitoring and Targeting

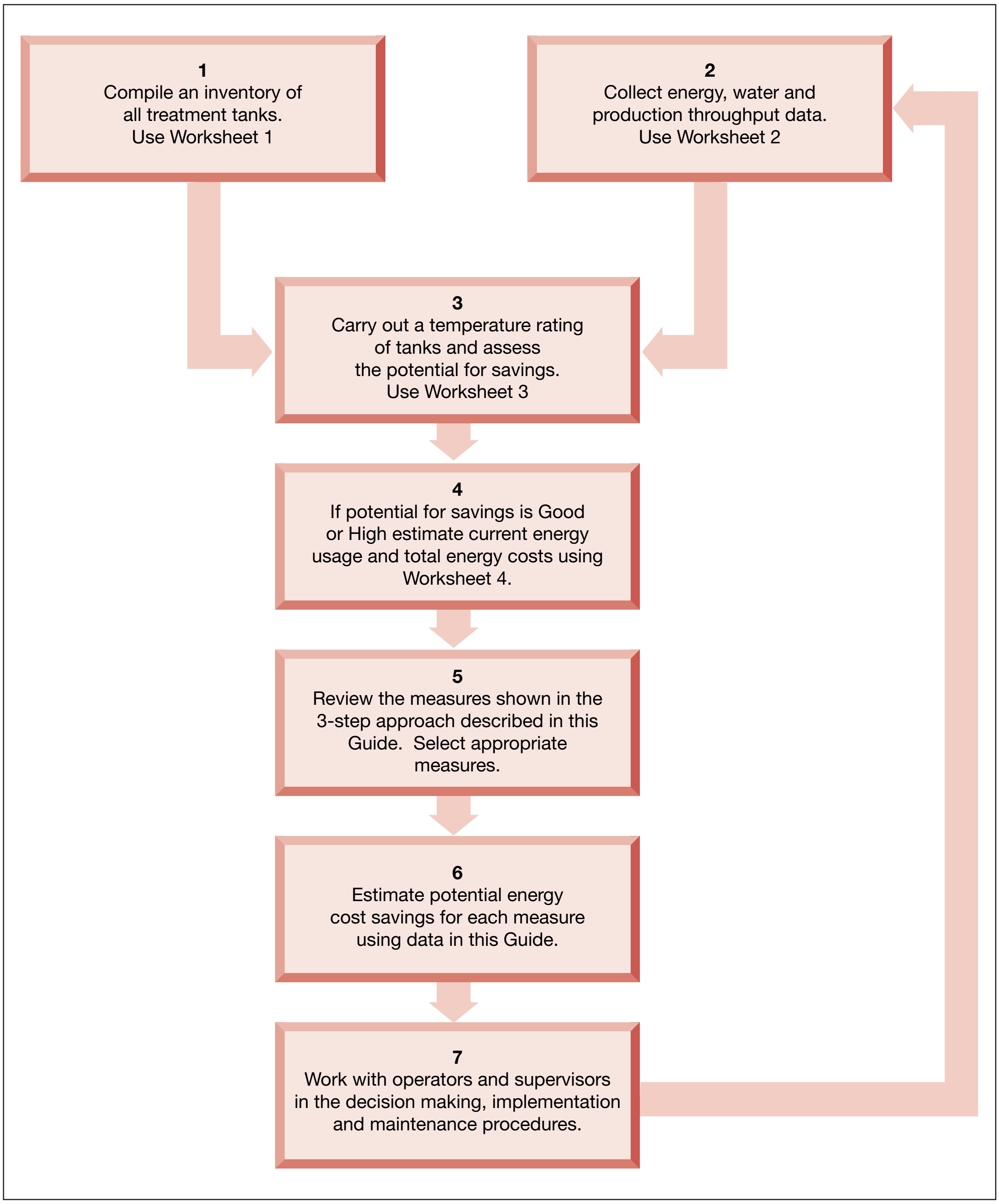
The success of any action plan needs to be evaluated and the results publicised within the company as a motivational tool to encouraging further cost savings. It important therefore to monitor the results following the structure laid out in Section 5 and Worksheets 1 to 3 in

Appendix A. This should be repeated after 6 to 12 months to compare performance before and after the implementation of measures.

7.2 Framework for an Action Plan

The flow chart below provides a framework for getting started on an action plan. It assumes that there is already a firm commitment from management and that there is a company energy policy in place to drive such issues forward. Further help on how to set up a company energy policy and practical advice on successful project management of energy efficiency measures are available in GPG 213.

ACTION PLAN FLOW CHART:



APPENDIX A

Worksheet 1 - Tank Data Collection Form

Tank no.	Treatment process	Extract ventilation/ tank agitation	Length m	Width m	Height m	Op temp °C	h/day	Days/ wk	Total h/week
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Resource	**Units**	**Annual (A)**	**Cost £ (B)**	**Average unit cost (B/A)**	
Electricity	kWh				£/kWh
Gas/Oil	kWh				£/kWh
Water	m^3				£ /m^3
Production throughput	kg or tonnes of metal				
Efficiency of heating system					

Total energy cost	= *Electricity + gas costs*	£
Total utilities cost	= *Total energy + water costs*	£

Total energy cost per tonne of production	= *Total energy cost/production throughput*		£/tonne
Total utilities cost per tonne of production	= *Total utilities cost/production throughput*		£/tonne

Worksheet 2 - Utility Resources Collection Form

		Tank temperature range			
		20 - 35°C	**36 - 55°C**	**56 - 75°C**	**>76°C**
Tank No.	**Treatment process**	**Hrs/wk**	**Hrs/wk**	**Hrs/wk**	**Hrs/wk**
1					
2					
3					
4					
5					
6					
7					
8					
9					
Total hours for temp range		A=	B=	C=	D=

Total hours t = A+B+C+D	

Note: Enter the

	Temperature Rating of Tanks			
	20 - 35°C	**36 - 55°C**	**56 - 75°C**	**>76°C**
	No significant savings	Low potential for energy reductions	Good potential for energy reductions	Very good potential for energy reductions
% hours of use in each temperature range	= A/t %	= B/t %	= C/t %	= D/t %
Enter score from above				

totals of your annual bills for the whole factory to work out the average unit costs

APPENDIX B

Selecting the optimum size of busbar

Power loss (W) per metre of busbar	Bushbar cross section mm²												
Current	**1000**	**1100**	**1200**	**1400**	**1600**	**1800**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**
100	0.172	0.157	0.144	0.123	0.108	0.096	0.086	0.069	0.057	0.049	0.043	0.038	0.034
200	0.690	0.627	0.575	0.493	0.431	0.383	0.345	0.278	0.230	0.197	0.172	0.153	0.138
300	1.552	1.411	1.293	1.108	0.970	0.862	0.776	0.621	0.517	0.443	0.388	0.345	0.310
400	2.758	2.508	2.299	1.970	1.724	1.532	1.379	1.103	0.919	0.788	0.690	0.613	0.552
500	4.310	3.918	3.592	3.079	2.694	2.394	2.155	1.724	1.437	1.231	1.078	0.958	0.862
600	6.206	5.642	5.172	4.433	3.879	3.448	3.103	2.483	2.069	1.773	1.552	1.379	1.241
700	8.448	7.680	7.040	6.034	5.280	4.693	4.224	3.379	2.816	2.414	2.112	1.877	1.690
800	11.034	10.031	9.195	7.881	6.896	6.130	5.517	4.413	3.678	3.152	2.758	2.452	2.207
900	13.964	12.695	11.637	9.975	8.758	7.758	6.982	5.586	4.655	3.990	3.491	3.103	2.793
1000	17.240	15.637	14.367	12.314	10.775	9.578	8.620	6.896	5.747	4.926	4.310	3.831	3.448
1100	20.860	18.984	17.384	14.900	13.038	11.589	10.430	8.344	8.953	5.960	5.215	4.636	4.172
1200	24.826	22.569	20.688	17.733	15.516	13.792	12.413	9.930	8.275	7.093	6.206	5.517	4.985
1300	29.136	28.487	24.280	20.811	18.210	16.186	14.568	11.654	9.712	8.324	7.284	6.475	5.827
1400	33.790	30.719	28.159	24.136	21.119	18.772	16.895	13.516	11.263	9.654	8.448	7.509	6.758
1500	38.790	35.264	32.325	27.707	24.244	21.550	19.395	15.516	12.930	11.083	9.698	8.820	7.758
1600	44.134	40.122	36.779	31.525	27.584	24.519	22.087	17.654	14.711	12.610	11.034	9.808	8.827
1700	49.824	45.294	41.520	35.588	31.140	27.680	24.912	19.929	16.608	14.235	12.456	11.072	9.965
1800	55.858	50.780	46.548	39.898	34.911	31.032	27.929	22.343	18.619	15.959	13.934	12.413	11.172
1900	62.236	56.579	51.864	44.455	38.898	34.576	31.118	24.895	20.745	17.782	15.559	13.830	12.447
2000	68.980	62.691	57.467	49.257	43.100	38.311	34.480	27.584	22.987	19.703	17.240	15.324	13.792
2100	76.028	69.117	63.357	54.306	47.518	42.238	38.014	30.411	25.343	21.722	19.007	16.895	15.206
2200	83.442	75.856	69.535	59.601	52.151	46.356	41.721	33.377	27.814	23.840	20.860	18.543	16.688
2300	91.200	82.909	76.000	65.143	57.000	50.666	45.600	36.480	30.400	26.057	22.800	20.267	18.240
2400	99.302	90.275	82.752	70.930	62.064	55.168	49.651	39.721	33.101	28.372	24.826	22.087	19.860
2500	107.750	97.955	89.792	76.984	67.344	59.861	53.875	43.100	35.917	30.786	26.938	23.944	21.550
2600	116.542	105.948	97.119	83.245	72.839	64.746	58.271	46.617	38.847	33.298	29.136	25.898	23.308
2700	125.680	114.254	104.733	89.771	78.550	69.822	62.840	50.272	41.893	35.908	31.420	27.929	25.136
2800	135.162	122.874	112.635	96.544	84.476	75.090	67.581	54.065	45.054	38.618	33.790	30.036	27.032
2900	144.988	131.808	120.824	103.563	90.618	80.549	72.494	57.995	48.329	41.425	36.247	32.220	28.998
3000	155.160	141.055	129.300	110.829	96.975	86.200	77.580	62.064	51.720	44.331	38.790	34.480	31.032
3100	165.676	150.815	138.064	118.340	103.548	92.042	82.838	66.271	55.225	47.336	41.419	36.817	33.135
3200	176.538	160.489	147.115	126.098	110.336	98.076	88.269	70.615	58.848	50.439	44.134	39.231	35.308
3300	187.744	170.876	156.453	134.103	117.340	104.302	93.872	75.097	62.581	53.641	48.936	41.721	37.549

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
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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
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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.